Clewiston Installs Reverse Osmosis to Get Off Sugar

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1.0 Project Background

The City of Clewiston owns and operates the City's water distribution system; however, currently the City purchases potable water from U.S. Sugar Corporation. The City of Clewiston is located on the south shore of Lake Okeechobee, which is Florida's largest fresh water lake (see Figure 1). The existing U.S. Sugar water treatment plant treats raw surface water drawn from Lake Okeechobee. Recently, the City has been considering alternatives for discontinuing the use of Lake Okeechobee as a source of drinking water. Reasons cited for the proposed change include taste and odor problems related to algae blooms, reliability problems due to drought, and conflicts with the South Florida Water Management District (SFWMD) related to water management operations to control levels in the lake. In addition, on August 18, 2003, U.S. Sugar Corporation notified the City that they would like to discontinue the sale of potable water to the City by September 2006. U.S. Sugar Corporation has since postponed this date until September 2007.

In 2003, the City commissioned a report that evaluated three alternatives for future potable water supply for the City. The report concluded that construction of a new Floridan aquifer raw water supply and low-pressure reverse osmosis water treatment plant (LPRO WTP), to be owned and operated by the City, was the most appropriate alternative to meet the City's needs.

The City requested Statements of Qualifications from qualified firms for professional engineering services associated with design and construction of the raw water supply, water treatment, and concentrate disposal facilities recommended in the preliminary engineering report. Pursuant to the selection process, on February 16, 2004, the City selected Camp Dresser & McKee Inc. (CDM) to perform these services.

2.0 Project Scope

The primary features of this project include:

- The raw water system will consist of four upper Floridan aquifer wells, submersible well pumps, wellhead assembly, raw water transmission piping to the WTP, and associated electrical and instrumentation improvements.
- The treatment process will utilize low-pressure reverse osmosis, with a design recovery rate of 75 percent and a raw water blending rate of up to 7.5 percent.
- The WTP will be on a site adjacent to the City's public works facility which is located on the south side of the City.
- Concentrate disposal will be through one new deep injection well (DIW), which will be located at the City's wastewater treatment plant site.

Figure 1 – Site Location Plan

- Plant improvements will include one 1.5 million gallon (MG) finished water ground storage tank and four high service pumps, each of which will have a capacity of 1,600 gpm, plus one jockey pump with a capacity of 750 gpm.
- Demand-related design criteria for the raw water supply, treatment plant, and high service pumping system, are as follows:
  - Capacity of wellfield = 4.0 mgd
  - Design average daily demand (ADD) 1.935 mgd
  - Design maximum day demand (MDD) 3.000 mgd
  - Design peak hour demand (PHD) = 4,638 gpm
  - Sizing of the high service pumps is based on meeting the PHD with one standby pump.

The plant is designed to operate 24 hours a day to produce design capacity.

3.0 Water Quantity and Quality

Raw water for the plant will be taken from four Floridan aquifer wells which are both on and off the site. Because it is anticipated that water quality conditions may deteriorate over time as a result of pumping, membrane performance projections were performed at both the initial and expected worst case (degraded) feed water quality.

Table 1 summarizes the average values from the results of three samplings taken from test/production well no. 1 (PW 1), which was initially constructed to obtain raw water quality, identify the best production zone(s), and to conduct membrane pilot testing.

Table 1

PRELIMINARY RAW WATER ANALYSIS (PW 1)

COMPOUND	RESULT (mg/l)
Bicarbonate	103
Calcium	130
Chloride	1,333
Magnesium	118
pH	7.6
Sodium	715
Sulfate	530
Sum of Ions	3006

Since actual feed water quality was available for only one of the production wells, a margin of safety was included on the specified initial raw water quality for startup conditions. In addition, the system was designed to accommodate raw water quality at the "future (degraded) condition." A summary of feed water, product water, concentrate and discharge characteristics is provided in Table 2 below:

