Money Saving Ideas from the North Lee County Reverse Osmosis Plant Expansion Project

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Lee County Utilities (LCU) began as a small community water utility in 1968, and has grown with southwest Florida over the past few decades. Today, LCU owns and operates six water treatment plants that provide services to more than 255,000 customers in unincorporated areas of Lee County.

The LCU North Lee County Water Treatment Plant (WTP), located in North Fort Myers, treats brackish water using reverse osmosis (RO) and provides needed capacity in the County's north service area. Since beginning operation in October 2006, the WTP's 5-million-gallon-per-day (mgd) nameplate RO capacity had never been met because of design deficiencies that did not allow the WTP the ability to respond to changes in feed water quality, and process control deficiencies that resulted in, among other things, irreversible fouling of the RO membranes. In addition, the WTP staff struggled to deal with reliability issues pertaining to corroded equipment, maintainability of chemical injectors, and adequacy of sulfide removal.

In 2009, LCU began a project to restore the facility's nameplate capacity, address deficiencies, and expand the RO production capacity to 10 mgd. To maintain full customer service, LCU required that the expansion project be substantially complete by March 15, 2011, meaning that it would be able to produce the required flow rates at the desired quality. The urgency stemmed from the WTP's companion plant, the Olga WTP, which has historically needed to reduce flows or shut down during the spring season, beginning in mid-March.

The LCU decided to use a progressive design-build delivery model for the rehabilitation and expansion of the WTP to take advantage of multiple benefits:

1. *Fast-track schedule.* By reducing the engineering design deliverable to only what was required for permitting and definition of project scope, and allowing prepurchase (direct purchase by LCU) of long-lead equipment, LCU was able to shorten the overall project delivery schedule by eight months, making the March 15, 2011, substantial completion deadline plausible.
2. *Most qualified design-builder.* Conventional design-build delivery would require LCU to receive multiple bids from a variety of firms that may or may not have addressed its staff's needs or preferences. Following the progressive design-build delivery model allowed LCU to select and work closely with the most qualified design builder to develop the guaranteed maximum price (GMP) during the progressive design phase, thereby ensuring that the scope of the GMP met LCU's needs, while still allowing the design-builder to offer cost-saving features to the project.
3. *Single-party performance liability.* The ability to assign a single entity, the design-builder, the responsibility to guarantee that the design and construction would result in a project that would reliably achieve its nameplate capacity over the long term. During the progressive design phase, LCU worked with the design-builder to establish the conditions for a performance warranty. The cost of this performance warranty was incorporated into the design-builder's final GMP proposal.
4. *Well-defined scope and firm GMP.* The progressive design-build method allowed LCU to incorporate operations and maintenance staff values and preferences during the design phase of the project, before a GMP was offered. This approach reduced costs associated with changes that would have been required using other delivery methods.

The progressive design-build delivery method used for this project, and highlights of the time- and money-saving ideas that were implemented during its delivery, are presented.

Source Selection and Contracting Approach

As LCU began to identify the need and scope of this project, it recognized how the previous delivery method had failed when the plant was originally built. For the original project, LCU entered into separate contracts with an engineer who designed the facility, and a construction manager who delivered the work using a "construction management at risk" contract based upon a guaranteed maximum price that was generated, based upon 90 percent design plans. When LCU started operating the plant, the RO process did not perform as expected, and both the engineer and construction manager pointed fingers at each other. The LCU was left with a project that did not meet its needs or expectations, and was not able to resolve the performance problems.

A delivery method was sought by LCU for the rehabilitation and plant expansion project that would resolve its previous problems. To complicate this already technically complex project, LCU also needed the expanded plant capacity in a relatively short time frame to meet the water demand of its customers. By using the design-build project delivery method, LCU was able to designate a single point of responsibility for the project, holding it responsible for both the on-time delivery and performance of the plant. This also enabled LCU to minimize its administrative burden and avoid being the "middle man" in coordinating or resolving any conflicts between the engineer and contractor. The LCU's qualifications-based procurement encouraged the selection of a design-build team that had previously worked together, so teamwork and trust between team members were already established.

The design-build team selection process for the WTP expansion project was initiated by LCU to select the most qualified design-build team, which would then work collaboratively with the utility to provide an on-schedule delivery that would: (1) modify the facility to achieve the original nameplate production capacity of 5 mgd, (2) expand the

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production capacity from 5 mgd to 10 mgd, and (3) improve operability and maintainability. The sections that follow describe the selection of the design-build team and the contract format used for the WTP expansion project.

Design-Build Team Selection Process

The LCU used a direct selection method based solely on qualifications to choose the design-build team. This selection method was best suited to minimize the owner's risk by allowing selection of the most capable team to deliver this progressive design-build project. Prospective design-build teams submitted their Statement of Qualifications (SOQ) on July 28, 2009, in response to LCU's Request for Qualifications for Progressive Design Build Services for On-Schedule Delivery of the North Lee County WTP Expansion Project (RFQ 09-08). Ten SOQs were received, and after reviewing them, LCU invited three design-build teams to give an oral presentation to its Evaluation Committee. A history of this selection process, including audio taped presentations and Evaluation Committee deliberations can be found on LCU's website: http://www3.leegov.com/contracts/projdetail_T12_R483.htm

Criteria considered by LCU's Evaluation Committee during the selection process included:

- Submission of all required forms per the RFQ.
- Similar projects and experience of the design-build team related to design, permitting, and construction.
- Skills and experience of the project team, including those specific to RO water treatment systems.
- Project scope, approach, and understanding of establishing a collaborative working partnership with the owner; delivering a successful on-schedule project with special considerations and possible difficulties in mind; facilitating permitting, utility, and agency coordination; applying innovative approaches; and executing constructability reviews.
- Access to special equipment that may benefit the project.
- Comments and/or concerns with the standard contract included in the RFQ (DBIA Document No. 530 – Standard Form of Agreement Between Owner and Design-Builder – Cost-Plus Fee with an Option for a Guaranteed Maximum Price).
- Proof of meeting the insurance requirements.
- Ability to obtain a public payment and performance bond.
- Oral presentation given by the short-listed firms.

