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

REVERSE OSMOSIS MEMBRANE PERFORMANCE DEMONSTRATION 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 Reverse Osmosis Membrane Performance Demonstration Project.*"
City: El Segundo
County: Los Angeles
State: California

West Basin Municipal Water District (WBMWD/West Basin) has been involved with cutting edge membrane technologies (microfiltration and reverse osmosis) for use in advanced water recycling applications for nearly 20 years. Due to historical experience with these technologies, WBMWD fully understands that RO membrane performance is difficult to predict, particularly when using this technology to remove constituents in municipal secondary effluent of variable quality. As a result, WBMWD is certain that a performance demonstration project is necessary to generate field data to confirm the application of reverse osmosis (RO) membranes to achieve suitable advanced treated water quality.

As mentioned, WBMWD has experience with the implementation of previous advanced membrane technologies. This experience has afforded West Basin with the knowledge on how to demonstrate effective product performance. As an example, West Basin currently requires vendors to demonstrate RO product performance on West Basin's feedwater for 5,000 hours before the product is considered acceptable for application in West Basin's treatment system. West Basin has also learned, from previous efforts, that ozone pre-treatment prior to microfiltration (MF) can improve fouling rates. That said, pilot study observations have also suggested that ozone treatment ahead of the microfiltration increases the total organic carbon (TOC) passage through the RO membranes. As a consequence, application of RO for this proposed demonstration project will require West Basin to also consider RO membranes that can achieve acceptable levels of Total Organic Carbon (TOC) rejection, while also demonstrating acceptable fouling trends and efficient energy consumption.

This study is anticipated to require 12 months of investigation and demonstration, and is expected to be complete by June 2017.

Technical Research Study Description

The Edward C. Little Water Recycling Facility (ECLWRF), owned by West Basin is a

state-of-the-art water recycling facility located in El Segundo, California. This facility treats over 40 million gallons per day (MGD) of secondary effluent from the City of Los Angeles' Hyperion Wastewater Treatment Facility (Hyperion) for potable reuse (injection into seawater intrusion barrier wells); industrial reuse applications (Chevron Refinery Boiler feeds); and disinfected tertiary uses (i.e. irrigation). For the potable reuse application, a combination of ozone, MF, RO, ultra-violet light, and hydrogen peroxide are used to treat the water. West Basin's Barrier injection permit, issued by the Los Angeles Regional Water Quality Control Board (LARWQCB), limits the TOC concentrations in the final product water. The permit limit considers the percentage of recycled water content that has been injected into the groundwater during the previous five years, and the calculated limit typically ranges between 0.5-1.0 mg/L. As West Basin's recycled water content approaches 100%, the permit limit for TOC will become 0.5 mg/L, which mirrors the current California Code of Regulations for subsurface application of recycled water (TOC of 0.5 mg/L) Title 22. Division 4. Chapter 3. Article 5.2. Although West Basin is not permitted based on the limits in these regulations, it is anticipated that future permits will include the new regulation limits. For this reason, West Basin has made it a goal to maintain compliance with the proposed regulatory limits.

With the Phase V expansion in 2013, West Basin added ozonation of the secondary effluent prior to MF to reduce fouling from large organic molecules present in the feedwater. West Basin was one of the first to adopt this treatment step as a strategy of MF fouling control. Phase V also included the addition of a Pall Microza microfiltration membrane system, which has performed well with the ozone pretreatment. However, with the ozone pretreatment implementation an increase in TOC passage was seen at the RO systems downstream of the MF treatment step. Subsequent investigation and field testing suggests that ozone has modified the large chain organic molecules into lower molecular weight molecules that more readily pass through the RO membrane, leading to an increase in permeate TOC concentrations. This increase in permeate TOC concentrations will make it challenging, to achieve the groundwater recharge regulation requirement of <0.25 mg/L TOC in the product water for the first 20 weeks of operation of the membrane system.

In the last decade, the RO membrane market has evolved rapidly, and new products have been developed that claim to be more resistant to fouling, degradation, and operate at lower feed pressures than their predecessors. This proposed study aims to investigate the ability of commercially available RO membrane models to achieve groundwater recharge water quality requirements specific to TOC on ozonated feedwaters. The elements will be characterized for TOC removal under West Basin's full-scale ozonated conditions, and the individual energy consumption associated with each membrane will be documented. An important body of data will be produced that will be of use in the selection of RO membranes for all indirect and direct potable reuse projects that are considering the use of ozone as pretreatment to MF.