Table 2

Feed Water, Product Water, Concentrate And Discharge Charateristics

Parameter	Initial	Future (degraded) Condition
Raw Well Water Supply		
- Flow, mgd	4	4
- Sum of Ions, mg/l	3,319	3,588
RO System Product Water		
- Flow, mgd	2.75	2.94
- Sum of Ions, mg/l	70	75
Blended Product		
- Flow, mgd	3	3
- Sum of Ions, mg/l	332	357
RO System Concentrate*		
- Flow, mgd	1	1
- Sum of Ions, mg/l	13,074	14,085

The membrane permeate will be blended with approximately 7.5% of filtered feed water to produce the product water shown in Table 2 (before post treatment chemical addition).

4.0 Pilot Testing

Pilot testing was performed for a period of two months with a minor interruption due to Hurricane Katrina, which did major damage in the Clewiston area. Feedwater for the pilot testing was drawn from the first test/production well that was drilled on site (PW 1), which was completed prior to the start of pilot testing. The pilot unit was configured in a 2:1 array to model the 16:8 array of the full scale units. Pretreatment chemicals dosed to the feedwater were antiscalant and 93 percent sulfuric acid. The membranes tested were Hydranautics ESPA2-4040, a four-inch version of the ESPA2-8080, which was one of the named membranes in the technical specifications for the full-scale plant. The pilot unit was also equipped with a 5-micron cartridge filter. The pilot process was operated at the same flux rate as proposed in the design basis. The objectives of the pilot testing program were to:

- Confirm and demonstrate that the membrane system would operate successfully at the design conditions
- Verify that the pretreatment chemicals specified would result in stable operation
- Characterize the permeate quality for conformance with treatment objectives and for permitting purposes

The conclusions of the pilot testing program were:

- The membrane tested performed as projected
- No fouling tendencies were noted during the test period
- No membrane cleaning was required during the testing period
- The cartridge filters did not require replacement during the test period. No sand was noted on the filter element, indicating that the proposed pretreatment was sufficient.
- Silt Density Index (SDI) values measured upstream of the cartridge filters were consistently low
- Permeate from the pilot unit met all applicable drinking water standards.

5.0 System Design

5.1 Raw Water Supply

Raw water will be supplied from four upper Floridan aquifer supply wells. Figure 2 presents an aerial photograph of the project area showing the location of the off-site production wells and the WTP. Figure 3 presents a site plan of the WTP showing the on-site production well and major yard piping. Well pumps will be stainless steel submersible turbine type. Wellhead piping will also be stainless steel. Each the two off-site well sites will include a chain-link fence enclosure with lockable gate, concrete pad, wellhead piping, meter, and valving, and above-ground electrical panel in a stainless steel enclosure. Telemetry will be included to provide supervisory control and data acquisition for the well system, such as well operation control and status, and monitoring of flow and discharge pressure. Backup power for the two on site wells will be provided by the backup generator.

Underground raw water transmission piping from the supply wells to the water treatment plant will be high density polyethylene (HDPE), SDR 13.5. All transmission piping will be located in City right-of-way or City-owned easements.

