Controlling Your Own Water Destiny

How the City of Clearwater Addressed the Politics and Implementation Of Florida's First Arsenic-Removal-Prior-to-Membranes Facility

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In 1999, the city of Clearwater initiated a study to determine its water supply future. The city examined whether it could economically sustain its water production facilities for the long term and, in so doing, reduce its reliance on regional supplies while providing its rate payers a buffer against future regional water rate increases. The answer was yes.

Clearwater has produced water from its local wellfield since the 1920s. Due to increased mineralization, notably iron and chlorides, over time officials abandoned certain wells and shifted production away from the coast and southern portion of the city. This shift in production has reduced the amount of water produced from the city's own wells to approximately 3 million gallons per day (mgd). To cover its additional water needs, Clearwater bought approximately 12 mgd from Pinellas County, whose water is supplied by Tampa Bay Water, meeting a total average demand of about 15 mgd.

The cost of water has increased slightly over time, and the city was buying water at a cost of $1.79 per 1,000 gallons; however, due to increased capital and operations changes, the price of water is destined to increase in the near future. Increases in regional water costs are forecast to be as high as $2.78 per 1,000 gallons in 2006.

Water Supply Conditions in Clearwater

The city of Clearwater is located in Pinellas County in west-central Florida. The city serves a population of about 108,000 with approximately 36,000 customers. The water supply system includes three ground storage reservoirs.

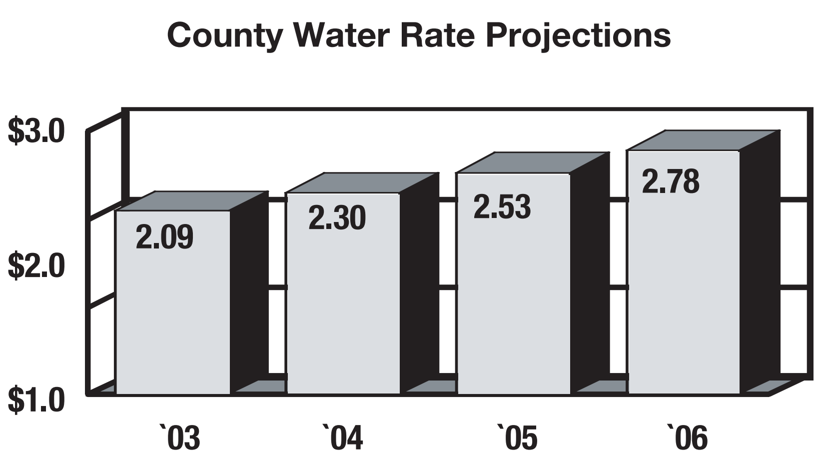
- Reservoir 1 is located in the central portion of Clearwater; contains pumping facilities, disinfection facilities, and a 5-million-gallon (mg) storage tank; and produces approximately 1.4 mgd.
- Reservoir 2 is located closer to Tampa Bay; also contains pumping facilities, disinfection facilities, and a 5-mg storage tank; and produces 0.7 mgd.
- Reservoir 3 is located in the northern portion of the city; features pumping facilities, disinfection facilities, and two 5-mg storage tanks; and produces approximately 1.0 mgd.

Water is blended with regional supplies at Reservoirs 2 and 3. Reservoir 1 is served by local production, although water at this facility can also be blended with distribution system water. The remaining balance of about 12 mgd was purchased from Pinellas County.

City Looks for Ways To Control its Own Water Destiny

With water costs rising, the city began exploring ways to control its own water destiny. In 1988 Briley, Wild & Associates studied Clearwater's water supply situation and reported that reverse osmosis (RO), or membrane treatment, was an option; however, if no additional treatment were provided, the city would need to purchase additional water from regional supplies. During this time period, the city was producing approximately 6 mgd from its own wellfield, with pumping reduced significantly over the subsequent years.

Table 1: Water Rate Projections for Pinellas County



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In 1996, SDI and CDM prepared a wellfield management plan that included provisions for control of chlorides by controlling pumping rates and dispersing wells. That plan also concluded that treatment would be necessary to sustain future production.

