Orange County Triples South Plant Capacity for under $1.50 per Gallon in Record Time

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The South Water Reclamation Facility (SWRF), with a design capacity of 30.5 million gallons per day (mgd), is the largest of three water reclamation facilities owned and operated by Orange County Utilities (OCU). The SWRF provides wastewater treatment for a service area that encompasses most of Orange County south of the city of Orlando. Effluent from the SWRF is reused in several ways, including groundwater recharge by rapid infiltration basins (RIBs), citrus irrigation, and urban reuse.

Because of these effluent reuses, the facility is required to meet Florida standards for both unrestricted reuse and groundwater recharge—5 mg/L total suspended solids (TSS), 10 mg/L nitrate nitrogen, and high-level disinfection. The plant is also required to remove viruses and to limit the effluent concentration of numerous constituents to satisfy quality requirements stipulated in contracts with citrus growers.

In 1999, the SWRF consisted of two independent liquid-treatment trains and a common sludge-handling train. The Phase I treatment train (now called the North Plant) was last modified and expanded between 1984 and 1988, when it was converted to an advanced secondary-treatment facility (MLE configuration) with a capacity of 23.0 mgd. The 7.5 mgd-Phase III (South Plant Complex) improvements were completed in 1991 and increased the permitted capacity of the SWRF to 30.5 mgd. These Phase III improvements included two Carrousel™ oxidation ditches, three 135-foot diameter final clarifiers with a return and waste-activated sludge (RAS/WAS) pumping facility, automatic backwash (ABW) filters, and chlorination.

The county did not have adequate funds at the time of the 1991 expansion to equip both Carrousels™, so only the east Carrousel™ unit (now named the South East Plant) was completed and put into service. The west Carrousel™ unit (now named the South West Plant) was used for flow equalization of the South East Plant final clarifier effluent prior to filtration and freeze-protection water storage. The common sludge-handling facilities include dissolved-air flotation (DAF) thickening, anaerobic digestion, and belt filter press dewatering facilities. Dewatered sludge is land-applied by a contract hauler. **Figure 1** shows a process-flow schematic of the treatment facilities.

In the winter of 1999, OCU faced multiple challenges. Continued expansion of the Orange County Convention Center was expected to soon create a demand for additional wastewater-treatment capacity. At the same time, the aging traveling-bridge clarifiers, located in the North Plant, had failed. In order to have facilities ready in concert with the approaching deadline for completion of the convention center and to replace the failed clarifiers at the SWRF, OCU elected to use a fast-track design/build procurement method and an innovative biological wastewater treatment technology. Using an engineer, procure, and construct management

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(EPCM) approach, the county selected CDM/Sverdrup, a joint venture (design-builder) to upgrade the South Plant's overall capacity to provide a firm 30.5-mgd average

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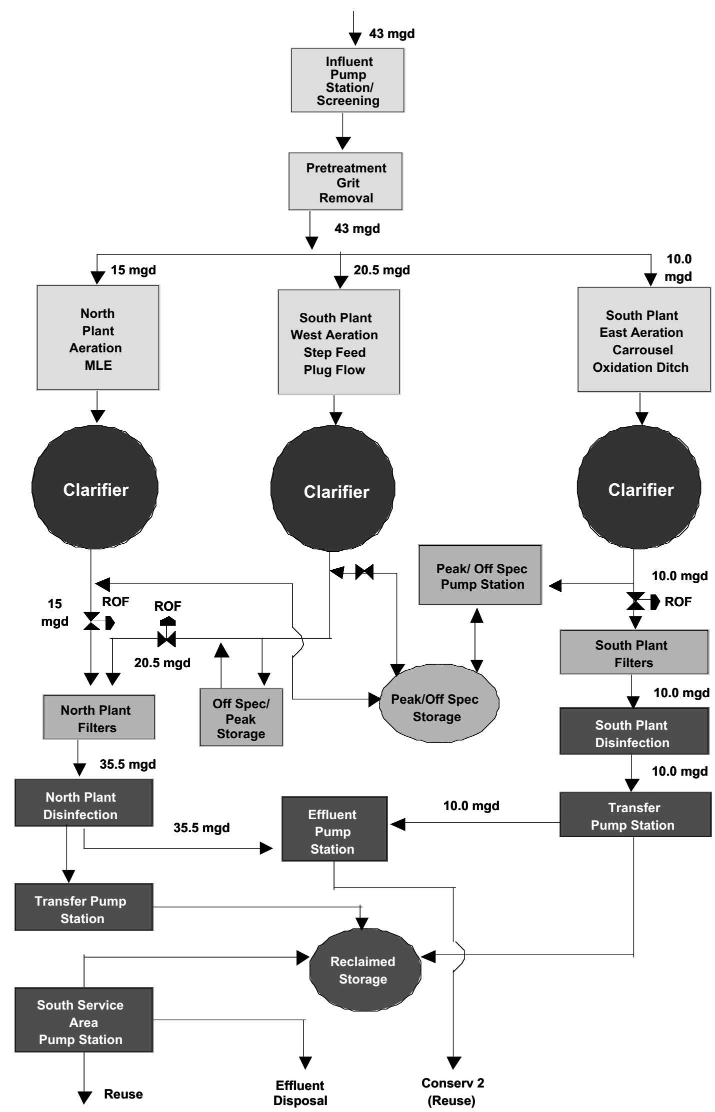

