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WATER QUALITY

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From the Editor

By: Dave MacNevin

In this issue, we are pleased to share three articles with you, looking at three significant water quality challenges common to membrane treatment.

The first article looks at West Basin Municipal Water District's approach to microfiltration/ultrafiltration (MF/UF) membrane replacement at the Edward C. Little Water Recycling Facility. The article presents results from pilot testing of six different varieties of pressurized polyvinylidene fluoride (PVDF) MF/UF modules. The pilot test investigated the impacts of feed water quality on membrane performance, while also seeking to identify the maximum sustainable membrane flux.

The second article looks at the Town of Jupiter Utilities, 14.5 MGD Nanofiltration (NF) plant, which is part of the Town's 30 MGD water treatment facility. In 2014, the Town commissioned a 267 gpm NF pilot unit, in attempt to evaluate the ability of their process to reject trace organic compounds (TrOCs), should they ever be present in Jupiter's raw water supply. The article presents the findings of numerous investigations regarding the removal of TrOCs by NF after their addition to the pilots' feed water supply.

The third article looks at El Paso Water's Kay Bailey Hutchison (KBH) Desalination Facility (27 MGD), which treats brackish groundwater using low pressure reverse osmosis, with bypass blending. Since startup in 2007, the total dissolved solids (TDS) of many wells has increased gradually, with the TDS of many wells now above 3,000 mg/L compared to 1,000-1,500 mg/L at startup. This article describes how the KBH facility adjusted operations for the increase in TDS, and planned upgrades to increase total plant capacity.

We hope you enjoy these articles and find them relevant to some of your membrane applications. We welcome and appreciate your feedback on this issue. If you, are interested in submitting an article for a future edition of Solutions, submissions can be sent to Dave MacNevin (dave.macnevin@tetratech.com).

Dave MacNevin

West Basin's Universal Membrane System – Pressurized PVDF Performance Pilot Results

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Introduction

West Basin is a public agency that provides imported drinking water and recycled water to 17 cities and nearly one million people in the coastal Los Angeles area. West Basin is member agency of the Metropolitan Water District of Southern California. West Basin is an internationally recognized expert in water recycling, conservation, water education and water resource management, and currently treats over 40 million gallons a day (mgd) of secondary municipal effluent to produce five different recycled water qualities.

Historically, the majority of major microfiltration (MF) and ultrafiltration (UF) membrane systems have been provided by suppliers that incorporate proprietary features into their modules and system designs. These proprietary features are not easily adaptable to alternative concepts when equipment repair or membrane replacement is required. As a result, membrane replacement is usually sole-sourced to the proprietary system supplier and subject to the commercial practices and potential limitations of the equipment and membranes provided by that supplier. West Basin found that retrofit/replacement of the 25 older proprietary microfiltration units used at various locations was more expensive than simply replacing the system itself.

West Basin's Universal Design Approach

As part of the on-going effort to improve operation at its facilities, West Basin began to review specifications for some of the latest generation of pressurized MF/UF modules and found that there is a substantial level of consistency among current PVDF product offerings as shown in Table 1.

Next criteria for the membrane pilot unit were established. Figure 1 shows the overall process arrangement of the proposed membrane unit.

A key element of the specification development was the decision that parameters for operation for each of the membrane modules could be individually programmed through the operational interface. This approach increases the flexibility to control the unit, and eliminates the need for a programmer to make changes to the process sequence. In order to facilitate operation, the pilot system was provided with an internet connection for remote operation and transfer of historical data. Plans and specifications for construction of the pilot unit were competitively bid, and construction was awarded to H2O Innovations. Figure 2 shows the Pilot Unit installed at West Basin's Edward C. Little Water Recycling Facility.

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The pilot unit was received in July 2015. Installation was delayed by site specific issues and active commissioning was delayed until early October 2015.

PVDF Module Selection

While the pilot system was being constructed, a survey of pressurized MF products was made, identifying products of similar physical configuration, membrane properties and operating processes to determine modules for evaluation. The preliminary test plan indicated that a total of 6 membranes would be evaluated. A technical memorandum was prepared to identify membrane modules for evaluation and preferences with the common characteristics listed in Table 2.

Based upon discussions with various entities, the membrane modules listed in Table 3 were ultimately selected.

Tertiary Filtered (a.k.a. Title 22) Recycled Water from ECLWRF was used as feed water to the universal pilot unit. This water, shown in Table 4 was chosen as the supply for this evaluation as being representative of water that is available within the West Basin distribution system including satellite facilities located in Carson and Torrance, CA.