In 1999, Clearwater requested that McKim & Creed perform a study to determine if the city could produce its own water supplies while maintaining costs below that of purchased water. That same year, the city submitted a Water Use Permit (WUP) renewal application to the Southwest Florida Water Management District for continued use of its wellfield.

In the early stages of this permit application, Clearwater requested a 6.25-mgd permit, although the former permitted quantity was 8 mgd. During the permit period, production dropped to about 3 mgd, due to increased mineralization, including chlorides. The water management district required a commitment from the city to build treatment facilities to produce quantities higher than 3 mgd. The district also required the city to continue monitoring chloride levels, as well as any impacts to adjacent legal users as withdrawal quantities were increased.

The McKim & Creed report, published in 2000, identified membrane technology as the most cost-effective method of treating well-source water within city limits. The report also focused on methods to control trihalomethanes (THMs) in the city's water supply (at that time, Tampa Bay Water had not yet decided on using monochloramines for disinfecting the regional supply).

The study indicated that the city could use membrane technology to remove salts and to reduce organics at two of its reservoir sites and blend at the third site to meet forthcoming Clean Water Act regulations on THM formation in drinking water that were to go into effect in December 2002. McKim & Creed also reported that the city could boost its water production from 3 mgd to 5 mgd with membrane technology, at a cost of $1.68 per 1,000 gallons. Additionally, membrane technology would enable the city to retain production from its wellfield while managing increased chlorides concentration.

The $1.68 per 1,000 gallons was based on the contingency that the city construct an $8.2 million facility, with anticipated operations and maintenance costs of $1.2 million annually. Those estimated costs were revised during construction, with construction costs reduced to $8.1 million and operating costs projected to be $1.0 million, which lowered the unit cost to $1.51 per 1,000 gallons.

The new facility was designed to provide 3 mgd, combined with 2 mgd from the remaining wells feeding Reservoirs 2 and 3, for a total city production of 5 mgd. The remaining 10 mgd required to meet city customer demands will be purchased from Pinellas County.

Regional Solution Considered

While the city was exploring ways to become more self-sufficient in terms of water production, Tampa Bay Water was reviewing options for increasing regional supply to offset future demands. Tampa Bay Water was driven by time; the agency needed to get additional production facilities online within about a year, due to regional permit limitations in light of forecast demand.

Once the city had decided to build an RO water facility, Tampa Bay Water offered to take control of Clearwater's water production facilities once the plant was built. This was unacceptable, since the city would still end up paying regional water rates of $1.79 per 1,000 gallons and higher, which directly impacted its customers. Clearwater's goals were to reduce the impact of future regional water rate hikes and increase production from local wellfields, while meeting anticipated regulations.

Tampa Bay Water then proposed a design-construct agreement whereby Tampa Bay Water would, for a guaranteed price, design and build the facility, which would then be maintained, owned, and operated by the city. This effort was supported by water management district co-funding, and Clearwater and Tampa Bay Water agreed to come to terms on a guaranteed maximum price by February 2001.

Initial discussions with Tampa Bay Water revealed that Reservoir 1 would be the best location to build the treatment plant, since the city already had plans to rehabilitate and modify four well sites serving this facility, and sufficient area existed to accommodate the additional footprint. A project group was established—including representatives from Tampa Bay Water, city staff, consultants, and a Clearwater citizen interested in the project—and charged with developing the framework for the design-construct agreement.

The group discussed a number of issues, including destination and anticipated characteristics of the concentrate from the plant, review of well operational reports and the potential to achieve additional production of 2 mgd from city wells, siting of facilities, public involvement, and costs. One key issue was understanding the nature and effects of the concentrate stream and where this flow should go. Options included: 1) a reject water injection well, 2) gulf or bay disposal, and 3) receiving this flow at the city's wastewater treatment plant(s).

The team visited Dunedin's membrane plant to review operation and learn from Dunedin's experience. The first two options were costly and presented potential problems with permitting. Since evaluations of the ability for the city's wastewater treatment plant to acceptably operate with concentrate flow blended with the raw wastewater flow proved positive, the decision was made to send the concentrate to the city's wastewater treatment facilities.