Figure 1: South Water Reclamation Facility Phase IV-A improvements process flow schematic

Continued from page 29

annual daily flow (AADF) capacity without the use of the existing traveling-bridge clarifiers within 18 months. In a second phase, the CDM/Sverdrup team will provide a capacity increase to 43.0 mgd, and upgrade and expand the plant's solids-handling facilities.

The CDM/Sverdrup team proposed and later implemented an innovative modification to the approach requested in the request for proposals (RFP), which provided firm-treatment capacity faster while allowing the entire North Plant to be taken out of service to facilitate replacement of the failed North Plant clarifiers. The EPCM approach calls for the SWRF work to be completed in three phases. The first phase, Phase IV-A, upgraded portions of the South Plant Complex to provide additional liquid-treatment capacity, keeping the total plant capacity at 30.5 mgd. This was necessary so that the entire North Plant could be removed from service for modifications during the Phase IV-B rehabilitation. **Figure 2** shows the site plan following the Phase IV-A improvements.

The second phase, Phase IV-B (presently in construction), will repair the North Plant liquid-treatment facilities and expand the solids-handling and odor-control facilities to treat 43.0 mgd AADF. The third phase, Phase IV-C, will add supplemental aeration to the South East Plant, convert the existing anaerobic digesters to a temperature-phased, anaerobic-digestion (TPAD) process to produce Class A residuals, and add new reuse storage tanks.

Project Scope for Phase IV-A

The major improvements in the Phase IV-A project included:

- Retrofitting the South West Plant to provide step-feed biological nutrient removal (BNR) treatment;
- Adding two new 165-foot diameter final clarifiers and RAS/WAS pumping station.

Since these improvements were completed, the South West Plant and South West clarifiers are able to treat 20.5 mgd AADF, and the South East Plant is able to treat 10 mgd AADF. This provides a total treatment capacity of 30.5 mgd AADF and allows the North Plant to be taken out of service for rehabilitation.

Project Approach

The driver for the Phase IV-A and IV-B improvements is the need to have treatment capacity ready for the Orange County Convention Center expansion and associated development when it is completed. The county signed a contract with the design-builder to design the plant improvements; procure the equipment, materials, and installation services; and manage the construction of the improvements. OCU negotiated a pre-construction fee for engineering/design and pre-construction planning services to bring the design for Phase IV-A to the 65-percent stage.

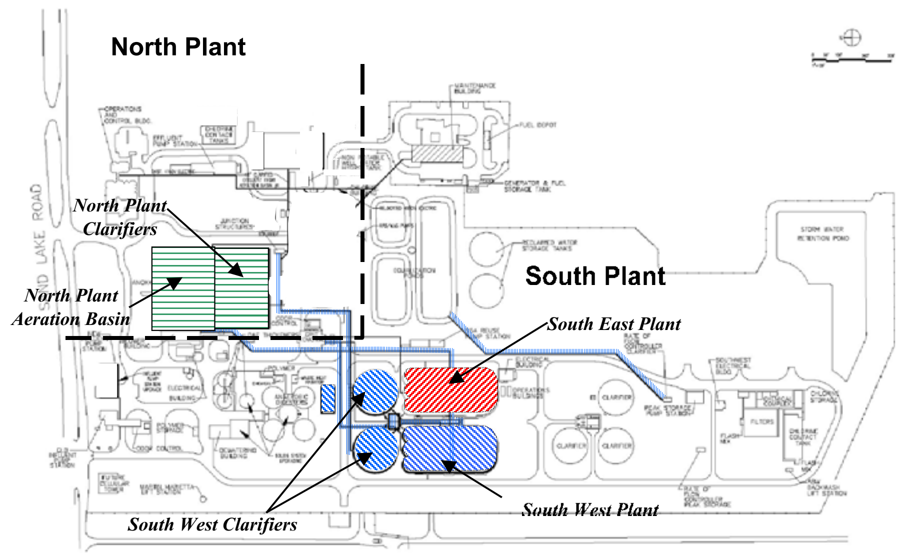

Figure 2: South Water Reclamation Facility Phase IV-A improvements: overall site plan

