FIRST YEAR PERFORMANCE AT THE LVL WTF

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Abstract

The Leo J Vander Lans Water Treatment Facility (LVLWTF) was originally commissioned in 2002 by the Water Replenishment District of Southern California (WRD), producing 3.0 million gallons per day (mgd) from tertiary municipal wastewater effluent from the adjacent Los Angeles County Sanitation District's (LACSD's) Long Beach Water Reclamation Plant (LBWRP). The original facility included microfiltration (MF) ahead of reverse osmosis (RO), followed by ultraviolet light (UV) treatment for disinfection and destruction of trace nitrosamine compounds. Product water from the facility is used as a supplemental source of injection water in the Alamitos Barrier, a coastal seawater intrusion barrier. The primary source of barrier injection supply is domestic water which makes up the roughly 8.0 mgd required to operate the barrier. Injected waters migrate into a potable water aquifer, making the project supplies a source of indirect potable reuse (IPR) and subject to regulations by the State of California.

The facility was master planned for up to 8.0 mgd of product water capacity and in 2012, WRDSC proceeded with expanding the facility. 8.0 mgd is the peak flow requirement into the barrier and so with the expansion, LVLWTF product water would become the primary source of supply. The expanded facility design was developed concurrently with recently promulgated regulations in the State for IPR projects. The main process train of the facility was largely unchanged, with the exception of the UV system which was converted to a UV-advanced oxidation (UVAOP) process. One larger exception was however made—the target operating recovery of the facility. The original LVLWTF had a daily residuals discharge limit of 0.76 mgd. Because of capacity limitations on the local sewer system, the expansion needed to be accomplished without increasing the flow of wastes—essentially increasing the end-to-end process recoveryfrom 80 percent up to 92 percent.

A pilot test program was implemented that proved a concept of reclaiming backwash waste from the MF process units and RO brine from the RO trains. MF backwash is treated through dissolved air flotation (DAF) and secondary backwash treatment MF. RO brine is fed to a subsequent concentrator RO system. The full scale facility expansion was constructed with this separate residuals processing train accompanying the primary treatment system units, within the site limits that were planned on expanding only the primary treatment train equipment. The facility was successfully commissioned at the end of 2014. As the end of 2015 approaches, this paper looks back at the first year of facility operations.

Project Background

Since 1959, WRD has managed groundwater in the Central and West Coast Basins shown in Figure 1.

Groundwater within the basins meets roughly 40 percent of the local water demand of the population within the service area—4 million residents in 43 cities. Product water from the LVLWTF is injected into the Alamitos Gap Barrier Project (Alamitos Barrier) shown in the southern portion of the service area.

Figure 1 WRD Service Area

The Alamitos Barrier has been an active seawater intrusion barrier since 1964. The initial 3.0 mgd phase of the LVLWTF was completed in 2002. Since that time the barrier has received a mix of imported water supplies and recycled water, evidencing no degradation of groundwater quality in contiguous aquifers from the injection of recycled water.

An increase in LVLWTF capacity was envisioned in the original plant construction which was master planned for 8.0 mgd—the maximum barrier injection flow requirement. WRD began discussing the potential expansion of the facility with State regulators in 2005. A preliminary design report for expansion was issued in 2011; and a pilot testing program supporting final project design was run from December 2011 through May 2012. Primary goals of the pilot test were to demonstrate a stable operating flux of the primary RO trains of 12.2 gpd/ft^2 (gfd) at 85 percent recovery as well as the RO concentrator system operating at up to 52 percent recovery. Other coincident tests looked at potential DAF and secondary MF operations based on batch samples.

The full scale facility was a cooperative design between CDM-Smith and Separation Processes Inc. (SPI). Construction documents were completed in May 2012, with bids accepted in September of the same year. A roughly 20 month construction period followed, with the facility successfully passing its performance demonstration test in December 2014. The facility is run by operators of the Long Beach Water Department (LBWD) under contract to the WRD.

Treatment Process

Main components of the expanded treatment process are discussed below.

