Dania Beach Goes Gold with Nanofiltration Plant

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The City of Dania Beach was the first city to be incorporated in Broward County. Most of its original residents, beginning in 1904, were Danes, so the name "Dania" was selected. The City's water system began development in the 1920s, using wells in what is currently the downtown area. As these wells deteriorated due to excessive pumping, new wells were constructed and a new facility to treat water from these wells was installed on the current plant site. Since 1952, the City has owned and operated a lime softening water treatment plant located one mi east of I-95 on Stirling Road. The plant, which was expanded in 1962 and refurbished in 1992, serves just over 16,000 residents in the eastern half of the city. Much of the current water distribution and sewer collection system was developed between 1950 and 1975. A five-acre multipurpose property that has served as the water plant and public works staging area has been reworked to include a new community center, a gated public works complex, and the upgraded water treatment plant facility.

Production from the City's current well field is permit-limited due to the potential for salt water intrusion, which necessitated an agreement to participate in a regional wellfield with the County in 1992 for supplemental raw water. However, the Broward County raw water is higher in disinfection byproducts precursors, color, and iron than the City's raw water, which adversely impacts the operation of the current lime softening treatment facility. Difficulty in meeting future regulatory requirements for color, trihalomethanes, and organics are more difficult with lime softening, and the ability to expand the lime softening system for future development complicated the water quality solutions.

Strategic Planning

In 2003, the City developed its first comprehensive water, sewer, and stormwater strategic plan. Water improvements for the City's five-year capital improvements program were identified, including the need to upgrade water treatment capacity. The City looked at options to treat the water from fresh and salt water sources, use different treatment processes, and purchase water from neighboring utilities. After evaluating the options of buying water from neighboring Broward County, City of Hollywood, and City of Fort Lauderdale, the City determined that it was less costly to increase the capacity of its existing water treatment plant. The use of nanofiltration at the plant was identified as the best option to meet operations and water quality goals.

With the local commissioners, the City reiterated its commitment to control its own destiny with respect to water treatment so that community development goals and desires could be achieved without hindrance. The initial facilities plan was approved in 2004, and it was submitted to the State Revolving Fund (SRF) program for potential funding.