Through this process, LCU selected the contractor-led design-build team of Mitchell & Stark Construction Company (in association with Carollo Engineers Inc. and Harn R/O Systems). After selection of the design-build team, a contract to execute the project using progressive phasing (i.e., design phase leading to GMP, followed by construction) was negotiated between the owner and design-builder.

Contract Format

Standard form contracts are common in construction markets and serve to provide an economical and convenient way for parties to enter into contractual agreements. As the design-build movement has grown over the years, the industry has responded by creating families of design-build contracts. Various sponsoring agencies have developed standard forms, as described (Cushman & Loulakis, 2001):

1. *Design-Build Institute of America (DBIA)* – DBIA contracts are applicable to both competitive and negotiated selection processes. The contracts are neutral as to how the design-build team is organized.
2. *American Institute of Architects (AIA)* – AIA's design-build contracts are applicable to a negotiated selection process and require the use of a two-part contracting system.
3. *Associated General Contractors of America (AGC)* – Similar to the DBIA contracts, the AGC design-build contracts are applicable to both competitive and negotiated processes, and are neutral as to how the design-build team is organized.
4. *Engineers Joint Contract Documents Committee (EJCDC)* – EJCDC contracts are meant for engineer-led projects and anticipate a competitive negotiation process.

Progressive Design-Build Contract Format

A cost-plus fixed fee, not to exceed $1.17 million, was awarded for securing the design-builder's services during the first phase of the project (i.e., progressive design leading to a GMP proposal in collaboration with the owner). Following the GMP proposal, LCU awarded the construction phase contract based upon the GMP to the design-builder. The $17.3 million GMP included a 10 percent contingency, which was available upon the LCU's approval for the design-builder's use for costs incurred in performing work that was not included in a specific line item or the basis for a change order. All unused contingency was to be returned to LCU.

Basis of the Contract

Current industry standard form design-build contracts can provide an excellent starting point for contract negotiations. (Cushman & Loulakis, 2001, pg. 19). To develop a contract for this project, LCU began with DBIA Document No. 530 – Standard Form of Agreement Between Owner & Design-Builder – Cost-Plus Fee with an Option for Guaranteed Maximum Price. Since this is the standard document LCU uses for its best value (GMP or traditional) design-build projects, and the intent of the DBIA contracts is to provide a clear concise contract that can be easily modifiable, LCU felt that this contract document was a logical starting place for creating the contract documents that were used for this progressive design-build project. LCU made the following modifications to the standard contract document:

- Addition of an "off-ramp" clause giving LCU the option to terminate the agreement without cause at any time. This allowed LCU an escape from the contract if an equitable fee or GMP could not be negotiated with the design-builder.
- Addition of a "performance guarantee" clause holding the design-builder responsible for the performance of the WTP through the first year after final completion of the project.
- Addition of a "checks and balances" clause allowing LCU the option to hire, at any time, a third party to investigate or double check any portion of the project.
- Replacement of the DBIA Termination for Convenience (T4C) clause with the standard clause from LCU's construction contract.
- Adjustment of the indemnification to include payment of liquidated damages from the design-builder to LCU if scheduling delays pushed substantial completion past the date specified in the contract. This is discussed in more detail in the following section.
- Addition of direct material purchase language giving LCU the right to execute direct material purchases for any and all materials provided to the project. Because, as a government agency, LCU is exempt from state sales tax, this provided LCU the ability to realize a significant tax savings.

The RFQ included the unmodified version of DBIA Document No. 530 – Standard Form of Agreement Between Owner & Design-Builder – Cost-Plus Fee with an Option for GMP. The LCU typically includes the contract with the advertisement so the contractor has an idea of what the contract looks like. The changes described previously were made prior to signing the contract with the selected design-builder.

Performance Warranty

Based upon LCU's past experience at the WTP, where the treatment plant failed to perform to expectations, LCU wanted the design-builder to guarantee the performance of its work in the context of the treatment plant's successful operation. So, LCU and the design-build team negotiated a performance warranty to ensure that the finished product lived up to LCU's expectations in terms of quality, cost, and schedule adherence.

The terms of the performance warranty were negotiated during development of the GMP, and were included in the contract for the construction phase of the project. The design-builder's engineer developed a preliminary draft of the performance warranty that was discussed and reviewed by all parties (e.g., owner, engineer, design-builder, and subcontractors). After feedback and revisions, final terms were agreed to that satisfied LCU's needs. Performance was verified through testing that included the following requirements for the performance warranty to be satisfied:

- *Substantial Completion Testing* – Water meets quality and quantity specifications. Hydraulic and electrical systems are fully tested to demonstrate the required range of operation that can be met using both utility and emergency power. Some temporary measures that bypass automated control are acceptable (due to a fast-track schedule).
- *Final Completion Testing* – Requirements are the same as substantial completion, but all controls functions are complete and the plant is fully automated.
- *One-Year Testing* – Same as final completion testing after one year of operation.