MF System

A new primary MF system was installed consisting of six Pall Microza 100 module quad racks. The existing Pall- based MF system units were repurposed for treatment of backwash from the new primary system. The system has a rated capacity of 8.72 mgd, a design flux of 35 gfd, and a target recovery of 94 percent.

Figure 2 Primary MF Units

Feed water to the system is a nitrified tertiary effluent from the Long Beach Water Reclamation Plant (LBWRP) adjacent to the facility which is owned and operated by the County Sanitation Districts of Los Angeles County (LACSD).

The treated water from LBWRP is pumped into the LBWD recycled water distribution system. A branch from that system serves the LVLWTF. Incoming pressure is roughly 60 psig and is stepped down through a control valve to the operating pressure required by the primary MF units. Pretreatment includes addition of sodium hypochlorite and ammonia to achieve a monochloramine residual along with automatic strainers. Modulating valves on each of the primary MF units control flow through the membranes and operate to maintain a level set point in the downstream MF filtrate tank which equalizes and stores the treated water ahead of the RO system.

Each unit undergoes a programmed backwash process at fixed intervals—either based on processed volume or time. The system is configured such that the primary control is the processed volume trigger; backed up by an elapsed time set point. This helps maintain the system recovery target at variable flows to some extent. Each unit is also capable of receiving a daily maintenance clean to maintain permeability. More robust clean-in-place (CIP) sequences are called for when the system permeability declines beyond a set threshold. Cleaning solutions are made up in either of two cleaning tanks—acid or caustic depending on the cleaning solution employed. Spent solutions are neutralized prior to disposal.

RO System

The existing 3.0 mgd primary RO train was re-rated at 3.7 mgd due to the higher flux demonstrated during the pilot test program. An inter-stage booster pump was added to better distribute flow through the 2-stage train configured in a 72:36 pressure vessel array and operating at 85 percent recovery. A second equivalent train was constructed as well.

Each train is fed by a dedicated in-line high pressure feed pump. The inline pumps are fed from a series of three pumps drawing from the MF filtrate storage tank. The RO feed water is pretreated through the addition of sulfuric acid and an antiscalant followed by cartridge filtration.

Figure 3 Primary RO Train

Concentrate from the two primary RO trains is routed directly to the inline feed pumps associated with one of three third stage RO trains. These pumps are in turn controlled to maintain a pressure set point in the respective concentrate line. A nested control algorithm adjusts the speed of the pumps to allow the concentrate valves on the respective primary trains to open to 95 percent.

UV/AOP System

The expanded UV system incorporates advanced oxidation through the addition of up 3.5 mg/L of hydrogen peroxide to the system feed water. Two new triple stacked 72-lamp reactors operate in parallel with the original unit. The combined system is intended to achieve a net log removal of n-nitrosyldimethylamine (NDMA) between 1.62 – 2.03; along with a 0.5 log reduction of 1,4 Dioxane.

Figure 4 UV Train

Product water from the RO system flows directly to the above grade UV reactors. An online analyzer measures the transmittance of the product water from the RO system and automatically adjusts the applied UV system dose. The UV controller also calculates the requisite dose of hydrogen peroxide.

During commissioning, startup was a challenge as the units were subject to draining back through the supply manifold located at grade level. This was addressed by modifying the operating sequence of the UV train inlet valves and associated RO system permeate flush supply storage tank which is connected to the UV system influent header.

Residuals Handling System

The main residuals treatment units include the MF backwash and RO concentrate recovery units. For the MF backwash, a single DAF unit is provided to pretreat the backwash from the primary units, achieving an effluent turbidity of less than 3.0 NTU. The inlet water to the DAF is pre-dosed with ferric chloride. Initial operations have shown that the effluent turbidity is best achieved at a ferric dose between 3.0 – 5.0 mg/L. The DAF effluent flows to a basin that stores the water ahead of treatment by the backwash treatment or BWT MF units. The solids laden waste from the DAF drains to the main plant waste basins for transfer to the LACSD sewer.

