WaterSMART: Water Recycling and Reuse Research under the Title XVI Water Reclamation and Reuse Program for Fiscal Year (FY) 2016

CUSTOM ENGINEERED MEMBRANE FILTRATION PILOT TEST PROJECT

Los Angeles County, California

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Technical Proposal

EXECUTIVE SUMMARY

Date: April 20, 2016
Applicant Name: West Basin Municipal Water District
Project Name: "*West Basin Municipal Water District's Custom Engineered Membrane Filtration Pilot Test Project.*"
City: El Segundo
County: Los Angeles
State: California

Membrane Filtration (MF) systems, including microfiltration and ultrafiltration, have long been developed as proprietary systems where interchangeability between membrane modules was not possible. In recent years, the industry has been slowly transitioning towards MF systems designed by original equipment manufacturers (OEM) that can be adapted to operate a handful of membrane module types. This offers both competitive pricing when membrane module replacement is required and operational flexibility if the existing membrane module becomes ineffective or too costly at treating the source water. Often referred to as Universal MF Systems, this nomenclature is misapplied because the systems can neither accept all commercially available modules, nor are the systems designed robustly enough to treat every type of feedwater quality with the adaptable modules. The OEM MF systems are often designed generically around a set of membrane module manufacturer guidelines, and not necessarily designed based on the empirical performance observed for the module on the unique water being treated. This could lead to some MF system designs not being appropriate for a specific water quality, and the owner not fully realizing the fact until after the full scale installation has been accepted.

Membrane filtration is a critical treatment process in water recycling of municipal effluents where reverse osmosis (RO) is required for the reduction of Total Dissolved Solids (TDS) or contaminants of emerging concern (CEC). The complex nature of municipal effluents, which can include both residential and industrial waste streams, makes it imperative to validate system design conditions before assuming the various membrane modules will operate within the envelope of operational capabilities offered by an OEM MF system.

The West Basin Municipal Water District (West Basin) recently commissioned a skid mounted MF pilot unit that allows three separate membrane modules to be operated simultaneously on a single feedwater while operating at separate design conditions for backwash, chemically enhanced backwash (CEBW), and Clean in Place (CIP). The proposed research study will be conducted over the course of a year in two different phases. It is anticipated that this testing will be completed by April 2017. West Basin will use this pilot equipment to define a set of design parameters for a future full-scale custom-engineered MF system with a capacity of 5.88 million gallons per day (MGD) on disinfected tertiary recycled water, as well as gather design conditions for an ozonated secondary effluent stream in the future. Unlike a generic OEM design, the custom engineered MF system design will be tailored to the specific water being treated and based on empirical membrane performance, ensuring the full-scale system is neither over designed nor under designed for any of the six different membrane modules that will be tested.

Technical Research Study Description

West Basin has constructed a Custom Engineered MF Pilot System which is capable of independently operating up to three different pressurized MF modules in parallel. The pilot system will be used by West Basin to evaluate pressurized hollow fiber microfiltration or ultrafiltration membranes for future consideration at West Basin's facilities. Pilot testing for 6 membranes will be conducted over the course of a year in two different phases. The difference in the two phases of testing involves differences in the backwash/CEBW operation and will determine if the manufacturer specified or a common West Basin preferred backwash strategy provides acceptable results.

Objectives

The objectives of the Custom Engineered MF System Pilot Testing Program for membrane filtration are as follows:

1. Determine the maximum stable operating design flux for six membrane modules using the manufacturer's standard backwashing and CEBW protocol.
2. Determine if a standardized backwash and CEBW protocol affects the membrane flux.

Process Description

- **Feed Water Supply**

Disinfected tertiary filtered product water from the West Basin Edward C. Little Water Recycling Facility (ECLWRF) will be used as feed water to the Custom Engineered MF pilot unit. This water was chosen as the supply for this evaluation as it is representative of water that is available within the West Basin distribution system including facilities located in Carson and at the Exxon-Mobil refinery located in Torrance, CA.

West Basin is considering the replacement of existing proprietary MF equipment located at those facilities with a Custom Engineered MF system, as well as a planned expansion for the Tesoro Refinery. Evaluation of membranes would provide information necessary to qualify suppliers that may be used as part of a replacement or future expansion effort.

Testing of ECLWRF feedwater, i.e. Hyperion Wastewater Treatment Plant (WWTP) secondary effluent, is not planned as part of this testing, but may be performed at a later date.

Feedwater quality is shown in Table 1.

Table 1: 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

Parameter		Raw Water	
		Avg.	Range
	Manganese	0.16	0.11-0.21
	Bicarbonate (mg/L as CaCO3)	269	236-336
	Chloride	320	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

- **Membrane Modules**

New membrane elements for the pilot demonstration will be provided by six different membrane manufacturers. These manufacturers are Toray, Dow, Scinor, Hydranautics, Econity, and Pall. Characteristics of these membrane modules are presented in the table below.

These membranes have the following common features:

- Thermally Induced Phase Separation (TIPS) Manufacturing
- Bottom Feed Conncction
- Top Backwash Connection
- Top Filtrate Connection
- Surface area ranging from 50 to 105 square meters / module.