Figure 2
Floridan Production Wells

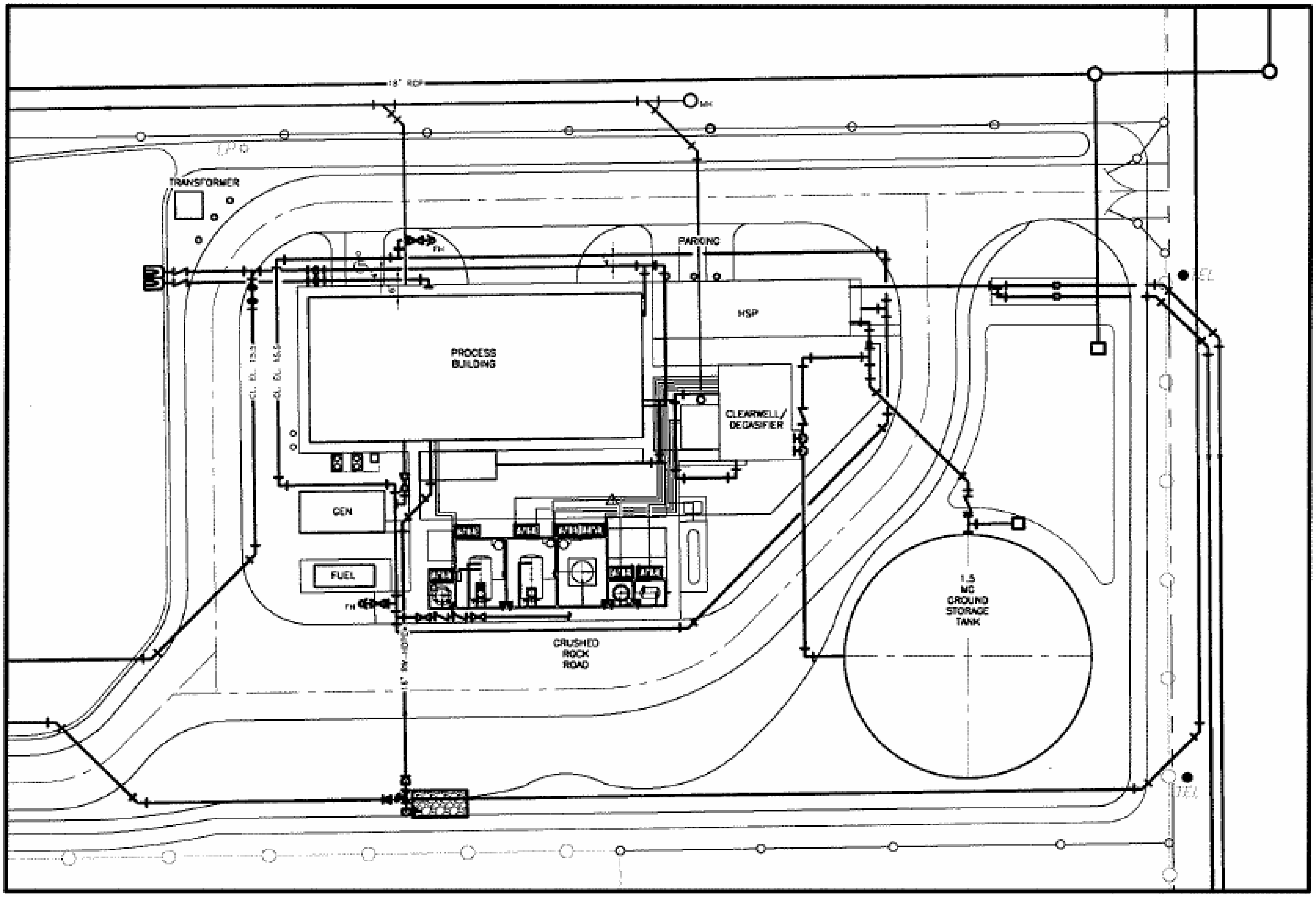

Figure No. 3
City of Clewiston, Florida
Site plan

CDM

5.2 Pretreatment

Raw water from the Upper Floridan aquifer is typically of high quality and, for this reason, raw water pretreatment is fairly straightforward. As shown in the process schematic presented in Figure 4, the pretreatment system will consist of two chemical dosing systems, one for acid and one for antiscalant. Acid will be injected in both the raw water going to the membrane treatment process and bypass water going to the degasifer. Due to the hydrogen sulfide content of the raw water, the pH of the bypass water will be lowered to keep the hydrogen sulfide in the dissolved gas phase which facilitates removal of the gas in the degasifier. Antiscalant is used to control the scale formation of sparingly soluble salts such as calcium, barium and strontium sulfate.