Upon installation, the individual manufacturers specified the operational sequences to be programmed into the unit. Programming of the operational interface allows the operator to establish valve position, flow and duration, uniquely for each membrane module and for each sequence. The test schedule is provided in Table 4.

In order to determine the maximum stable membrane flux, membranes located on the pilot unit were operated for a period of one week. At the end of the week, the performance was reviewed, and if the performance of the membrane appeared to be stable, (e.g. an increase in TMP of less than 25 percent of the maximum allowable TMP for the module considered over the period of 7 days) a decision was made to increase the flux to the next highest amount

Table 1
PVDF Module Offerings

Membrane	units	Dow	Econity	GE	Hydranautics	Pall	Puron	Scinor	Toray
General									
Material	Polymer	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF
Model	Part Number	SFD-2880	PF-90M	ZW-1500	HYDRAcap MAX 80	UNA-620A	MP 8081-102	SMT600-P50	HFU-2020
Configuration	Direction	Outside In	Outside-In	Outside-In	Outside-In	Outside-In	Outside-In	Outside-In	Outside-In
MFG Process	Type	DIPS/NIPS	TIPS+Stretch	TIPS	TIPS	TIPS	n/a	TIPS	TIPS
Supported	unsupported	unsupported	unsupported	unsupported	unsupported	unsupported	Polyester	unsupported	unsupported
Pore Size	microns	0.03	0.1	0.02	0.08	0.1	0.03	0.1	0.01
Inside Diameter	mm	0.7	0.7	0.47	0.6	0.65	1.5	0.7	0.9
Outside Diameter	mm	1.3	1.2	0.9	1.2	1.1	2.6	1.3	1.5
Area	ft2	829	969	550	1130	538	546	538	775
Area	m2	77	90	51.1	105	50	50.75	50	72
Operating Flux	gfd	24-70	25-100	20-80	20-65	20-80	20-80	30-70	20-80
Operational									
Static Pressure	psi	90	38	40	73	45	45	60	44
Max. Forward TMP	psi	30	22	40	30	35	25	45	44
Backwash TMP	psi	38	38	40	30	35	10	35	44
Maximum Temperature	C	40	40	40	40	40	40	40	40
Operating pH Range	units	2-11	1-9	5-10	4-10	3-11		1-11	1-10
Backwash	type	air/water	air-water	air/water	air/water	air/water	air/water	air/water	air/water
Air Flow/module	SCFM	7 scfm		7 scfm	7.3-9.1 SCFM	3 SCFM	9 SCFM	3.1-7.5	3.5 SCFM
Water Direction	Feed/Filtrate	Filtrate	Filtrate	Filtrate	Feed	Filtrate	Feed/Filtrate	Filtrate	Filtrate
Cleaning									
Cleaning Temperature	C	40	40	40	40	40	40	40	40
Cleaning pH Range	units	2-11	2-11	2-11	1-13	3-12	1.8-10.5	1-13	0-12
Maximum Free Chlorine	mg/L	2000	1000	1000	5000	5000	1000	5000	2000
Periodic Cleaning (CEB)	yes/no	yes	yes	yes	yes	yes	yes	yes	yes
Frequency	hours	12-72	12-72	12-72	12-72	12-72	12-72	12-72	12-72
Duration	min	20-60	20-60	20-60	20-30	20-60	20-60	20-60	20-60
Chlorine Concentration	mg/L	200	200	200	200	200	?	200	200
Physical									
Length	mm	2360	2000	1920	2340	2160	2060	2160	2160
Diameter	mm	225	260	180	250	180	220	180	216
Feed Connection	mm	50	80	50	50	50	32	50	50
Feed Connection	orientation	off axis	on-axis	on axis	on axis	on axis	off-axis	on axis	on axis
Feed Connection	Style	victaulic	victaulic	victaulic	victaulic	victaulic	victaylic	victaulic	victaulic
Filtrate Connection	mm	50	80	50	50	50	32	50	50
Filtrate Connection	orientation	off axis	off axis	on axis	on axis	on axis	off-axis	on axis	on axis
Filtrate Connection	Style	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic
Backwash Connection	mm	50	65	32	50	32	32	32	50
Backwash Connection	orientation	on axis	on-axis	off axis	off axis	off axis	on-axis	off axis	off axis
Backwash Connection	Style	union	victaulic	union	victaulic	union	victaulic	union	victaulic
Air Scour Connection	Style	3/8"	n/a	n/a	3/8"	n/a	1/2"	n/a	n/a
Air Scours Size	in/mm	NPT	n/a	n/a	NPT	n/a	OD Tube	n/a	n/a

(target). If the membrane exceeded its maximum TMP during the period of testing, the membrane would be removed from service and cleaned prior to restarting.