Risk Assumption and Allocation

Risks borne by the design-builder were shared among the design-build team and a cost was assigned for carrying this risk. Because this project was driven by the need for an adequate, safe, and cost-effective quantity of potable water to meet LCU's needs, the primary risk was associated with meeting the project completion schedule. Successful performance of the project was tied to meeting schedule milestones; while there were technical aspects of the project that may be viewed as "risk", the primary risk, contractually, was the on-schedule delivery of the project.

To avoid a gap in water supply to the North Lee County service area, substantial completion of the project was scheduled for March 15, 2011. If this substantial completion was not met, LCU could have suffered damages that were difficult to predict. The LCU estimated the cost of buying water from neighboring utilities to meet the shortfall not met through the timely completion of the WTP expansion could range from $2,000 per day to $16,700 per day, depending on the actual demand of water and the neighboring water agency from which the needed water was otherwise purchased. These cost figures are based upon historical demands and water purchase prices. To share the owner's risk, the contract specified that the design-builder would be obligated to pay LCU $2,000 as liquidated damages for each day that substantial completion extended beyond March 15, 2011. The liquidated damages would be in lieu of actual damages incurred by LCU.

As the design-builder by contract, Mitchell & Stark assumed the financial risk for the on-time delivery and performance of the project. The financial risk was transferred to the other design-build team members by contract with Mitchell & Stark. Late delivery of goods and services resulting in missing contract completion dates would be carried through to the design-builder's subcontractors accordingly. This shared risk created incentive for team members to remain focused on the project schedule. Additionally, Mitchell & Stark and its subcontractors are all local in Lee County, so failure to perform and deliver the project on schedule would risk their professional reputations.

Design-Build Project Schedule

The progressive design phase was awarded in November 2009 and culminated in a final GMP proposal in March 2010. Construction phase services commenced, and substantial completion was reached, one year later in March 2011. Figure 1 summarizes the project schedule.

Prepurchase of equipment by LCU saved eight months on the project schedule and $237,000 in construction costs as LCU is not required to pay sales tax. This eight-month time savings also helped LCU avoid purchased water costs from other utilities, resulting in a cost avoidance of $488,000, and up to $4,148,000.

Adding Value to the Project

One of the tenants of the design-build concept is that team members (e.g., owner, engineer, and contractor) work together from the onset of the project. This builds in multiple opportunities for value engineering and constructability reviews throughout the process. Although the rehabilitation and expansion of the WTP came with its share of project challenges, one of the primary goals of the team was to optimize operations at the North Lee County plant.

This section discusses the operational improvements implemented by LCU and the design-build team as part of the expansion project. Optimization measures included improvements that:

- Enhanced operator safety
- Increased plant reliability
- Improved process controllability
- Reduced operating costs by increasing energy efficiency and reducing chemical usage

Eliminating the Use of Sulfuric Acid

Before the expansion project, pretreatment of the RO membrane feed water at the WTP consisted of pH adjustment using a

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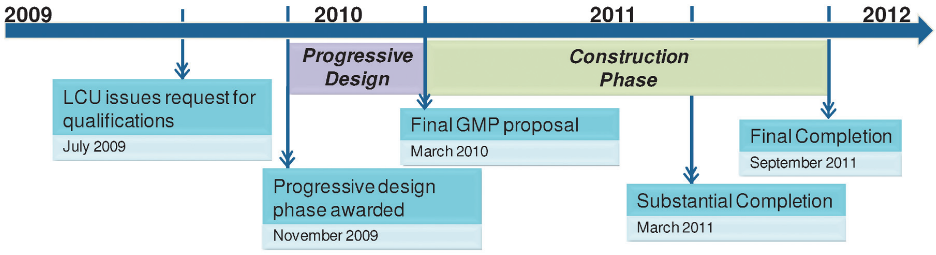

Figure 1. Design-Build Project Schedule for the North Lee County Water Treatment Plant Expansion Project

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strong mineral acid (sulfuric acid), to prevent calcium carbonate scaling, and a scale inhibitor.

Strong mineral acids are commonly used to reduce the pH of membrane feed streams at RO facilities to control calcium carbonate scaling. Sulfuric acid is often the mineral acid of choice due to its availability and relatively low cost. Despite these advantages, the use of this highly corrosive chemical introduces concerns related to operator safety and plant reliability. Sulfuric acid can also aggravate the precipitation of sulfate-based scale (e.g., $CaSO_4$, $SrSO_4$, and $BaSO_4$). The results of an element autopsy of the original membranes commissioned in 2006 indicated that the original membranes installed at the WTP were fouled with strontium sulfate, resulting in permanent membrane damage and loss of salt rejection.