The pretreatment system will also include three vertical cartridge filters of fabricated 316 stainless steel construction to remove suspended particles prior to the membrane feed pumps and membrane modules. The cartridge filters are designed for conservative loading rates of 3.1 gpm per ten inches of filter cartridge length. In addition to the pretreatment cartridge filters for the membrane system, two additional cartridge filters will be provided to remove any suspended particles from the blending stream.

5.3 RO System and Process Building

Design features of the membrane treatment system are summarized in Table 3. The membrane system will consist of three treatment units with a capacity of 925,000 gpd per unit. The combined capacity per unit including the 7.5 percent blend flow is 1 mgd. The membrane units will be arranged in a 16:8 array. In addition, space has been provided in the building for the future addition of a fourth treatment unit.

The RO facility is modeled after a project recently completed by CDM of a similar size for Gloucester County, Virginia, and utilizes the existing building layout and equipment arrangement as much as possible. In addition to reducing design costs, this expedited the design and assisted in meeting the aggressive project schedule. The membrane system design is based on a "dedicated" type pumping arrangement in which each membrane unit has its own dedicated feed pump, located adjacent to the unit. The dedicated pump arrangement allows the operator to adjust the output of the pump to meet the optimum performance of the associated membrane unit in terms of flow and pressure requirements based on the current conditions of the membranes in that unit. The membrane feed pumps will be stainless steel vertical turbine type mounted in 316 stainless steel suction barrels. Each membrane feed pump will be equipped with a variable frequency drive (VFD).

A membrane cleaning system will be provided consisting of a stainless steel cleaning pump, two fiberglass cleaning tanks, stainless steel cartridge filter and associated piping and valves.