Table 2: Membrane Supplier Matrix

Membrane		Toray	Dow	Scinor	Hydranautics	Econity	Pall
Group		A	A	A	B	B	B
General							
Material	Polymer	PVDF	PVDF	PVDF	PVDF	PVDF	PVDF
Process		TIPS	TIPS	TIPS	TIPS	TIPS+ Stretching	TIPS
Model		HFS-2020-N	SFD-2880	SMT600-P50	HYDRAcap MAX 80	PF-90M	UNA-620A
Configuration	Direction	Out-In	Out-In	Out-In	Out-In	Out-In	Out-In
Pore Size	microns	0.02	0.03	0.1	0.1	0.1	0.1
Inside Dia.	mm	0.9	0.7	0.7	0.6	0.7	0.65

Outside Dia.	mm	1.5	1.3	1.3	1.2	1.2	1.1
Area	ft^2	775	829	538	1130	969	538
Area	m^2	72	77	50	105	90	50
Operating Flux	gfd	20-80	24-70	20-120	20-65	25-100	20-80
Operational							
Static Pressure	psi	44	90	60	73	38	45
Forward TMP (max)	psi	44	30	45	30	22	35
Backwash TMP	psi	44	38	45	30	38	35
Max Temp.	C	40	40	40	40	40	40
Operating pH	units	1-10	2-11	1-11	4-10	1-9	3-11
Backwash	type	air/water	air/water	air/water	air/water	air/water	air/water
Water Direction	Feed/Filtrate	Filtrate	Filtrate	Filtrate	Feed	Filtrate	Filtrate
Cleaning							
Cleaning Temp	C	40	40	40	40	40	40
Cleaning pH	units	0-12	2-11	1-13	1-13	2-11	3-12
Max Free Chlorine	mg/L	2000	2000	5000	5000	1000	5000
Periodic Clean	yes/no	yes	yes	yes	yes	yes	yes
Frequency	hours	12-72	12-72	12-72	12-72	12-72	12-72
Duration	min	20-60	20-60	10-60	10--60	20-60	20-60
Chlorine Conc.	mg/L	200	200	200	200	200	200
Physical							
Length	mm	2160	2360	2330	2340	2000	2160
Diameter	mm	216	225	160	250	260	180
Feed	mm	50	50	50	50	80	50
Feed	orientation	on axis	off axis	On axis	on axis	on-axis	on axis
Feed	Style	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic
Filtrate	mm	50	50	50	50	80	50
Filtrate	orientation	on axis	off axis	On axis	on axis	off axis	on axis
Filtrate	Style	victaulic	victaulic	victaulic	victaulic	victaulic	victaulic
Backwash	mm	50	50	32	50	65	32
Backwash	orientation	off axis	on axis	Off axis	off axis	on-axis	off axis
Backwash	Style	victaulic	union	victaulic	victaulic	victaulic	Union

- **Pilot Unit Specifications**

The Custom Engineered MF pilot unit provided is capable of operating three different membranes simultaneously for side by side comparison. The pilot is fully equipped with strainer, tanks, pumps, compressors, instrumentation and controls and other ancillary systems needed for operation during the pilot testing (including direct filtration, backwash, CEBW, and CIP). CIP is performed manually.

Figure 1: Pilot Test Unit

Key design aspects of the pilot unit are as follows.

- Feed Pump: 80 gpm @ 50 psi maximum
- Backwash Pump: 40 gpm @ 39 psi TDH
- CIP Pump: 20 gpm @ 20 psi
- Sodium Hypochlorite (Feed dosing) (16 gpd) Sodium Hypochlorite
- Sodium Hypochlorite CEBW (76 gpd)
- CEBW Chemical 2 (Citric Acid) (76 gpd)

The membrane unit has a common feed tank, filtrate tank, and CIP/CEBW make up tank. Sodium Hypochlorite can be added to the feed water to maintain a nominal chloramine residual of 3-5 mg/L. Each section of the membrane unit can be configured to operate any module. Adapters (spool pieces) have been provided that will connect the membrane module to the permanent piping network. The Scinor membrane module uses the same spool pieces as the Pall membrane module. Once the membrane modules are installed, the operational sequences can be programmed into the unit.

The primary sequences that require programming are identified below:

- Filtration (flow setpoint)
- Backwash (using MF filtrate)

- Chemically Enhanced Backwash (using RO permeate, and Sodium hypochlorite or Citric Acid)
- Integrity Testing (Feed or Filtrate)

Programming of the operational interface allows the operator to establish valve position, flow and duration each membrane module for each sequence. The air flow required for backwashing is set manually using the rotometer provided.

CIP (chemical cleaning) is performed manually on one module section at a time. Because of the manual nature of CIP, the other membrane module will not be able to perform a CEBW while a CIP is occurring. It will be necessary to stop operation to perform a Clean Water Flux Test, although it may be possible to perform this test using feed water.

Program Schedule

- **Phase 1 Testing (Months 1-6)**

The testing period will be divided in two phases, each with an anticipated duration of six months. During each Phase (1, 2) six different modules will be tested in two different groups. (Group A, Group B). Each group of modules will be tested for a period of approximately 3 months.

