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Zero Liquid Discharge Project Extends Potable Water Supplies

Diminishing potable water supplies, increasing regulatory restraints, and conservation initiatives have prompted utilities to evaluate and implement the use of alternative water supply sources. One Florida utility implemented a concentrate zero liquid discharge process to achieve water recovery through concentrate treatment. BY RYAN R. POPKO, PHILLIP J. LOCKE, AND FRED J. GREINER

USING UNCONVENTIONAL sources often requires implementing new process applications to meet potable water treatment requirements and demands. Effectively treating waste streams can be an essential part of meeting alternative water supply goals. Although membrane treatments, specifically reverse osmosis and nanofiltration, feature significant benefits in treating water to a consistently high level, managing the treatment process by-product, or concentrate, can be a challenge.

MEETING THE CHALLENGE

The city of Palm Coast, Fla., explored methods to develop alternative water supplies, recover and reuse water, and reduce the utility's environmental impact. Because the city's consumptive use permit limited source water supplies and regulatory constraints required an alternative method of concentrate disposal, the city's Water Treatment Plant (WTP) No. 2 membrane softening facility chose to treat and recover its concentrate as an alternative water supply using a unique zero liquid discharge (ZLD) process.

The ZLD process currently treats 1.2 mgd of low-pressure reverse osmosis (RO) concentrate using lime/soda ash softening, membrane filtration, and disinfection. The ZLD process allows the city to treat and recover nearly 100 percent of WTP-produced concentrate that previously had been discharged to a surface water body. The ZLD process treats the concentrate stream to a level at which, when blended with the plant's finished water, complies with drinking water standards. The process increases the facility's capacity by 1.2 mgd without additional source water supplies.

The ZLD process evolved after the city's most recent National Pollutant Discharge Elimination System concentrate discharge permit renewal, as the US Environmental Protection Agency (USEPA) and Florida Department of Environmental Protection (FDEP) determined the use of an extended mixing zone for water quality compliance was no longer feasible. The city then evaluated 12 alternative disposal methods of concentrate based on treatability, feasibility, and economics. After bench-scale and pilot testing, it selected ZLD for its WTP No. 2. The concentrate ZLD option provides for concentrate recovery as an alternative water supply for potable use and for beneficial reuse of solids removed from the concentrate stream. The local water management district's push for the use of alternative water supplies was also a factor in ZLD selection.

PROCESS DESIGN

Palm Coast WTP No. 2 has a permitted capacity of 6.4 mgd, which includes 1.6 mgd of raw water bypass. The membrane softening system currently operates

An aerial view of WTP No. 2 shows many of the facilities built to treat and recover the plant's concentrate as an alternative water supply using the ZLD process, including (clockwise from top left) a sludge dewatering facility, a lime silo, a post-treatment and ultrafiltration building, and solids contact clarifiers.

PHOTOGRAPHS: CITY OF PALM COAST, FLA.

at approximately 80 percent recovery and is designed to produce 4.8 mgd of permeate, with a resultant 1.2-mgd flow of concentrate. The ZLD treatment process uses the concentrate as its source water supply, and the ZLD-treated water is blended with the combined permeate and raw water bypass water so the resulting blended water quality meets current drinking water standards and city water quality goals. Adding the ZLD process increased WTP No. 2's production capacity to 7.6 mgd (4.8 mgd permeate, 1.6-mgd raw water bypass, and 1.2 mgd ZLD treated water).

Primary components of the ZLD process include a softening system, sedimentation, an ultrafiltration (UF) feed system, UF system components, a UF backwash/cleaning system, a disinfection system, a process recycle and recovery system, a solids-handling system, a sludge dewatering system, process and yard piping, electrical systems, and instrumentation and control systems. The table on page 18 presents the water quality parameters used to design the concentrate ZLD system.

As shown in the process flow diagram on page 19, the concentrate ZLD process consists of softening by chemical precipitation followed by UF to primarily reduce carbonate and noncarbonate hardness as well as some total organic carbon and color. Lime and soda ash are used to precipitate carbonate and noncarbonate hardness in two solids contact clarifiers, and a polymer is added to enhance settling. The pH of the softened water is adjusted, and a scale inhibitor is added before water is transferred to the UF feed tank. The UF feed pumps transfer the softened water through automatic backwash strainers and a pressurized vertical UF system that removes most of the remaining suspended solids. The UF system was designed to provide for 100 percent treatment capacity when one of the plant's four trains is off-line for cleaning, maintenance, or repair. The UF elements are cleaned through chemically enhanced backwash and clean-in-place (CIP) operations.