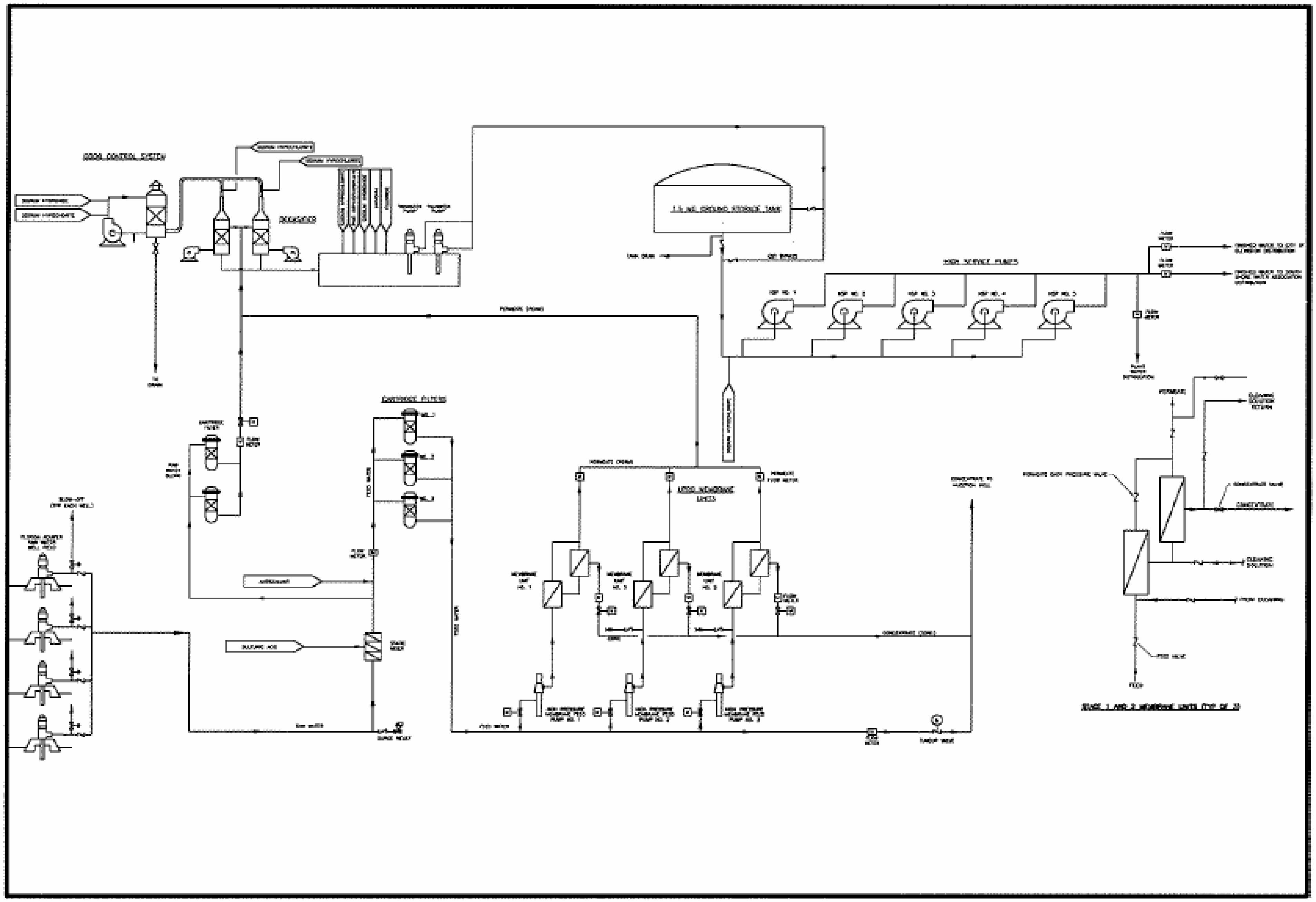

Figure No. 4
City of Clewiston, Florida
Process Flow Diagram

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Table 3
Reverse Osmosis System Design Basis

Membrane System Design and Operating Criteria

Membrane Feed Pumps	
Number of Membrane Feed Pumps	Three
Design Flow per Pump (gpm)	857
Total Installed Capacity (gpm)	3,429
Firm Capacity (gpm)	2,571
Design Discharge Pressure (ft) (TDH)	650
Pump Type	Vertical Turbine
Motor Size (HP)	200
Assumed Efficiency (%)	80
Drive Type	Variable Frequency
Membrane Treatment Skids	
Total Permeate Capacity (mgd)	2.775
Number of Skids	3
Capacity per Skid (mgd)	0.925
Expected Design Recovery (%)	75
Number of Stages	2
Array Configuration	16:8
Elements per Pressure Vessel	7
Average Permeate Flux (gfd)	13.8
First Stage Permeate Backpressure (psi)	20
Total Permeate Backpressure (psi)	15

Figure 5 presents a plan view of the process building. The main RO building frame will consist of a prefabricated, galvanized steel frame with a gabled roof. Building construction will be concrete block lower walls with fabricated steel upper walls and roof. Secondary roof framing will consist of purlins supporting a metal deck standing seam roof. All exterior building walls will be able to resist major hurricane winds and meet local building codes. The main building floor will consist of a slab on grade with trenches for piping. Figure 6 depicts a photograph of the full-scale Gloucester County RO plant, after which the Clewiston plant design was modeled.

5.4 Post Treatment

Permeate from the RO system will be piped to degasifiers for removal of dissolved hydrogen sulfide and carbon dioxide gas. The degasifer system will consist of two forced-draft, packed tower type units with one blower each. The units will include a fiberglass reinforced plastic (FRP) vessel, internal random dumped packing and packing support system, blowers, influent and effluent piping, ductwork, and associated electrical and controls. One packed tower type odor control scrubber system is included. Table 4 presents a summary of the degasifier and odor control system design basis.