Table 3: Overall Program Schedule

Test Phase (Group)	Approximate Duration	Target Membrane Flux (gfd)	Feed Water	Backwash & CEB
1A	3 month	Flux at 25 to 40 gfd	Title 22	Manufacturers
1B	3 month	Flux at 25 to 40 gfd	Title 22	Manufacturers
2A	3 months	Flux at 25 to 40 gfd	Title 22	Common
2B	3 months	Flux at 25 to 40 gfd	Title 22	Common

- **Operating Flux Determinations**

In the first phase of testing, the maximum stable operating flux for the membrane module will be determined. The membrane module supplier will provide the protocol for filtration, backwashing and daily chemical cleaning (CEBW). Table 4 provides a summary of the overall strategy to determine the operating membrane flux for the various membrane modules.

Table 4: Schedule for Phase 1 (Group A shown, Repeat for Group B)

Test	Duration	Flux (gfd)	Backwash/CEBW
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

*** 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.**

Based upon prior evaluations it is anticipated that the operating membrane flux for the membrane to be tested will be between 25 and 40 gallons per square foot per day (gfd), In order to determine the maximum stable membrane flux, membranes located on the pilot unit will be operated for a period of one week. At the end of the week, the performance will be reviewed, and if the performance of the membrane appears to be stable, (e.g. an increase in transmembrane pressure (TMP) of less than 25 percent of the maximum allowable TMP for the module considered over the period of 7 days) a decision will be made by West Basin and its consultants Separation Processes, Inc. (SPI) and Suez Environment, S.A. to increase the flux to the next highest amount (target). If the membrane exceeds its maximum TMP during the period of testing, the membrane will be removed from service and cleaned prior to restarting. Table 5 provides the flow rates for the various membrane modules to be evaluated.

Table 5: Operating Flow Rates of various membrane modules

Flux (area ft^2) (gfd)	Toray (775 ft^2) (gpm)	Dow (829 ft^2) (gpm)	Scinor (538 ft^2) (gpm)	Hydranautics (1130 ft^2) (gpm)	Econity (969 ft^2) (gpm)	Pall (538 ft^2) (gpm)
25	13.5	14.4	9..3	19.6	16.8	9.3
30	16.1	17.3	11.2	23.5	20.2	11.2
35	18.8	20.1	13.1	27.5	23.6	13.1
40	21.5	23.0	14.9	31.4	26.9	14.9

For this project, the term membrane flux is based upon the operating or actual instantaneous membrane flux through the membrane unit. Normalized or temperature compensated flux strategies will not be used as the planned use of the water is as a supply to a reverse osmosis system. The RO process requires a constant amount of flow to the unit during normal operation.

Once the maximum operating flux has been determined, the membrane will be cleaned and placed into operation for a period of not less than 21 days, but not more than 30 days. If at the end of the 21 day test, the membrane has not exceeded the maximum TMP, the membrane will be cleaned and the test repeated. Two consecutive filtration runs without exceeding the maximum TMP will be considered a successful demonstration of the membrane flux.

If the membrane reaches 30 days without reaching the maximum TMP, the West Basin has the option to increase the operating flux for the next evaluation.

The operation of the pilot system will begin with a CIP and a clean water flux test. Cleaning efficiency will be determined by a clean water flux test after the CIP process has been completed.

At the end of each group testing, membrane modules will be chemically cleaned, placed into a preservative solution (1 percent sodium bisulfite or similar preservative) and stored until required.

- **Backwash and CEBW**

For all membrane modules, process sequences are developed in order to assure proper operation of the membrane. A process sequences consists of a number of steps that are programmed into the unit for operation. Many of the steps are associated with common names, although some suppliers have created and/or translated terminology with seemingly inconsistent nomenclature (i.e. reverse filtration). In order to maintain a simplified approach, a single set of terminology will be used to describe individual steps associated with the manufacturer's sequences. Examples of terms are shown below.

- Backwash: Feed Valve closed. Filtrate pumped through membrane module to drain (top and bottom backwash valve open.
- Backwash with Aeration: Feed valve closed. Filtrate pumped through membrane module with top valve drain open. Air applied to outside of membrane module.
- Aeration: Air applied to membrane module top backwash drain open, feed valve closed
- Aeration with Fill: Air applied to membrane module, feed valve open, top backwash drain open
- Fill: Feed applied to membrane module, top backwash drain open.
- Drain: Top and Bottom Drain Open, Feed valve closed.

Membrane suppliers will provide the initial backwash and CEBW regimes for pilot operation using the available steps as described in Table 6 and Table 7, respectively. Manufacturers may also provide alternative steps that may be programmed into the unit. The frequency of both backwash and CEBW might be increased during some parts of Phase I in order to establish optimal operation, for example an increased frequency might be required as the flux will be increased.

Prior to initiating testing, manufacturers will be requested to attend a project site visit to the project site and requested to review the programmed backwash and CEBW strategy used in the system to confirm that the sequence is appropriate and meets the requirements of their product. This strategy will be implemented to confirm that the sequence is appropriate and meets all requirements before proceeding.

Backwash is performed with the common filtrate collected. CEBW's will be performed with RO permeate, as the filtrate contains a significant amount of ammonia in the water that would react with sodium hypochlorite and form a chloramine residual which is less effective than a free chlorine residual normally used for the CEBW process.