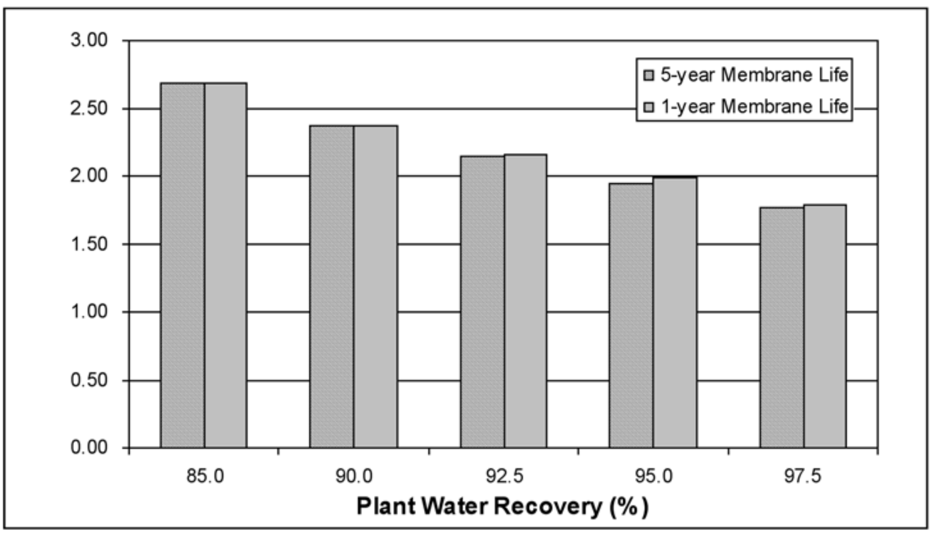

Figure 1. Effect of Water Recovery Between 85 and 97.5 Percent in Water Cost

Nanofiltration Defined

Nanofiltration is a reverse osmosis (RO) process designed to remove organics, hardness, and metals from water. The option has been pursued extensively among south Florida communities because of its ability to easily and effectively remove the trihalomethane precursors that occur naturally in the surficial groundwater. Based on projects in Hollywood, Hallandale, Fort Lauderdale, Boca Raton, Deerfield Beach, and Collier County, the co-location of a lime softening plant on the same site as a nanofiltration plant was deemed an additional benefit, since the combining of the two waters tends to reduce chemical use for both facilities. However, disposal of concentrate is problematic, so larger facilities tend to pursue Class I injection wells to dispose of the concentrate. Deep wells are not cost-effective for small facilities, so improving recovery and reducing concentrate can offer a potential solution for disposal to the sanitary sewer system. An analysis of the available concentrate disposal options indicated that the most cost-effective solution was to use the existing sewer collection system to the City of Hollywood's wastewater treatment plant, and the City of Hollywood concurred with this option. This approach significantly reduced the project capital cost, but introduced concentrate disposal fees and a maximum discharge limit of 200,000 gal per day (gpd).

Greater recovery, however, requires increases in the driving force due to buildup in osmotic pressure, which implies higher concentration gradients, concentration polarization, and increased wear on the membrane and pumping equipment (Bloetscher et al, 2006; Sethi et al, 2006). Hence, materials and construction costs will increase to address the higher pressure requirements, while operation and maintenance costs will also be higher due to power demands to achieve higher recovery. In addition, as recovery increases, more intense pilot testing is required to guarantee process reliability at full scale, which also increases the cost (Lee et al, 2005). Higher costs from higher recovery are associated with fouling or accumulation of dissolved solids on the membrane surface. Fouling typically reduces membrane life, increases energy consumption, increases maintenance costs associated with more frequent cleaning cycles, and necessitates more extensive pretreatment (Lin et al, 2005; Ng, 2004; Chen and Seidel, 2002; Vrijenhoek et al, 2001; Kilduff et al, 2000). It also creates a risk issue by complicating startup.

Pilot Testing

Florida Atlantic University (FAU) and CDM Smith undertook a project to pilot-test membrane efficiency. Initially, CDM Smith performed the first- and second-stage testing, while FAU did the third and fourth stages, but there were no issues with going to a third stage and 92 percent recovery, so the system was reconfigured to a three-stage nanofiltration, plus a fourth-stage RO, with FAU's focus on the RO portion. A preliminary cost analysis was prepared comparing systems with water recoveries at 85 percent, 90 percent, 92.5 percent, 95 percent, and 97.5 percent, and considering the following (Toro et al, 2007):

- System flows, including feed, concentrate, and permeate
- Capital and operation and maintenance costs estimates provided by CDM Smith to the City of Dania Beach in its preliminary nanofiltration test report (CDM, 2007)
- Impact of power, chemical consumption, membrane replacement, and maintenance of the fourth stage using projection B
- Raw water purchase from Broward County
- Concentrate disposal fees
- Alternative water supply fees

This study determined that it may be technically feasible to increase the recovery of nanofiltration systems up to 95 percent when the nanofiltration concentrate is treated with a low pressure RO system. Stable operation was reached in the RO pilot unit with Hydranautics ESPA2-4040 and Filmtec BW30-400 membranes when flux was between 10 and 11 gal per sq ft of membranes per day (gfd) and concentrate pH was between 6.0 and 6.2. If water recovery beyond 95 percent is implemented, it will reduce the typical concentrate volume by at least 50 percent and will increase the water usage by 5 percent. The positive impact of this increase in water recovery will be greater as the water treatment plant size is increased because of the increase in volumes processed, thus reducing the need for alternative water supplies.

In addition, the preliminary cost analysis was performed under the following assumptions (Toro et al, 2007):

- Raw water costs = $0.27/Kgal (Broward County, FY 2007)
- Concentrate disposal fees through the City of Hollywood Wastewater Treatment Plant = $2.35/Kgal (City of Hollywood, FY 2007)
- Alternative water supplies fees were estimated by the authors to cost $5.50/Kgal
- Plant life = 20 years
- Membrane life in the fourth stage = One year in the worst case scenario or five years in the best case scenario
- Interest rate = 7.5 percent

The results of the preliminary cost evaluation for the incorporation of a fourth stage and the impact of increasing the recovery up to 95 percent was cost-effective, as shown in Figure 1 (Toro, 2007).