The City had the opportunity to transfer this flow to either its Marshall Street Advanced Pollution Control Facility (APCF) or Northeast APCF, and plans were made to

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Table 2: Unit Costs

	Budget	Actual
Capital	$8.2 M	$8.1 M
Annual O&M	$1.2 M	$1.0 M
Unit Cost [$/1000 Gal.]	$1.68	$1.46

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install concentrate pipelines to both facilities in the event of future capacity issues. The city's wastewater collection system was studied to ensure that sufficient current and future capacity existed at the plants, and a toxicity study concluded that there would not be adverse impacts on the wastewater treatment plants' permit compliance by receiving the concentrate from the water plant.

Wellfield reports were studied to determine which wells should be reactivated, which should be rehabilitated, and what additional water production could be achieved. These reviews showed that water production could be increased from 3 to 5 mgd.

The southern portion of Clearwater's Sid Lickton Park, an area located near Reservoir 1 and featuring baseball fields and open space, was selected as the site for the new plant. Renderings were produced and plans prepared that illustrated the layout of equipment, chemicals, and yard piping.

Meeting Format Proves Key To Addressing Citizen Concerns

Three public meetings were conducted in the early planning stages. The first public meeting was almost a disaster. Although well planned from both the city's and Tampa Bay Water's points of view, there was public outcry about potential sinkhole development from the proposed increase in water production.

Both staffs studied this ahead of time and anticipated questions. The meeting was conducted in an open forum, with the public utilities director giving a prepared speech, followed by a panel discussion.

This format disintegrated into a chorus of concerns over current subsidence and potential for increased sinkhole activity. The explanations provided—that the city actually had experienced higher production levels in the past without incident, that the geology was favorable for water production without sinkhole development, and the fact that the water management district would not issue a permit for increased production if sinkhole development was thought to be likely—fell on deaf ears. Other issues that the city and Tampa Bay Water felt were of more concern, such as more self-reliance for water supplies, a hedge against regional rate increases, and the application of membrane technology to continue meeting safe drinking water regulations, were not discussed at any length by the public.

A second public meeting was organized, using information stations in lieu of a presentation, to better explain all aspects of the project without the likelihood of the "group effect" of outbursts. Experts were assigned specific areas: plant layout and siting, water conservation issues, geology/sinkhole formation potential, regional water supply issues, and proposed pipeline routings.

The geology station was attended by a number of people throughout the evening, and a professional geologist provided explanations of area geology for individuals and small groups. The information presented was the result of evaluations conducted under direction of the city of Clearwater regarding the impacts of increased sinkhole activity that may result from increased groundwater withdrawal.

This evaluation concluded that sinkhole activity would not necessarily increase, since water production had been historically higher than the proposed withdrawals without evidence of sinkhole inducement and that the knowledge of the geology in the wellfield area indicated that adequate separation of the Upper Floridan Aquifer and the surficial aquifer existed.

The reported data was evaluated and reviewed by the city staff, commission members, Tampa Bay Water staff and consultants, as well as the project geologists. The results of this evaluation and review effectively addressed the concerns of the community, while avoiding public confrontation.

As the preliminary design effort proceeded and the details on the agreement between Clearwater and Tampa Bay Water were developed, there came a point of separation between the two parties. The guaranteed maximum price, including all items requested by the city (emergency power back-up, telemetry, etc.) was $9.6 million—$1.4 million above the original estimate. This was a deal-breaker.

Clearwater decided to pursue the project on its own at the estimated capital cost of $8.2 million and commissioned McKim & Creed to complete the design of the wellfield improvements, oversee construction of raw water and reject water piping, and complete the design of the membrane treatment facility. After the city assumed management of the project, review of the original siting location revealed that the facility would be more effectively located adjacent to existing Reservoir No. 1 facility in the northern portion of Sid Lickton Park.

A third public meeting was held to obtain public comments on the revised siting location and address any lingering questions regarding geology and the formation of sinkholes. This meeting was sparsely attended, and the city commission subsequently approved the new siting location, equipment purchase, and facility construction contracts.