The chemically enhanced backwash uses sulfuric acid, sodium hydroxide, or sodium hypochlorite. CIP operations use citric acid, sodium hydroxide, or sodium hypochlorite. The UF system is housed in a pre-engineered metal building designed to accommodate additional UF membranes and other components to allow for a future expansion of the ZLD process to 1.8 mgd. The UF filtrate then is conveyed to the UF filtrate/backwash tanks. The filtrate from the UF filtrate/backwash tanks is disinfected before blending with the combined permeate and raw water bypass water directly upstream of the existing ground storage tank.

In addition to the main ZLD process stream, two additional process streams

Water Quality Data and Goals

The ZLD treatment process uses the concentrate as its source water supply. The ZLD-treated water is blended with the combined permeate and raw water bypass water so the resulting blended water quality meets current drinking water standards and city water quality goals.

Water Quality Parameter	RO Permeate	Raw Water Bypass	RO Concentrate	ZLD Treated Water Goal	Total Blended Water Goal*
Total Hardness (mg/L as $CaCO_3$)	4.1	349	1,650	<155	100
Calcium Hardness (mg/L as $CaCO_3$)	2.7	321	1,470	<100	85
True Color	0	23	53	<65	<15
Total Dissolved Solids (mg/L)	54	469	2,500	<2,320	<500
Iron (mg/L)	0.02	0.43	1.7	<1.25	<0.3
Chloride (mg/L)	11.1	115	600	<1,380	<250
Turbidity (NTU)	0.10	0.82	8.8	<0.40	<0.3

*Total Blended Water Goal meets or exceeds USEPA and FDEP drinking water requirements.

are associated with the concentrate ZLD process: a solids stream and a recycle stream. The system recovers 98.5 percent of the concentrate, and the remaining 1.5 percent is lost through water contained in the dewatered lime sludge and water used in the CIP operations. To achieve the required concentrate recovery, five recycle/recovery streams combine in the equalization tank where they're recycled to the head of the ZLD process. The recycle streams include solids-laden softened water from the UF feed tank, UF pretreatment automatic backwash strainer waste, UF-neutralized chemically enhanced backwash water, gravity sludge thickener supernatant, and belt filter press filtrate. The recovery and recirculation of the various streams within the concentrate ZLD process are key to successful implementation. The ZLD system was designed to produce lime sludge with approximately 50 percent dry solids.

The UF elements are cleaned through chemically enhanced backwash and clean-in-place operations.

Sludge removed from the solids contact clarifiers is transferred to a gravity sludge thickener. Solids removed from the gravity sludge thickener are conveyed to the solids-handling and dewatering system. Sludge is dewatered with two belt filter presses, which allow for 100 percent redundancy. The dewatered solids are hauled from WTP No. 2 by the city's contract hauler, and they're mixed with shell and sand for use as road base.

The ZLD process is integrated into WTP No. 2 so the overall plant operates as a single facility. The concentrate ZLD system is located on the plant's site to minimize the site and carbon footprints, reduce environmental impacts, and allow for ease of operation and maintenance.

PROJECT CHALLENGES

Recycle Streams. One of the project's biggest challenges was handling all of the recycle streams, which increase the recovery to approximately 98.5 percent. Because of each stream's varying volume, duration, and frequency, an equalization tank with a capacity of approximately 80,000 gallons was designed and sized to provide ample capacity for the flows. In addition to providing the requisite storage for the recycle flows, the equalization tank was also fitted with a mixing system that includes jet-type mixing eductors and a pumping system to keep solids from settling in the tank.

Three recycle pumps are included for the equalization tank to transfer the various recycle flows back to the head of the ZLD process, directly upstream of the solids contact clarifiers, where the flows are mixed with the influent concentrate. However, with the equalization tank's fairly large capacity, flow control of the recycle stream is required to avoid surges and upsets to

The ZLD process provides an environmentally responsible solution for concentrate management by eliminating a wasteful discharge and extending potable water supplies.

the ZLD treatment process. As a result of the recycle flows, the process units are designed to treat flows higher than the 1.2-mgd concentrate flow to accommodate the recycle streams. For the 1.2-mgd concentrate, the treatment process is designed to handle an additional 0.65 mgd of recycle flow.