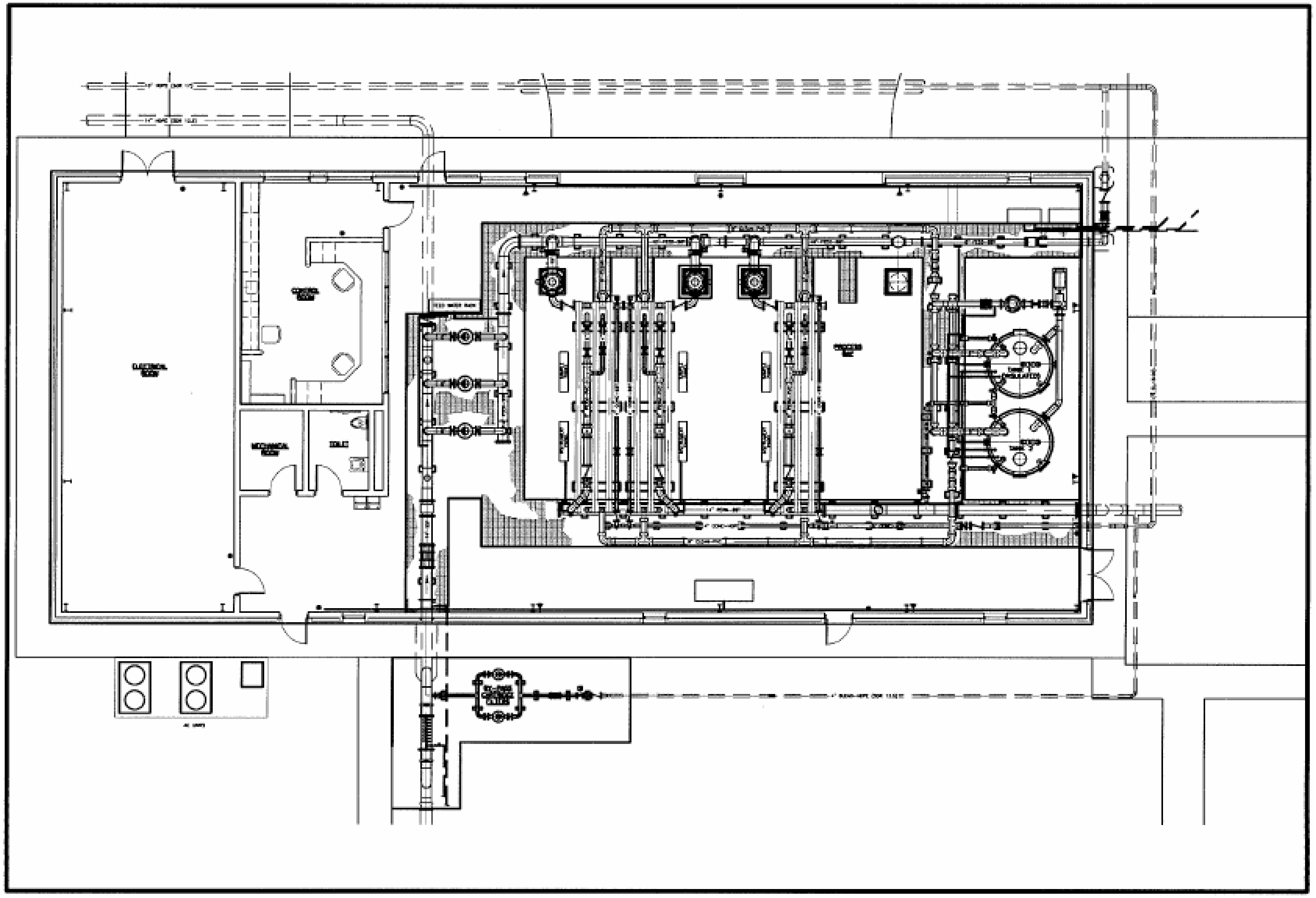

Figure No. 5
City of Clewiston, Florida
Mechanical Layout

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Table 4

Product Water Post Treatment Design Basis

Permeate Post-Treatment Systems Design and Operating Criteria

Degasification System	
Design Flow Basis (mgd)	3.0
Maximum Hydrogen Sulfide Concentration (mg/L)	5
Minimum Removal Efficiency (%)	95
Inlet Water pH	< 6.0
Number of Towers	2
Tower Diameter (ft)	6.5
Number of Blowers	2
Blower Hp	10
Air Flow Rate per Tower (cfm)	4,172
Odor Control Scrubber System	
Number of Towers	1
Type of Odor Control Scrubber	Single Stage Counter-Flow
Design Air Flow Basis (cfm)	8,430
Average Hydrogen Sulfide Concentration (ppm)	157
Minimum Removal Efficiency (%)	98
Tower Diameter (ft)	5.5
Number of Recirculation Pumps	2 (One Active/One Standby)
Recirculation Pump Motor (HP)	2.0

Figure 6 – Gloucester Membrane Train

5.5 Finished Water Storage and Pumping

Following degasification and chemical post-treatment, the finished water will be pumped from the clearwell to the 1.5 million gallon prestressed concrete ground storage tank using variable speed vertical turbine transfer pumps. The transfer pump system will include two pumps, each rated at 100% of the plant capacity rating of 3.0 mgd.

From the ground storage tank, the finished water will be pumped to distribution with a new high service pump system. The pump station design includes four 1,600 gpm pumps, plus a 750 gpm jockey pump, all equipped with variable frequency drives. Pumps were selected to maintain a constant discharge pressure into the distribution system at the plant site of 65 to 75 psi. Pumps will be cast iron, bronze fitted horizontal split-case type. The pumps will be located outdoors on a concrete pad. The system will include pressure-based controls utilizing a programmable logic controller (PLC). Table 5 presents a summary of the transfer and high service pumping systems design basis.

Table 5

Transfer and High Service Pumping Systems Design Basis

Product Transfer Pumps	
Number of Transfer Pumps	2 (one duty/one standby)