Treatment Issues Addressed In Design of New Facility

Clearwater's water supply is produced from the primarily fresh water zone of the Upper Floridan Aquifer on the Pinellas Peninsula, but the city's production of water from the wellfield has continued to decline, due to increasing chlorides and iron levels. Without treatment facilities to address these constituents, the city was forced to reduce pumpage to maintain targeted water quality; therefore, the primary treatment objective of Clearwater's new facility was to meet long-term increases in chlorides from the existing wellfield.

With the proposed investment in treatment capability, the city can increase production from groundwater sources. The raw water quality is considered to be fresh water, with a chlorides concentration anticipated to be 250 parts per million (ppm), increasing to 500 ppm or greater over a 25-year time frame. These concentrations are less than concentrations expected from the deeper brackish water sources evaluated by the city and Tampa Bay Water in preliminary studies.

The raw water from the Upper Floridan Aquifer has the best water quality and is less costly to treat than the brackish water source. Additionally, the decision to use the fresh water zone was driven by the methods available for cost-effectively disposing of the membrane concentrate and the time required for permitting disposal options.

Arsenic became a significant treatment process consideration, due to the EPA's arsenic-in-drinking-water rule that reduces the existing 50 parts per billion (ppb) standard for arsenic in drinking water to a 10 ppb standard. The rule went into effect February 22, 2002, and systems must comply with the new 10 ppb standard by January 23, 2006.

McKim & Creed evaluated numerous approaches to treating arsenic, iron, and chlorides. Air stripping was reviewed for possible oxidation of iron and for removal of hydrogen sulfides. It was determined that the level of sulfides in the raw water was not an overriding cause of concern.

Arsenic can be removed by membrane treatment; however, while evaluating treatment approaches, the valence state of arsenic was tested to determine the effectiveness of removal. The arsenic was found in a higher percentage of As +3 valence form, with membrane removal effectiveness estimated at approximately 70 percent. Oxidation to As+5, with subsequent filtration, improves removal efficiency above 95 percent. Although oxidation prior to membrane treatment is not normally practiced, the removal rate for arsenic via membrane treatment was not considered sufficient for the levels measured.

Another consideration in evaluating treatment systems was the need to remove iron prior to membrane treatment and to lower the raw-water Silt Density Index in order to effectively extend the life of the membranes and reduce cleaning. This pretreatment approach first considered an activated filter media to reduce arsenic and iron. The basis of design centered on the mineral greensand treatment approach that would require regeneration of the media.

During evaluation of proposals by reverse-osmosis equipment manufacturers (ROEMs), alternative strategies were developed and evaluated. The final design of the pretreatment system was based on more traditional multi-media filters in vertical pressure filter vessels. The pretreatment system provides for sodium hypochlorite chemical feed into the raw water stream to oxidize the arsenic and iron in the raw water. Ferric chloride is also injected at a dosage of about 2 ppm to enhance precipitation of iron and arsenic and removal through the dual media filters.

This approach to filtration was selected over greensand filtration because of the cost considerations of greensand media and the absence of high concentrations of manganese. The pretreatment system will treat 100 percent of the raw water flow to Reservoir 1 in order to provide iron and arsenic removal.

Two-stage membrane treatment follows pretreatment for a portion of the flow stream. The bypass flow of approximately 13 percent of the feedwater flow enhances stabilization of the finished water from the membrane treatment.

The membrane treatment step is preceded by chemical addition of up to 4.0 ppm of an anti-scalant, about 28 ppm of sulfuric acid for pH adjustment, and up to 14 ppm of sodium bisulfite dechlorination chemical. Dechlorination protects the membranes from sodium hypochlorite feed introduced in the previous filtering step. The membranes are also protected by standard cartridge filters, designed to remove particulate matter in the range of 0.1 to 50 microns prior to membrane treatment.

The membranes that were selected for use in the new facility are the Osmonics DESAL® AG8040F spiral wound polyamide (PA) elements, which are designed to handle the relatively low TDS levels present, but are capable of treating the increased TDS levels anticipated over time. The design operating pressures are expected to be in the 175 psi range. Recovery is expected to be in the 80 percent range. Blending with bypass flow occur downstream of the membrane system.

One area of concern for the city was the impact the new treatment process would have on the existing, aged distribution system. At the same time that Clearwater was preparing to alter water quality by implementing the membrane treatment facility at Reservoir 1, the other city water source was being altered as a result of Tampa Bay Water's development of new water sources.