Table 6: Initial Backwash Regime to be used in Custom Engineered MF membrane pilot testing

Common Backwash Steps

	Feed Valve	Upper Backwash Valve	Lower Backwash Valve	Aeration Valve	Filtrate Valve	Backwash Supply Valve	Backwash Flow Rate	Air Flow Rate	Feed Flow Rate	Time
	BFV-1-X	BFV-4-X	BFV-5-X	SV-1-X	BFV-2-X	BFV-3-X				
Aeration	Closed	Open	Closed	Open	Closed	Closed	0 gpm	3 scfm	0 gpm	sec
Aeration with Forward Flush	Open	Open	Closed	Open	Closed	Closed	0 gpm	3 scfm	10 gpm	sec
Backwash	Closed	Open	Open	Closed	Closed	Open	10 gpm	3 scfm	0 gpm	sec
Backwash with Aeration	Closed	Open	Closed	Open	Closed	Open	10 gpm	3 scfm	0 gpm	sec
Fill	Open	Open	Closed	Closed	Closed	Closed	0 gpm	0 scfm	10 gpm	sec
Drain	Closed	Open	Open	Closed	Closed	Closed	0 gpm	0 gpm	0 gpm	sec

BW Pump 40 gpm @ 90 feet TDH with VFD

Table 7: CEBW Regime to be used in Custom Engineered MF membrane pilot testing

Common CEB Steps

	Feed Valve	Upper Backwash Valve	Lower Backwash Valve	Aeration Valve	Filtrate Valve	Backwash Supply Valve	Backwash Flow Rate	Air Flow Rate	Feed Flow Rate	Chemical Metering Dose SHC	Chemical Metering Dose Chem 2 (Citric)	Time
	BFV-1-X	BFV-4-X	BFV-5-X	SV-1-X	BFV-2-X	BFV-3-X						
Aeration	Closed	Open	Closed	Open	Closed	Closed	0 gpm	3 acfm	0 gpm			sec
Aeration with Forward Flush	Open	Open	Closed	Open	Closed	Closed	0 gpm	3 acfm	10 gpm			sec
Backwash	Closed	Open	Open	Closed	Closed	Open	10 gpm	3 acfm	0 gpm			sec
Backwash with Aeration	Closed	Open	Closed	Open	Closed	Open	10 gpm	3 acfm	0 gpm			sec
Backwash with Chemical	Closed	Open	Open	Closed	Closed	Open	10 gpm	0 acfm	0 gpm	200 mg/L	200 mg/L	sec
Fill	Open	Open	Closed	Closed	Closed	Closed	0 gpm	0 acfm	10 gpm			sec
Drain	Closed	Open	Open	Closed	Closed	Closed	0 gpm	0 acfm	0 gpm			sec
Soak	Closed	Open	Closed	Closed	Closed	Closed	0 gpm	0 acfm	0 gpm			sec

* CEB uses RO Permeate for Supply water
BW Pump 40 gpm @ 90 feet TDH with VFD

Note: The use of a CEBW was designed into the membrane pilot system. Some membrane suppliers use the CIP system instead of the backwash system to perform cleanings. There are subtle differences between the two different approaches. These are as follows.

- CEBW Based Process – chemical introduced into the filtrate and allowed to soak in the membrane module for a period of 30 minutes or so before being flushed.

- CIP Based Process – chemical is introduced into the feed of the membrane module and recirculated through the membrane feed and filtrate connection using the CIP system. Once this process is completed, the membrane is drained and flushed to remove chemicals.

Normally CEBW or CIP processes are performed with free chlorine as the cleaning agent. In order for free chlorine to be effective, the membrane module has to be flushed with RO permeate to remove residual ammonia in the water that will react with ammonia to form chloramine, which is a less effective cleaning agent.

The CEBW is simpler to implement than the CIP process, requires less automation and may be less susceptible to ammonia contamination of the CIP solution. It is possible to automate valving on the pilot system to automate the CIP system in the event that there is a specific need for the use of CEBW. Some suppliers may heat the cleaning solution used for daily cleaning of the membrane modules with the CIP process. For this project, daily cleaning solutions will be prepared at ambient temperature.

- **Integrity Testing and Clean In Place**

Membrane integrity testing will be performed once per week and after a CIP. In the case of an integrity failure, (i.e. PDT >0.2 psi/min) the membrane module will be retested. The membrane module will be removed from service if an integrity failure is confirmed. Broken fibers will be pinned (by manufacturer's representative) and the operation will resume with the same membrane element. Membranes that exhibit repeated failure of fibers, or a significant loss of integrity, will be removed from consideration.

CIP will be performed based on manufacturer recommendations, as presented in or as suggested by the membrane manufacturer.

- **Phase 2 (Months 7-12)**

Phase 2 is designed to demonstrate the performance of the membrane modules at the selected flux rate during Phase 1. In Phase 2 of the testing, membranes will be evaluated with a common backwash and CEBW between the membrane module suppliers. Prior to commencement of the testing, membrane supplier will be advised of the parameters that will be used in backwashing. The steps used for backwashing or CEBW of the membrane module will be the same. There may be differences in air and/or backwash water flow rates and durations necessary to compensate for difference in membrane module surface area and other considerations. Table 8 provides a summary of the testing to be completed.