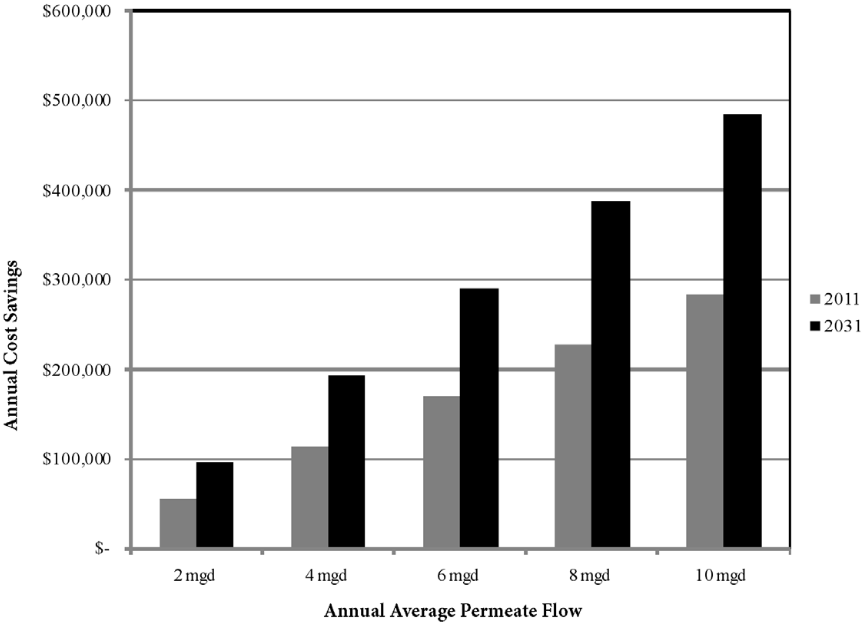

Figure 2. Acid Elimination: Chemical Cost Savings vs. Annual Average Permeate Flow

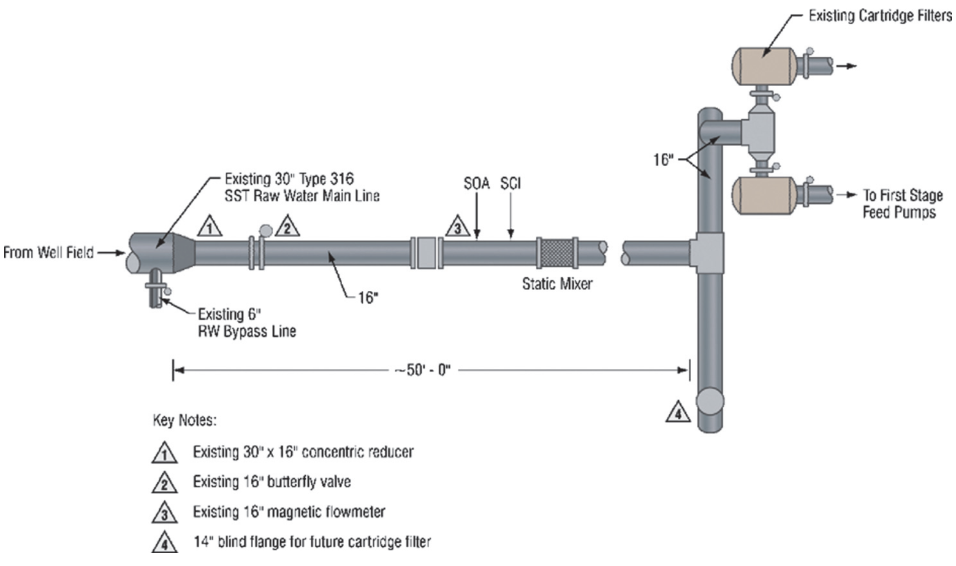

Figure 3. Original Raw Water Main Configuration

Continuous injection of scale inhibitor alone (without pH adjustment) can often control membrane fouling resulting from calcium carbonate and sulfate-based scales. A pilot test was performed at the WTP during which several scale inhibitors were tested to determine their ability to prevent membrane fouling without pH adjustment of the RO feed water. Results of pilot testing indicated that the use of the scale inhibitor alone provided sustained performance of the RO membranes at 80 percent recovery, without the addition of sulfuric acid to the feed water.

For source waters containing hydrogen sulfide (H_2S), post-treatment processes must be considered when eliminating or reducing acid addition to the RO feed water, since acid may still be required for post-treatment. To completely eliminate the use of sulfuric acid in the WTP process, a carbon dioxide storage and feed system was installed as part of the WTP expansion. Carbon dioxide creates carbonic acid when added to water, and is used to lower the pH of the blended permeate to 5.8 prior to degasification to achieve optimal hydrogen sulfide removal. The use of carbon dioxide also increases the alkalinity of the finished water. At the finished water pH of 8.3 to 8.5, the dissolved carbon dioxide in the water is converted to bicarbonate alkalinity, a critical component in the stabilization of the finished water.

As shown in Figure 2, eliminating sulfuric acid from the membrane feed water will reduce annual chemical costs in 2011 by approximately $56,700 to $283,000, depending on average annual permeate production. Assuming conservative values of annual inflation, the savings in 2031 are expected to reach approximately $500,000 per year at maximum annual average permeate production. These figures include the chemical cost savings offset by additional RO post-treatment chemical costs (i.e., carbon dioxide injection upstream of degasifiers).

Improvements to Reverse Osmosis Process Hydraulics

A primary factor contributing to the inability of the WTP to meet nameplate capacity prior to the expansion was major deficiencies of the RO process hydraulics. Deficiencies included undersized raw water piping, undersized first stage feed pumps, and constant speed interstage boost pumps that did not facilitate control of permeate flux balance.

Improvements to Raw Water Hydraulics

Prior to expansion, the raw water main serving the RO process building was undersized for expanded plant flows. Figure 3 shows the configuration of the raw water main prior to expansion. The original raw water main consisted of a 30-in. diameter high-density polyethylene (HDPE) pipe that reduced in size to feed a 16-in. diameter stainless steel pipe upon entering the building. Raw water then flowed through a 16-in. magnetic flow meter, static chemical mixer after sulfuric acid (SOA) and scale inhibitor (SCI) injection, and 16-in. manifold, before entering the cartridge filters. At the expanded flows, the high velocities within the 16-in. raw water main would have created an excessive pressure drop within this segment of piping (i.e., 17 pounds per square inch gauge [psig]).