As an early adopter of membrane technology for water recycling, West Basin has long recognized the fact that RO membrane performance is challenging to predict for these organic-laden, highly variable source waters. As a result, West Basin has been qualifying RO membrane products prior to allowing their participation in the procurement process since 2003. Products were tested for a total of 5,000 hours, demonstrating rejection and fouling characteristics before consideration for installation in the full-scale systems. Criteria for success was developed based on full-scale expectations for performance, requiring a minimum TOC, Total Nitrogen (TN), and Total Dissolved Solids (TDS) rejection, and a minimum acceptable membrane permeability, or specific flux. Orange County Water District (OCWD) incorporated similar qualification testing for the facility shortly after the startup of the Groundwater Replenishment System (GWRS) in 2008. In both cases, the process has been very successful in minimizing the risk and expense of installing RO membrane products that may not satisfy the project goals for final product water quality, capacity, or long-term O&M costs.

The use of ozone pretreatment is believed to change the characteristics of the organic material present in the feedwater. While MF fouling potential may be reduced, lower molecular weight organic molecules are formed which appear to pass through the RO membranes more easily. With ozone addition prior to membrane filtration becoming more commonplace in treatment design, data collected during this testing would be beneficial to not only West Basin but also other agencies who have or are considering ozone addition upstream of membrane filtration.

Due to the large capacity of West Basin's facilities and its historically challenging feedwater, the District requires MF and RO membranes to be tested at the facility in order for the product to be considered for future replacements. West Basin has been conducting RO replacement qualification testing as far back as 2001 and has successfully completed five rounds of testing since then. Data from qualification testing is then used to determine if fouling rates and operating parameters exhibited by the membranes during testing are sustainable in the full scale plant. In addition to fouling rates, other parameters that are taken in consideration when evaluating membranes are energy consumption, chemical consumption, and permeate water quality. All previous rounds of membrane qualification testing were conducted prior to the implementation of ozone as pretreatment to the membrane systems. As such, this testing will not only characterize and document the TOC rejection of each membrane operating on West Basin's ozonated feed source, but also confirm the fouling performance and energy requirements for each model.

The objectives of this study are the following:

1. To document the ability of the current RO membrane market to meet groundwater recharge regulations, specifically in cases where ozone is included in the pretreatment process; and
2. To document the long-term performance of alternative RO membranes when

operated at the full-scale level on microfiltered ozonated secondary effluent at a permeate flux as high as 15 gallons per square foot per day (GFD). Testing parameters which will be monitored will include membrane permeability (fouling tendency) as well as removal rates of TN, TOC, total dissolved solids (TDS), and select constituents of emerging concern (CEC).

The tasks of this demonstration project include the following:

1. Recommission three existing test vessels located on RO Train 3 at ECLWRF;
2. Install three new test vessels on RO Train 5 at ECLWRF;
3. Survey membrane manufacturer literature and select five membrane models to be tested during the demonstration;
4. Load the six test vessels (three existing vessels on Train 3 and three vessels new on Train 5) with the selected test membranes and begin membrane demonstration testing at 13 gfd. Water quality analyses will be performed for TN, TOC and TDS in the feed and permeate; pressure and flow operating parameters of the membranes will be recorded;
5. Ozone dosage in the feedwater at the ECLWRF will be maintained based on achieving the targeted UVT setpoint. However, a phase of testing will include varying ozone dose for short periods of time in order to collect TOC rejection data. This is detailed in the table outlined in the test plan and test schedule. The membranes will be operated at a flux of 13 gfd; and
6. All data from the demonstration will be compiled and analyzed and a final report detailing the results of the test will be produced.

Scope of Work

The Scope of Work for this project will entail the six tasks listed above.

Task1. Recommission three existing test vessels located on RO Train 3 at ECLWRF.

The ECLWRF currently operates a total of eleven RO trains one of which (Train 3) is already equipped with three test vessels. These vessels can be controlled independently from the rest of the train while operating on the exact same feed water. Dedicated piping and instrumentation allow sampling and isolation of permeate and concentrate flows for control and data collection. The first task of the qualification testing will be to recommission the existing test vessels located on Train 3. The vessels will be visually inspected to ensure there is no debris or mechanical damage to the vessels. All instruments will be properly calibrated and checked for accuracy.

Task 2. Install three new test vessels on RO Train 5 at ECLWRF.

The next task of the qualification testing will be to construct three additional test vessels at another existing RO train (Train 5) to provide a total of 6 test vessels. This will allow West Basin to evaluate 5 different membranes in a side by side comparison along with one test vessel containing Hydranautics ESPA2 elements as a control (Hydranautics ESPA2 was selected as the control due to a long history of successful performance at West Basin and other recycled water treatment facilities). A P&ID showing the instrumentation and controls retrofitted to each vessel is shown below:

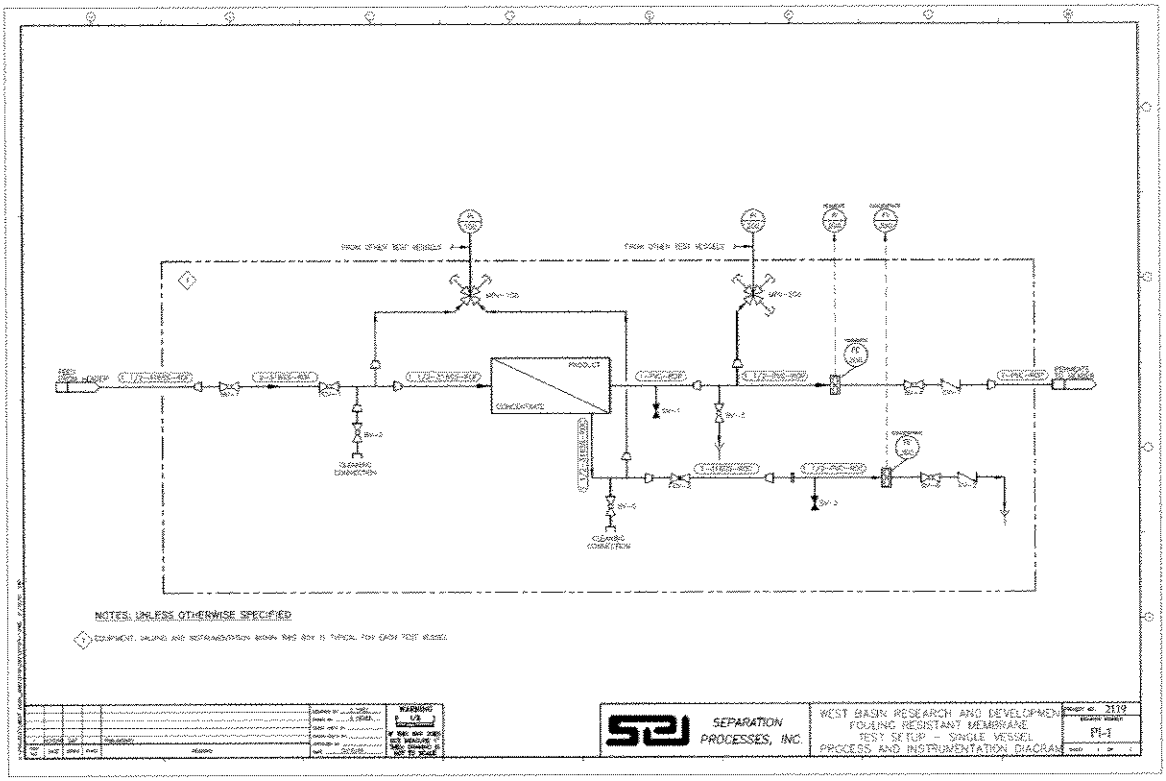

Figure 1: Test Vessel P&ID

Suez staff (an independent plant operation contractor) will procure and install all parts and equipment needed for the construction of the new test vessels. Drawings and specifications for all equipment and parts needed to construct and install the test vessels will be provided by West Basin and Separation Processes, Inc. (SPI), West Basin's engineering consultant on this project. The vessels will be constructed in similar fashion to the test vessels present on RO train 3.

Task 3. Survey membrane manufacturer literature and select five membrane models to be tested during the demonstration.

In the three years since the last round of RO membrane testing was performed by West Basin, the membrane market has evolved and many new membrane elements, as well as

new element manufacturers, are on the market. Literature from the various manufacturers will be reviewed to determine which models should be tested at the ECLWRF. Representatives from major suppliers such as Toray, Hydranautics, Dow, LG, and Lanxess will also be contacted to submit their input. Due to the challenging nature of the feedwater at ECLWRF, only 400 ft2 membranes with a feed/brine spacer thickness of at least 0.34 mm will be considered for testing. The table below shows typical characteristics for membranes that will be considered for selection.

Table 1: Membrane Criteria

Membrane Type	Active Area (ft^2)	Permeate Flow (gpd)	Rejection (%)	Net Thickness (mm)
Brackish RO	400	>9,000	>99.6	34

Task 4. Load the test vessels with the selected test membranes and begin membrane demonstration testing at 13 gfd. Water quality analyses will be performed for TN, TOC, and TDS in the feed and permeate; pressure and flow operating parameters of the membranes will be recorded.

Under this task, five sets of seven new RO membranes will be tested and compared with the control membranes. Each will be tested at a flux of 13 gfd on ozonated secondary effluent. A flux of 13 gfd was selected based on current first stage flux operating data from existing RO trains at ECLWRF. The first period of operation will last 18 weeks to analyze the membrane performance. The specific flux or permeability is expected to decline over the first 8 week period and then stabilize. The post "break in period" permeability decline will be observed during the remaining 10 weeks. After 18 weeks, the membranes will be cleaned and will be rerun at 13 gfd for 10 more weeks. A summary of the test schedule for this task is presented in the table below.