Table 8: Phase 2 Testing

Test	Duration	Flux (gfd)	Backwash/CEBW
2A-0	1 day	CIP + Clean Water Test	n/a
2A-1	21 days*	Flux from Phase 1	Manufacturers
2A-2	21 days	Flux from Phase 1	Common
2A-3	21 days	Optimized Flux	Common
2A-4	21 days	Optimized Backwash	Common

*CIP and Clean Water Test Performed

Data Requirements and Sampling Frequency

Operational and water quality data shall be collected at regular intervals during the period of membrane testing, as indicated in Table 9.

Sample log sheets for the project will be developed operator monitoring of unit parameters and chemical analyses. The monitoring of unit parameters will augment the SCADA data that is being collected.

Table 9: Frequency of Sampling

Parameter	Method	Frequency	Location	
			Feed	Filtrate
General Water Quality Parameters				

	Method	Frequency	Location	
Chlorine Residual	DPD	Daily	X	
Alkalinity (mg/L as $CaCO_3$)	From ECL	Weekly	X	
Conductivity (µS/cm)	From ECL	Weekly	X	
Iron (mg/L)	From ECL	Weekly	X	
pH (units)	From ECL	Daily	X	
Hardness (mg/L as $CaCO_3$)	From ECL	Weekly	X	
Membrane Unit Operating Parameters				
Temperature (^{O}C)	SCADA	5 min	X	
Flow (gpm)	SCADA	5 min	X	X
Pressure (psi)	SCADA	5 min	X	X
Turbidity (NTU)	SCADA	5 min SCADA	SCADA	Grab (weekly)
Membrane Calculated Parameters				
Membrane Inst Flux (gfd)	Calc	SCADA Log	n/a	
Membrane TMP (psid)	Calc	SCADA Log	n/a	
Membrane Permeability gfd@20 deg C./psi)	Calc	SCADA Log	n/a	
Membrane Integrity Testing (psi/min)	Operator Noted	Weekly and before/after CIP	n/a	
Membrane Process Analytical Requirements				
TOC (mg/L)	Grab	1/wk	X	X

Evaluation Criteria

Evaluation Criterion 1: Statement of Problems and Needs

Microfiltration System design for complex municipal wastewater recycling can be challenging.

In the past, site specific proprietary MF vendor testing was required to demonstrate cost-effective, sustainable performance ahead of system procurement. With the advent of so-called 'Universal MF Systems', the industry puts less emphasis on pilot testing membrane products because end users are told that non-performing membranes can simply be replaced with a different manufacturer's modules. The need for empirical performance of membrane products on unique water qualities is often ignored, but is nonetheless a critical component in successful MF system design for water recycling.

West Basin perhaps knows this better than most, as it has nearly 20 years of recycling experience with membrane filtration at the ECLWRF. Through four expansions of the ECLWRF with MF (1997, 2001, 2006, 2013), and construction of two satellite facilities (1999, 2000), West Basin has experienced many issues associated with membrane filtration treating a challenging feed source, including a highly variable and ever increasing feedwater concentration of turbidity and Total Suspended Solids (TSS). As a consequence, West Basin continues to see diminished production from its existing recycled water system. Currently, West Basin's total MF capacity has experienced a 26% decrease in production from original design values, with some older MF systems experiencing as much as 50% reduction. As a consequence, potable water is often required to supplement the lost product water capacity resulting from the poor MF performance, creating a heavier reliance on imported water supplies within West Basin's service area. To many of West Basin's customers, this experience has portrayed recycled water as not being the panacea for reliability that is often portrayed in the industry.

This proposal will illustrate the need for site specific pilot testing of MF modules on a challenging wastewater effluent, documenting design criteria for six different membrane modules. It is anticipated that this study will reveal that not all membranes products offer sustainable performance this source water. The study will lead to a system design that will offer future operational flexibility and alleviate West Basin's issues with challenging operation, reinforcing that recycled water can be a reliable resource if designed conservatively enough to account for deterioration of municipal effluent quality attributed to conservation, drought, and changes to the potable water sources.

Evaluation Criterion 2: Water Reclamation and Reuse Opportunities

Feedwater water quality for the ECLWRF has become increasingly challenging over the years. Feedwater turbidity, TSS, and ammonia concentrations have all experienced significant increases and variability since 1995. While this water quality is within the Hyperion WWTP's treatment goals, the increased concentrations have proven to be challenging for West Basin's Barrier microfiltration system. Specifically, excessive membrane fouling has caused a loss of capacity for older MF technologies during the past decade. This source is considered to be a challenging feedwater source for recycling. West Basin has observed a degradation of feedwater quality over the past 20 years. Secondary effluent turbidity has increased from an average of approximately 5 NTU to nearly 15 NTU, with an increase in the frequency of spikes to >30 NTU. Additionally, ammonia has increased from approximately 25 mg/L to nearly 50 mg/L. The TDS in the secondary effluent has increased from approximately 800 mg/L to nearly 1200 mg/L.

The change in feedwater quality is attributed to several issues, none of which are unique to West Basin or Hyperion WWTP. The recent years of drought in California have significantly increased water conservation efforts, and the potable water supply has shifted from a heavy reliance on imports from Northern California to the Colorado River. Additionally, Hyperion has made operational changes over the years that favor their ability to achieve ocean discharge limits rather than suitability for water recycling.

