GRANT APPLICATION PACKET

California Department of Water Resources
Drainage Reuse Grant Program (Prop. 204)

SELF-ADAPTIVE HIGH RECOVERY DESALINATION OF AGRICULTURAL DRAINAGE WATER WITH CONCENTRATE SALT HARVESTING

Project Director and Principal Investigator
Yoram Cohen, Ph.D.
UCLA Water Technology Research Center
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Project Manager and Co-Principal Investigator
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Authorized Representative
Flora O'Brien
UCLA Office of Contract and Grant Administration

Project Partner
Dennis Falaschi
Panoche Drainage District

UCLA WATER TECHNOLOGY RESEARCH CENTER

UCLA ENGINEERING
Henry Samueli School of Engineering and Applied Science

PANOCHE DRAINAGE DISTRICT

The Regents of the University of California, Los Angeles
Office of Contract and Grant Administration, MC 951406
11000 Kinross Avenue, Suite 211
Los Angeles, CA 90095-1406

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UCLA Engineering
HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE
Chemical and Biomolecular Engineering Department

UCLA WATER TECHNOLOGY RESEARCH CENTER

Professor Yoram Cohen
Chemical and Biomolecular Engineering Department
5531 Boelter Hall, Box 951592
University of California, Los Angeles
Los Angeles, CA 90095-1592

January 1, 2015

Maggie Dutton
California Department of Water Resources
Integrated Regional Water Management
South Central Region Office
3374 E. Shields Avenue
Fresno, CA 93726

Dear Ms. Dutton,

We are pleased to submit the proposal "Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Salt Harvesting" for the California Department of Water Resources Drainage Reuse Grant Program (Prop. 204).

The proposed project is for a two year period and will focus on the demonstration and further development/refinement of a high recovery desalination process with salt harvesting that targets the challenging San Joaquin Valley agricultural drainage water. The project will be conducted at the Panoche Drainage District (PDD) in partnership with PDD at a site that has been set aside specifically for the project. Moreover, a recently constructed RO plant with self-adaptive capabilities will be utilized (provided as in-kind) for the proposed project. This plant will be integrated with a chemically-enhanced seeded precipitation process for treatment of primary RO (PRO) concentrate that will serve to both desupersaturate the PRO concentrate and also to harvest mineral salts. A secondary RO unit will be interfaced with the system to reach high recovery (up to and in excess of 90%).

The proposed work will build on extensive research and development and experience that was gained over the last several years on the development of the process and the UCLA/PDD team are now positioned to demonstrate the practical deployment of high recovery RO with salt harvesting. To our knowledge, the UCLA team with its membrane monitoring technology and self-adaptive operation is the only group that has been able to carry out sustained RO operation without mineral scaling at PDD. Based on our past experience and fundamental approach we are confident that the proposed project will succeed in demonstrating a technically and economically feasible solution to agricultural drainage water desalination management.

We look forward to a positive evaluation of our proposal and to productively contribute to solving one of California's most pressing water issues.

Sincerely,

Yoram Cohen

Yoram Cohen
Professor, Chemical and Biomolecular Engineering Department
UCLA Luskin Scholar
Director, Water Technology Research Center
UCLA

Email: yoram@ucla.edu; Phone: (310) 825-8766; Fax: (310) 206-4107

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Attachment 1, Part I – Application Cover Sheet

Application for a grant under § 78645 of the Safe, Clean, Reliable Water Supply Act of 1996

The The Regents of the University of California
(Exact legal name of local entity applying for the grant)

Of University of California, Los Angeles, Office of Contract and Grant Administration,
(Mailing address of local entity)

MC 951406, 11000 Kinross Avenue, Suite 211, Los Angeles, CA 90095-1406

Of the County of Los Angeles, State of California, does hereby apply to the California Department of Water Resources for a grant in the amount of $ 300,000.

For the following project under the Drainage Reuse Grant Program of the Safe, Clean, Reliable Water Supply Act of 1996:

Of Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Salt Harvesting
(Specify project title)

By [signature] Date 12/18/2014
(Signature of authorized representative)

Flora O'Brien — Contract & Grant Officer
(Print or type name of authorized representative) — *(Title)*

Telephone (310) 206-0807 E-mail flora.obrien@research.ucla.edu

Brief Proposal Description:

In partnership with Panoche Drainage District, UCLA researchers will demonstrate high recovery desalination with salt harvesting using a field deployed smart desalination plant to treat high salinity subsurface agricultural drainage water. A reverse osmosis (RO) desalination plant, specifically designed for handling brackish water of high mineral scaling propensity, will be optimized for high product water recovery levels. Self-adaptive plant operation that ensure scale-free operation will be enabled via the aid of real-time membrane monitoring and dynamic process optimization. A novel chemical-enhanced seeded precipitation process will be interfaced with the RO plant to field demonstrate RO concentrate treatment which will allow for both concentrate salt harvesting (primarily gypsum) and concentrate desupersaturation. Desupersaturated RO concentrate will be then be desalted in a secondary RO system (also integrated with the primary RO plant) to further enhance product water recovery. Cost of water treatment/desalination will be analyzed based on field data and suitable process models. It is expected that the proposed project will provide the necessary technical information/knowledge and cost data for implementing practical and cost-effective strategies for on-farm high recovery RO desalination with salt harvesting.

Attachment 1, Part II – Applicant's Representatives

Project Name: **Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Salt Harvesting**

Primary Project Contact (Administrative)

Name : Flora O'Brien Title: Contract & Grant Officer / Authorized Representative

Address: UCLA OCGA, 11000 Kinross Avenue Suite 211, Los Angeles, CA 90095-1406

Telephone: (310) 206-0807 FAX: (310) 943-1654

E-mail: flora.obrien@research.ucla.edu

Primary Project Contact (Technical)

Name: Yoram Cohen Title: Professor

Address: UCLA Chemical and Biomolecular Engineering Department, Henry Samueli School of Engineering and Applied Science, 5531 Boelter Hall; University of California, Los Angeles (UCLA), 420 Westwood Plaza, Los Angeles, CA 90095-1592

Telephone: (310) 825-8766 FAX: ( ) N/A

E-mail: yoram@ucla.edu or profyc@gmail.com

Alternate Project Contact (Technical)

Name: Anditya Rahardianto Title: Asst. Researcher

Address: UCLA Chemical and Biomolecular Engineering Department, Henry Samueli School of Engineering and Applied Science, 5531 Boelter Hall; University of California, Los Angeles (UCLA), 420 Westwood Plaza, Los Angeles, CA 90095-1592

Telephone: (310) 948-7773 FAX ( ) N/A

E-mail: andi@ucla.edu

Type of Organization Public University
(city, county, water district, university, etc.)

Attach a copy of the applicant's charter and the names and titles of its officers.

Applicant's Charter

The University of California is a ten-campus public system of higher education that is governed by a 26-member Board of Regents, as established in Article IX, section 9 of the California State Constitution. The governing documents of the Board can be accessed via the web from: http://regents.universityofcalifornia.edu/governance/

Applicant's Officers

The Officers of the Regents of the University of California are:

- Anne Shaw, Secretary and Chief of Staff
- Charles F. Robinson, General Counsel
- Jagdeep Singh Bachher, Chief Investment Officer
- Sheryl Vacca, Chief Compliance and Audit Officer

Attachment 1, Part III – Summary of Project Costs

Provide a summary of the financing information about the proposed project, including cost share (if applicable).

		% of Total Cost
Total Cost of Project:	$ 518,074	
Amount Requested (CWC §78645):	$ 300,000	58%
Amount of Cost Share[1]:	$	
Amount of Federal Contribution:	$	
In-kind Contributions:	$ 218,074	42%
Amount to be Funded by Others Sources: (Describe below in table.)	$	

Sources of funds from partner agencies for this project, if applicable:

Amount	**Name of Source**	**Status of Funds[2]**
$		
$		
$		
$		
$		
Total: $		

Additional explanation, if necessary:

In-kind contributions, valued at a total of $218,074, include:

1. Time committed by the Principal Investigator (PI, Prof. Y. Cohen) during the academic year, valued at $30,930
2. Use of specialized field equipment, including the UCLA Smart Water Treatment and Desalination plant. The total amortized value is $137,144 for two years.
3. Field infrastructure support provided by Panoche Drainage Distict (PDD) is valued at $50,000 per PDD support letter.

Notes:

1. No cost share is required; however, grantees are required to show cost share (e.g., federal, local, or other funds) if an awarded project costs more than the grant amount.
2. Identify the current status of funds: available, planned/budgeted, awarded or pending.

Attachment I, Part IV – Authorizing Resolution

The Office of Contract and Grant Administration (OCGA) of the University of California Los Angeles has the authority from the **Regents of the University of California** to file applications and execute agreements with government, non-profit, and higher education organizations. For the grant application to the **California Department of Water Resources** entitled "**Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Salt Harvesting**", the assigned **Authorized Representative** is:

Name: Flora O'Brien

Title: Contract & Grant Officer

Address: UCLA OCGA, 11000 Kinross Avenue Suite 211, Los Angeles, CA 90095-1406

Telephone: (310) 206-0807

Fax: (310) 943-1654

E-mail: flora.obrien@research.ucla.edu

An endorsement of the submission of the attached grant application to the **California Department of Water Resources**, signed by the **Authorized Representative**, is attached.