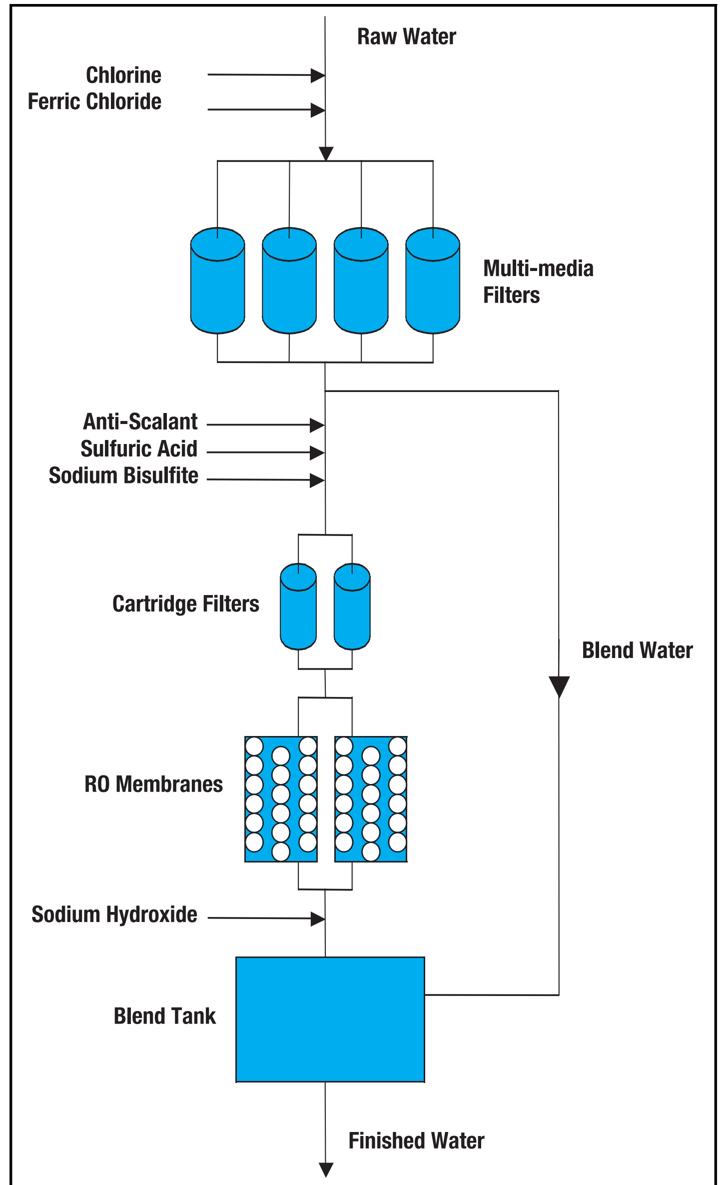

Figure 1: Reservoir No. 1 Water Treatment Plant Process Diagram

To address possible impacts and to develop design guidelines to minimize those impacts, pipe loop studies were conducted, utilizing membrane-treated water from a pilot unit. The studies determined that a target pH of 7.8 to 8.2, while higher than traditional water sources, would result in a more stable water source and minimize impacts to the distribution piping system. Thus, post-treatment stabilization using sodium hydroxide feed and blending with the bypass flow was determined to provide a stable finished water for city customers, with an alkalinity of 80 to 100 and a pH of between 7.8 to 8.2. Figure 1 provides an overview of the process being implemented.

The cost of operating the new facility was considered in determining the feasibility of the project. Specifically, costs for labor, chemicals, electricity, concentration disposal, and other operating factors were examined. Preliminary estimates anticipated operating costs would be approximately $1.2 million annually. After a review of treatment costs as projected by the ROEM selected for this project and the city's development of more detailed staffing plans, the costs for operating the facility have been updated.

The highest operating expense was expected for chemicals used in pre- and post-membrane treatment, at an annual cost of $280,000 to $300,000, or approximately $0.26 per 1,000 gallons. Another significant expense was expected to be operation and maintenance labor, assuming operators staff the plant for an estimated cost of $50,000 a year, including benefits, or $0.23 per 1,000 gallons.