In order to meet the demanding schedule, the design-builder identified, negotiated, and procured long-lead equipment at the 65-percent design stage. Bids were accepted for each package and subcontracts were awarded to the most responsive bidder. Upon completion of the 65-percent design, construction costs were negotiated as a guaranteed maximum price (GMP).

The GMP was again revised at the 100-percent design stage and included a contingency fund managed by OCU that was used to cover the cost of any clarification to the 100-percent design package, including costs on bid packages that exceeded the design-builder's estimate for that bid package. The original construction budget for the Phase IV-A improvements was approximately $21.6 million. After bids were received, the GMP was reduced to $18.65 million.

Project Schedule

OCU's fast-paced schedule for the design and construction of the Phase IV-A improvements required that the improvements be completed in 18 months following the notice to proceed. As the design team prepared drawings and specifications—producing an initial design report within two months—the construction specialists mobilize equipment and materials to the site. In order to meet the stringent schedule, the entire design team—consisting of members from eight architectural and engineering firms and several county departments—met frequently, often once a week during critical periods, enabling quick design decisions and efficient identification and resolution of design issues.

Figure 3 shows a simplified project schedule for the Phase IV-A improvements. The first construction milestone, reached in April 2001, was the commissioning of the 20.5-mgd AADF South West Plant. Six months later in October, the new clarifiers, mixed-liquor splitter box, and RAS/WAS pumping facilities were brought online.

Overview of the South West Plant BNR Process

The South West Plant, prior to Phase IV-A, was a 5.65-million-gallon (MG) tank used for freeze protection and off-spec storage of clarified effluent. The process basin was originally configured to be a Carrousel-type oxidation ditch with a capacity of 7.5 mgd AADF. In order to meet the existing permitted conditions of 30.5 mgd AADF, the basin-treatment capacity needed to be tripled in order to take the North Plant offline.

This was accomplished by converting the basin to a four-pass, modified step-feed arrangement with sequential anoxic, aerobic, and swing zones created by adding a new splitter box internal to the tank and new interior baffle walls. Mixed liquor in the anoxic zones is mixed using mechanical platform mixers. Swing zones are equipped with both mechanical platform mixers and perforated membrane diffusers. The aerobic zones have a fine-pore diffused aeration system using 9-inch circular ceramic diffusers.

Baffle walls were constructed at the anoxic zone/aerobic zone interfaces and the aerobic swing/anoxic zone interfaces in each of the four passes. Also, a complete partition wall was constructed just north of the exist-

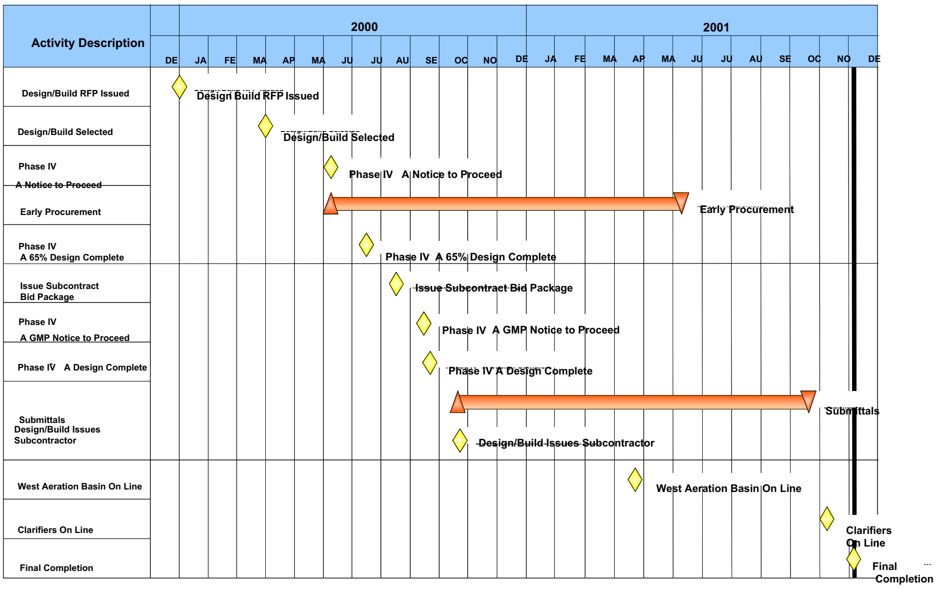

Figure 3: South Water Reclamation Facility Phase IV-A improvements: design-build schedule