Table 2: Test Schedule

Weeks	Flux (gfd)
1-18	13
19-20	13

The run parameters for this test will be based upon the active area of the membranes tested. The permeate flow will be adjusted to attain a flux rate of 13 gfd for each of the membranes types. For example, the Hydranautics ESPA2 membrane contains 400 square feet of membrane area, and the pressure vessels in West Basin WRP Train 3 contain 7 membranes. Therefore, the permeate flow for 13 gfd operation on ESPA2 will be:

$$\left(\frac{13\,\text{gallons}}{\text{ft}^2\text{ - day}}\right) \text{X } (7\,\text{membranes}) \text{X} \left(\frac{400\text{ft}^2}{\text{membrane}}\right) \text{X} \left(\frac{1\,\text{day}}{1440\,\text{minutes}}\right) = 25.3\,\text{gpm}$$

Figure 2 illustrates the flow distribution for this example.

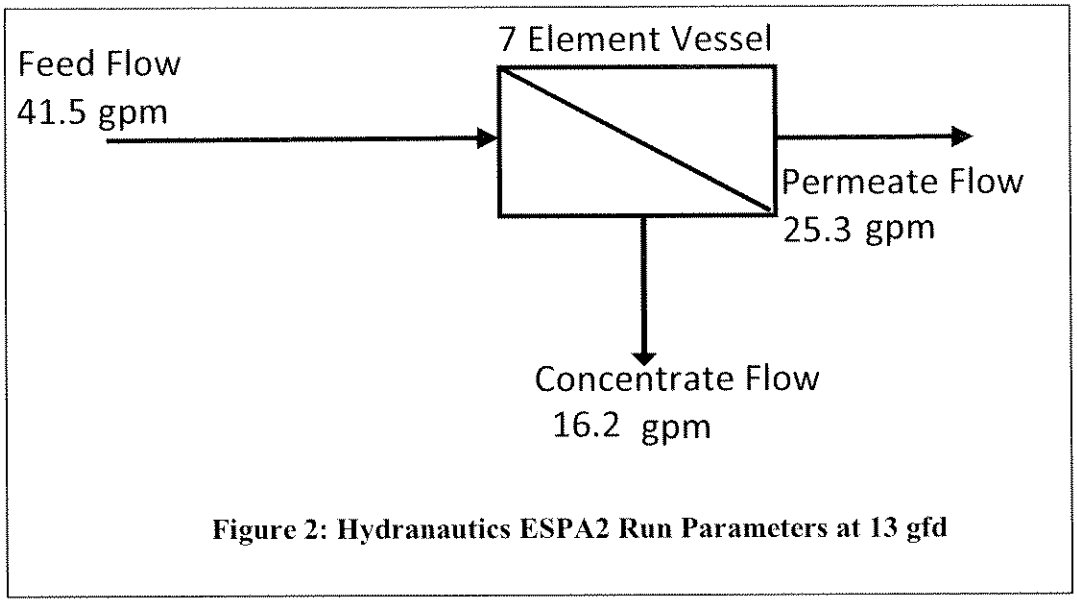

Figure 2: Hydranautics ESPA2 Run Parameters at 13 gfd

The permeate flow will be adjusted by throttling a valve on the feed line of the test vessel to reduce the feed pressure to the test membranes. The concentrate flows will be adjusted such that a uniform recovery is attained for each test vessel. The vessel recovery will be 61%. The use of 13 gfd and 61% recovery duplicate the conditions found in the typical first stage of a RO train at West Basin. Fouling from feedwater components occurs most rapidly in the first stage of an RO system.

Typical feedwater quality of the two trains which will contain the test vessels is listed in the tables below. These values represent the average for the year 2015.

Table 3:
West Basin WRP Acidified Feed Water Quality (2015)

Constituent	Units	Train 3 Average Value	Train 3 90th Percentile	Train 5 Average Value	Train 5 90th Percentile
Temperature	°F	81	84	80.5	84
pH	Units	6.5	6.5	6.5	6.5
Total Dissolved Solids	mg/L	986	1100	1157	1246

Table 3: West Basin WRP Acidified Feed Water Quality (2015)					
Constituent	**Units**	**Train 3 Average Value**	**Train 3 90th Percentile**	**Train 5 Average Value**	**Train 5 90th Percentile**
Bicarbonate (as $CaCO_3$)	mg/L	222	255	227	248
Chloride	mg/L	260	299	252	293
Sulfate	mg/L	285	307	268	301
Sodium	mg/L	199	220	192	223
Calcium	mg/L	64	68	60	65
Magnesium	mg/L	29	32	28	31
Total Hardness	mg/L	280	295	266	287
Potassium	mg/L	20	21	19.5	21
Silica	mg/L	19	19.5	19	19.8
Ammonia (NH_3 as N)	mg/L	43	47	41	45
Nitrate (NO_3 as N)	mg/L	1.7	2.4	1.3	2.2
Nitrite (NO_2 as N)	mg/L	0.4	0.4	0.7	1.0
Total Nitrogen (as N)	mg/L	26	47	43	47
Total Organic Carbon	mg/L	12.1	13	12	13

Standard Procedures

To ensure the accuracy of all collected data, sampling methods will be consistent with respect to location, timing, and the technique must be maintained. Additionally, for samples analyzed at off-site laboratories, consistency in sample preservation, packaging and shipping is required. Membrane operational parameters such as flow, pressure, and temperature will be recorded at the time of sampling.