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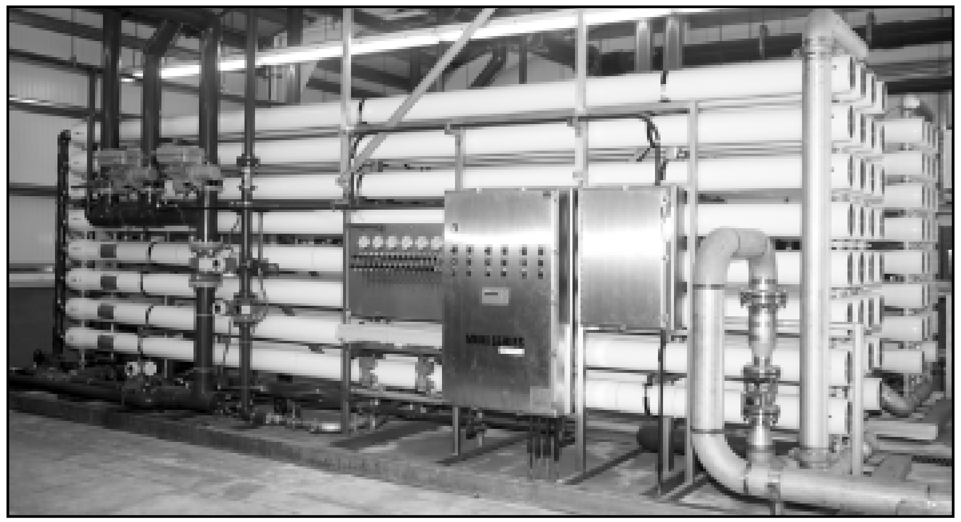
The dual media filters, together with chemical pre-treatment, are the key elements for arsenic removal, as well as removal of iron and other particulates from raw water.
PHOTO BY LEIGH WHITLEY, McKim & Creed



Pictured here are the two reverse osmosis membrane skids, which provide an installed capacity of approximately 1.0 mgd per skid, with roughly 1.0 mgd of water bypass for blending with permeate for final stabilization.
PHOTO BY AEROPHOTO

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Power consumption was projected to be 4,700 kilowatt-hours per day at $0.05 per kilowatt-hour, for an annual cost of $90,000, or $0.08 per 1,000 gallons. Costs for cleaning and cartridge filter replacement were expected to be $0.03 per 1,000 gallons. Additional costs for membrane replacement funding, pumping of concentrate, and other miscellaneous expenses brought the total operating cost with capital recovery to $1.46 per 1,000 gallons, which is below the originally estimated cost of $1.68 per 1,000 gallons.

The original RO water treatment plant design data submitted to the Pinellas County Department of Health (PCDOH) identified design flow of 3.66 mgd and future flow of 5.00 mgd. The new construction authorized under the permit issued by the PCDOH allowed for the new water treatment facilities to have an existing permitted capacity of 3 mgd, with a future design capacity of 5 mgd. Specific Condition Number 11 classified the water plant as a Category 1 Class A water treatment plant, requiring a Class C or higher operator 24 hours a day for 7 days per week, with the lead/chief operator being a Class A.

City operations staff met with the PCDOH to request a reclassification from a Category 1 Class A facility to a Category 1 Class B facility. A letter was sent with this request, explaining that, although designed for expansion for up to 5 mgd, the plant will initially have an influent flow of 3.66 mgd and a finished water flow of 3.0 mgd. The level of automation was also described and included the following:

- An in-plant Supervisory Control and Data Acquisition (SCADA) system programmed with set points for automatic RO shutdown and process control.
- Wells that are controlled and monitored by the in-plant SCADA system, using a matrix for individual well and flow control to the plant.
- An external SCADA system that monitors the citywide SCADA with alarms and dial-up notification to the on-call operator.

Based on this information, the city of Clearwater formally requested, and received, the reclassification of this facility from a Category 1 Class A facility to a Category 1 Class B facility. When the facility is expanded to above 3 million gallons, the city will re-evaluate the classification and permit.