UNIVERSITY OF CALIFORNIA, LOS ANGELES **UCLA**

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December 18, 2014

Maggie Dutton
California Department of Water Resources
Integrated Regional Water Management
South Central Region Office
3374 E. Shields Avenue
Fresno, CA 93726
AgDrainageGrants@water.ca.gov

UCLA PI:	Professor Yoram Cohen
Period of Performance:	June 15, 2015 – June 14, 2017
Total Amount Requested:	$300,000
Total Amount of In-Kind:	$218,074
Project Title:	*Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Salt Harvesting*

Dear Ms. Dutton:

On behalf of The Regents of the University of California, Los Angeles campus (UCLA) and Dr. Yoram Cohen, I am pleased to endorse the attached proposal materials to your organization for consideration of the above named project in response to the Department of Water Resources Drainage Reuse Grant Program Guidelines and Proposal Solicitation dated October 2014. We are submitting this application in anticipation of an agreement subject to mutually agreeable terms and conditions.

Future awards should be issued to The Regents of the University of California, Los Angeles and forwarded to this office. Questions regarding the technical components of this application can be directed to Dr. Cohen at Yoram@ucla.edu. Questions concerning contractual and administrative matters should be referred to me at flora.obrien@research.ucla.edu or by telephone at (310) 206-0807.

Sincerely,

Flora O'Brien
Contract and Grant Officer

Enc

(UCLA Reference No. 20152693)

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Attachment 3 – Eligibility Requirements

The Regents of the University of California, Los Angeles is considered to be a local agency per the definition in the California DWR Drainage Reuse Grant Program and is therefore an eligible grant applicant. Specifically, the Guidelines and Proposal Solicitation Package of the Drainage Reuse Program states that "… public universities, including the University of California, are considered to be a local agencies for this grant program."

The Regents of the University of California was established as prescribed by the provisions of Section 9 of Article IX of the Constitution of the State of California.

The Regents of the University of California, as represented by the Office of Contract and Grants of the University of California Los Angeles (UCLA), has legal authority to enter into a grant agreement with the State of California. To ensure performance of the proposal and tracking of funds, the principal investigators will be supported by the UCLA offices of Contract and Grants Administration (OCGA) and Extramural Fund Management (EFM) in conducting the proposed project. The UCLA OCGA office provides grant management support, while the UCLA EFM office provides financial management support. Financial management support of sponsored project funds includes financial reporting, invoicing, cash management, accounts receivable management, financial compliance oversight (effort reporting, cost transfers, unallowable expenses), and audit support.

The proposed demonstration project will be conducted at the Panoche Drainage District Treatment Site, in partnership with the Panoche Drainage District. The project is consistent with the goals and intentions of the applicable Regional Water Quality Control Plan (Basin Plan). A commitment letter from Panoche Drainage District is provided in the proposal (Attachment 2, Section 1.2).

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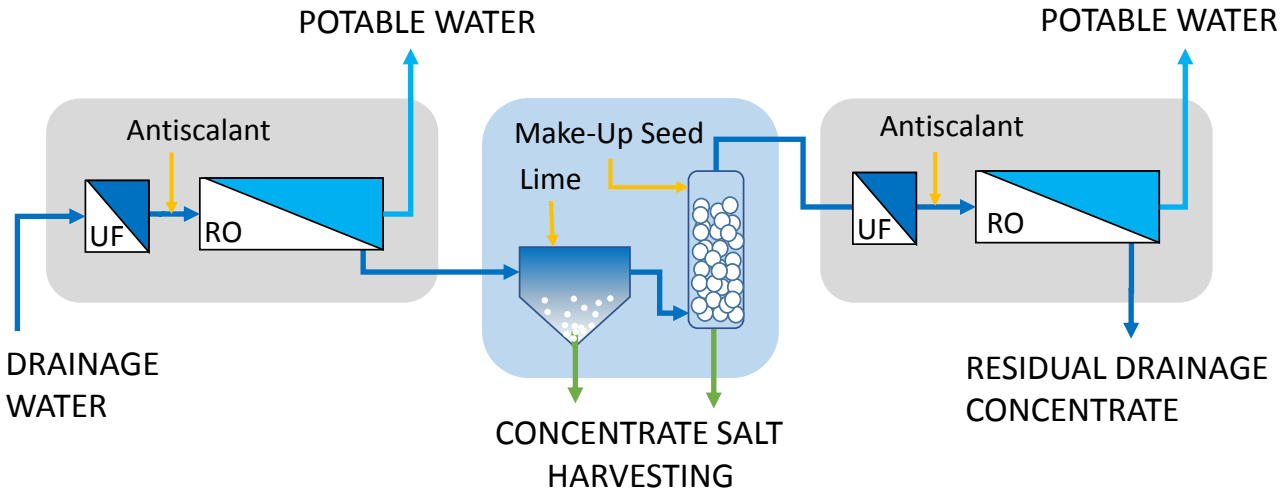
Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Salt Harvesting



Principal Investigators
Yoram Cohen, Ph.D.
Anditya Rahardianto, Ph.D.

UCLA WATER TECHNOLOGY RESEARCH CENTER

Project Partner
Dennis Falaschi

PANOCHE DRAINAGE DISTRICT

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MAJOR ABBREVIATIONS AND ACRONYMS

AMRO-DISH	Autonomous multi-step RO desalination with integrated salt harvesting; integrated PRO-CCESP-SRO process/plant.
RO	Reverse Osmosis
CESP	Chemically-Enhanced Seeded Precipitation; a two-step process concept for RO concentrate desupersaturation and salt harvesting
CCESP	Continuous CESP; an implementation of CESP for continuous, steady-state operation of concentrate desupersaturation and salt harvesting
CDPH	California Department of Public Health
CWC	California Water Code
CEQA	California Environmental Quality Act
DP-25	Drainage Point 25 at Panoche Drainage District
DWR	California Department of Water Resources
DRGP	Drainage Reuse Grant Program, Proposition 204, California DWR
ICP-MS	Inductively coupled plasma mass spectrometry; for analysis of ion/metal content
IAP	Ion Activity Product (e.g., $IAP = (Ca^{2+})(SO_4^{2-})$ for gypsum, $CaSO_4 \cdot 2H_2O$).
K_{spx}	Solubility Product (e.g., $K_{spx} = (Ca^{2+})_{eq}(SO_4^{2-})_{eq}$ for gypsum, $CaSO_4 \cdot 2H_2O$).
MCL	Maximum contaminant limit
MeMo	Membrane Monitor; UCLA patented technology for direct, real-time detection and monitoring of membrane fouling/scaling
NEPA	National Environmental Policy Act
PI	Principal Investigator
PD	Project Director
PM	Project Manager
PDD	Panoche Drainage District
PRO	Primary Reverse Osmosis
SEM-EDS	Scanning Electron Microscopy with Electron Dispersive Spectroscopy; analytical method for high resolution imaging and elemental analysis of surfaces
SIx	Saturation index with respect to mineral salt x (e.g., c: calcite, g: gypsum)
SRO	Secondary Reverse Osmosis
SWTD	UCLA Smart Water Treatment and Desalination system/unit. This existing system will be utilized for primary RO desalination in the proposed project
TS-3	Tile Sump No. 3 at PDD treatment site
UCLA	University of California Los Angeles
UF	Ultrafiltration
WaTeR	UCLA Water Technology Research (WaTeR) Center

1. Principal Investigators & Project Partner

1.1 List of Principal Investigators and Partner

Principal Investigator (PI) and Project Director (PD)
Name: Yoram Cohen, Ph.D.
Title: Professor
Affiliation: UCLA Water Technology Research Center, Chemical and Biomolecular Engineering Department
Phone: 310-825-8766
Email: yoram@ucla.edu
Co-Principal Investigator (Co-PI) and Project Manager (PM)
Name: Anditya Rahardianto, Ph.D.
Title: Assistant Researcher
Affiliation: UCLA Water Technology Research Center, Chemical and Biomolecular Engineering Department
Phone: 310-948-7773
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Authorized Representative
Name: Flora O'Brien
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Affiliation: UCLA Office of Contract and Grants
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Email: flora.obrien@research.ucla.edu
Project Partner
Name: Dennis Falaschi
Title: General Manager
Affiliation: Panoche Drainage District
Phone: 209-364-6136
Email: dfalaschi@aol.com

1.2 LETTER OF SUPPORT

PANOCHE DRAINAGE DISTRICT

52027 WEST ALTHEA, FIREBAUGH, CA 93622 • TELEPHONE (209) 364-6136 • FAX (209) 364-6122

December 10, 2014

Maggie Dutton
California Department of Water Resources
Integrated Regional Water Management
South Central Region Office
3374 E. Shields Avenue
Fresno, CA 93726

Dear Ms. Dutton,

Panoche Drainage District (PDD) and Firebaugh Canal Water District (FCWD) are pleased to support the UCLA proposed field project "Self-Adaptive High Recovery Desalination of Agricultural Drainage Water with Concentrate Harvesting", submitted to the California Department of Water Resources, for funding considerations under the Drainage Reuse Grant Program (DRGP) through proposition 204 (the Safe, Clean, Reliable Water Supply Act of 1996).