Figure 5 DAF Unit

The BWT MF units have a capacity of 0.42 mgd and a target operating flux of 24 gfd. Recovery is designed at 89 percent. The actual units were reconfigured from the original plant's primary MF units. In that configuration, there were 8 units mounted on a four racks. Each unit had 25 Pall MF modules. Two of the racks were kept and refurbished to serve as the BWT system units. New modules and rack distribution headers were provided, while the original valve racks, compressed air system, and cleaning system equipment were maintained. The four units are fed from the DAF effluent wetwell by three vertical turbine pumps. The inlet water is pretreated with automatic strainers. Product water from the BWT units is integrated with filtrate from the primary units for feed to the RO system. The backwash residual from the units is sent to the plant waste equalization basins for sewer discharge.

For the RO system, concentrate from the two primary RO trains is further treated by three independent concentrator trains arranged in a two operating, one standby configuration. The system has a treated water capacity of 0.67 mgd. The trains operate at an average flux of 10 gfd and recovery of 52 percent. Each train is arranged as a single stage with eight membrane elements in series housed in sets of two 4 element pressure vessels. Automated valves direct the flow of concentrate from the primary trains to the third stage units. Additional sulfuric acid is dosed to the concentrate feed lines. Provisions are included for adding additional antiscalant as well, but to date

Figure 6 Concentrator RO Trains

supplemental antiscalant dosing has not been implemented. Based on the pilot test program, an operating interval between in place cleanings was estimated at roughly three weeks, compared to the roughly six month interval experienced by the primary trains. Due to the increased frequency, an automated cleaning system was provided that is a separate standalone system from the primary RO cleaning system.

First Year Operations

The LVL WTF nears the end of its first year of operations with a mixed record of success. The overall facility main process units have performed well with some exceptions. Larger impacts resulted from latent construction issues, warranty call backs, SCADA completion, and operations transfer. Flows to the Alamitos Barrier were more restricted than originally anticipated as well. Each of these issues is described below.

Latent Construction and Warranty Issues

The expanded facility was commissioned over a three month period. Startup was challenging owing to limitations on the disposal of test water and complex interactions among the treatment processes. Several lessons were learned, including the importance of proper integration of SCADA screens developed by multiple system vendors, proper understanding of system testing requirements in terms of operating flows, and the proper timing of vendor field personnel. An additional challenge related to the integration of new equipment and facilities with original plant equipment and systems.

As a consequence, SCADA integration with the main LBWD operations group took most of the first quarter to accomplish. Completion of the final SCADA screens and integration with the LBWD supervisory system was required to allow remote 24-hr monitoring of the facility by offsite duty operators. Without this integration, the facility was limited to 8-hr operating windows when the facility itself was staffed.

Significant warranty issues occurred with the DAF unit and one transfer pump variable frequency drive (VFD). The launders in the DAF unit experienced gross mechanical failure and required replacement. The pump VFD caught fire in the electrical room for unknown reasons and required a full incident investigation.

Beyond these events, operations also revealed that certain equipment items remaining from the original facility were reaching the end of their useable life and needed replacement. Primary among these items were several chemical metering pumps in sodium hypochlorite, antiscalant, sulfuric acid and sodium hydroxide services. LBWD has instituted a process of replacing these components starting mid-year.

As a consequence, the LVL WTF did not initiate 24-hr continuous operations until September of this year. The facility ran for close to a month before operations at the LBWRP curtailed the availability of supply. The plant is now effectively off line until January of next year.

Barrier Injection Flows

During periods of operation, all product water from the LVL WTF is sent to the Alamitos Barrier injection wells. The injection well system is maintained by the County of Los Angeles (County), and all facility operations must be closely coordinated with them. In the initial operations phase, the County wished to introduce product water from the facility at a rate of 3.0 to 3.5 mgd to demonstrate stable operation. In some cases flows as low as 2.5 mgd were requested. This range of flow variability was not figured into the original plant expansion design—which is effectively equipped with two 4.0 mgd process trains. The limiting process is the RO system, which has less turn down capability at fixed recovery than the MF or UV/AOP systems. As a consequence we were forced to explore novel ways to increase the reduction in flow from the RO system. The solution was to allow the recovery of the primary RO trains to decrease, but always maintain the same flow of concentrate to the concentrator system. Figure 7 below is a snapshot of the flow set point table that was developed for operators to adjust to variable rates of facility production. The table columns outlined in red highlights the parameters input to the facility SCADA system to control operation of the primary RO trains.