Both on-line and bench-top analytical equipment will be used for on-site analyses. For parameters where both on-line and bench-top instruments are used (such as pH), comparisons between the two readings will be made to check for data consistency. At a minimum, these comparisons will be made weekly. All analyses will be performed according to Standard Methods[i]. All laboratory analyses will be performed by West Basin ECLWRF Laboratory or contracted through qualified, specialty laboratories.

Data Handling Protocol

The successful implementation of the RO membrane demonstration testing will require detailed coordination and constant communication between all testing participants. Activities shall be thoroughly documented. Documentation shall include field logbooks, photographs, data sheets, and chain-of-custody forms.

The data management system used in the demonstration testing program shall involve the use of computer spreadsheets and manual recording of operational parameters for the membrane equipment on a daily basis.

These trains are equipped with a Supervisory Control and Data Acquisition (SCADA) system which will be used for recording testing data into a database. Specific parcels of the computer databases for operational and water quality parameters will then be downloaded by manual importation into Excel (or similar spreadsheet software) file. These specific database parcels shall be identified based upon discrete time spans and monitoring parameters. In spreadsheet form, the data will be manipulated into a convenient framework to allow analysis of membrane equipment operation. At a minimum, backup of the computer databases to an external source disk will be performed every other week.

In the case when a SCADA system is not available, operators will record data and calculations by hand in laboratory notebooks. (Daily measurements shall be recorded on specially-prepared data log sheets as appropriate.) The notebooks will be stored on-site; copies will be forwarded to the SPI at least once per week during each testing phase. Operating logs will include a description of the membrane equipment (description of test runs, description of any problems or issues, etc.); such descriptions will be provided in addition to experimental calculations and other items.

The database for the project shall be set up in the form of custom-designed spreadsheets. The spreadsheets shall be capable of storing and manipulating each monitored water quality and operational parameter from each task, each sampling location, and each sampling time. All data from the laboratory notebooks and data log sheets will be entered into the appropriate spreadsheet. All recorded calculations will also be checked at this time. Following data entry, the spreadsheet will be printed out and the print-out shall be checked against the handwritten data sheet. Any corrections will be noted on the hard-copies and corrected on the screen, and then a corrected version of the spreadsheet shall be printed out. Each step of the verification process shall be initialed by the testing operator or engineer performing the entry or verification step.

Operating Parameters and Data Collection

The following parameters are necessary to evaluate the performance of the RO membranes. These parameters shall be recorded daily and logged on the run sheets.

Table 4: Daily Operational Data Parameters

Measurement	Feed	Permeate	Concentrate	Frequency
Water Temperature	X			Daily
Conductivity	X	X	X	Daily
pH	X			Daily
Pressure	X	X	X	Daily
Flow (per vessel)		X	X	Daily

A daily operating log is to be maintained by the operating staff. The RO System operations logbook will include a record of events (equipment starts, stops, maintenance, and instrument calibrations) and description of any problems or issues. The original data sheets will be stored on-site; and copies sent electronically to SPI.

Laboratory Data

For each test vessel, feed (common), permeate, and concentrate samples shall be gathered after the initial 24 and 72 hours of operation, and then following weeks 15, 19, and 20. The samples will be analyzed for the following constituents:

pH	Chloride	Potassium
Alkalinity	Nitrate	Silica
Bicarbonate	Nitrite	Ammonia
Carbonate	Calcium	Total Nitrogen
Hydroxide	Magnesium	Electrical Conductivity
Sulfate	Sodium	TOC
Phosphate		

In addition to these constituents, samples will be taken and analyzed for the following constituents of emerging concern. These constituents are either currently regulated or being monitored. All laboratory samples will be analyzed at the ECLWRF on-site laboratory, or contracted through a qualified, specialty laboratory.