The equalization tank was installed below-grade to allow for gravity flows to it, so self-priming pumps were selected instead of submersible pumps in large part because of the potentially corrosive equalization tank water. Submersible pumps would need to be fully constructed of stainless steel to withstand the environment, which wasn't economically feasible. Flow control evaluations considered variable frequency drives, motorized v-port discharge ball valves, and multiple pumps.

Variable frequency drives were eliminated from consideration because of concerns about keeping the pumps primed at low motor speeds. Three pumps, along with a flow-controlled v-port ball valve on the common recycle line, were chosen.

Disinfection. Another significant challenge for the project was how to disinfect the ZLD-treated water without exceeding disinfection by-product limitations. The city currently provides 4-log virus treatment in accordance with the Ground Water Rule through free chlorine addition to the blended permeate and raw water bypass in the clearwell before chloramination.

The project's original concept was to combine the ZLD-treated water with the permeate and the raw water bypass streams in the clearwell, but higher TOC concentrations in the ZLD-treated water were a concern. Because the lime/soda ash softening combined with membrane filtration can provide 2-log virus inactivation, the ZLD-treated water was disinfected separately with free chlorine to provide the remaining 2-log virus treatment before chloramination.

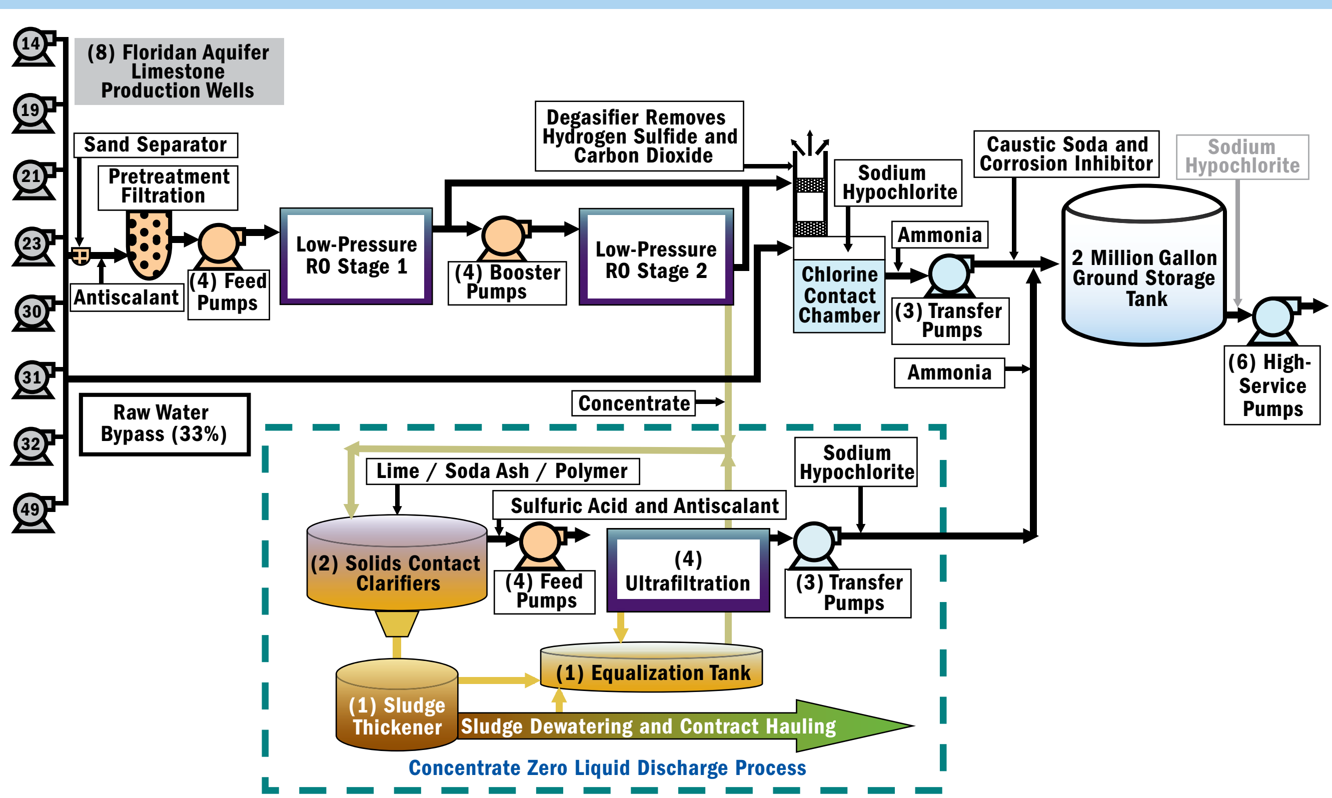
After the formation of chloramines, the ZLD-treated and disinfected water is combined with the facility's finished water. The separate disinfection operation minimizes impacts to the existing clearwell, transfer pumping, and piping systems, allowing for future plant expansion capacity as well as minimizing DBP formation potential.