LVL Operations Scenarios													
										3rd Stage RO			
Plant Feed Rate	Total RO Feed	RO Train Feed	Total Train Recovery	Total Permeate Flow Rate	Stage 2 Permeate Flow Rate	Train Conc. Flow Rate	Total Primary RO Conc.	Production w/ 1 RO Train	Production w/ 2 RO Trains	% Rec	Conc.	Permeate	Total LVL Production
MGD	MGD	gpm	%	gpm	gpm	gpm	gpm	MGD	MGD		gpm	MGD	with 3rd stage
8.70	8.62	2,993	85%	2,543	815	450	900	3.66	7.33	52%	432	0.67	8.00
8.50	8.42	2,924	85%	2,474	799	450	900	3.57	7.13	52%	432	0.67	7.80
8.25	8.17	2,838	84%	2,388	773	450	900	3.44	6.88	52%	432	0.67	7.56
8.00	7.93	2,752	84%	2,302	753	450	900	3.32	6.63	52%	432	0.67	7.31
7.75	7.68	2,666	83%	2,216	728	450	900	3.19	6.39	52%	432	0.67	7.06
7.50	7.43	2,580	83%	2,130	708	450	900	3.07	6.14	52%	432	0.67	6.81
7.25	7.18	2,494	82%	2,044	683	450	900	2.95	5.89	52%	432	0.67	6.57
7.00	6.94	2,408	81%	1,958	658	450	900	2.82	5.64	52%	432	0.67	6.32
6.75	6.69	2,322	81%	1,872	639	450	900	2.70	5.40	52%	432	0.67	6.07
6.50	6.44	2,236	80%	1,786	615	450	900	2.57	5.15	52%	432	0.67	5.82
6.25	6.19	2,150	79%	1,700	591	450	900	2.45	4.90	52%	432	0.67	5.57
6.00	5.94	2,064	78%	1,614	568	450	900	2.33	4.65	52%	432	0.67	5.33
5.75	5.70	1,978	77%	1,528	545	450	900	2.20	4.40	52%	432	0.67	5.08
5.50	5.45	1,892	76%	1,442	522	450	900	2.08	4.16	52%	432	0.67	4.83
5.25	5.20	1,806	75%	1,356	500	450	900	1.95	3.91	52%	432	0.67	4.58
5.00	4.95	1,720	74%	1,270	478	450	900	1.83	3.66	52%	432	0.67	4.33
4.75	4.71	1,634	72%	1,184	452	450	900	1.71	3.41	52%	432	0.67	4.09
4.50	4.46	1,548	71%	1,098	431	450	900	1.58	3.16	52%	432	0.67	3.84

Figure 7 Primary RO Train Flow Summary

At this time the facility has been successfully operated at production flows as low as 2.0 mgd. The 24-hr operating period in September saw continuous operations at 4.0 mgd. Current total flows into the Alamitos Barrier are between 6.5 and 7.0 mgd. The County is still seeking further assurance of the facility's ability to operate reliably 24-hrs per day before allowing an increase of flow up to the full injection requirement.

Treatment System Performance

This section focuses on the performance-to-date of the MF and RO system, both primary and BWT/concentrator units. The performance of the DAF and UV/AOP systems has been acceptable once described equipment and operating issues were addressed.

<u>MF Systems</u>

The primary MF system includes six equivalent membrane units. Figure 8 shows the temperature corrected specific flux for each over the initial operating period. While there is some spread in the individual unit data, overall permeability of the membranes has been successfully maintained. This is particularly encouraging due to the fact the daily chemical washes of the membranes have not been implemented during this period of operation.