PDD and FCWD are within the Grassland Drainage Area (GDA) – a 100,000 acre region of highly productive farmland located on the Westside of the San Joaquin Valley. The GDA is underlain by coastal range sediments that are generally heavy clays and contain a variety of dissolved minerals including boron and selenium. These soil conditions have contributed to a healthy and productive agricultural environment but their heavy clay nature has also created a saline perched water table that threatens this productivity and must be managed. PDD and FCWD participated in the development of the Westside Regional Drainage Plan (WRDP) to address this problem. The WRDP is a regional plan for reducing the volume of saline agricultural drain water that is discharged to the San Joaquin River through source control, groundwater management, as well as treatment and reuse. The WRDP includes a number of components, including drainage treatment to desalinate the perched water and make it usable again. The proposed project directly addresses the following elements of the DWR DRGP Prop 204 program priorities:

(1) A field demonstration of a continuous process of RO concentrate treatment and salt harvesting will be demonstrated. The basis for the approach, which was developed at UCLA, was previously evaluated via laboratory testing and a preliminary semi-batch field study was conducted at Panoche that indicated the merits of moving forward with a continuous process. This part of the study specifically addresses the DRGP objective of developing sustainable and environmentally acceptable methods to concentrate and harvest salts and remove potentially toxic elements from drainage water;

(2) The proposed project will make use of a unique technology of self-adaptive filtration (MF/UF) and RO to desalt agricultural drainage and subsurface brackish water along with the concentrate

Board of Directors: John F. Bennett, *President* • Suzanne Redfern-West, *Vice-President* • Michael Stearns, *Secretary*
Stephen Smith • Michael Linneman • Dennis Falaschi, *General Manager*

treatment and salt harvesting. The proposed approach integrates primary RO, followed by concentrate treatment/desupersaturation and salt harvesting, and finally secondary RO desalting to attain high overall water recovery that could reach as high as 95%. In this regard, the proposed project meets the second program priority which is to "Develop viable desalination technologies for subsurface agricultural drainage water and brackish groundwater underlying drainage-impaired lands";

(3) The project will integrate a novel approach to RO concentrate treatment which will result in salt harvesting. Preliminary field testing at Panoche demonstrated harvesting of high purity gypsum in addition to other salts. Given the ability to concentrate the RO brine stream enables meeting with the third priority of the DRGP program to "Use concentrate from desalination processes for recycling of valuable salts....."; and

(4) The proposed project will demonstrate and further refine/optimize the high recovery desalting process with salt harvesting developed by the UCLA team along with support by PDD directly at the PDD drainage reuse area. The demonstration project addresses critical elements of the Westside Regional Drainage Plan that is in line with the regional goals defined in CWC 10537 and therefore also meets CWC 10544. Thus, the proposed project directly meets the DWR DRGP program priority which strive to "include regional projects or programs identified in California Water Code §10544." Moreover, the UCLA project will be carried out within and as part of the PDD regional projects/programs that are integral part of the overall water management plans that are consistent with CWC 10537 and seek to: (a) Reduce water demand through agricultural and urban water use efficiency, (b) Increase water supplies for beneficial use through a host of activities that include, but are not limited to, desalination, water recycling, surface storage, water-use efficiency, improve operational efficiency and water supply reliability via conveyance facilities, system reoperation, and water transfers, and (e) improve stewardship of resources resource that include, but are not limited to, agricultural lands, ecosystem restoration, recharge, groundwater management, and watershed management.

Desalination of San Joaquin Valley Water is particularly challenging given the high mineral scaling propensity of agricultural drainage water and subsurface brackish water. Moreover, brackish water at PDD is unique in its chemical composition with seasonally variable salinity. Therefore, it has been technically challenging to develop treatment techniques for high recovery desalination operations that would minimize concentrate generation and at the same time enable salt harvesting. To this end, the UCLA team developed and along with PDD have demonstrated a novel smart water treatment and desalination process and system for brackish water desalination. The mobile, containerized plant is a self-adaptive integrated MF/UF/RO

plant equipped with a unique membrane scale monitoring system that enables optimization of antiscalants dosing and assures system operation outside of the mineral scaling regime. The UCLA mobile plant technology has been developed at UCLA, over the last decade, with specific emphasis on brackish water/agricultural drainage water in the San Joaquin Valley and through collaborations and support of PDD, the California Department of Water Resources, and six industry affiliates. The UCLA mobile plant is presently deployed at the Panoche Drainage District Treatment Site, has a feed capacity of up to 30 gallons/minute and is installed in a 40-ft ISO container on a mobile trailer chassis. This plant is autonomous, self-adaptive with remote monitoring and supervisory control capabilities. Efforts, to date, have demonstrated that with self-adaptive UF operation and optimal RO control and scale monitoring to optimize antiscalants dosing, it is feasible to deploy continuous fouling and scale-free RO operation at PDD at recovery of up to about 65% for the water source of highest salinity (up to ~ 14,000 mg/L TDS) and mineral scaling propensity. Water quality is temporally variable, and results to date, suggests that it may be possible to drive the system up to perhaps 75%.

The proposed project will leverage the one-of-a kind UCLA mobile desalination plant by interfacing the system with a novel RO concentrate salt harvesting system that builds on the chemically-enhanced-seeded-precipitation process developed by UCLA, along with a self-adaptive approach to ensuring robust operation. To date, CESP has been evaluate under laboratory conditions and in simple batch studies in the field at Panoche. Process analysis by the UCLA team has shown that it is both technically and economically feasible to integrate integration CESP with RO desalting to attain high recovery desalting, via the addition of a secondary RO stage, in excess of 90%. It is important to note that the infrastructure for the proposed project is already in place and UCLA proposes to bring to the field site at Panoche a continuous CESP pilot system along with a secondary RO system. Both will be interfaced with the existing SIMS which will generate the primary RO concentrate. The Districts have worked closely with the UCLA project team to develop and evaluate various aspects of the proposed study in order to ensure effective field deployment of the proposed high recovery water filtration/desalination with salt harvesting system, assess needed infrastructure support, and develop a collaboration that will maximize the level of information that will emerge from the study.

An important technical goal of the proposed project is to demonstrate the ability to (continuously) desalt SJV brackish water, while harvesting salt, while attaining the maximum feasible recovery with a robust system operation that adapts in real-time to varying water quality scaling/fouling potential. The project will also provide information regarding the feasibility of distributed water filtration/desalination and provide the data necessary for developing a comprehensive process model for process scale-up and determination of process/plant economics for full-scale deployment.

We are looking forward to working closely with the UCLA project team and to support the proposed field pilot study. Given the modularity of the SIMS systems, as well as the accompanying UCLA continuous CESP pilot and self-adaptive secondary RO system, there could be opportunities for field testing with different water sources at PDD, thereby refining the system design and operational strategy for long-term deployment and system scale-up. We are committed to working with the UCLA project team and provide the necessary support for the planned pilot-field study. The Districts will provide the following project support:

- Infrastructure support that will include, but is not limited, to the following:
    - 6,000 square foot field demonstration site with access to drainage water for a continuous flow-through operation

- Provide access to a power outlet at the site. The power outlet will need to operate a pump to maintain a flow through of up to 30 gallons per minute
- Field site preparation
- Provision of necessary electrical power
- Enclosed space for both the primary and secondary RO systems and the CESP system
- Necessary plumbing (including auxiliary intake pumping if needed) for feed delivery and concentrate disposal

- Field staff support to assist with the field study
- Provide drainage water quality data (historical and during the field study)
- Review of system performance relative to regulatory and other agricultural water use requirements
- Handling of any required permitting for the field study. The UCLA mobile plant is already deployed at the Panoche Drainage District (PDD) treatment site. Mixed concentrate and permeate stream from the plant is being managed through existing PDD drainage management infrastructure, which is covered under existing CEQA and NEPA permits. Therefore, no additional permitting is anticipated.
- Provisions for disposal of any system cleaning chemicals
- Dismantling of the study site infrastructure as deemed appropriate
- Participation in periodic project planning and review meetings
- Assistance with system installation at the field site

We estimate that the above in-kind support would be equivalent to project support of about $50,000 for the two-year study. We do not expect any time constraints with respect to the planned in-kind support. The above in-kind support will be available as needed by the project so as to ensure that the project progresses on schedule.

We look forward to your support of the proposed pilot study technology that will advance the technology for new water resources and a modernized water infrastructure.

Very truly yours,

Panoche Drainage District

Dennis Falaschi
General Manager

2. Scope of Work and Project Description

2.1 Scope of Work

In partnership with Panoche Drainage District, UCLA researchers will demonstrate autonomous multistep RO-desalination with integrated salt harvesting (AMRO-DISH) to treat high salinity subsurface agricultural drainage water. The AMRO-DISH plant will integrate primary RO desalination, concentrate salt harvesting, and secondary RO desalting. Primary RO desalination unit, specifically designed for handling brackish water of high mineral scaling propensity, will be optimized for high product water recovery levels. Self-adaptive primary RO unit operation that ensures scale-free operation will be enabled via real-time membrane monitoring and dynamic process optimization. A novel chemically-enhanced seeded precipitation process unit will be interfaced with the primary RO unit to field demonstrate RO concentrate treatment which will allow: (a) concentrate salt harvesting (primarily gypsum), and (b) concentrate desupersaturation. The desupersaturated RO concentrate will be further desalted in a secondary RO (SRO) unit (also integrated in the AMRO-DISH plant) to enhance the overall product water recovery in excess of 90%. Both traditional steady-state RO (SSRO) and cyclic RO (CRO) will be evaluated for SRO, the latter (CRO) of a lower plant footprint for the same recovery level. The cost of water treatment/desalination will be analyzed based on field data and suitable process models. It is expected that the proposed project will provide the necessary technical information/knowledge and cost data for implementing practical and cost-effective strategies for on-farm high recovery RO desalination with salt harvesting.