During the early stages of design, an opportunity was recognized for the WTP to reduce first-stage RO feed pumping energy costs by increasing the diameter of the raw water main and eliminating the existing static mixer. A chemical injection side stream was designed to facilitate mixing of pretreatment chemicals. Figure 4 shows the improvements to the raw water main.

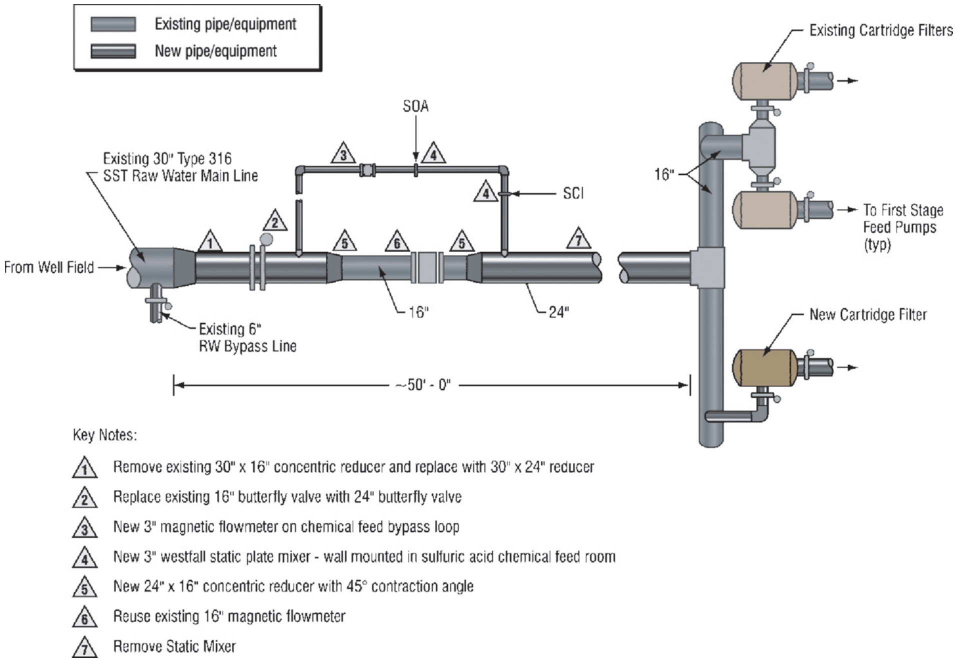

Figure 4. Raw Water Main Improvements

Apart from a reduction in pumping costs, the raw water main improvements provide several additional benefits, including:

- *Improved reliability* - The addition of the chemical mixing bypass piping provides better access to the chemical diffusers for maintenance. This improves the reliable operation of the WTP by minimizing downtime required for maintenance activities.
- *Improved safety* - Removing the chemical injectors from the pipe trench improves operator safety by locating the points of chemical injection within the chemical feed rooms where spills are readily visible and easily controlled.
- *Improved sustainability* - Sustainable operation of the WTP is improved by reducing the head loss through the existing piping. This reduction in head loss helps to conserve energy and fuel (during emergency power outage events).

The results of a hydraulic evaluation of the raw water main improvements are summarized in Table 1. The increased raw water main diameter results in an increase in RO feed pump suction pressure of up to 4.5 psig, with a subsequent reduction in first stage feed pump power requirement of up to 34.4 horsepower (hp), depending on raw water flow rates.

Table 1. Raw Water Main Improvements

Parameter	Units	Case	Average Annual Flow(1) (MGD) 2.5	5.0	7.5	10
Feed Pump Suction Pressure	(psig)	Before	41.3	39.7	36.8	33.1
		After	41.7	41.1	39.6	37.6
Total Feed Pump Power(2)	(hp)	Before	207.1	419.4	645.3	882.0
		After	206.5	415.0	630.6	847.6
Suction Pressure Increase	(psig)	After	0.4	1.4	2.8	4.5
Power Reduction	(hp)	After	0.6	4.4	14.7	34.4
Energy Cost Savings(3)	($/Yr.)	2011	$330	$2,088	$7,584	$17,806
	($/Yr.)	2031	$646	$4,741	$15,838	$37,062

Notes:

(1) Design Memorandum No 1 Raw water flow rates are based on an RO membrane recovery rate of 80 percent.

(2) Design Memorandum No 2 Total feed pump power requirements during operation of four RO trains.

(3) Design Memorandum No 3 Energy cost savings in 2031 based on expected escalation of energy rates. Energy escalation estimates based on data provided by the Energy Information Administration.

Capital costs associated with these improvements were approximately $200,000. Based on current energy rates and their expected escalation (Energy Information Administration, 2009), the payback period resulting from annual energy cost savings will be approximately nine years if the plant is operated at full capacity, with an 80 percent RO membrane recovery. Figure 5 presents a graph of the energy cost savings provided by the raw water main improvements in 2011 and 2031, and shows that the greatest savings occur at the maximum average annual plant flow rates. The greater energy cost savings in 2031 are reflective of the energy rate escalation expected to occur during this 20-year period.

Although the economic benefits of the raw water main replacement were clear from a design standpoint, one of the biggest challenges the design-builder faced during construction was the replacement of the raw water main that brings water into the RO treatment plant. Although the plant would realize many benefits from this replacement, the task presented several challenges:

- The replacement required a complete plant shutdown since this pipe provides the plant's only water source. The time frame

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for the shutdown had to be relatively short (i.e., less than five days) since shutting down the plant limited LCU's ability to provide water to its customers. If the work was not well planned and properly executed, the shutdown could have extended beyond five days and put LCU in a precarious position.
- Field welding of the stainless steel was undesirable due to its impact on the pipe's ability to resist corrosion. Flanged and grooved couplings were preferred for all joints.