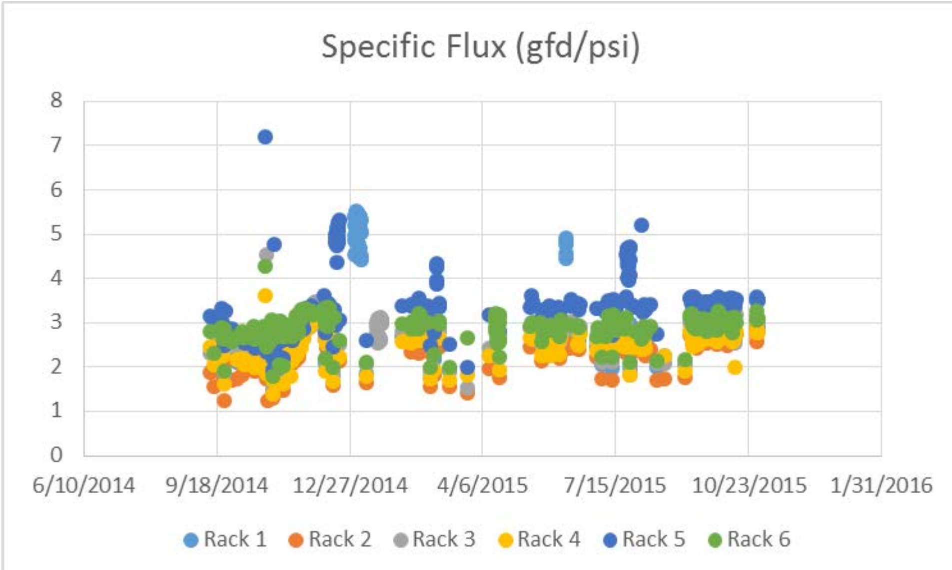

Figure 8 Specific Flux of Primary MF Units

In addition, system recovery has been maintained proximate to the 94 percent target for the majority of the operating period as shown no Figure 9. In some periods, lower recoveries were observed when all six process units were operating at low flow, causing the backwash sequences to trigger based on elapsed time rather than volume. This has been corrected by taking individual units offline during periods of low flow.

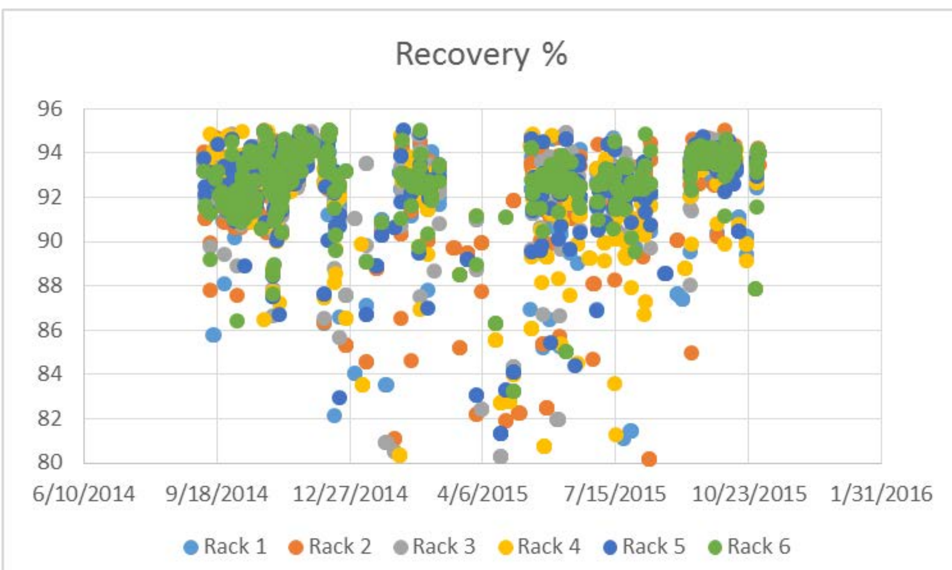

Figure 9 Primary MF System Recovery

Similarly, the four BWT MF units have performed well. There is a noticeable drop in specific flux of these units which is understandable given the higher solids load associated with the service. Still, overall permeability has been well maintained, again without the implementation of any cleanings to date.