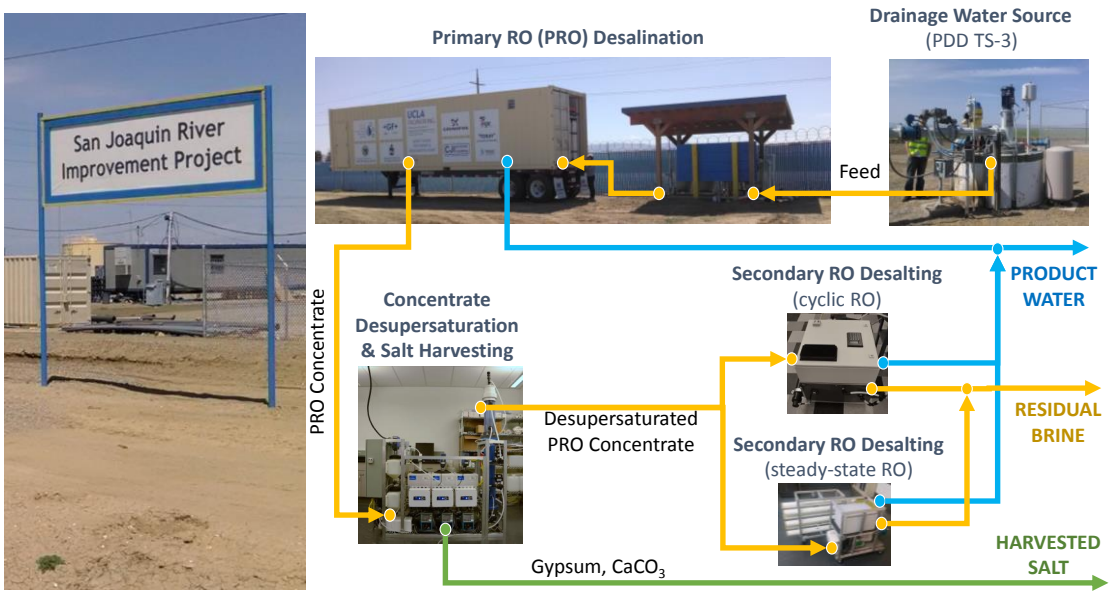


***Figure 2.1**. Location and field infrastructure for field demonstration of autonomous multi-step desalination with integrated salt harvesting (AMRO-DISH).*

2.2 PROJECT DESCRIPTION

2.2.1 Overview of Project Motivation, Goals, and Objectives

The proposed project addresses the critical challenge of achieving high water recovery (up to 90 % or higher) in agricultural drainage water desalting under variable drainage water salinity and mineral scaling potential. Utilizing existing UCLA and Panoche Drainage District (PDD) field equipment and infrastructure, the proposed project will field demonstrate self-adaptive, multi-step RO desalination with integrated salt harvesting (AMRO-DISH; **Fig. 2.2**). The goal is a long-term demonstration of the technical and economic viability of the process as a practical approach for maximizing water recovery in drainage water desalting while also enabling salt harvesting. In achieving this goal, the first objective will be a field demonstration of self-adaptive primary RO operation. This will involve adaption and further development of UCLA's "soft sensors" process monitoring and control methodologies for optimizing and directing RO operations near the maximum water recovery limits (up to 70-75% or higher), while adapting to changes in feed water conditions. Process control will be guided by real-time membrane mineral scale detection, enabled by UCLA Membrane Monitor (MeMo) technology. In order to enhance product water recovery beyond primary RO water recovery limits, a novel UCLA technology of continuous chemically-enhanced seeded precipitation (CCESP) will be utilized for RO concentrate desupersaturation and concentrate salt harvesting. CCESP field development objectives include effective antiscalant removal (>90%) and concentrate desupersaturation (gypsum saturation index <1.2), along with sustained production of concentrate salts (primarily gypsum for PDD drainage water). Enhanced water recovery will be realized through secondary RO desalting. Long-term integrated PRO-CCESP-SRO operation of the AMRO-DISH plant will serve to establish technical viability and cost performance for on-farm drainage water treatment and concentrate salt harvesting.

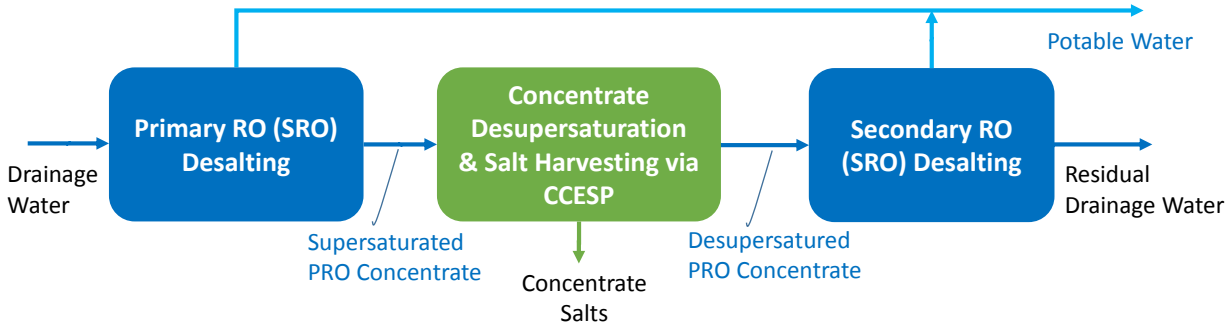


Figure 2.2. *Schematic of the proposed AMRO-DISH approach for achieving high recovery desalination of agricultural drainage water.*

2.2.2 Overview of Project Tasks and Deliverables

The proposed project is composed of six development/demonstration tasks, along with one reporting task, as summarized in **Fig. 2.3**. In the first year, the proposed project will focus on optimizing primary RO desalting of the AMRO-DISH plant for self-adaptive operation (**Task 1**), as well as developing CCESP capabilities for effective antiscalant removal (**Task 2**), concentrate desupersaturation (**Task 2**), and concentrate salt harvesting (**Task 3**). Two project milestones will be achieved during this period: a) technical readiness of CCESP for concentrate salt harvesting (**Milestone 1**) and b) optimal self-adaptive PRO desalination with concentrate salt harvesting (**Milestone 2**). In the second year, the project will focus on long-term demonstration of the overall AMRO-DISH plant, including integrated operations of PRO and CCESP units (**Task 4**) and demonstration of enhanced overall product recovery via secondary RO desalting of PRO desupersaturated concentrate. An economic model will also be developed based on field data in order to assess the overall cost performance of the AMRO-DISH process for drainage water management. Project deliverables include quarterly progress reports and invoicing, a final technical report, a post-completion report and final invoicing. Biannual project review meetings will be scheduled to update project progress with all stakeholders.

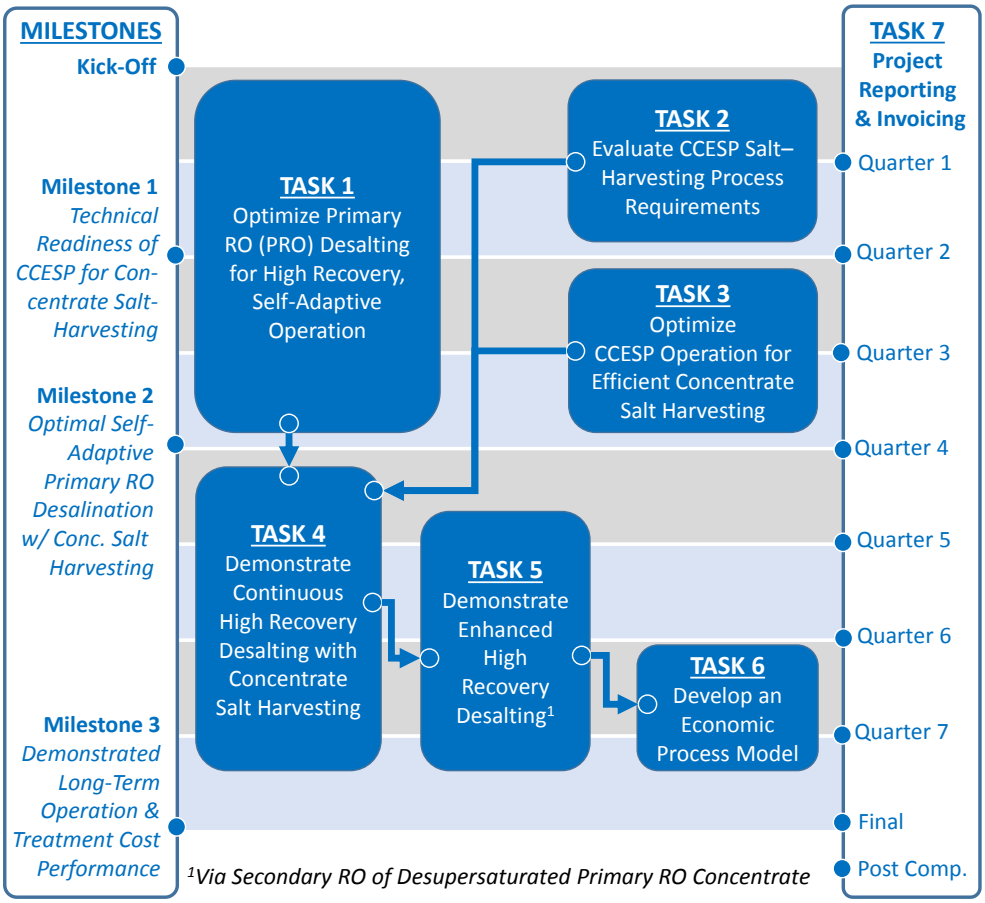


***Figure. 2.3**. Overview of project milestones, tasks, schedule, and deliverables.*

2.2.3 Existing Agreements and Memorandum of Understanding

The AMRO-DISH plant, which will be provided for use in the proposed project as an in-kind contribution, will integrate an existing UCLA mobile smart water treatment and desalination (SWTD) unit (also known as smart integrated membrane system or SIMS). The SWTD unit was recently completed and field deployed through federal (U.S. Bureau of Reclamation), California State and local agencies support, as well as in-kind contribution from various industry affiliates. Through a memorandum of understanding, a consortium of water agencies and industry partners was established that provided support for the SWTD system development and construction, as well as a general framework for sharing technical information. Industry affiliates in the consortium include:

- Georg Fischer, LLC
- Grundfos Pumps Corporation
- CJI Process Systems
- Inge GmbH (subsidiary of BASF)
- Toray Membrane USA
- BWA Water Additives

The proposed project will benefit from the above Consortium, particularly through access to specialized system components and their related deployment in the AMRO-DISH plant.