Design Flow per Pump (gpm)	2,300
TDH (ft)	42
Horsepower	30
High Service Pumps	
Number of High Service Pumps	5 (up to four duty/one standby)
Design Flow per Pump (gpm)	1,600
TDH (ft)	150
Horsepower	100

5.6 Finished Water Distribution

Connection to the existing distribution systems will employ wet taps so no interruption in service or reduction in pressure will occur. Finished water will be pumped from the site through two metered mains connecting to the two separate water distribution systems that the City currently serves, the City of Clewiston and the South Shore Water Association.

Degasified permeate will be collected in a concrete baffled, below-grade clearwell located beneath the degasifiers, where sodium hydroxide, hypochlorite, ammonia, zinc orthophosphate, and fluoride will be added for pH adjustment, disinfection, and stabilization.

5.7 Concentrate and Waste Stream Disposal

All plant waste streams (RO concentrate and spent cleaning solution) will be sent to the deep injection well located at the City's wastewater treatment plant. The well will be a 10-inch diameter well cased to approximately 2,850 feet below land surface (BLS). The well will be of a tubing and packer construction and will have a fiberglass injection tubing with a fluid-filled pressured annulus.

5.8 Electrical

Primary power for the site will be 480 volt, 3 phase power will be obtained from a new transformer on site connecting to the existing local power grid. Low voltage motors (480 VAC & 120 VAC) will be totally enclosed fan cooled with high efficient ratings for most services. Grounding to the site will be provided via a grounding grid composed of a ground loop in the substation area and embedded concrete rebars in the RO building connected to strategically placed grounding rods. Lightning protection/prevention will be provided for the RO building.

All instrumentation that requires a separate power source other than loop power will be powered by an uninterruptible power supply (UPS) system which will provide 120 VAC, 60 Hz, 1 phase clean power.