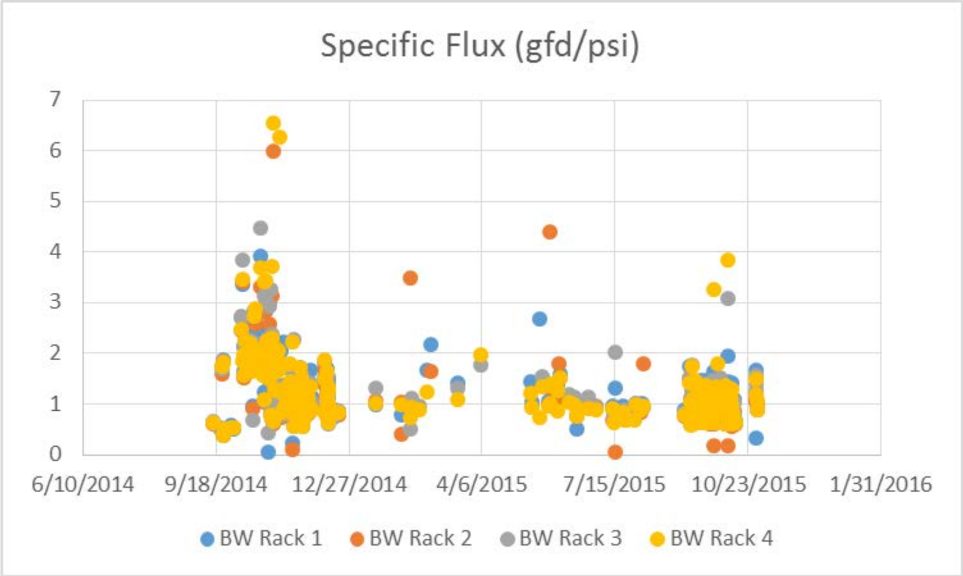

Figure 10 Specific Flux of the BWT MF Units

Similar to the primary MF units, target recoveries have been maintained for the majority of the operating period. Again, periods of low flow towards the end of the year saw a decrease in recovery due to the increased frequency of backwashing. Current practice similar to the primary system is to take units offline during periods of low flow.

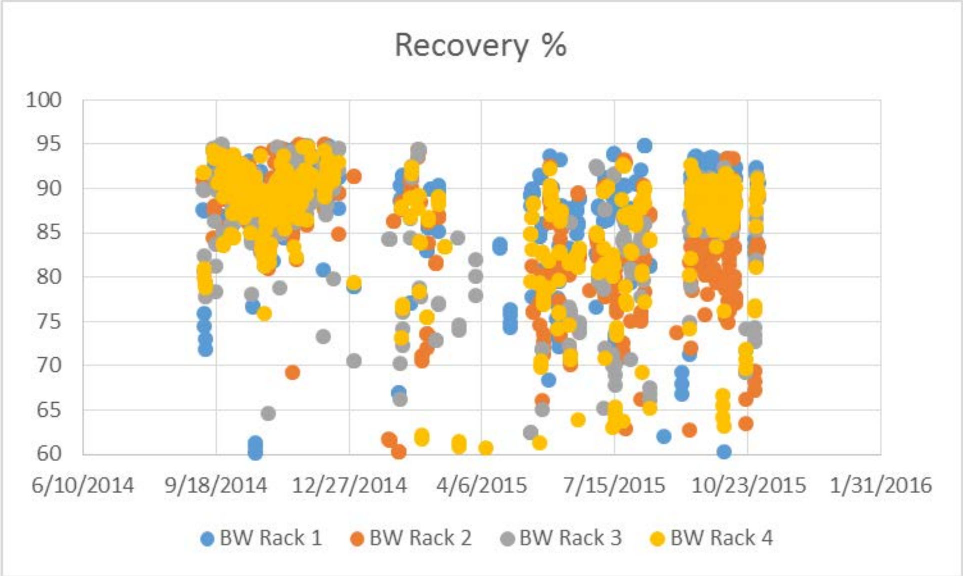

Figure 11 BWT MF System Recovery

RO Systems

Initial operation of the primary RO trains has been very stable as well. While flows from the plant as a whole have been roughly half of the system design capacity, operation of the RO trains has rotated, meaning each operates near its rated capacity. Similar to the MF system data, we have included plots of specific flux for each train, which indicates the absence of any appreciable loss of permeability to date. The data is separated to show specific flux of each stage of the trains. While both have remained stable, the specific flux of the second stage is understandably lower than the first stage membranes.