Having crossed the concentrate barrier, the project was assigned as a capstone design project to two groups in FAU's civil design class. The students were not given a budget, but were given some threshold criteria, such as energy conservation and on-site improvements. The students found that off-grid power was difficult to create on the site without significant investments ($4.25 million for solar cells and mini-wind turbines to create the power needed to operate the plant). In pursuing the power issue, they decided to use the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) criteria. Figures 2 and 3 show the students' designs.

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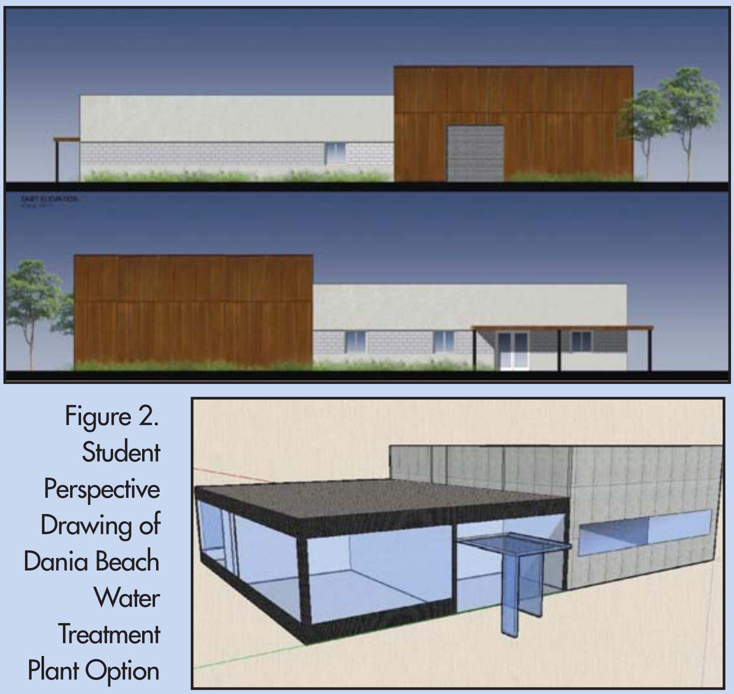

Figure 2. Student Perspective Drawing of Dania Beach Water Treatment Plant Option

Figure 3. Student Perspective Drawing of Dania Beach Water Treatment Plant Option

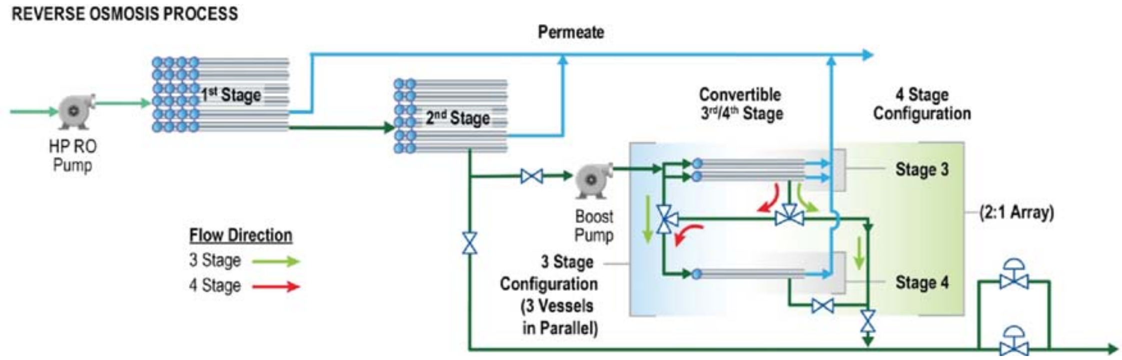

Figure 4. Nanofiltration with Third-Stage Reverse Osmosis *(courtesy of CDM Smith)*

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Procurement Process

The building program involved the following programmatic requirements:

- Optimized nanofiltration system, with areas for chemical storage, membrane cleaning facilities, pipes, pumps, and other appurtenances
- Operations center (400 sq ft)
- Two offices (150 sq ft each)
- Maintenance area (200 sq ft)
- Americans with Disabilities Act (ADA) public-access restroom with safety shower (125 sq ft)
- Water quality laboratory (400 sq ft)

In addition, the bid included on-site piping, pretreatment, nanofiltration skids, building, chemical storage, cleaning system, electrical connections, parking improvements, connections to the clear well, and other ancillary items. Having a green building was deemed a desirable goal.