Constituents	Common Use	Required/Optional
Sucralose	Artificial Sweetener	Required
TCEP	Flame Retardant	Required
Iohexol	Radiographic Contrast Agent	Required

Constituents	Common Use	Required/Optional
1-4 Dioxane	Solvent	Required
NDMA	Chemical by-product	Required
DEET	Insect Repellant	Optional
Gemfibrozil	Cholesterol Medication	Optional
Iopromide	Radiographic Contrast Agent	Optional
17- Estradiol	Hormone	Optional
Triclosan	Antibacterial/Detergent	Optional
Acetaminophen	Pain Reliever	Optional
Caffeine	Stimulant	Optional

Task 5. Ozone dosage in the feedwater at the ECLWRF will be maintained based on achieving the targeted UVT setpoint. However, a phase of testing will include varying ozone dose for short periods of time in order to collect TOC rejection data. This is detailed in the table outlined in the test plan and test schedule. The membranes will be operated at a flux of 13 gfd.

During this task, feed and permeate samples will be taken twice for each of the ozone doses listed in Table 5 below in order to determine the effect of ozone dosage on the performance of the various membranes. Each of these ozone doses will be maintained for a period of 2 days and feed and permeate samples will be taken from each vessel on each day then sent to the lab to be analyzed for TOC. During this time, all other operating parameters will remain unchanged. This test will be repeated two to three times during the Task 4 testing.

Table 5.

Days	Ozone Dose (ppm)	Flux (gfd)
2	0	13
2	4	13
2	8	13
2	12	13

Task 6. All data from the demonstration will be compiled and analyzed and a final report detailing the results of the test will be produced.

The primary purpose of this demonstration testing is to develop a body of data that shows the relative performance of RO membranes to help guide not only West Basin, but other users in the selection of membranes for achieving desired TOC rejection when utilizing ozone treatment as pretreatment to MF. All water quality and operating data will be analyzed and presented in a detailed report that will be available for other

agencies and users to use as a reference guide. Relative energy consumptions and cleaning effectiveness for each membrane product will also be documented.

Evaluation Criteria

Evaluation Criterion 1: Statement of Problems and Needs

The California Code of Regulations stipulates requirements for water recycling within California. (Title 22. Division 4. Chapter 3). These regulation were updated on July 18, 2014 to specify requirements for recycled water use in both surface (Article 5.1) and subsurface (Article 5.2) applications for groundwater recharge, Both articles recognize TOC as a measure of the level of treatment, but the regulations for subsurface application include a firm limit for TOC of 0.5 mg/L (Title 22. Division 4. Chapter 3. Article 5.2). Additionally, Article 5.2 requires that RO membrane products must achieve a TOC concentration of $\leq$0.25 mg/L during the first 20 weeks of operation.

These regulations also require proposed RO membranes to meet specific nominal performance criteria, largely based on the manufacturers' factory testing for sodium chloride rejection. However, TOC rejection by RO membrane is not well correlated to sodium chloride rejection, and membranes may not reject TOC sufficiently to achieve the 0.5 mg/L requirement, let alone the initial requirement of 0.25 mg/L for the first 20 weeks. Additionally, based on West Basin's operational experience, full advanced treatment systems utilizing ozone treatment ahead of RO trains may not be able to achieve the 0.25 mg/L requirement at all.

This study will confirm the TOC rejection from several commercially available RO membrane products that could be used in full advanced treatment scheme for subsurface application. The study will generate a body of data that other agencies can use for membrane selection within their treatment scheme, and be particularly useful to those agencies considering ozone as a treatment step ahead of MF and RO.

Evaluation Criterion 2: Water Reclamation and Reuse Opportunities

Feedwater water quality for the ECLWRF has become increasingly challenging over the years. Feedwater turbidity, Total Suspended Solids (TSS), and ammonia concentrations have all experienced significant increases in both quantity and variability since 1995. While this water quality is within the Hyperion wastewater treatment plant's treatment goals, the increased concentrations have proven to be challenging for West Basin's Barrier MF system. Specifically, excessive membrane fouling has caused a loss of capacity for older MF technologies in the past decade. This source is considered to be challenging feed water 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. In recent years of drought in California, conservation has increased significantly 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 that 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 ozone, MF, and RO are appropriate for water recycling in other scenarios.

Evaluation Criterion 3: Description of Potential Alternatives

In an effort to improve MF performance, ozone pretreatment ahead of MF was investigated, and eventually included in the Phase V design after a successful pilot study. Ozone pretreatment was installed ahead of all the phases of MF at ECLWRF. Ozone is dosed into the plant influent in order to oxidize long-chain organics that have been shown to contribute to the MF fouling. Many of these organics are dissolved, and their presence is not necessarily indicated by turbidity, TSS, or TOC. The system was designed to control the ozone dose based on the Ultraviolet Transmittance (UVT) through the influent water. UVT was considered an acceptable means of controlling ozone dose based on early pilot testing, as it is a quantifiable measure of organic material in the water (dissolved or colloidal). The ozone system can dose up to 18 mg/L of ozone in order to maintain a target UVT of 55% for the MF feedwater.