The design-build format helped enable the team to overcome these challenges to make this portion of the project a reality. Having the engineer and the contractor working together on the same team offered the benefit of collaborating on the information needed to ensure fast and correct construction. The team overcame the challenges using a multi-faceted approach:

- The engineer completed a 3-D laser survey, accurate to 1 millimetre (mm), during design, allowing the team the ability to prefabricate all the piping sections (with the preferred joints). The survey also brought to light a 3-in. elevation difference between the existing flanges in the building and the point at which the new pipe would be connected. Having this knowledge before beginning construction helped the team avoid construction delays that would otherwise have resulted, due to what would have been an unexpected condition.
- The engineer was able to identify appropriate mechanical restraints for the piping construction joints with the contractor to ensure that they could build a safe, working, and cost-effective system.
- Acceptable alternative piping connections were predetermined by the engineer and contractor, providing the contractor a contingency plan and the flexibility to respond to unforeseen circumstances.
- The contractor had these means and methods ready and on-hand to facilitate the fastest possible shutdown of the treatment plant. For example, the contractor had spare parts and contingency equipment available (e.g., welding equipment).
- The contractor was proactive in avoiding construction delays through careful scheduling of the work.

Replacement of Interstage Boost Pumps and Implementation of Energy Recovery

Prior to expansion, the RO trains at WTP were equipped with 75 hp constant speed interstage pumps that served to increase permeate flux in the second stage of the membrane trains. As constant speed pumps, they did not facilitate precise control of second-stage permeate flux. Due to fluctuations in parameters such as feed stream total dissolved solids (TDS), temperature, and membrane fouling, the pressure boost provided by the interstage pumps did not always result in optimal second-stage permeate production. Precise control of permeate flux reduces the fouling potential of the first-stage elements as both particle and organic fouling increase exponentially at high flux rates. Flux balancing also improves overall permeate quality and reduces overall pumping costs by reducing the first-stage feed pump's discharge pressure.

During the early stages of the WTP expansion, an opportunity was recognized to incorporate energy recovery into the design of the new and existing RO trains. A portion of the pressure energy in the concentrate stream that was previously throttled by each train's concentrate control valve could be recovered for useful purposes. Several energy recovery devices (ERDs) have been developed for use in brackish water reverse osmosis (BWRO) applications. A preliminary review of available technologies indicated that two types of ERDs were most suited for use at the WTP:

1. *Pressure Exchangers* – The pressure exchanger (PX) reduce the power requirements of the first-stage feed pumps through a direct exchange of energy between the RO concentrate and first-stage feed streams. The PX uses a rotating cylinder with multiple flow tubes to transfer pressure energy

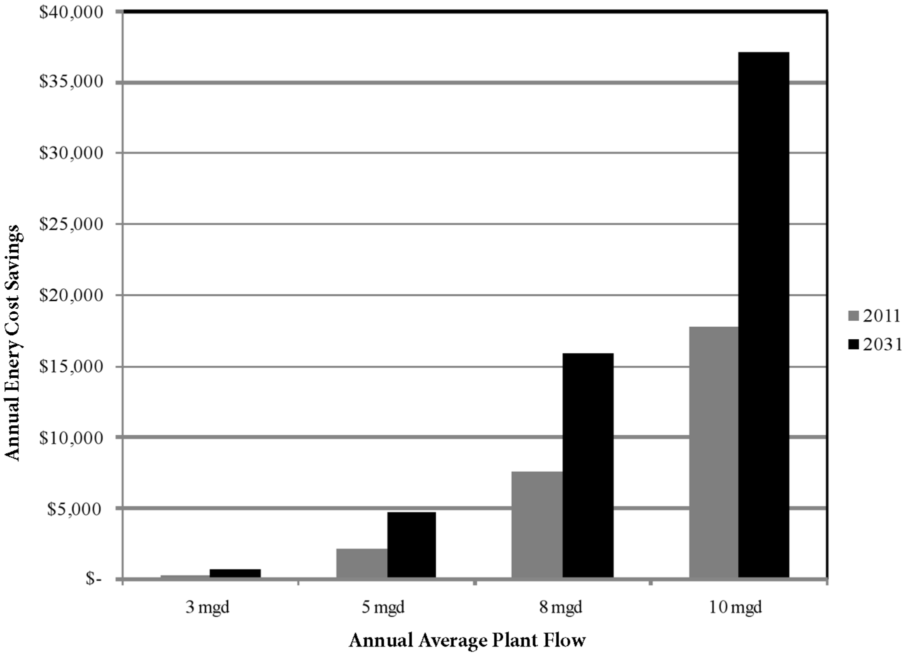

Figure 5. Energy Cost Savings Associated with Raw Water Main Improvements

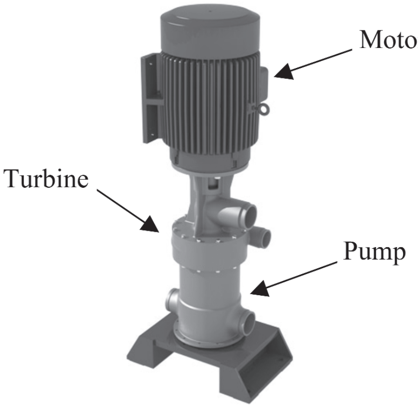

Figure 6.
LP-HEMI Energy
Recovery Device

from the concentrate stream to the first-stage feed stream by direct hydraulic contact. The project team determined that two pressure exchanger modules would be required for each RO train. Together, these modules would boost a first-stage feed flow equivalent to the concentrate flow from a single train. This flow would then bypass the feed pump and reduce the overall feed pump size—thereby reducing energy use.