A number of discussions took place on the means to bid the project. The facilities plan had identified design-build as a potential option, which had worked in Golden Gate City in 2000. Timing for funding and costs were also issues. Of even more importance to the City, using the design-build approach allowed it to obtain firm pricing for all the project costs in approximately four months, from advertisement to receiving bids. With the traditional design-bid-build approach, it is estimated that the City would have required approximately one year for completion of the detailed design and the receipt of bids and incurred over $500,000 in added fees.

Design-build was pursued using a two-step process. The first part was qualification-based: the contractor, engineer, and membrane constructor were identified and evaluated by the selection committee. Qualifications were received from seven firms. The five-person selection committee evaluated the seven qualifications, and the scoring indicated that two of the firms had much higher scores than the rest of them. As a result, the selection committee requested cost proposals from the two top-ranked firms, both of which asked for copies of the FAU student projects as a means to guide them in the bidding process.

After receiving and evaluating design-build proposals and conducting interviews with the two prequalified bidders, the City awarded the project for design and construction of the 2-mil-gal-per-day (mgd) nanofiltration process addition and associated improvements to CDM Smith, which had the lowest bid from the prequalified bidders. The successful proposal included careful scheduling of improvements for the integration of the new nanofiltration water treatment plant facilities with the existing lime softening plant. This minimized disruption of water treatment plant production during construction and prevented temporary purchases of water from the interconnection with the City of Hollywood.

One of the primary advantages of the design-build procurement process was that it saved the City time in the overall completion of the project. If the City would have stayed with the original design-bid-build procurement process, it was estimated to take 178 weeks to move from the 30 percent design to final completion. With the design-build procurement process, the time from 30 percent design to final completion took 104 weeks, which is a 74-week reduction in the project schedule.

State Revolving Fund and American Recovery and Reinvestment Act

The SRF program was identified from the beginning of the process as the solution for funding. Florida statutes provide for loans to local government agencies to finance the construction of water facilities through SRF loans. To secure the loans, the Florida administrative code rules required City authorization to apply for loans, establish pledged revenues, designate an authorizing representative, provide assurances of compliance with loan program requirements, and enter into a loan agreement. The SRF loan priority list designated the Florida Department of Environmental Protection (FDEP) Project No. DW 0604050 for financing of construction activities associated with the design and construction of the City's nanofiltration process facility. The City entered into an $8,820,923 loan agreement with FDEP under the SRF for project financing.

The design-build approach allowed the City to take advantage of a relatively narrow window of opportunity to obtain $2.55 million of American Recovery and Reinvestment Act (ARRA) stimulus funding within an $8.82 million SRF loan agreement. The ability to obtain the level of stimulus funding was a determining factor that allowed the City to proceed with the implementation of the facility. The nanofiltration process cost was estimated at $7,500,000; the actual bid cost was $7,445,923. The SRF program concurred with the design-build approach and the intent of building green.

Design and Construction

A process schematic for the design of the full-scale system is provided in Figure 4. The first two stages of the membrane treatment system consist of a nanofiltration system that is designed to operate at 90 percent recovery. An interstage booster pump was provided to boost the pressure of the concentrate leaving the second stage of the nanofiltration unit and feed it to a third-stage low-pressure reverse osmosis unit. This provides the City with the flexibility to meet its concentrate discharge limits when operating at recoveries in the 92 percent range in the three-stage configuration, or to increase system recovery by operating in a four-stage configuration. Operating at this higher recovery provides the City an opportunity to reduce its concentrate disposal and raw water purchase costs.

The design also incorporated elements of green building for possible LEED certification and for function, aesthetics, security, and safety.