This study will assist agencies considering the recycle of challenging source waters make decisions about treatment processes to include in their overall treatment scheme. The study will produce a body of data that can be used to determine whether custom-engineered microfiltration systems offer enough design and operational flexibility on a challenging feedwater to be considered for other projects.

Evaluation Criterion 3: Description of Potential Alternatives

Many agencies throughout the United States are turning to water recycling as a new water resource, either to offset potable usage with recycled water supplies, or investigating potable reuse through advanced treatment techniques. There is a role for membrane filtration at either end of the spectrum, as it can be used as a tertiary filtration process, or as one of several barriers in the full advanced treatment scheme. The performance concerns will be the same in any situation. Membrane filtration is prone to fouling, and irreversible fouling leads to capacity loss. The organic fouling inherent in water recycling can be particularly problematic, but the use of coagulants such as ferric chloride upstream can present an entirely different set of challenges such as iron fouling. The typical cleaning regimes applied to MF systems may not be sufficient for maintaining performance from the membrane.

West Basin has firsthand experience with these challenges, having operated membrane filtration systems since 1997 on secondary effluent from the City of Los Angeles' Hyperion WWTP. Initially built as a raw sewage discharge plant into the Santa Monica Bay, Hyperion WWTP has been upgraded over the years to secondary and full secondary treatment. Hyperion WWTP treats raw sewerage utilizing coarse bar screens for removal of large debris, as well as sedimentation for grit removal. Primary treatment at Hyperion WWTP includes coagulation, oil and grease removal, and solids separation prior to secondary treatment. Secondary treatment uses high-purity oxygen for better BOD oxidation prior to settling and clarification. Treated secondary effluent at Hyperion WWTP is either diverted to West Basin's ECLWRF for further treatment or discharged to the ocean.

The high purity oxygen-activated sludge process at Hyperion WWTP only provides BOD removal and does not have nitrification/denitrification (NdN) capabilities. A summary of the treated secondary effluent water quality originating from Hyperion WWTP and sent for further treatment at West Basin's ECLWRF is provided in Table 10 below Table.

Table 10: Summary of General Secondary Effluent Water Quality at Hyperion WWTP (2012-2014)

Item	Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Turbidity (NTU)	Ammonia (mg/L)
Minimum	192	9.0	9.6	2.9	33.4
10th percentile	222	15	16	5	37
Average	248	20	20	6	41
90th percentile	273	24	24	7	44
max	348	70	86	36	48

West Basin has observed decreased MF capacities and increased Operation and Maintenance (O&M) costs as a consequence of Hyperion WWTP's secondary effluent quality. This proposal will document the performance of six commercially available membrane filtration modules treating disinfected tertiary effluent originating from the Hyperion WWTP. This body of data can be utilized by other agencies considering the treatment of similar waters, and will demonstrate the similarities and differences in performance observed for the modules. For West Basin, this information will be applied to a robust full scale design allowing for the future operational flexibility to change modules should performance change. For other agencies, this proposal may demonstrate that not all membranes perform similarly enough on wastewater effluents to be incorporated into an OEM MF system, potentially limiting their choices for future module replacement. By recognizing this early, and adjusting their design expectations, agencies will be able to broaden the capability of their MF systems.

Evaluation Criterion 4: Stretching Water Supplies

Regional agencies responsible for developing water supplies are increasingly turning to water recycling as a means to increase their water supply portfolio. This can range from non-potable reuse, indirect potable reuse, and even direct potable reuse in some regions of the United States. MF system performance is critical to the overall sustainability of any recycled water program utilizing membrane filtration. Recycled water customers affected by operational downtime of MF systems must employ alternate sources of water, often from potable supplies imported from state or federal facilities.

This study will assist agencies in making informed decisions pertaining to their adoption of potable reuse options, and in planning for the level of treatment necessary to achieve their specific treatment goals. For West Basin specifically, the study will ensure an appropriate MF design that will be robust enough to treat 5.9 MGD of recycled water, which would otherwise need to be supplemented with potable water from state and/or federal supply facilities.

Evaluation Criterion 5: Environment and Water Quality

Secondary effluent from Hyperion WWTP is normally discharged to the Santa Monica Bay through a 5-mile ocean outfall. West Basin purchases approximately 10% of Hyperion WWTP's treated effluent for advanced treatment at the ECLWRF, and subsequently distributes the recycled water for irrigation, industrial, sea water barrier, and indirect potable reuse applications. The use of microfiltration is necessary to achieve the high levels of treatment required for many of these product waters. Data from the proposed study will allow West Basin, and other agencies facing source water quality challenges, to remain operationally flexible in regard to their MF systems and maintain treatment capacity during full-scale implementation. With increased reliability and decreased system downtime, West Basin can maximize the ECLWRF capacity to treat effluent wastewater which would otherwise have to be diverted to the Santa Monica Bay as ocean discharge.