2. *Turbine-Assisted Boost Pumps* – Turbine-assisted boost pumps consist of a pump, energy recovery turbine, and variable speed motor, coupled to a common shaft to recover available concentrate energy, while precisely controlling the balance of permeate flux between membrane stages. The low-pressure hydraulic energy management integration (LP-HEMI) is the turbine-assisted interstage boost pump considered for this project. Figure 6 presents the typical configuration of an LP-HEMI turbine-assisted interstage boost pump. The variable speed motor sits atop the unit with the energy recovery turbine situated between the motor and the interstage pump below.

Both ERD alternatives were evaluated based on four primary evaluation criteria:

1. *Motor Size Evaluation* – The total installed power requirement of the first-stage feed and interstage boost pumps for each ERD alternative to reliably produce the required flow for each train.
2. *Financial Evaluation* – What are the capital costs and energy savings associated with each alternative?
3. *Influences to Finished Water Flow Rate* – What are the impacts to finished water flow rate based upon differences in permeate quality that would affect blending flow rates?
4. *State of Technology* – Is the ERD technology proven in BWRO applications and mature enough to be implemented at the WTP considering the aggressive project schedule?

Each ERD alternative was evaluated based on its performance relative to a baseline configuration that did not incorporate energy recovery technology. Major features of the baseline configuration consisted of the following:

- Replacement of the existing undersized 75 hp first-stage feed pumps with new 250 hp pumps, motors, and variable frequency drives (VFD).
- Replacement of the existing 75 hp constant speed interstage boost pumps with new 100 hp variable speed pumps, motors, and VFD.

The PX alternative reduced the size requirement of the first-stage feed pumps from 250 to 200 hp. The size of the interstage boost pumps remained unchanged at 100 hp. Similar to the baseline configuration, the LP-HEMI alternative required a 250 hp first-stage feed pump, but the size of the interstage boost pump was reduced from 100 to 60 hp. A summary of pump size requirements for each alternative is presented in Table 2.

Table 2. Pump Sizing Summary

Configuration	First Stage Feed Pump (hp)	Interstage Boost Pump (hp)	Total Installed Power (hp)
Baseline	250	100	350
PX	200	100	300
LP-HEMI	250	60	310

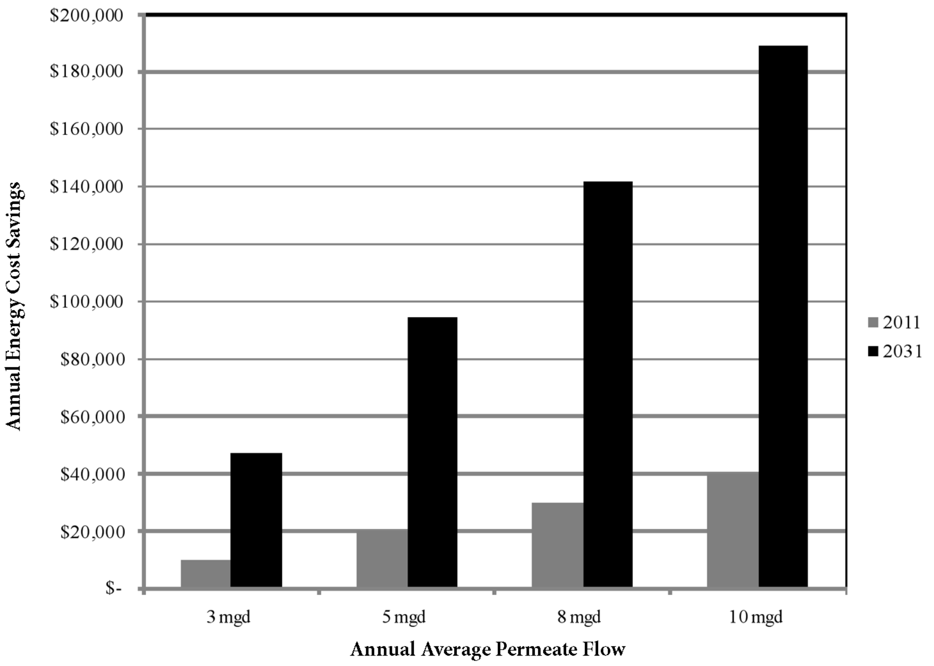

Figure 7. Annual Energy Cost Savings of Energy Recovery at the North Lee County Reverse Osmosis Water Treatment Plant

The LP-HEMI configuration offered the lowest capital cost option compared to the costs associated with installing new 100 hp interstage boost pumps and VFD for the baseline configuration, and the costs associated with additional piping required by the PX alternative. A desktop-scale energy evaluation of both the PX and LP-HEMI alternatives revealed comparable energy savings. No significant difference in finished flows (blended permeate) was predicted for either candidate ERD technology. At the time the evaluations were made, PX technology had not been implemented successfully in municipal BWRO applications. The project team determined that demonstration-scale testing of PX technology at the WTP would be required if this technology were selected.

Due to the lower capital costs associated with the LP-HEMI alternative and the need for demonstration-scale testing of pressure exchanger technology in municipal BWRO applications, together with an aggressive project completion schedule, the project team decided that turbine-assisted interstage boost pumping was the best choice for energy recovery at the North Lee County plant.