The current plant remained in service at all times. Operator safety and plant security were both important issues. Storm drainage was required to comply with requirements of the South Florida Water Management District (SFWMD) and the Broward County Environmental Protection Department (BCEPD). Figures 5 to 8 show construction stage photographs; also noted are the LEED credits that are incorporated with these improvements. Figures 9–14 outline the finished process.

Leadership in Energy and Environmental Design

The FAU students identified a pathway for LEED certification of the City's plant. The LEED is a process to highlight aspects of building projects that encompass the concepts of green building. There are five categories that are used to evaluate the buildings:

1. *Sustainable Sites* – The intent is to use an existing disturbed site, as opposed to a virgin site. In addition, the idea is to increase green space on the site. The nanofiltration facility is located on the same site as the current lime softening plant, which will be refurbished and available to supplement the nanofiltered water. The improvements integrate the new nanofiltration water treatment plant facilities with the current facilities, and coordination of construction minimized disruption to current activities. The final site plan proposed to increase the amount of perviousness on the site by reducing asphalt and removing unused structures and pervious pavement. To encourage employee use of alternative transportation, spaces were provided for carpooling, alternative-fuel, and low-emission vehicles. A bus stop is located at the boundary of the site. Showers and a bike rack were provided as well.
2. *Water Use* – The plant will have a minimum recovery of 90 percent, which is greater than most membrane systems. The goal to achieve 95 percent will improve plant efficiency by 10 percent. In addition, low-flow toilet fixtures, waterless urinals, and low-flow faucets and showerheads were used. The project expects to save half the water use compared to a similar structure, or roughly 100,000 gal per year, in addition to the increased water savings from process improvements (up to 36 mil gal per year). The City altered its irrigation ordinance to preclude the need to irrigate when Florida-Friendly Landscaping™ plants are used. Rainfall capture for runoff storage and treatment (worth two LEED points) were installed.
3. *Energy and Atmosphere* – This was difficult, since the plant process is power-intensive. However, lights were changed to compact fluorescent bulbs, eliminated, or turned off when not in use (automatically), and variable frequency drives (VFDs) were employed to increase energy efficiency. The project evaluated energy recovery turbines on the permeate and concentrate streams. The building includes a white roof, which has been found to lower attic temperatures by 30 degrees (to under 10 degrees above ambient). Insulation was provided to increase energy efficiency. The heating, ventilation, and air conditioning (HVAC) system uses the high seasonal energy efficiency ratio (SEER). Automatic systems to adjust temperatures are employed. The goal is to reduce energy use by 30 percent over a similar building, in addition to process improvements. Interior energy use is expected to be reduced by 2 kW hrs, while the increase demands for the nanofiltration plant may save 20-30 kWhr. The actual submittal captured significant LEED points for energy savings.
4. *Materials* – Recycled concrete and steel were available locally. All materials met the "Buy American" clause and many were purchased within 500 mi of the site, which reduced

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Figure 5. Existing Lime Softening Water Treatment Plant

Figure 6. Erection of Steel for Membrane Building Using Recycled Local Materials

Figure 7. Nanofiltration Building Showing White Reflective Roof (Reduced Heat Island Effect) and Concrete Walls Built From Recycled Local Materials *(courtesy of CDM Smith)*

Figure 8. Operators area, which includes low volatile organic contaminant paint and glue for tile, carpeting, and cabinetry, which was good for four LEED points. Also, 95 percent of the building receives sunlight (another LEED point).

Figure 9. Sand Separators (Local Materials) Used to Remove Bulk of Sand from Raw Water

Figure 10. Chemical Feed Systems and Post-Treatment Degasifier to Remove Excess Carbon Dioxide

Figure 11. Cartridge Filters Used to Remove Sand and Particulates Prior to Membrane Treatment

Figure 12. Membrane Skid Testing Bank

Figure 13. Membrane Skid

Figure14. Final Treatment Plant Site with Green Areas, Stormwater Swales, and Improved Site Access *(courtesy of CDM Smith)*

Figure 15. Building Dedication on March 27, 2012

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transportation costs (and achieved two LEED points). All concrete and steel removed on the site was recycled to the maximum extent possible and all construction debris was separated and recycled to minimize landfill impacts. Crushed concrete and asphalt can easily be recycled, which was a goal of the project. The contractor was able to achieve over 95 percent material recycling and recovery, thereby reducing landfill costs.