The overall objective was to identify the membrane flux that resulted in stable operation over a 21 to 30 day projected cleaning interval, which is historically used at West Basin's facilities. Normalized or temperature compensated flux strategies were not being used as the planned use of the water is as a supply to a reverse osmosis system. RO is a process that requires a constant amount of flow to the unit during normal operation. However, the District should consider applying a temperature correction factor as part of the final design, as there is historical evidence to suggest that the water quality is more challenging, necessitating a lower membrane flux, or more frequent cleaning when water temperature is lower. Performance data is shown with both the actual flux and temperature corrected flux in order to show the effects of the changing temperature on the system and how performance goals would vary during the winter and summer seasons.

Phase 1A Operational Results

The pilot unit began operation on recycled water on October 20, 2015 with the first set of three membranes: Toray, Dow, and Scinor. Upon start up, all three modules were operated at a flux of 25 gfd for a period of approximately 1 week. The flux was then increased for all three modules to 30 gfd per module. However, several faults due to issues with the backwash pump and queue programming led to several shutdowns and ultimately the unit was taken offline for approximately 5 days in order to correct the issues. The unit was once again restarted with all three modules at a flux of 25

Table 2
Module Characteristics

Common Characteristics	
PVDF Membrane	MF or UF viewed as equally acceptable
Homogenous Fiber Cross Section (TIPS or Similar)	Low incidence of fiber breakage
Bottom Feed	Compatible with chloraminated water

Table 3
Selected Membranes

Group A	Group B
Toray – HFU-2020	Econity – PF-90M
Dow – SFX-2880XP	Hydranautics - HYDRACap Max 80
Scinor – SMT600-P50	Pall – UNA-620A

Table 4
Feed Water Quality (2014, monthly averages, mg/L unless stated otherwise)

Parameter		Raw Water	
		Avg.	Range
Inorganic Constituents (mg/L unless otherwise stated)	Sodium	199	172-235
	Calcium	63	46-73
	Magnesium	30	23-36
	Potassium	20	18-22
	Iron	0.28	0.25-1.55
	Manganese	0.16	0.11-0.21
	Bicarbonate(mg/L as CaCO3)	269	236-336
	Chloride	20	260-378
	Sulfate	160	121-191
	Nitrate-(mg/L as N)	2.0	0.9-3.85
	Ammonia (mg/L as N)	41	32-49
	Total Phosphate	1.09	8.83-1.75
	Orthophosphate	0.74	0.46-1.12
	Silica	16	13.5-18.1
General Parameters Physical Characteristics	Total Dissolved Solids (mg/L)	934	640-1100
	Total Hardness (mg/L as CaCO3)	297	222-419
	Alkalinity(mg/L as CaCO3)	269	236-306
	Turbidity, (NTU)*	1.3	0.8-2.3
	Temperature (°C)	25	20-29
	pH, (pH units)	7.1	6.8-7.4
	Total Organic Carbon (mg/L)	10.0	8.5-13.2

Table 5
Schedule for Phase 1 (Group A shown, Repeat for Group B)

Test	Duration	Flux (gfd)	Backwash/ CEB
0	1 day	CIP + Clean Water Test	n/a
1A-1	7 days*	25 gfd	Manufacturers
1A-2	7 days*	30 gfd	Manufacturers
1A-3	7 days*	35 gfd	Manufacturers
1A-4	7 days*	40 gfd	Manufacturers
1A-5	21 -30 days	Flux at TBD gfd	Manufacturers
1A-6	21 -30 days	Flux at TBD gfd	Manufacturers

* Subject to change, In the event that maximum TMP for the membrane is exceeded the run will be terminated and the membrane will be cleaned and restarted at a lower flux.

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gfd. The unit ran at these flows for approximately 5 days then flux was increased on all three modules to 35 gfd. Soon after, the Scinor module was CIP'd after reaching terminal TMP values and following the cleaning the flux was reduced for the Scinor module back to 30 gfd. The Toray and Dow module fluxes were increased to 40 gfd. This flux was found to be unsustainable and was reduced back to 35 gfd after less than 48 hours. During this time, changes were also being made in order to incorporate caustic CEB's into the regime and refine CEB sequences and timing. Although it is somewhat unusual for caustic to be incorporated into the CEB sequence, for this water it appeared to provide a benefit.