INTEGRATION WITH THE EXISTING FACILITY

The concentrate ZLD process is complex, and it needed to be fully integrated with

Process Flow Diagram

The ZLD process was integrated into WTP No. 2 so the plant operates as a single facility.



PROJECT BENEFITS CHECKLIST

ZERO LIQUID DISCHARGE REINFORCES SUSTAINABILITY

The zero liquid discharge (ZLD) project implemented by the city of Palm Coast, Fla., has accomplished several objectives and provided multiple environmental benefits, including the following:

- Brought the city into regulatory compliance by eliminating the use of an extended mixing zone
- Eliminated the discharge of concentrate, the need for a National Pollutant Discharge Elimination System concentrate discharge permit, and associated monitoring and sampling costs
- Meets the city's green initiative goals for water conservation and waste recovery
- Integrated the ZLD system into the existing treatment plant so the plant operates as one facility
- Increased the plant's capacity by approximately 1.2 mgd without the need for developing additional source water supplies
- Delays the costs of potential wellfield and water treatment plant expansions
- Conserves water by recovering the concentrate and an alternative water supply, meeting the local water management district's requirements
- Provided an environmentally responsible solution for concentrate management by eliminating a wasteful discharge and maximizing the use of groundwater withdrawals
- Produces high-quality drinking water that meets US Environmental Protection Agency and Florida Department of Environmental Protection primary and secondary standards as well as city water quality goals

its respective components. Additionally, the entire ZLD process needed to be integrated into the existing plant so the plant operates as a single facility. This operational approach complies with the operating permit that was issued to incorporate the concentrate ZLD process and increase the plant's overall capacity. Integrating the ZLD process into the existing plant included several critical considerations, including electrical, instrumentation, and SCADA improvements.

The design intent for the concentrate ZLD project was to provide operators with the ability to observe, monitor, and control the entire facility's operations, including the ZLD process, from the existing operations room as well as additional control from the new UF building. The ZLD process was automated to minimize maintenance by operations staff.

The instrumentation and SCADA system associated with the ZLD process was integrated into the facility's existing SCADA system to provide for seamless and automated operations, monitoring, and control. The electrical system for the ZLD process was integrated into the existing facility's electrical system and includes emergency power for the overall facility to comply with regulatory requirements.

OPERATIONAL CONSIDERATIONS

Instrumentation and Electrical. The existing instrumentation and SCADA system at WTP No. 2 consists of a centralized plant control system, providing monitoring and operating capability from a centralized computer system. Plant operations have been directly wired into the control room's programmable logic control cabinet. The existing system was expanded to incorporate and completely integrate all of the ZLD processes into the modified SCADA system. This integration allows the operators to monitor and control all of the plant's operations and processes from a single location.

Electrical and Standby Power. The electrical system for the existing facility was expanded and upgraded to include the ZLD process. The existing emergency generator was rehabilitated and used for the concentrate ZLD process. A new emergency generator was installed to reinforce the plant's reliability. This approach was more cost-effective than replacing the emergency power system with a larger system to safeguard plant operations, including the ZLD process.

Yard Piping and Underground Utilities. The in-place raw water bypass piping was relocated to accommodate the new UF building. A significant amount of piping and other underground utilities exist on-site. As a result, new piping and other underground utilities' placement was challenging—a common issue when improving a facility. The keys to success were identifying existing piping and utilities early in the project through the use of record drawings, subsurface utilities excavations, and staff knowledge of previous plant improvements.

PROJECT SUMMARY

The concentrate ZLD project includes a softening process with sedimentation, chemical treatment, membrane filtration, and disinfection. The ZLD-treated water is blended with finished water from WTP No. 2, increasing the plant's capacity by approximately 1.2 mgd without the need to obtain additional source water supplies while eliminating the use of an extended mixing zone to achieve regulatory compliance.

To achieve 98.5 percent recovery of concentrate for potable use, several process streams that would normally be disposed of are treated and recycled to the head of the process for additional treatment. Overall, the ZLD process provides an environmentally responsible solution for concentrate management by eliminating a wasteful discharge and extending potable water supplies.