***Figure. 2.4**. UCLA industry affiliates at the inauguration of the UCLA mobile SWTD unit (May 2014), an integral part of the proposed AMRO-DISH plant for high recovery RO desalting and salt harvesting.*

In addition to the SWTD Consortium, the UCLA and Panoche Drainage District (PDD) have an existing cooperative agreement supporting the AMRO-DISH field deployment and operation at

the PDD treatment site. This agreement will be extended to accommodate the proposed project (see PDD Support Letter, Section 1.2). Under the current PDD/UCLA agreement, the operational capabilities of the primary RO desalination unit (i.e., SWTD) ,which will be part of the proposed AMRO-DISH for desalting subsurface agricultural drainage water, are being explored and refined, but without concentrate salt harvesting (i.e., via CCESP) or implementation of high recovery desalting via secondary RO (SRO). Essential water quality data are also being generated through analytical support from the Bryte Laboratory of the California Department of Water Resources. This ongoing field work will provide additional foundational knowledge and field experience that will benefit the proposed work of integrating concentrate salt harvesting with high recovery desalination. Furthermore, the ongoing work will ensure that the proposed project will be ready-to-proceed by the proposed start date of June 15, 2015. For the proposed project, Panoche Drainage District has also agreed (see PDD support letter in **Section 1.2**) to continue providing basic infrastructure support, including a secure test area, all needed permitting (already in place), drainage water supply, electricity, waste management, and field technical support.

2.2.4 Project Location

The proposed project will be conducted within the boundaries of the PDD Treatment Site at 11000 North Russell Avenue, Firebaugh, CA, which is located about an hour west of Fresno, CA (**Fig. 2.5**). The site, owned and operated by PDD, is part of the San Joaquin River Improvement Project under the Westside Regional Drainage Plan (WRDP). The WRDP is a regional plan for reducing the volume of saline agricultural drain water that is discharged to the San Joaquin River through source control, groundwater management, as well as treatment and reuse.

Figure. 2.5 Project site location.

For the proposed project, the UCLA AMRO-DISH plant will be operated at the same current deployment's location (**Fig. 2.6**), where all of the required infrastructure is already in place (**Fig. 2.6**). Current infrastructure includes a 50 ft. x 150 ft. secure test area (i.e., fenced and gated), equipped with electrical outlets (460 V 3 phase), sand filters, hydro-pneumatic tanks, and drain water flow control (i.e., valves). Using a submersible pump, up to 35-40 gallon/minute of subsurface drain water can be delivered from PDD Tile Sump No. 3 to the test area through an existing underground piping. In the present UCLA desalination plant operation at the site, RO permeate and concentrate is mixed and discharged into the RP-1 irrigation ditch, which is located next to the test area (**Fig. 2.6**). The RP-1 irrigation ditch is owned and operated by PDD and is covered under PDD's existing CEQA and NEPA requirements.

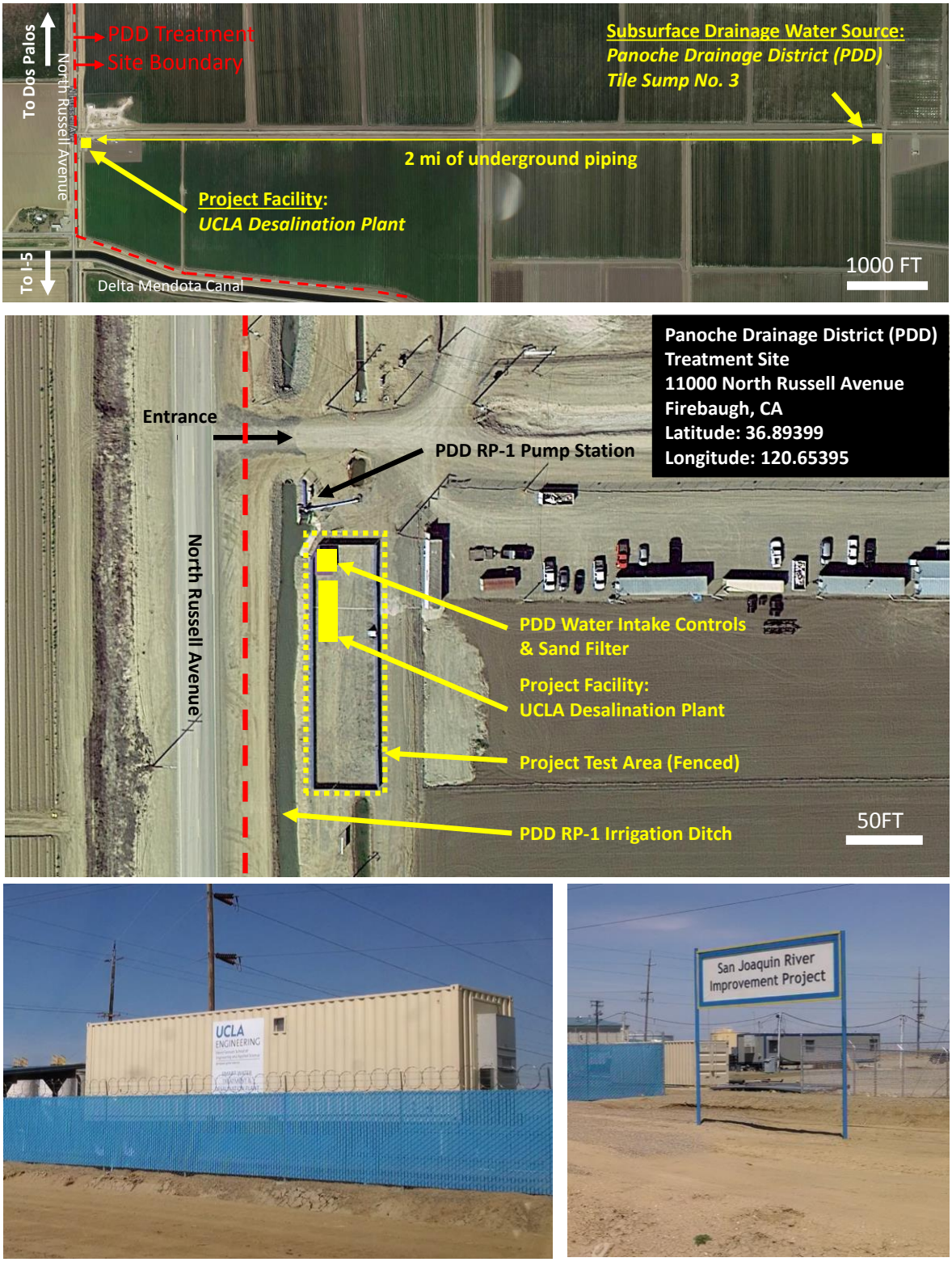


***Figure. 2.6**. A pictorial map of the project site at the Panoche Drainage District Treatment Site and the current UCLA SWTD system.*

3. Project Objectives and Program Priorities

3.1 Problem Statement

Reverse osmosis (RO) has become the most dominant desalination technology due to its relative simplicity, compactness, modularity, and scalability [1, 2]. With the utilization of electrical energy for pressure generation, pressure-driven RO desalination has significant deployment flexibility for harnessing renewables (e.g., solar photovoltaic cells and wind turbine), while maintaining consistent operational availability via conventional power grid as backup power [3, 4]. Various approaches to reducing RO energy consumption are also well established, such as use of energy recovery devices and staged operation with booster pumps [5, 6]. RO water production is pressure driven, avoiding the complexity, relatively larger energy requirements, and high capital costs (due to material costs of distillation equipment) of osmoticallly- or heat-driven desalination processes (i.e., forward osmosis, membrane distillation, solar evaporation) [7, 8]. In fact, osmotically-driven (with thermolytic draw solutions) and heat-driven desalination processes are cost-effective only if low-cost heat sources (or "waste heat") are readily available locally [7, 8]. More importantly, unlike most other desalination technologies, RO desalination technologies have proven commercial success; RO desalination operations and maintenance are supported by diverse and well-established supply chain of off-the-shelf components and consumables (i.e., membrane elements, prefilters, compatible antiscalants, etc.).