Evaluation Criterion 6: Legal and Institutional Requirements

Through twenty years of operating MF systems on municipal effluent, West Basin has observed how both variability and increasing concentration of feedwater quality impact the long-term sustainability of MF system operation. As a consequence, they commissioned the construction of a MF pilot unit that would allow the simultaneous investigation of up to three membrane modules either at the same, or different operating conditions for backwash, CEBW, and CIP. This provided West Basin with a very flexible piece of equipment that can be used to fairly quickly and inexpensively validate MF design conditions on any type of water, generating a body of data that directly compares operational performance and O&M costs, and offers the ability to adjust parameters for the purposes of optimization. This equipment has already been procured and will be available for use in this study.

There is not uncertainty in the timing of this research because West Basin is proceeding with a full-scale, 5.9 MGD MF system design that will rely on the outcome of this testing.

This study will assist other agencies in making informed decisions pertaining to their adoption of potable reuse options, and in planning for the level of treatment necessary to achieve their specific treatment goals. For West Basin specifically, the study will ensure an appropriate MF design that will be robust enough to treat 5.9 MGD of recycled water.

Evaluation Criterion 7: Renewable Energy and Energy Efficiency

The Custom Engineered MF System design approach lends itself to ensuring energy efficiency by allowing direct comparison of MF products and performance on the specific source water. West Basin will not only use the pilot performance data to design a full-scale system, but they will procure membrane modules based on the product that provides the lowest energy and chemical consumption, while also providing sustainable, long-term performance. Should the performance of the initially selected product change over time, West Basin will have the operational flexibility to change modules, or even optimize operating conditions utilizing the pilot equipment in the future.

For this study specifically, the energy costs associated with each module type operating on disinfected tertiary effluent originating from Hyperion WWTP will be calculated in order to assess total overall costs. Energy costs associated with module performances are impacted by TMP requirements across the different modules, backwash frequencies, backwash aeration, backwash pumping, CEBW and CIP effectiveness. By performing side-by-side testing, West Basin can quantify the energy consumption for each of these items and use this value in the overall lifecycle costs that will be used in full scale procurement.

Evaluation Criterion 8: Watershed Perspective

The implementation of this study will assist West Basin in achieving the stated District goals identified within the West Basin Board of Directors Strategic Business Plan. The goals emphasize the District's ability of providing reliable water resources throughout the region via a diversified water supply portfolio, which includes recycled water. The MF system plays an integral role in the advanced treatment of recycled water, and allows for West Basin to reduce regional reliance on imported water sources. Regional partnerships with businesses, agencies, and cities outside of the West Basin service area are proof that recycled water treated at the ECLWRF benefits the region as a whole. West Basin collaborates with entities such as the City of Torrance, Los Angeles Department of Water and Power, and the Water Replenishment District of Southern California to supply recycled water to industries and areas normally dependent on imported water supplies. Indirect impacts of this project also extend regionally as this will aid in making water supplies more readily available throughout the state by reducing imported supplies.

Environmental Compliance

1. *Will the research study activities impact the surrounding environment (i.e., soil [dust], air, water [quality and quantity], animal habitat, etc.)?*

   No, the proposed study will not impact the surrounding environment. The proposed study will not involve any earth-disturbing work or any work that will affect the air, water, or animal habitat in the research study area.

2. *Are you aware of any species listed, or proposed to be listed as a Federal endangered or*

threatened species, or designated Critical Habitat in the research study area? If so, how would they be affected by activities associated with the proposed research study activities?

The proposed study does not anticipate affecting any endangered or threatened species. The proposed research study will take place entirely within the ECLWRF. There are no federally endangered or threatened species within the research study area, nor is there a designated Critical Habitat in the research study area.

3. *Are there wetlands or other surface waters inside the research study boundaries that potentially fall under Federal Clean Water Act jurisdiction as "waters of the United States?" If so, please describe and estimate any impacts the research study activities may have.*

   No, there are no wetlands or other surface waters inside the proposed research study boundaries. The proposed research study does not anticipate having any impact upon waters of the United States.

4. *Are there any known archeological sites in the research study activities area? If so, please describe and estimate any impacts the research study may have.*

   No, there are no archaeological sites inside the proposed research study area. No archeological sites are anticipated to be found because the study will not require any excavation activities. The proposed research study does not anticipate having any impact upon archaeological sites.

5. *Will the proposed research study activities have a disproportionately high and adverse effect on low income or minority populations? If so, please describe and estimate any impacts the research study may have.*

   No, the proposed research study will not have any adverse effects on low income or minority populations.

6. *Will the research study activities limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands? If so, please describe and estimate any impacts the research study activities may have.*

   No, the proposed research study will not limit access to, or ceremonial use of, Indian sacred sites. The proposed research study will not result in any impacts on tribal lands.

7. *Will the research study activities contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area? If so, please describe and estimate any impacts the research study activities may have.*

   No, the proposed research study will not have any impact upon noxious weeds or non-native invasive species in the area.

Required Permits or Approvals

Not applicable – No permits or approvals are required.

Official Resolution

The official Board-adopted Resolution will be considered at the West Basin Board of Directors' regularly scheduled Board Meeting on April 25, 2016. Subsequent to this meeting, the board resolution will be mailed to the appropriate contact at Bureau of Reclamation (Reclamation).

Research Study Budget

Funding Plan and Letters of Commitment

(1) *How will you make your contribution to the cost share requirement, such as monetary and/or in-kind contributions and source funds contributed by the applicant (e.g., reserve account, tax revenue, and/or assessment)?*

This Program will include funds from West Basin in the amount of $273,000 through the Capital Improvement Program budget for FY 16/17 and FY 17/18. This Project will further advance MF technology for the benefit of West Basin and agencies that use these membranes as a pretreatment for recycled water.