The first successful 21 day run for all three modules began on December 12, 2015. After the first week of this run, the unit went offline for two days due to a leak in the feed piping. The piping was repaired and the unit came back online on December 21, 2015. The unit ran successfully until January 17, 2016 when it was taken offline and all three modules were cleaned. All three modules ran for a total of 35 days before the unit was taken offline due to TMP values nearing the maximum value and issues with the unit backwash programming and equipment. The unit was offline for approximately two weeks while various repairs and programming changes were implemented.

All three modules were cleaned and the unit started up at fluxes of 35, 35, and 30 for Toray, Dow, and Scinor respectively. Once again the unit experienced several faults due to equipment failure and programming issues which delayed the start of the second 21 day minimum test run.

For the Scinor module, the second successful run began on February 24, 2016 and the unit ran for >40 days at a flux of 30 gfd. NTMP values during the first week of this run were high while the CEB regime was optimized. After the optimized CEB regime was in place, NTMP values for this module were exceptional, ranging between 6-10 psi for greater than 3 weeks. This module was left online at 30 gfd until April 17, 2016 when the flux was increased to 35 gfd where it ran for an additional 2 weeks before the entire universal pilot unit was taken offline.

The second successful test run for the Toray module began on February 29, 2016 and the module ran for approximately 24 days at a flux of 30 gfd. During this time trends for this module were stable with NTMP values ranging from 10-14 psi for the majority of the run and specific flux values ranging from 2-3 gfd/psi. The second successful run for the Dow module also began on February 29, 2016 and the module ran for 25 days at a flux of 30 gfd. NTMP values for the Dow module fluctuated between 8-14 psi for the