While promising, applications of conventional RO desalination approaches for on-farm drainage water treatment, reuse, and reduction remain technically and economically challenging [9-11]. Some of the primary challenges that must be addressed include, but are not limited to, the following:

1. High potential for mineral salt precipitation

Agricultural drainage water often contain high levels of precursors (e.g., calcium, sulfate, barium, strontium, silica) to sparingly water soluble mineral salts (e.g., gypsum, silica, calcium carbonate, barium sulfate, strontium sulfate) [9, 12]. As product water is recovered during desalination, mineral salt precursors in the RO retentate stream may become concentrated beyond their solubility limits and precipitate as mineral salts. The potential for mineral salt precipitation, as quantified by the solution saturation indices with respect to the mineral salts of concern ($SI_x=IAP_x/K_{sp,x}$, where IAP_x and $K_{sp,x}$ are the ion activity and solubility product of mineral salt x, respectively), exists when the saturation index of the limiting mineral salt exceeds unity (SI_x >1). If not effectively suppressed (i.e., with the appropriate dosage of antiscalants), <u>mineral salt precipitation will lead to membrane mineral scaling, loss of water productivity, and eventual membrane damage.</u> Although modular construction of conventional RO systems allows for

relatively simple and fast replacements and/or chemical cleaning of mineral-scaled RO elements, frequent replacements and cleaning are undesirable due to increased operational costs.

The challenge of mineral scaling is not unique to RO desalination, but is also inherent in other processes for brackish water desalination. Thus, irrespective of the desalination process, effective methods for mitigation of mineral scaling are required. For example, in a recent pilot study of solar desalination via multiple effect distillation (MED) at Panoche Drainage District (PDD) [13], significant decline (>50%) in the overall heat transfer coefficient (i.e., which governs the rate of heat transfer and thus water evaporation rate) was observed after a short, 20-day period of operation. The decline was attributed to mineral scaling of heat transfer surfaces, which necessitated opening and manual cleaning of MED plates [13]. Mineral scaling in emerging desalination processes such as forward osmosis (FO) and membrane distillation (MD) are also well documented in the literature [7, 14]. In all of these processes, the use of antiscalants at sufficient dosages are necessary for suppressing mineral scaling, but desalination recovery is limited even with antiscalants use [7, 13, 14]. Furthermore, recent UCLA study [15] has also demonstrated that effective feed filtration (well below the commonly accepted standard turbidity level for RO desalting) prior to desalination is critical to effectively remove particulates (to the submicron level) that can promote scaling due to enhanced mineral crystal nucleation.

2. High Temporal Variability of Water Salinity and Mineral Scaling Potential

High temporal variability of water salinity and mineral scaling potential present significant challenges in conventional operations of RO desalination. Under conventional practices [16], RO desalination operations are typically fixed at or near a design water recovery level, selected based on an acceptable range of mineral scaling potential (i.e., saturation index of the limiting mineral scalant). The acceptable range must be selected to be within the limits of antiscalant effectiveness (e.g., **Fig. 3.1**), either based on a conservative or a more progressive estimates provided by antiscalants manufacturers [17]. The desired RO recovery level is typically achieved through either manual or basic automated control of RO feed pressure and retentate flow rate [16]; an operator must manually input the pressure and flow set-points into the control interface. Furthermore, antiscalants are commonly dosed at a constant level based on a maximum expected mineral scaling potential in the RO system (at the design water recovery level). Potential occurrence of membrane mineral scaling is determined indirectly via monitoring of normalized permeate flow, which can be used to trigger an alarm for manual operator intervention [16]. While adequate for conventional applications such as seawater desalination, the above conventional practices are ineffective when there are measurable and frequent changes in feed water salinity and membrane scaling potential.

As shown in **Figs. 3.1-3.2**, water salinity and mineral scaling potential (i.e., saturation indices) of agricultural drainage water can vary significantly (>50%) due to seasonal variations of drainage water quality, as well as due to the impact of local activities of agriculture and drainage water

management. Under such challenging dynamic conditions, maintaining water recovery at or near the design level using conventional practices would be impractical; significant operator expertise and frequent operator intervention would be needed to adjust RO feed pressure and retentate flow set-points to the required levels. Furthermore, operations under fixed RO recovery and antiscalant dosage levels are risky when there is a significant variability in mineral scaling potential. For example, a system optimized for operation in the conservative operating range of antiscalant effectiveness (**Fig. 3.1**) may (and without operator knowledge) slip into the progressive range or even the unsafe operating range when there is an increase in mineral scaling potential. In such a case, timely adjustments to antiscalant dosage would be needed in order to avoid underdosing of antiscalants, while reduction of RO recovery may also be necessary to avoid slipping into unsafe operational zone (**Fig. 3.1**). Such adjustments are difficult to make in the absence of real-time information regarding the onset of mineral scaling/fouling. In this regard, it is noted that normalized permeate flow monitoring is of insufficient resolution to enable early detection (or onset) of mineral scaling/fouling [15, 18].

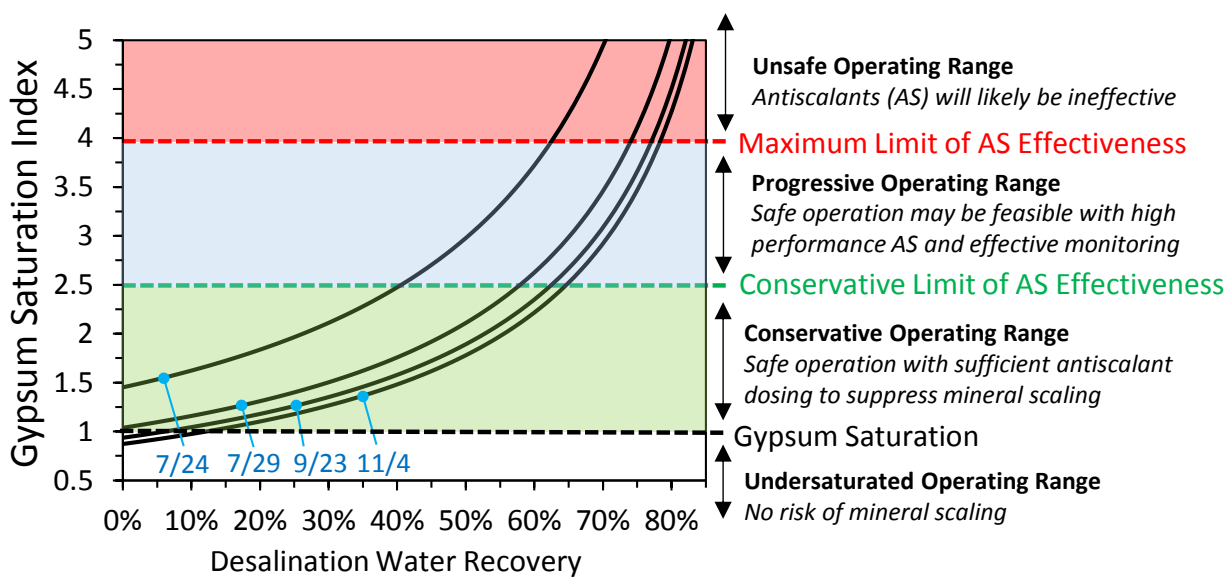


Figure 3.1. *Relationship between gypsum saturation index in desalination concentrate and product water recovery, calculated based on water quality data of Panoche Drainage District (PDD) Tile Sump No. 3 (July-November 2014). Limits of antiscalant effectiveness are based on typical recommendations of antiscalants and RO membrane manufacturers [17].*

The difficulty in applying conventional practices for RO desalination of agricultural drainage water is evident from previous studies in at Panoche Drainage District (PDD, [19]) in which catastrophic membrane failure was observed for water recovery above 50% (**Fig. 3.3**). New RO operational methods are therefore needed to enable RO operations that can automatically handle or "self-adapt" to high temporal variability of feed water salinity and mineral scaling potential. In self-adaptive RO operations, RO recovery and antiscalant dosing are automatically

varied based on real-time information of mineral scaling potential, with automated adjustments of pressure, retentate flow, and antiscalant dosing rate set points to maintain safe RO operations and avert mineral scaling. Consequently, capabilities for real-time membrane scaling detection, coupled with real-time model-based optimization and control, are critical.

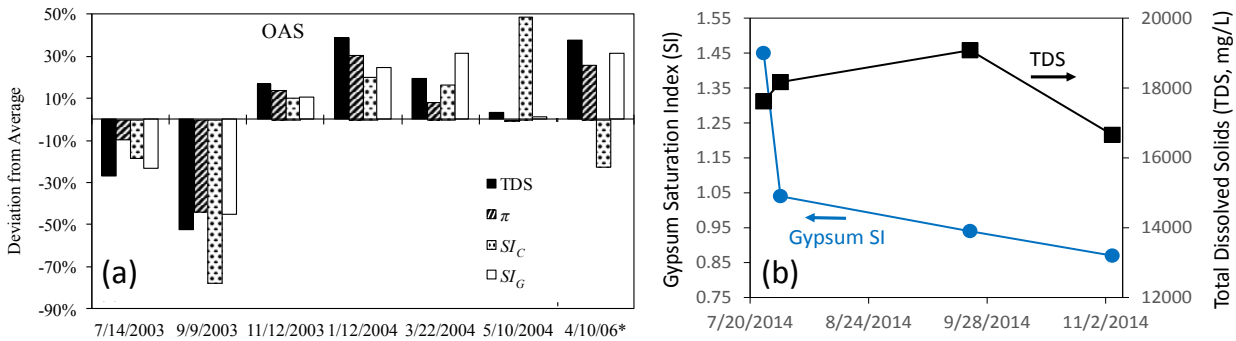


Figure 3.2. *Measured temporal water quality variations at: a) OAS 2548 drainage monitoring station [9], and b) Panoche Drainage District (PDD) Tile Sump No. 3 in in California San Joaquin Valley. TDS: total dissolved solids, π: osmotic pressure, SI_C: calcite saturation index, SI_G: gypsum saturation index.*

Figure 3.3*. Salt deposits in RO tail element encountered during USBR RO Pilot Study at Panoche DP-25 test site (2005) [19].*

3. The need for high water recovery to minimize residual drainage water volumes

In order to minimize the impact of temporal water quality variability, conventional RO application for drainage water desalting is often only technically feasible at low water recovery levels (e.g., typically up to ~50% at PDD) within the conservative operating range of antiscalants (e.g., 42-64% at PDD; see **Fig. 3.1**). However, low water recovery levels are not economically practical for drainage water volume reduction and management [20]. Thus, new RO operational methods for self-adaptive operation must address the need to maximize RO water recovery, which would necessitate robust, self-adaptive RO operation near the mineral scaling threshold (i.e., within the progressive operating range of antiscalants; **Fig. 3.1**). At PDD where gypsum mineral scaling is the recovery-limiting mineral scalant, recent water quality data indicated significant potential for RO operation up to 78% water recovery (**Fig. 3.1**).