The graph presented in Figure 7 shows that immediate financial benefits are provided through the use of energy recovery technology at the North Lee County plant. A savings of up to $40,000 is possible during the first year (2011) of operation, depending on first-year annual average plant flows. Annual savings increase to as much as $189,000 by year 20

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(2031) as energy prices escalate and concentrate pressure, with corresponding energy recovery, increases. This energy savings reduces greenhouse gas emissions (associated with power plant operation) by as much as 800 tons of carbon dioxide per year, which is equivalent to removing 140 passenger vehicles from the road annually.

The energy savings calculations account for the projected escalation of energy rates, based on a review of historical energy utility billing data at the North Lee County facility. This energy rate escalation is in agreement with the long-term energy forecasts provided by the Energy Information Administration (2009).

Improvements to Scale Inhibitor Usage

Before the expansion, the programmable logic controlling the scale inhibitor metering pumps did not incorporate feedback from the scale inhibitor flow meter. A manual dose was set by the plant operator in SCADA, and the scale inhibitor metering pumps modulated their speed to maintain the setpoint dose based on pump capacity data obtained during regular calibration column drawdowns. This method of scale inhibitor dose control did not protect the RO membranes from the damaging effects of fouling resulting from a loss of scale inhibitor flow in the event the following occurred:

- Pump capacity data was incorrectly entered into SCADA.
- A failure of the metering pump diaphragm.
- A leak was present in the scale inhibitor injection line between the scale inhibitor metering pumps and the injection point.

As previously discussed, the original membranes had been damaged by strontium sulfate scaling and were replaced prior to the expansion at an estimated cost to the County of between $548,000 and $588,000. One contributing factor leading to the scaling of the original membranes may have been the lack of scale inhibitor flow feedback in the logic controlling the metering pumps. After the expansion, because the number of operating trains had been increased from two to four, the estimated cost to replace the RO membranes would be twice that incurred to replace the original membranes, or about $1.1 million.

It is also possible that the scale inhibitor was periodically overdosed prior to the WTP expansion. Chemical flows based entirely on chemical metering pump calibration data can often be in error by ±10 percent of the setpoint dose. At a design dose of 2.5 mg/L (Nalco Permacare PC-5600), with the plant operating at maximum permeate production capacity, an error in scale inhibitor flow of +10 percent would result in any waste of up to 900 gallons of scale inhibitor per year. At 2011 prices, this would result in additional annual scale inhibitor costs of up to $12,000, depending on average annual plant flows.

As part of the expansion, a pretreatment chemical dosing side stream was added, which located the scale inhibitor injection point outside of the process trench (previous location) to a location within the chemical feed area that facilitated easy access to the chemical injector for inspection and repairs. A new coriolis-type mass flow meter was installed in the scale inhibitor chemical injection line at the point of injection. Locating the flow meter at the point of injection ensures that leaks in the scale inhibitor feed piping between the metering pumps and the point of injection will be detected as a loss of flow at the injection point. The logic controlling the scale inhibitor metering pumps was modified to include actual chemical flow (as measured by the coriolis flow meter). The programmable logic controller (PLC) controls the speed of the scale inhibitor metering pumps based on the calculated feed rate. The scale inhibitor feed rate is calculated by the PLC based on a setpoint chemical dose and the process flow rate (RO membrane feed). The PLC compares the actual flow (as measured by the coriolis flow meter) to the calculated chemical feed rate. If the flow provided by the metering pump(s) is too high, metering pump speed is automatically reduced; if the chemical flow is too low, metering pump speed is automatically increased.

This method of scale inhibitor pump speed control ensures that correct dose of the scale inhibitor is always provided to protect the most critical component of the RO facility—the RO membranes.

Figure 8 presents a graph of the chemical cost savings provided by the improvements to the scale inhibitor feed control strategies in 2011and 2031. The chemical cost savings shown in Figure 8 are based on the assumption that, prior to the plant expansion, the scale inhibitor was being overdosed by 10 percent of the set point.

Figure 8 shows that the greatest savings occur at the maximum average annual plant flow rates. The savings in 2031 are expected to reach approximately $25,000 per year at maximum annual average permeate production

Conclusions

The rehabilitation and expansion of the North Lee County plant resulted in successful correction of treatment plant performance deficiencies and expansion of plant capacity to 10 mgd permeate capacity. The design-build method was used to deliver the project and offered several opportunities to save time and money during the project:

- It reduced the overall project schedule by eight months, saving LCU between $488,000 and $4,148,000 in purchased water costs.
- Directly prepurchasing long-lead equipment helped to facilitate the on-schedule project delivery, but also saved LCU $237,000 as it is not required to pay sales tax.

In addition to the money saved during construction, several operational changes were made to improve the sustainability of operations by reducing energy and chemical use:

- Energy Savings
  - At full plant capacity, improvements to the raw water main are expected to save the County up to $18,000 during the first year of operation. Annual savings at these permeate flows are expected to reach $37,000 by 2031.
  - The incorporation of energy recovery at the North Lee County plant is expected to save approximately $40,000 during the first year of operation (at maximum plant flows). At these flows, annual energy cost savings are expected to reach $189,000 by 2031.
- Reductions in Chemical Costs
  - At plant capacity permeate flows, the elimination of acid from the RO membrane feed stream is expected to save up to $283,000 in annual chemical costs during the first year of operation. The savings at these flows are expected to grow to approximately $500,000 annually by 2031.
  - The improvements to scale inhibitor usage are expected to reduce annual chemical costs by as much as $12,000 during the first year of operation. The potential for savings in 2031 is $25,000.

References

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- Energy Information Administration, "Annual Energy Outlook", Last Modified 12/2009, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_8.xls