5. *Indoor Air Quality* – The intent is to reduce air pollution, which means no materials with volatile organic contaminants (VOC), paints, or finishes were employed. Smoking will be prohibited in the building and the HVAC system will be attuned to inside conditions and occupancy. Low VOC materials were used on the rugs, floor glue, paint, and cabinetry. Exterior solar lighting was used to reduce power costs.

These innovations, including the increased water recovery and the potential to use the facility for educational purposes, helped to make this facility the first LEED-certified process building at any water or wastewater plant in the United States. The LEED certification process was administered by FAU. Students helped with some of the templates submitted for the LEED process. A total of 43 points were secured (39 are needed for Gold certification). Dedication of the facility occurred on March 27, 2012 (Figure 15) and the LEED Gold certification was received in April 2012.

A Showcase

Education was part of the plan for the LEED certification. The City already had constructed a LEED Gold-certified library building in 2008; the nanofiltration building was its second such builidng. However, water plants are somewhat uncharted territory, as only a few have attempted certification, and only two of those are certified or Silver-certified. The building was also recognized by the U.S. Environmental Protection Agency, which awarded the project the 2010 Drinking Water State Revolving Fund (DWSRF) Award for Sustainable Public Health Protection. This award recognizes the most innovative and effective DWSRF projects that further the goal of clean and safe water through exceptional planning, management, and finance.

The Florida Institute of Consulting Engineers (FICE) awarded the project its Engineering Excellence 2012 Grand Award, which recognizes firms in Florida for their innovative projects and studies. The facility also won an Honor Award from Florida Design-Build in the water/wastewater category. In addition, it won a Design Build Institute of America (DBIA) national award, which is presented to projects that demonstrate successful application of design-build best practices as defined by its manual of practice.

The American Council of Engineering Consultants (ACEC) provided the plant with its 2012 Engineering Excellence National Recognition Award, which honors the year's most outstanding engineering accomplishments and has become the engineering industry's highest profile award. Finally, FAU's Department of Civil, Environmental, and Geomatics Engineering is the grand prize winner of the 2012 National Council of Examiners for Engineering and Surveying (NCEES) Engineering Award for Connecting Professional Practice and Education due to the involvement of students in the project.

Summary

Many parties were instrumental in the design and construction of the new nanofiltration plant for the City of Dania Beach. The FAU faculty and student researchers within the College of Engineering and Computer Science, engineers, architects, and construction personnel from CDM Smith and the City of Dania Beach all worked together to complete the upgrade of the facility, and to make it the first water treatment plant in the world to receive a LEED Gold certification by the U.S. Green Building Council. An innovative membrane system design consisting of a two-stage nanofiltration membrane system with a convertible third-stage reverse osmosis unit was developed by FAU and CDM to provide the City the flexibility to operate at higher system recovery in order to minimize costs for raw water supply and concentrate disposal. The convertible third stage can either operate as a single-stage to allow operation at 92 to 95 percent recovery to meet concentrate disposal requirements, or it can easily be reconfigured in a third and fourth stage 2:1 array to maximize system recovery to reduce operating costs, something not done before. The membrane system design also includes the flexibility to achieve product water quality goals with variable raw water quality from both the City's wellfield and the Broward County wellfield.

Stimulus project funding was a critical factor in making the plans for a new 2-mgd nanofiltration water treatment facility to become a reality for the City. In order to meet the application schedule for the stimulus funding, the City changed the procurement process from a design-bid-build to design-build approach. The design-build approach enabled the City to obtain firm pricing for the project in approximately four months, whereas with the design-bid-build approach, obtaining firm pricing would have taken over a year, which may have cost the City the opportunity to obtain stimulus funding. The design-build approach not only expedited project execution sufficiently to save the opportunity for stimulus funding, but it also reduced the overall projected execution schedule by 74 weeks. In addition, design-build execution resulted in project cost savings of several hundred thousand dollars. Finally, the project has received five awards to date, which means recognition for the City as an innovative community, and one that is receptive to innovation and redevelopment.

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