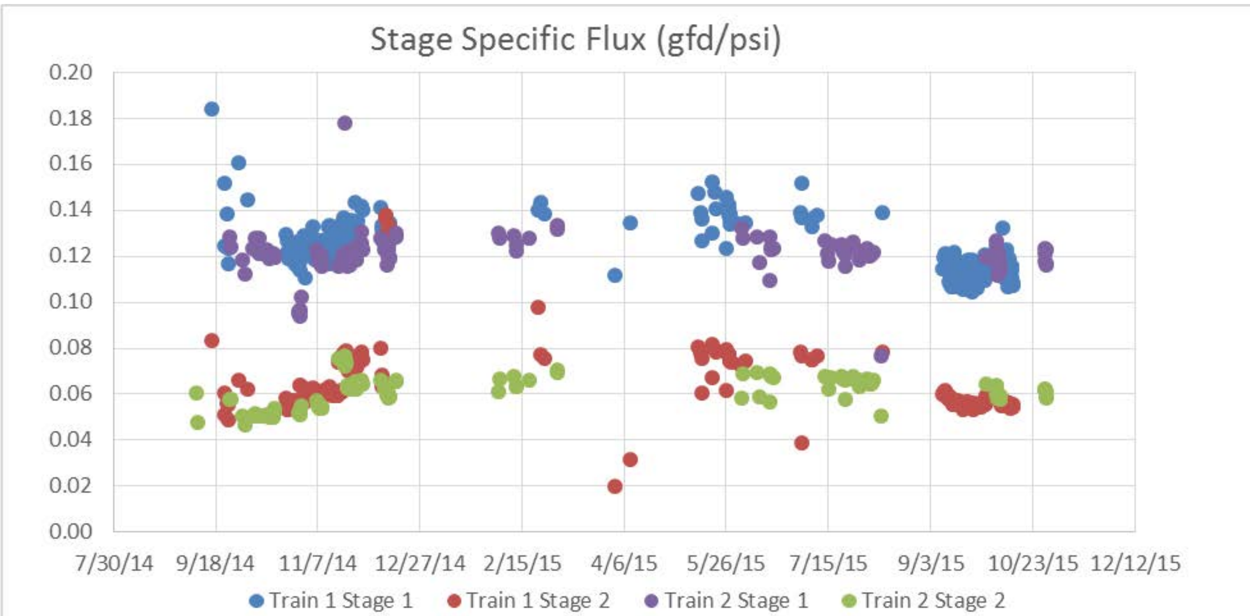

Figure 12 Specific Flux of Primary RO Trains

Lastly, we have included data for one of the third stage RO trains (Train 3) which is emblematic of the operation of the three trains but easier to view in isolation. From the pilot test we anticipate a roughly 21-day interval between cleanings for the third stage trains. However, the non-continuous operations to date have allowed extended operation on a calendar basis. All three trains have been successfully cleaned at this point; and permeability is generally stable as shown in the chart below.