The conditions and situation at West Basin are not unique. As indirect and direct potable reuse technology is more widely used in the reclamation of treated municipal wastewater, the field is investigating the processes available to improve MF performance. Ozone is one such process currently used at West Basin and the industry appears to be following suit and including ozone more frequently in proposed treatment schemes. Several other large systems in the design and investigation stages are also considering ozone pretreatment. The Monterey Regional Water Pollution Agency (MRWPA) has included ozone as pretreatment to their MF process. The City of San Diego included ozone as one of the treatment processes in their demonstration facility for the Pure Water San Diego project. The use of ozone as an important pretreatment step will need to be better understood so that these and other facilities to come will be able to gain the benefits of ozone treatment and avoid the potential issues that are beginning to be understood. The testing described in this investigation will produce a body of data that will allow future designers to select the RO membranes that exhibit the highest TOC rejection performance when operated on a feed that has been treated with ozone.

RO membrane rejection is often inversely related to the pressure required to drive water through the membrane. In general, the RO membrane models with the best rejection characteristics are also the most energy intensive to operate because of the higher pressures required. This study looks to not only characterize TOC rejection, but to also document the operating pressure requirements associated with the specific membrane models. With this data, West Basin (and others) will be able to identify and procure RO membranes for their projects that not only achieve the TOC requirements set forth in the state regulations, but also operate with minimal and sustainable energy consumption.

Evaluation Criterion 4: Stretching Water Supplies

Increasing urban water demands and unpredictable drought conditions have highlighted the need to expand water recycling efforts as an alternative to developing new water supplies or increasing diversions from existing natural sources. 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. Secondary treated effluent is plentiful in the region, and has historically been viewed as point-source pollution under the Clean Water Act (CWA) and subsequent National Pollution Discharge Elimination System (NPDES) program. However, with the continued development and proliferation of membrane technologies, secondary treated effluent can be accessed as a source of drought-proof water for both industrial application and potable reuse.

The proposed research study will promote increased efficiency and reliability in the RO membrane market, and will provide the data necessary for other agencies to evaluate the feasibility of adopting or expanding advanced treatment efforts as an alternative to increased diversions from State or Federal supplies.

In California, TOC has been identified as an indicator of membrane rejection and constituent removal in RO systems. However, West Basin's experience has shown that TOC removal is adversely impacted by the inclusion of ozone treatment upstream of their current membrane treatment systems.

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.

Evaluation Criterion 5: Environment and Water Quality

Advanced water treatment performed at ECLWRF not only reduces pollutant loading into local waterways, but also improves the quality of groundwater being recharged into the West Coast Groundwater Basin (WCGB). Secondary effluent from Hyperion is normally discharged to the Santa Monica Bay through a 5-mile ocean outfall. West Basin purchases

approximately 10% of Hyperion's treated effluent for advanced treatment at ECLWRF and subsequently distributes this recycled water for irrigation, industrial, saltwater barrier, and indirect potable reuse applications. RO membranes are 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 RO systems and to maintain or increase treatment capacity during full-scale implementation. With the results of this study supporting increased reliability and decreased system downtime, West Basin can fully maximize the ECLWRF capacity to treat Hyperion's secondary effluent, which would otherwise be diverted to the Santa Monica Bay as ocean discharge.

In addition to reducing total pollutant loading, improved data on RO treatment is specifically critical to mitigating groundwater quality issues in the WCGB. Historic overdraft of the coastal aquifers in the region has trapped a large plume of brackish seawater inland of the coast. This contamination is currently being mitigated through subsurface injection of advanced treated wastewater supplied by ECLWRF to the Water Replenishment District of Southern California (WRD). In tandem with West Basin operations at their Brewer Desalter facility in Torrance, CA, the extraction and treatment of brackish groundwater via RO membranes provides the region with up to 5 MGD of potable water.

Evaluation Criterion 6: Legal and Institutional Requirements

The California Code of Regulations stipulates requirements for water recycling within California. (Title 22. Division 4. Chapter 3). These regulation were updated on July 18, 2014 to specify requirements for recycled water use in both surface (Article 5.1) and subsurface (Article 5.2) applications for groundwater recharge. Both articles recognize TOC as a measure of the level of treatment, but the regulations for subsurface application include a firm limit for TOC of 0.5 mg/L (Title 22. Division 4. Chapter 3. Article 5.2). Additionally, Article 5.2 requires that RO membrane products must achieve a TOC concentration of $\leq$0.25 mg/L during the first 20 weeks of operation.

These regulations also require proposed RO membranes to meet specific nominal performance criteria, largely based on the manufacturers' factory testing for sodium chloride rejection. However, TOC rejection by RO membrane is not well correlated to sodium chloride rejection, and membranes may not reject TOC sufficiently to achieve the 0.5 mg/L requirement, let alone the initial requirement of 0.25 mg/L for the first 20 weeks. Additionally, based on West Basin's operational experience, full advanced treatment systems utilizing ozone treatment ahead of RO trains may not be able to achieve the 0.25 mg/L requirement at all.