(2) *Describe any in-kind costs incurred before the anticipated project start date that you seek to include as project costs. Include:*

[redacted]

(3) *What project expenses have been incurred*

The following program expenses have been incurred since July 1, 2015; however they will not be included in budget table 14 on the following page.

Table 11: Program Expenses To-Date

Consultant Name	Amount
H2O Innovations (Materials)	$24,346.82
Suez (Labor and Materials)	$60,584.55
Separation Processes Inc. (Labor)	$109,191.17
Total	**$194,122.54**

(4) *Provide the identity and amount of funding to be provided by funding partners, as well as the required letters of commitment.*

No letters of funding commitment are required since there are no other funding partners included in this Program.

(5) *Describe any funding requested or received from other Federal partners.*

No other funding will be received by other federal partners.

(6) *Describe any pending funding requests that have not yet been approved, and explain how the project will be affected if such funding is denied.*

There are no other pending requests.

Please include the following chart (table 12) to summarize your non-Federal and other Federal funding sources. Denote in-kind contributions with an asterisk (*). Please ensure that the total Federal funding (Reclamation and all other Federal sources) does not exceed 25 percent of the total estimated research study cost.

Table 12: Funding Sources and Amounts

Funding Sources	Funding Amount
Non-Federal Entities	
West Basin Municipal Water District – In-Kind*	$150,046.23
West Basin Municipal Water District – Cash	$363,000
Non-Federal Subtotal:	***$513,046.23***
Other Federal Entities	
None	$0
Other Federal Subtotal	***$0***
Requested Reclamation Funding:	***$150,000***
Total research study funding:	***$663,046.23***

Budget Proposal

Table 13: Funding Sources

Funding sources	Percent of total research study cost	Total cost by source
Recipient funding	77.4%	$513,046.23
Reclamation funding	22.6%	$150,000
Other Federal funding	0%	$ 0
Totals	**100%**	**$663,046.23**

Table 14. Sample Budget Proposal Format

Budget item description	Computation		Quantity type (hours/days)	Total cost
	$/Unit	Quantity		
Salaries and wages				

[redacted]

Travel				
N/A	$ -			$ -
Equipment				
N/A	$ -			$ -
Supplies/Materials				
Chemicals	$10,000	9	months	**$90,000**
Contractual/Construction				
Suez	$7,000	9	months	**$ 63,000**
SPI	$40,000	9	months	**$360,000**
[redacted]				
Total direct costs				**$602,769.30**
Indirect costs - 10%				**$60,276.93**
Total study costs				**$663,046.23**

Budget Narrative

Salaries and Wages

[redacted]

The total salaries and wages is **$45,872.60**.

Fringe Benefits

The fringe benefits for each employee described in the preceding Salaries and Wages section is the same cost for the fringe benefits. [redacted] The total cost for the fringe benefits is **$41,285.34**. Fringe benefits include vacation, sick, holiday, FICA expense, Medicare expense, education reimbursement, PERS, life insurance, disability insurance, health insurance, dental insurance, worker's compensation insurance, and out-of-pocket expenses. The employees, their rates, hours and total cost are shown in the table below.

[redacted]

Travel

There is no travel expenses anticipated for this project.

Equipment

There is no equipment costs included in the Project costs.

Materials and Supplies

The materials needed for this Project include chemicals at a total cost of $90,000, $10,000 per month for 9 months. These costs are based on previous experience with the type of chemicals used.

Contractual

There are 2 separate contracts required for this Project and are with the following entities: Suez and SPI. The following table shows the contractors, hours, and total costs for this Project. These costs were calculated based on previous invoices for similar type of work.

Contractual	Hours/ Month	Rate ($/hour)	Duration	Total Cost
Suez	142	49.30	9 Months	$63,000.00
Separation Processes, Inc. (SPI)	218	$183.48	9 Months	$360,000.00

Environmental and Regulatory Compliance Costs

This being a demonstration project, there are no environmental and regulatory compliance costs associated with this Project.

Other Expenses

The other expense with this Project is the reporting requirements set forth in the agreement. This will be performed by the Program Manager and counted as part of the in-kind contribution. The cost will be $2,481.40 [redacted] This rate is a combination of Salaries and Wages and Fringe Benefits.

Indirect Costs

The Indirect Costs associated with this Project includes overhead and indirect labor. For overhead this is calculated annually, and for the current fiscal year the rate is $62.22 for every hour worked. This is calculated based on the total overhead costs divided by the total direct labor hours spent. Based on the total labor hours for this project of 670, the cost is estimated to be $41,687.40. [redacted]

[redacted]

Total: [redacted] $33,466.40

The total for indirect costs is $41,687.40 and $33,466.40, totaling $75,153.80 which is 12.5% of the Project's total direct costs. Since the de minimis limit is set at 10% of the total direct costs, the amount included in the budget is $60,276.93.

Total Costs

The Project's total cost is **$663,046.23**. The federal cost share amount is **$150,000** (22.6%) and the non-federal cost share amount is **$513,046.23** (77.4%).