ing outlet box to isolate the end of Pass D from the beginning of Pass A. **Figure 4** shows a schematic diagram of the South West Plant.

An innovative flow-splitting structure, consisting of multiple slide gates and fixed weirs, was installed inside the center circular aeration zone on the north end of the tank. The splitting structure is designed to allow plant operations staff to change the flow split to Passes B, C, and D in the modified step-feed process. The splitter box has four fixed weirs for each pass with associated slide gates that can be opened and closed. Manually opening and closing different combinations of gates will vary the flow split to the last three passes.

Raw wastewater from the flow-splitting structure is directed to the anoxic zone of Passes B, C and D. Return-activated sludge (RAS) is added to Pass A and combines with the raw wastewater at the beginning of Pass B. The nitrates, produced from the oxidation of the influent total Kjeldahl nitrogen (TKN), are contacted with the raw wastewater and RAS. The nitrates, in the presence of a carbon source and without free oxygen, will be reduced to nitrogen gas, resulting in denitrification. In addition to denitrification, it is believed the use of the anoxic zones and the plug-flow configuration has resulted in the exceptional mixed-liquor settling velocities experienced in the modified plant.

Startup of the South West Facilities

Startup of the South West Plant, mixed-liquor splitter box, clarifiers, and associated RAS/WAS pumping facilities was done in two steps. In April 2001, RAS from the existing Phase III clarifiers was used to seed the South West Plant. Over several days, the RAS was diluted with reclaimed water to achieve a mixed-liquor suspended-solids (MLSS) concentration of 2,500 mg/L.

Once the seeding and dilution process had ended, the South East Plant was taken out of service and flow was initiated to the South West Plant at a flow rate of 15 mgd. This allowed the South West Plant to discharge to the existing Phase III clarifiers until construction of the new clarifiers was completed. The South West Plant began to nitrify almost immediately, producing effluent ammonia concentrations under 1 mg/L during the first several weeks. Effluent nitrate concentrations during the first several weeks after startup averaged around 5 mg/L. Treatment performance continued to improve for several weeks before stabilizing at an average effluent nitrate concentration of 3.7 mg/L.

By October 2001, the new South West clarifiers were placed in service. In the second phase of the startup, the South East Plant was returned to service and flow from the South West Plant was diverted to the new 165-foot diameter clarifiers. Immediately the flow to the South West Plant was increased to 20.5 mgd, allowing the North Plant to be taken offline for scheduled improvements.

Comparison of the South West and South East Plants

The new step-feed process has been online for approximately 10 months and is producing a superior effluent with an effluent water quality that is far below Florida Department of Environmental Protection (FDEP) discharge limits. The average effluent quality of the South West Plant since start-up is presented side-by-side with the water quality data from the South East Plant in **Table 1**.

Despite the differences in process configuration and capacity, the two process trains have comparable effluent quality. The effluent ammonia, nitrate, and total nitrogen in the South West Plant effluent has averaged 1.5 mg N/L, 3.7 mg N/L, and 6.7 mg N/L respectively, while the South East Plant effluent has averaged 1.4 mg N/L, 2.3 mg N/L, and 4.04 mg N/L. Nitrogen removal at both plants is exceptional, considering that they were designed to meet an effluent total nitrogen criterion of 10mg/L.

The removal of biochemical oxygen demand (BOD_5) and total suspended solids (TSS) is also similar for both plants. The filtered effluent for the South East plant averages 1.5 mg/L BOD_5, 1.8 mg/L TSS, and 1.4 NTU turbidity. The South West plant's averages are similar: 1.6 mg/L BOD_5, 1.9 mg/L TSS, and 1.5 NTU turbidity.