Figure 1
Universal Membrane System Schematic

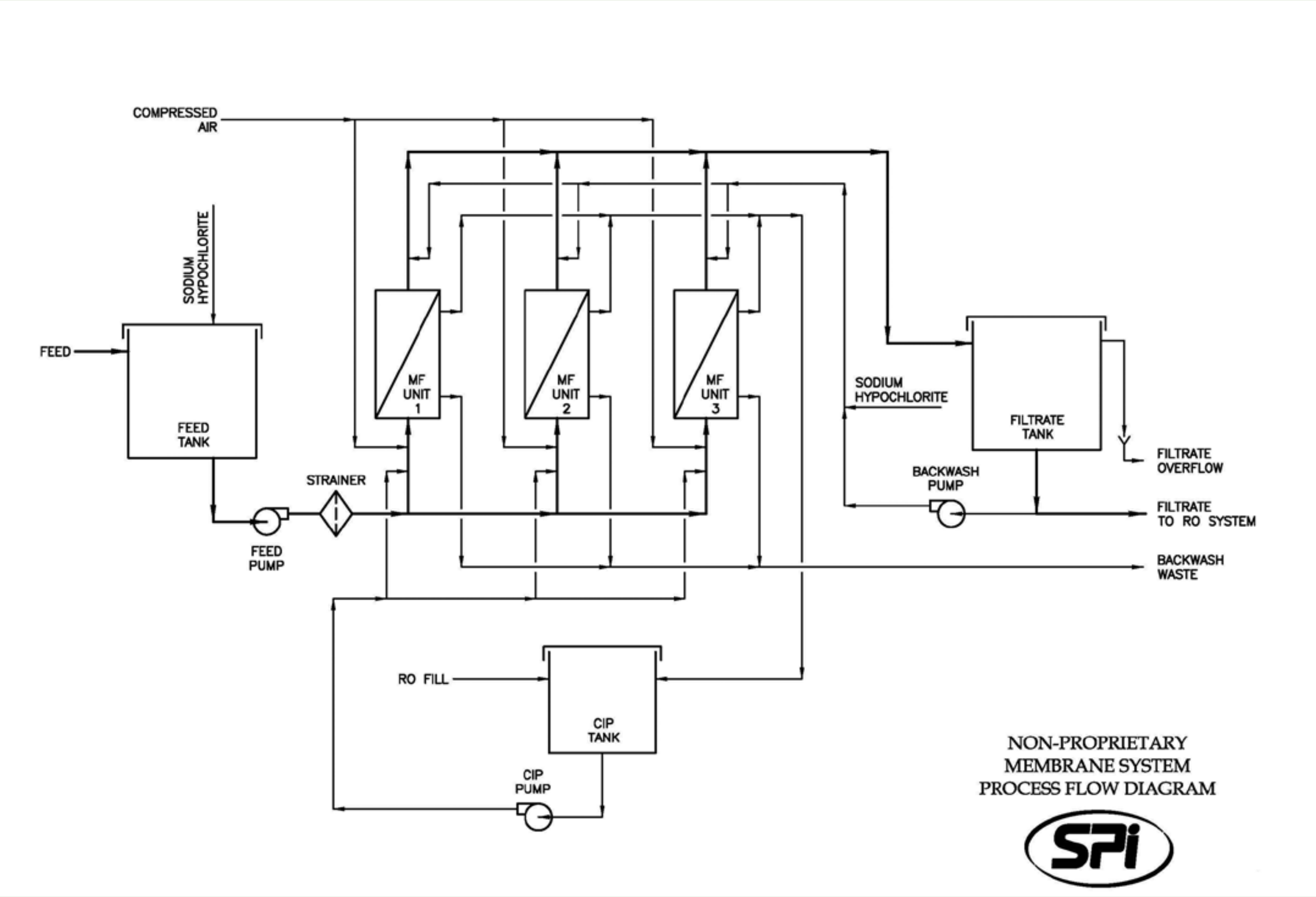

Figure 2
Universal Membrane System Pilot

Figure 3
Toray Performance

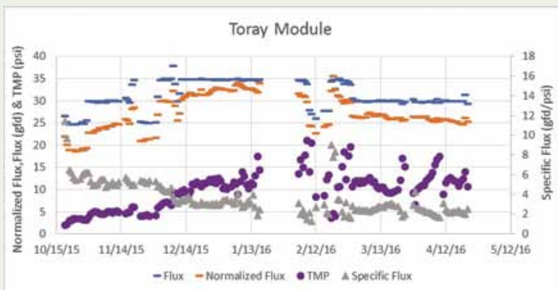

Figure 4
Dow Performance

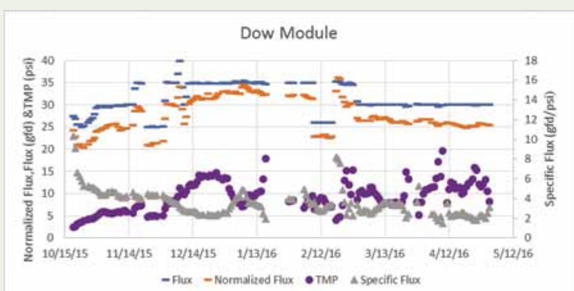

Figure 5
Scinor Performance

majority of the run and specific flux values between 2-4 gfd/psi. At the end of these runs both the Toray and Dow modules were cleaned on March 29, 2016.

Phase 1B Operational Results

Phase 1B of testing began on June 2, 2016 with the Econity, Hydranautics, and Pall modules starting up at 25 gfd. It should be noted that this testing was conducted during warm weather conditions. After approximately a week at 25 gfd, all three modules were increased to 30 gfd. Then after another week of stable operation flux was increased to 35 gfd for all three modules. All three modules ran at a flux of 35 gfd for 21 days without reaching terminal TMP values that would require a CIP. The flux on all three modules was once again increased to 40 gfd on July 11, 2016. The Econity module was the first to reach terminal TMP values following the increase to 40 gfd. After approximately a week at 40 gfd, the flux on the Hydranautics and Pall modules was increased to 45 gfd in an effort to reach terminal TMP values. The Hydranautics module faulted on high high TMP after 10 days at 45 gfd. Despite the other two modules hitting terminal TMP's, the Pall module remained online. Therefore the flux on this module was increased to 50 gfd. In addition, the CEB and backwash timer was increased in order to decrease the number of backwashes and CEB's per day so the membrane would foul faster. With the increased flux and changes to the CEB and backwash intervals, the Pall membrane finally reached terminal TMP values after approximately 1 week at 50 gfd and was then CIP'd.

The Econity and Hydranautics modules began their first 21 day test runs on July 26, 2016 at fluxes of 35 gfd and 40 gfd respectfully. The Econity module completed a 24 day run at 35 gfd after reaching terminal TMP values. The Hydranautics module ran at 40 gfd for a total of 27 days before reaching terminal TMP values and being taken offline. After being CIP'd, the Pall module was placed online at 40 gfd and began its first 21 day run. The Pall module ran for a total of 28 days and was then taken offline and CIP'd. All three modules were restarted in late September to begin a second 21 day test run however, the unit experienced several equipment failures causing the modules to fault. The modules were run intermittently throughout October but continued to fault due to mechanical issues. The pilot unit was taken offline for approximately one week in late October through early November to perform all the repairs and replacements necessary.