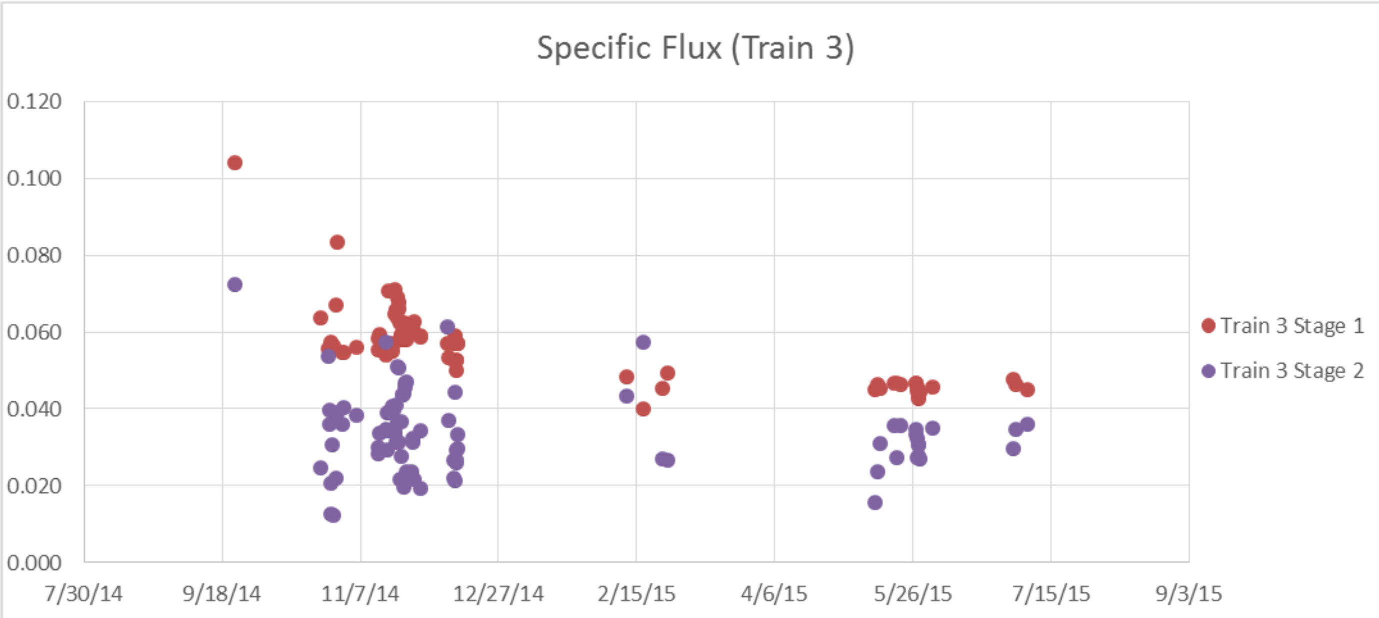

Figure 13 Specific Flux of RO Concentrator Train 3

Water Quality

Water quality for the facility's initial operations are provided in Table 1. The data are focused on the general mineral quality of the listed streams though the treatment process. The MF filtrate stream is representative of the feed water to the primary RO system. The RO product water is the combined quality of the primary and third stage trains' blended product stream. The final product water is representative of the post-UV and product stabilization. The quality of the primary RO and third stage RO brine streams are also included. The primary RO brine represents the quality of feed to the third stage trains; while the quality of the third stage concentrate is indicative of the overall concentration factor achieved through the combined RO process operating at an effective total recovery of 94 percent.

Table 1 Water Quality Data

Parameter	Stream Identification				
	MF Filtrate[1]	RO Product[1]	Final Product[1]	Primary RO Brine[2]	Third Stage RO Brine[2]
Alkalinity, mg/L CaCO3	170	5.1	35	1,160	2,100
Calcium, mg/L	53	<1	6.2	276	577
Chloride, mg/L	110	5.1	24	625	1,260
Iron, mg/L	0.068	ND	ND	0.28	0.53
Manganese, mg/L	0.05	ND	ND	0.12	0.26
Potassium, mg/L	16	<1	<1	77	153
Silica, mg/L	22	0.6	0.6	125	245
Sodium, mg/L	130	8	28	508	1,450
Sulfate, mg/L	89	2.5	2.5	508	1,180

Parameter	Stream Identification				
	MF Filtrate[1]	RO Product[1]	Final Product[1]	Primary RO Brine[2]	Third Stage RO Brine[2]
Total Organic Carbon, mg/L	6.53	0.13	0.13	41	80
Total Dissolved Solids, mg/L	520	31	100	3,290	6,630
Aluminum, mg/L	0.02	ND	ND	0.09	0.16
Fluoride, mg/L	0.57	0.09	0.09	4.0	7.2
Ammonia Nitrogen, mg/L as	1.0	0.2	0.2	2.6	7.2
Nitrate Nitrogen, mg/L as N	7.5	1.3	1.3	27	52

Notes:

1. Data collected during facility acceptance test.
2. Data collected during facility pilot test program.

While no destructive autopsies have been performed to date to characterize the foulant on the third stage membranes, it is presumed to be primarily silica based on the high concentrate of silica in the third stage brine. A destructive autopsy of an element used during the third stage pilot testing similarly revealed the presence of silica scale.