Contracting Equipment Separately From Construction Reduces Cost, Establishes Relationship with Vendor

A unique aspect of this project was the contracting methodology utilized. The city solicited bids from manufacturers for the membrane equipment and separate bids for general construction services. The ROEM was responsible for building, delivering, and testing all filter systems, membranes, and chemical feeds, and for providing staff training. The general contractor was responsible for building the facility and all associated piping, blend tanks, backwash tanks, and pumping equipment.

Contracting for equipment and construction services in this manner offered several advantages to the City, including:

- Reduced "mark-up" on the purchase price of the equipment by buying directly from the ROEM.
- The ability for the city to be directly involved in selecting the ROEM.
- The ability to evaluate ROEMs on the basis not only of price, but also process design support, maintenance support, experience, and company strength.
- The opportunity for the city to establish a direct working relationship with the ROEM for future support of the RO systems and training.
- Compression of the overall schedule by getting a head start on equipment procurement.

This project delivery method came with disadvantages as well, which included a higher degree of coordination required by the city and McKim & Creed, and a higher level of schedule coordination and communication with, and between, the ROEM and the general contractor.

To address these issues, Clearwater required the ROEM to provide a process guarantee for one year of operation, during which the ROEM conducts all testing to ensure the equipment meets the city's water quality requirements. Additionally, the city

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had the ability to obtain and review drawings and preliminary submittals from the vendor prior to completing the design and bidding the general construction package, which further reduced potential conflicts.

Clearwater conducted a two-step selection process for the ROEM. The first step was issuing a Request for Qualifications to solicit qualifications statements and preliminary equipment proposals. The ROEMs' Statements of Qualifications were evaluated for company qualifications and background, relevant experience, financial capability to meet the project requirements, and the technical and operational support capabilities.

From the original ROEM submittals, four firms were selected to receive the Request for Proposals (RFP) from the city. The RFP solicited not only prices for the treatment equipment, but also process details, along with expected operational costs of the proposed equipment. The proposals were evaluated for technical merits, process performance, capital cost, and operational costs. The top-ranked proposers were selected and a contract for equipment purchase was finalized. The successful proposer for the RO equipment was Osmonics Inc.

The water treatment plant facility construction, including the installation of the equipment being supplied directly by Osmonics, was bid as a separate contract. The successful bidder for this work was Westra Construction Company Inc. The raw water pipelines and the concentrate force main were installed under a separate contract that utilized an existing unit-priced contract for similar pipeline work, in order to expedite this portion of the overall improvements program. The well rehabilitation work was contracted directly with the city by Hausinger Inc.

Current Status

The three primary components associated with this project were:

- Wellfield improvements.
- Construction of raw water piping and concentrate disposal piping.
- Construction of the water plant.

The initial wellfield improvements were completed in 2002. Existing wells have been video logged, cleaned, and fitted with new casing liners. The antiquated SCADA system, which was limited to well monitoring, has been upgraded with a system that allows both control and monitoring.

Two new wells have been added to the wellfield system and two previously abandoned wells have been reactivated, expanding water production capability. Water production has increased with additional efforts being made to continue increasing production of groundwater to meet targeted levels.

Pipeline construction was completed in 2002 to connect the new wells and the reactivated wells with the raw-water pipe system. A concentrate force main was also completed in 2002 to connect the lift station serving the water treatment plant to the existing gravity sewer system.

Approximately 20 percent of the raw water delivered to the new facility is rejected as either filter backwash or concentrate from the membrane treatment. This discharge water is transported, via the new reject water force main, to the city's Northeast Advanced Pollution Control Facility for treatment and disposal, with the capability to also divert some portion of flow to the Marshall Street Facility.

Construction on the RO plant began in October 2002 and was completed in November 2003. The grand opening ceremony of the facility was held on December 16, 2003, and the facility has been operating continuously since that time. Currently, the operating costs of the facility are about $930,000 per year, which includes about $500,000 per year to purchase chemicals, cartridge filters, and electricity to operate the facility.

This is Florida's first arsenic-removal-prior-to-membranes facility, one of the first in the U.S. to comply with the EPA's new arsenic standard, enabling the city of Clearwater to proactively manage its own water destiny.