All three modules were CIP'd during the first week of November and the pilot unit was restarted on November 7, 2016 for the second 21 day test run. The Econity module operated at a flux of 35 gfd while the Hydranautics and Pall modules ran at a flux of 40 gfd. The Hydranautics and Pall modules were taken offline on December 2, 2016 after 25 day runs. The Econity module was taken offline December 4, 2016 after an approximately 26 day run. Although all three modules were able to complete the second 21 day minimum test run without a CIP, the lower temperature of the water made it much more challenging than the first run. On multiple occasions the modules faulted on high high TMP values and required multiple CEB's to decrease TMP values and continue operation.

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Universal Membrane System
Continued from page 7

Conclusions

Feedwater quality during the testing can be best characterized as highly inconsistent, making testing more challenging. Upsets in water quality resulted in increased TMP, sometimes to terminal values. Historically, West Basin feedwater quality is more challenging during the winter months with lower temperatures and more frequent upsets upstream that affect the downstream processes throughout the plant. Ultimately operation at a lower flux resulted in more consistent performance and resiliency to unanticipated water quality events.

Programming issues also plagued operation until they were resolved. The unit utilized a common pump supplied from two different tanks to perform CEB's. Errors in the underlying control programming were not always obvious to identify, nor could they be consistently repeated but were ultimately resolved.

West Basin believes that the use of a non-proprietary design offers the owner the following benefits:

- Greater control over the initial and future selection of membrane modules
- Elimination of expensive replacement proprietary component parts
- "Open Source" transparency in PLC and HMI programming
- Improved functionality of the operator interface.
- Flexibility in instrumentation and valve selection
- Customization of design to satisfy project specific space limitations

Acknowledgments

The team would like to acknowledge the efforts of the following personnel who have assisted and supported the piloting efforts.

- Henry Phan – Suez
- Dan Dragland – H2O Innovations
- Scott Sedey – H2O Innovations

Figure 6
Econity Performance

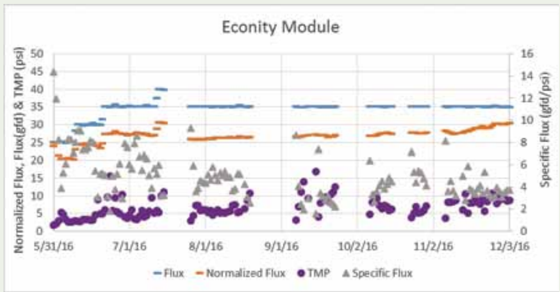


Figure 7
Hydranautics Performance

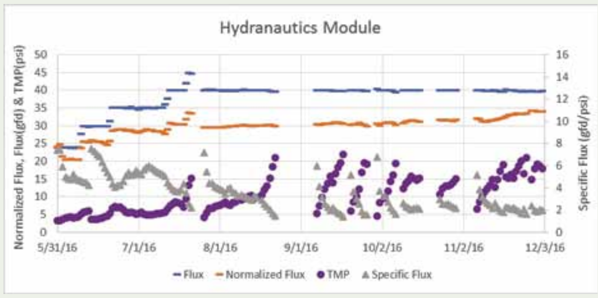
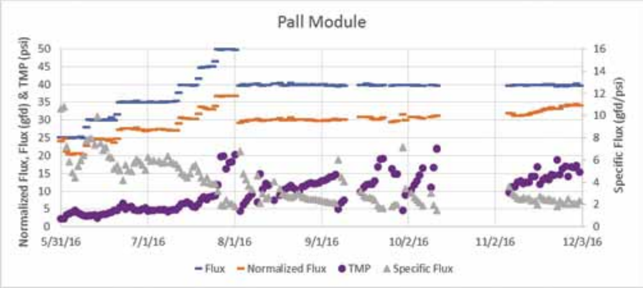


Figure 8
Pall Performance



Gabriela Handley

Gabriela Handley is an Engineer for SPI with a Bachelor of Science in Environmental Engineering. As part of the Membrane Support Services team at SPI, she provides engineering and technical support for a wide range of membrane applications. She has been responsible for data collection, monitoring, and normalization for West Basin's Universal Membrane System since start up. Don Zylstra is a Senior Water Resources Engineer for West Basin Municipal Water District and the District's Project Manager for the project. Jim Vickers is SPI's Project Manager and the design engineer for West Basin's Universal Membrane Pilot unit.

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