This study will confirm the TOC rejection from several commercially available RO membrane products that could be used in full advanced treatment scheme for subsurface application. The study will generate a body of data that other agencies can use for membrane selection within their treatment scheme, and be particularly useful to those

agencies considering ozone as a treatment step ahead of MF and RO.

Evaluation Criterion 7: Renewable Energy and Energy Efficiency

RO membrane rejection is often inversely related to the pressure required to drive water through the membrane. In general, the RO membrane models with the best rejection characteristics are also the most energy intensive to operate because of the higher pressures required. Energy consumption associated with operation of the RO membrane can account for a significant portion of the O&M costs for a full advanced treatment scheme. This study looks to document the operating pressure and energy consumption requirements associated with commercially available membrane models that may be selected for a full advanced treatment project. With this data, West Basin (and others) will be able to identify and procure RO membranes for their projects that not only achieve the TOC requirements set forth in the state regulations, but also operate with minimal and sustainable energy consumption over the life of the project.

Evaluation Criterion 8: Watershed Perspective

Points will be awarded based on the extent to which the proposal demonstrates that the research study will promote and apply a regional or watershed perspective to water resource management.

(1) Describe whether or the extent to which the research study is based off of recommendations from an existing plan that is sponsored or otherwise recommends research needs on a regional or national scale.

The District's Capital Implementation Plan (CIP) describes the ongoing efforts to increase the reliability and quality of the recycled water and one of the ways in which to do this is to have reliable equipment. This research is needed in order to achieve the goals set forth in the CIP in order to provide a reliable and high quality water supply to the customers within the service area.

(2) Explain any additional benefits of, or specific need for, the proposed research study within the sponsors watershed, regional area, and nationally.

The study will benefit both District, and other agencies, who seek to embark on similar efforts. This study will provide the data needed to make an informed decision for any future replacement or expansion of the RO units at the ECLWRF. The information will allow the District to make sound financial decisions on the appropriate technology to balance performance criteria such as fouling of the membranes, meeting the water quality requirements for the stated uses and minimizing the energy requirements for the RO treatment. The financial decisions by the District will serve to reduce increases in service charges to its retail agencies.

The results of the study can be utilized regionally by others that would use the same

source of recycled water as the District, and for those who wish to implement a similar effort. Energy savings can be shared locally and regionally. In addition, reduced energy use may reduce the peak power demands on power companies.

(3) *Describe how the research objectives will benefit other locations and the technical, economic, or institutional questions that will be answered by the research study.*

As described above, the research objectives will be useful to others that use the same source of supply. Expenses to others will be defrayed because the research has been completed.

In addition, results of the study can be used by the manufacturers to potentially modify their designs to better meet the performance criteria as established by regulatory agencies.

(4) *Explain how the research study includes or promotes and encourages collaboration among parties. Identify if there is widespread support for the research study.*

The groundwater basin within the District is mutually shared by many agencies and individuals. The protection and restoration of the groundwater basin is a benefit for local users of the groundwater basin. Furthermore, the more reliable the basin is the less groundwater producers place demands on imported water brought in through Metropolitan Water District of Southern California. This results in greater reliability for those that are heavily reliant on imported water.

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 – Permits and/or Approvals will not be 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 Reclamation.

Research Study Budget

The research study budget includes: (1) Funding Plan and Letters of Commitment, (2) Budget Proposal, and (3) Budget Narrative.

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 $155,372.25 through the Capital Improvement Program budget. This Project will further advance RO 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:*

West Basin does not seek to include any costs before the anticipated Program start date.

(3) *What project expenses have been incurred*

No Program expenses have been incurred.

(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. At this time, West Basin is not dependent on outside funding or funding partners to implement this study.

(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 1) 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 50 percent of the total estimated project cost.

Table 1. —Funding Breakdown

Funding Sources	Funding Amount
Non-Federal Entities	
West Basin Municipal Water District – In-Kind*	$46,641.30
West Basin Municipal Water District – Cash	$124,268.17
Non-Federal Subtotal:	**$170,909.47**
Other Federal Entities	
NA	$0
Other Federal Subtotal	**$0**
Requested Reclamation Funding:	**$56,969.83**
Total research study funding:	**$227,879.30**

Budget Proposal

Table 2. —Funding Sources

Funding Sources	Percent of Total Research Study Cost	Total Cost by Source
Recipient funding	75%	**$170,909.47**
Reclamation funding	25%	**$56,969.83**
Other Federal funding	NA	**$ -**
Totals	**100%**	**$227,879.30**