The two plants have significantly different performance records regarding one water-quality parameter: total phosphorus. Phosphorus, currently not regulated under the existing plant permit, is significantly lower in the South West Plant effluent. Microbial analysis of the MLSS for both plants found that BioP bacteria are present in each facility, as indicated by the presence of Neisser positive cell clumps. The increased phosphorus removal in the South West Plant

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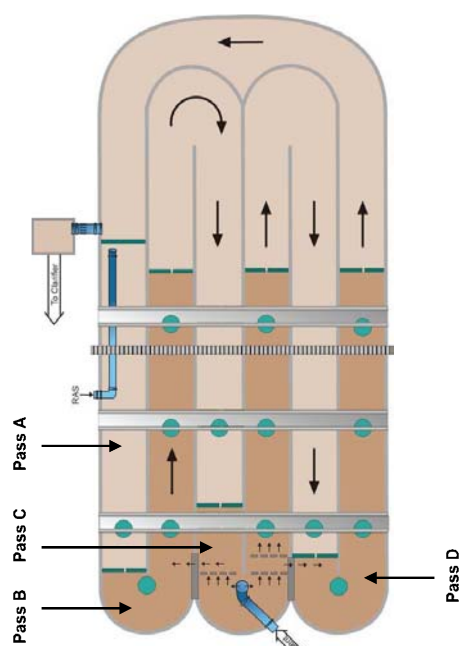

Figure 4: South Water Reclamation Facility Phase IV-A improvements: schematic view of the South West Plant

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might be attributed to the release of phosphorus in the anoxic zones with subsequent uptake in the aerobic zones.

Another interesting comparison is the sludge volume index (SVI) for both plants. As shown in Table 1, the values differ by almost 20 percent. The change in SVI was noted almost immediately after the South West Plant was brought into service. Plant operational staff quickly noted that the mixed-liquor suspended solids were settling at a much faster pace than previously. The design of the South West Plant assisted in conditioning the sludge to settle faster. The addition of the three anoxic zones in the reactor selects and conditions the biomass to have better settling characteristics by inhibiting the growth of filamentous microorganisms.

The increased sludge settleability presents the county with the potential to rerate the South West Plant in the future. The clarifiers were designed using the solids flux approach at a last-pass MLSS concentration of 2,667 mg/L and an SVI of 150 mL/g. At the same MLSS concentration and an SVI of 100 mL/g, the clarifiers could be potentially rerated to over 25 mgd AADF, bringing significant cost savings to the county in the future if supplemental capacity were required.

The difference in capacity between the South West and South East Plants highlights the greater efficiency of the step-feed BNR process for this application. The South East Plant was designed to treat an average day flow of 7.5 mgd and can treat only a maximum of about 12 mgd before the aeration system becomes inadequate to maintain dissolved oxygen in the tank. Yet each plant has similar-size tanks. The aeration basin volumes are 5.47 MG and 5.65 MG for the South West and South East plants, and each plant has about 43,000 square feet of clarifier surface area.

Constituent	Units	South West Plant	South East Plant
Flow (AADF)	mgd	17.4	6.5
Influent BOD_5	mg/L	144	
Influent TSS	mg/L	239	
Influent TKN	mg/L	36.1	
Influent NH_4-N	mg/L	22.2	
Influent TP	mg/L	9.7	
Effluent BOD_5	mg/L	1.5	1.5
Effluent NH_4-N	mg/L	1.5	1.4
Effluent NO_3-N	mg/L	3.7	2.3
Effluent TN	mg/L	6.7	4.0
Effluent TP	mg/L	1.9	3.6
SVI	mL/g	82	101
SRT	day	6.7	11.0

Table 1: Orange County South WRF comparison of the South West and South East Plant performance

The South East Tank is equipped with five, 125-horsepower, mechanical surface aerators, for a total connected power of 625 horsepower, or about 83 hp/mgd on average. By contrast, the South West plant, which has a capacity of 20.5 mgd AADF, is designed to use about 19,000 cfm of air at average conditions and about 33,000 cfm at peak loads (99th percentile). The design blower power required to provide these airflow rates is estimated to be 750 hp and 1,300 hp respectively, or about 36 hp/mgd on average.

Conclusion

The step-feed BNR process has been demonstrated to be a more efficient treatment technology than simultaneous nitrification and denitrification in an oxidation ditch for meeting typical permit limits for BOD_5, total suspended solids, and total nitrogen for groundwater recharge and urban reuse. At the Orange County South Water Reclamation Facility, the step-feed BNR process can treat about 170 percent more flow in the same-size aeration tanks and final clarifiers, while producing about the same effluent quality and using significantly less power for aeration.