Further enhancement of desalination water recovery requires concentrate desupersaturation (i.e., to reduce mineral scaling potential) followed by secondary desalination of desupersaturated concentrate [10, 12, 20, 21]. As illustrated in **Fig. 3.4** for the case of PDD drainage water, gypsum supersaturation level in the primary desalination concentrate can be reduced (to saturation index ~1) by inducing mineral salt precipitation. Subsequent secondary desalting of desupersaturated concentrate can then be undertaken to increase water recovery in excess of 90%. In the concentrate desupersaturation step, gypsum is the primary mineral salt that can be harvested (i.e., precipitated) at >98%wt purity. Other mineral salts such as calcium carbonate, strontium sulfate, calcium phosphate, and silica are also removed as was demonstrated in a previous preliminary batch concentrate desupersaturation study at PDD (**Figure 3.5**).

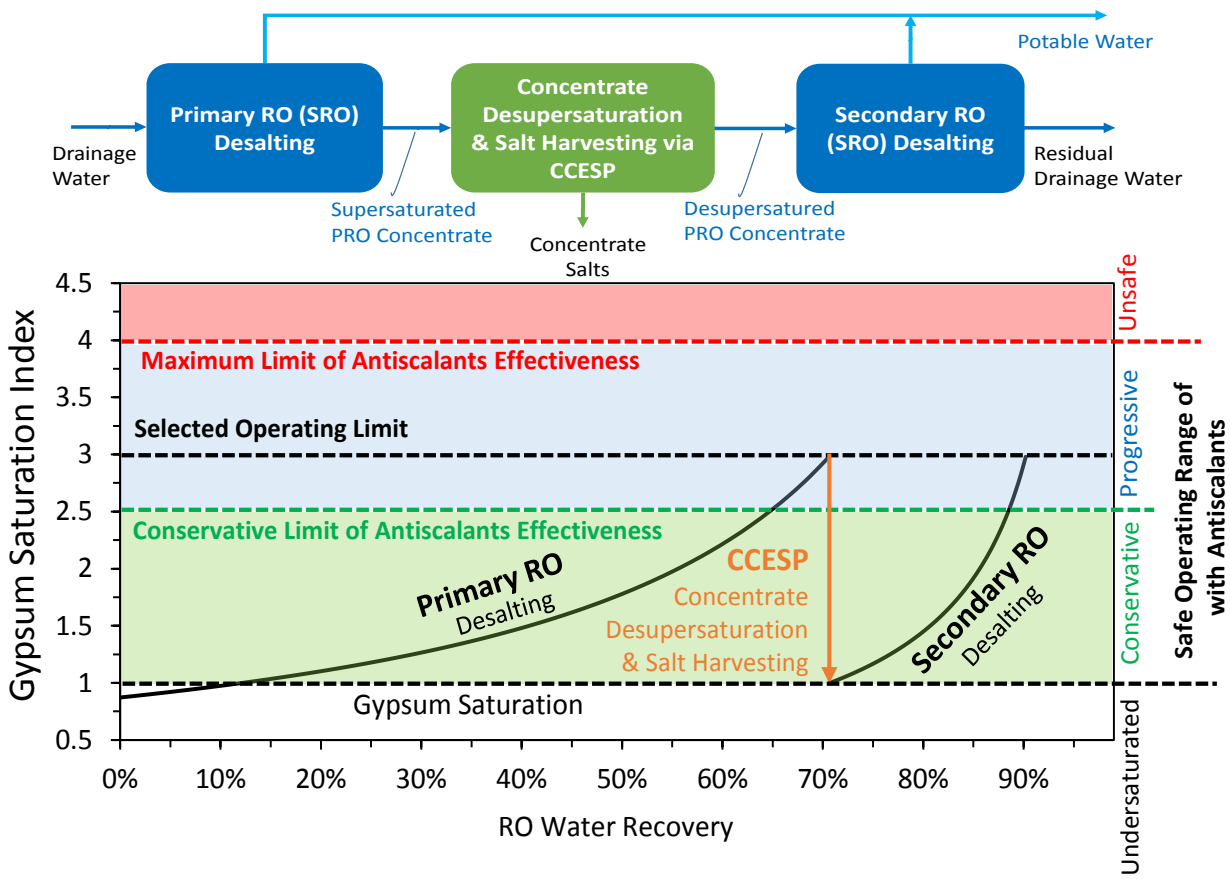


***Figure 3.4**. Evolution of gypsum saturation index in a two-step high recovery desalination process with intermediate concentrate desupersaturation. Gypsum saturation index is calculated based on water quality data of Panoche Drainage District (PDD) Tile Sump No. 3 (November 2014). CCESP: chemically-enhanced seeded precipitation for desupersaturation of primary RO concentrate.*

4. The need for reducing treatment costs

Economic feasibility of sustainable drainage water management relies on the ability to reduce the costs of drainage water treatment and volume reduction. This can be achieved by implementing an effective treatment strategy that can minimize drainage water volume to a level that is practical for disposal (i.e., evaporation), as well as produce valuable products (potable water and concentrate salts) for beneficial usage. Indeed, self-adaptive, high recovery RO desalination with intermediate concentrate desupersaturation can both reduce drainage volume and produce potable water (from desalting) and concentrate salts (from concentrate desupersaturation). Previous economic analysis have shown that application of the approach for drainage water desalting in California San Joaquin Valley can be cost effective [20]. For example, in the illustrative case of high recovery desalination of agricultural drainage water at PDD DP-25 (total dissolved solids ~11,000 mg/L) [20], previous process analysis indicated that concentrate desupersaturation can enhance RO water recovery from ≤62% up to 93%. The overall water production cost was estimated to be $826-913/acre-foot of product water (which included brine disposal cost but excluded potential cost-savings of self-adaptive operation). Given the relatively high labor-related operating costs (~19% of overall water production cost), self-adaptive operation, coupled with the remote plant monitoring capabilities, can potentially reduce water production costs to $709-$783/acre-foot of product water. At such competitive costs, beneficial usage of desalted drainage water can potentially offset treatment costs given that water value in California can be significantly above $1,000/acre-foot, especially during drought seasons[1].

It is noted that, for the above example, mineral salt precipitation for concentrate desupersaturation generates various mineral salts (primarily gypsum, but also calcium carbonate, strontium sulfate, barium sulfate, silica). High purity gypsum (>98%) can be generated at 1.2 metric ton/acre foot of product water. The potential of concentrate salt harvesting in reducing drainage water treatment cost will depend on the ability to secure local market or beneficial usage. Gypsum price can vary significantly. US Geological Survey reported mined crude gypsum price in 2012 averaged at $7/metric ton [22]. However, as a consumer product, market price of gypsum can go as high as $300/metric ton [23]. This suggests that gypsum salt harvesting can potentially reduce cost by $9-370/acre-foot of product water.

3.2 Critical Technology/Knowledge Gaps

Implementation of RO desalination and integration of concentrate salt harvesting for addressing the above challenges to agricultural drainage water management must address several critical technological gaps, summarized in **Table 3.1**. First, new RO desalination approaches must be developed to address the need for effective mitigation of membrane mineral

[1] http://www.bloomberg.com/news/2014-07-24/california-water-prices-soar-for-farmers-as-drought-grows.html

scaling under the challenging variable conditions of agricultural drainage water desalting. This effort should be directed toward developing methods for achieving high water recovery. The potential for concentrate salt harvesting should be considered as it may provide opportunities for beneficial usage that can offset treatment costs. Salt harvesting will also reduce mineral salt supersaturation levels, thereby enabling further recovery via secondary RO desalting of the desupersaturated primary RO concentrate. Finally, long term technical and economic feasibility must be established.