An emergency generator rated at 1,100 kva will power the system in case of an emergency. Fuel tanks are sized for 24 hours of operation at full load before refilling is required. Per FAC 62-555, the generator will allow the plant to produce, as a minimum, the average daily production of water meeting all secondary and primary drinking water codes.

5.9 Instrumentation and Controls

The control architecture for the RO plant will incorporate a programmable logic controller ("PLC") with a Plant Control Station and an engineering work station and various touch screen displays for operator control & annunciation. Remote input/output (I/O) racks will be distributed throughout the site in order to minimize the amount of wiring back to the main control room. The PLC will be powered by the UPS system located in the RO control building. For the project execution phase, an instrumentation specialty integrator will be used to develop the ladder logic, program the human interface screens and program the engineering workstation.

6.0 Construction Contract Structure

Since the project consists of an entirely new raw water supply, treatment facility, and concentrate disposal system, construction was broken into three contracts on a design bid, build basis. The first contract included drilling of the initial two test/production wells and hydrogeological testing. Drilling of the third and fourth production wells was subsequently added to this contract by change order.

The second (main) construction contract included installation of the well pumps, wellheads, well electrical and instrumentation, the raw water transmission piping system, all water treatment plant work, finished water transmission system improvements, and concentrate transmission piping to the DIW located at the City's wastewater treatment plant. Fabrication of the RO skids and procurement of the membrane elements were included under the main plant construction contract.

The third contract consisted of drilling of the DIW and construction of the injection wellhead. As shown in the schedule presented in Figure 7, design and construction of the three project components had to be closely coordinated in order to bring the plant on line by the target date of September 2007.

7.0 Project Implementation Schedule

An aggressive schedule was established to permit, design, construct, and commission the desalination facility prior to the deadline of September 2007. As shown on the schedule in Figure 7, plant commissioning should occur within 18 months of the contractor's notice to proceed. CDM was authorized to proceed with engineering services in January 2005. CDM completed design and advertised the main WTP construction contract for bid in October of 2005. The general construction contractor was issued the Notice to Proceed on April 3, 2006. The main WTP construction contract provides for 490 calendar days from the Notice to Proceed to Substantial Completion and 550 days to Final Completion. In addition to coordination of the three construction contracts, it was necessary to obtain approval from several governmental agencies that provided funding on various components of the project.

8.0 Bid Results

The contract for construction and testing of the first two test/production wells was awarded to Southeast Drilling Services, Inc. on April 15, 2005, in the amount of $900,000. Due to the fact that the first test/production well was on the critical path of the design (to provide water quality and pilot testing data), this contract was negotiated based on bidding results for similar Floridan aquifer production wells constructed in early 2005 by Southeast Drilling Services, Inc. for the nearby Lake Region Reverse Osmosis Water Treatment Plant for Palm Beach County, Florida.

Bids for construction of the main plant construction contract were received on December 21, 2005. Two bids were received, and the low bid of $13,295,000 was submitted by Widell, Inc. Following review of the bids by the Engineer, City, and funding agencies, the contract was awarded on February 3, 2006. The Notice to Proceed was issued to the Contractor on April 3, 2006.

One bid of $4,943,153 was received for construction of the deep injection well, which was submitted by Youngquist Brothers, Inc. Youngquist Brothers, Inc. has constructed nearly all of the Class I injection wells in South Florida in the last ten years. The contract was awarded on February 3, 2006. The Notice to Proceed was issued to the Contractor on March 27, 2006.

9.0 Project Status

Drilling of the first three production wells (PW 1, PW 2, and PW 4) is complete. Drilling of the fourth production well is under way at the date of this writing.

Construction of the WTP is under way. To date, the Contractor has encountered no delays, and it is expected that the plant will be brought on line in the third quarter of 2007, prior to the Substantial Completion date of August 6, 2007.

Construction of the DIW is also under way, with no delays to date. The well is expected to be brought on line in December of 2006, well in advance of plant start-up.