***Table 3.1**. Critical technology/knowledge gaps in high recovery desalination of agricultural drainage water.*

No.	Critical Technology/Knowledge Gaps
1	Mitigating mineral scaling in desalination of drainage water
2	Handling temporal variability of drainage water salinity and mineral scaling potential
3	Achieving high recovery in desalination of drainage water
4	Cost-effective and environmentally-friendly means for harvesting drainage water salts
5	Effectiveness of concentrate treatment to enable further water recovery
6	Design and scale-up of high recovery desalination processes and systems
7	Long-term technical feasibility and performance
8	Long-term operation and maintenance costs
9	Overall economics of high recovery desalination with salt harvesting for on-farm drainage water management

3.3 Project Goal and Objectives

In addressing the technology/knowledge gaps listed in **Table 3.1**, the goal of the proposed project is to establish the long-term technical and economic viability of self-adaptive RO desalination with concentrate salt harvesting as a practical approach for maximizing desalination product water recovery (up to 90% or higher). It is hypothesized that maximizing water recovery in RO desalination of agricultural drainage water can be achieved via autonomous multistep RO-desalination with integrated salt harvesting (AMRO-DISH; **Fig. 3.4**), characterized by:

a) Smart RO system operations with autonomous optimal adjustments of water recovery and antiscalant dosage, adapting to changes in salinity and mineral scaling potential of feed water with the aid of real-time membrane scale monitoring via direct membrane surface imaging;
b) Integration of RO desalination with concentrate treatment via intermediate continuous chemically-enhanced seeded precipitation (CCESP) process for primary RO concentrate desupersaturation (i.e., to reduce mineral scaling potential) and salt harvesting;
c) Enhancement of product water recovery through secondary RO desalination of the desupersaturated (post mineral salts solids removal) primary RO concentrate; and
d) Advanced cyber-infrastructure for enabling reliable process diagnostics and remote monitoring of process plant operations.

In order to achieve the primary project goal and evaluate the project hypothesis, the proposed project will focus on addressing the major research objectives listed in **Table 3.2**. The project is organized such that each project objective (see **Section 5**) will be addressed by a specific project task (see **Section 5**) with a well-defined performance target/measure (**Table 3.2**). Given the readiness-to-proceed and immediate availability of all project equipment and infrastructure, it is anticipated that the project goal and objectives can be attained within a period of two years.

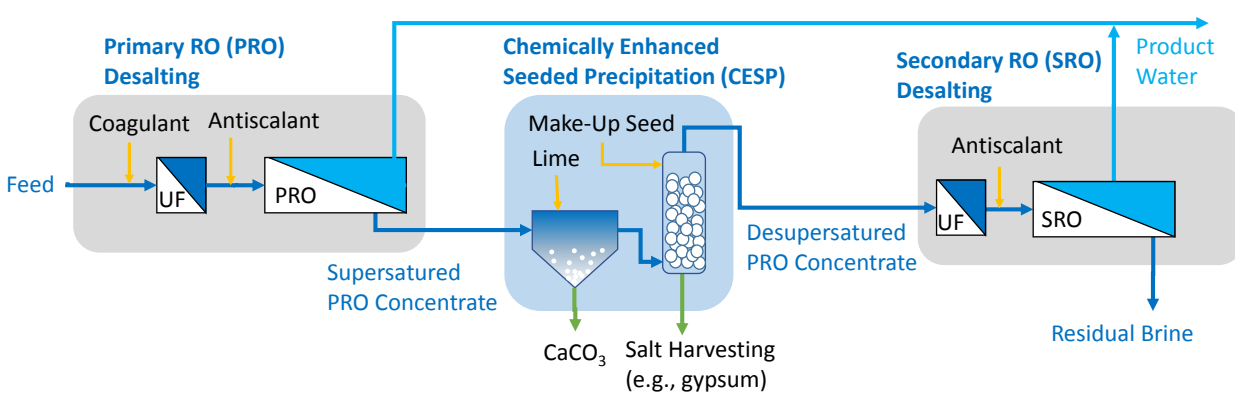


***Figure 3.4**. Process diagram of autonomous multistep RO-desalination with integrated salt harvesting (AMRO-DISH) for high recovery desalination of agricultural drainage water.*

***Table 3.2**. List or project objectives and their corresponding performance targets and measures.*

No	Objective	Performance Target/Measure	Knowledge Gaps Addressed	Related Project Task
1	Self-adaptive, high recovery operation of primary RO desalination	Water Recovery of 70-75% or higher with effective mineral scaling mitigation	1-3,6	1
2	Effective removal antiscalants in the (partial) lime pretreatment step of continuous CESP (CCESP)	>90% antiscalant removal	4,6	2
3	Effective concentrate desupersaturation in the seeded precipitation step of CCESP	Gypsum saturation index < 1.2	4,6	2
4	Gypsum salt production via crystal seeding in CCESP	Sustained gypsum production	4,6	3
5	Long-term integrated operation of PRO-CCESP steps of AMRO-DISH	6-9 months	7	4
6	Self-adaptive, high recovery operation of secondary RO desalination	Enhance overall water recovery up to 90% or higher	1-3, 5	5
7	Demonstrated long-term performance as a basis for cost analysis	Comprehensive and scalable process cost model	8-9	6

3.4 Project Relationship to Drainage Reuse Grant Program Priorities

The proposed project addresses all four of the DWR Drainage Reuse Grant Program (DRGP) Priorities as detailed below.

DRGP Priority 1: Develop sustainable and environmentally acceptable methods to concentrate and harvest salts and potentially toxic elements from drainage water

The proposed project will develop and field demonstrate AMRO-DISH, integrating high recovery RO desalination with an intermediate process of continuous chemically-enhanced seeded precipitation (CCESP). The approach meets DRGP Priority 1 because:

- The proposed approach will generate valuable freshwater and concentrate salts (primarily high purity gypsum (>98%) for the case of PDD drainage water, with other mineral salts including calcium carbonate, strontium sulfate, and barium sulfate), while reducing residual drainage concentrate volume and therefore the associated residual concentrate management costs. Recent UCLA analysis has indicated that, with reduced residual drainage volume, beneficial use of RO product water may potentially offset overall costs and make drainage water management more sustainable [20].
- Reverse osmosis is currently the most widely used desalination technology due to its relative simplicity, compactness, scalability, and deployment flexibility [1]. The technology is well established and practiced across many industries, with high reliability when correctly operated [16] and with self-adaptive capability to handle water quality variations. Significant knowledgebase exists for managing and minimizing potential environmental impacts [24].
- The synergism that exists between RO and CCESP promotes high recovery operation [10, 21]. Specifically, the CCESP driving force is generated through the concentrating effect of RO desalting; maximizing RO recovery enhances CCESP performance for RO concentrate desupersaturation and salt harvesting. RO concentrate desupersaturation allows secondary desalting to enhance the overall product water recovery.
- Required chemical additives (coagulant, antiscalants, lime, and gypsum seed crystals) are minimal, non-toxic, and widely used in common water treatment practice.
- The overall process is operated within a self-contained system (i.e., not in open space) in a fenced area and thus with minimal exposure to wildlife and the environment.

DRGP Priority 2: Develop viable desalination technologies for subsurface agricultural drainage water and brackish groundwater underlying drainage-impaired lands

Applications of conventional practices for RO desalination of subsurface agricultural drainage water and inland brackish groundwater often have low technical and economic viability due to: a) the high levels and variability of salinity and mineral scaling potential, particularly in the San Joaquin Valley [9], and b) the need for high recovery operation [9]. The proposed project directly

addresses these key challenges and thus DRGP Priority 2. First, the proposed project will develop, implement, and field demonstrate a unique real-time optimization and control framework that integrates online monitoring of membrane mineral scaling via a unique UCLA membrane monitor (MeMo) technology [11, 15, 18, 25]. Using this framework, RO operations are continuously adapted to changes in water recovery limits as affected by real-time feed water salinity levels and mineral scaling potential. Such self-adaptive operations will maximize RO water recovery, while ensuring effective mitigation mineral scaling (e.g., [25]). Second, the proposed project will integrate a novel CCESP process [21] for concentrate desupersaturation, thereby reducing the potential for mineral scaling [9, 20, 21, 26]. An integrated secondary RO desalting of the desupersaturated primary RO concentrate allows for further enhancement of overall recovery. Thus, the proposed project will serve to demonstrate that high recovery RO desalination of agricultural drainage water is technically and economically viable through MeMo-enabled, self-adaptive operations, integrated with concentrate desupersaturation via CCESP [21] that will additionally facilitate salt harvesting.

DRGP Priority 3: Use concentrate from desalination processes for recycling of valuable salts, such as gypsum, sodium sulfate, magnesium and calcium chlorides, etc.

In the proposed field demonstration project, RO concentrate will be generated from a field-deployed, pilot-scale desalination unit, treating high salinity subsurface drainage water at the PDD treatment site (see **Sections 4.2.2-4.2.4**). A CCESP system will harvest valuable salts (primarily gypsum) from the RO concentrate [20]. Thus, the project meets DRGP Priority 3.

DRGP Priority 4: Include regional projects or programs identified in CWC §10544.

As indicated by the Panoche Drainage District in its support letter (**Section 1.2**), the proposed demonstration project addresses critical elements of the Westside Regional Drainage Plan that are in line with the regional goals defined in CWC 10537 and thus includes regional projects as identified in CWC 10544. Therefore, the proposed project directly meets the DWR DRGP program priority which strives to "include regional projects or programs identified in California Water Code §10544." Moreover, the UCLA project will be carried out within and as part of the PDD regional projects/programs that are integral part of the overall water management plans that are consistent with CWC 10537 and seek to: (a) Reduce water demand through agricultural and urban water use efficiency, (b) Increase water supplies for beneficial use through a host of activities that include, but are not limited to, desalination, water recycling, surface storage, water-use efficiency, improve operational efficiency and water supply reliability via conveyance facilities, system reoperation, and water transfers, and (c) improve stewardship of resources resource that include, but are not limited to, agricultural lands, ecosystem restoration, recharge, groundwater management, and watershed management.

4. Materials, Methods, and Scientific Merit

The proposed study will integrate, refine, advance, and field demonstrate new and novel enabling technology components and methodologies for high recovery inland brackish water desalination, developed at UCLA WaTeR Center over the past decade. The UCLA team has developed diagnostic and process analysis methods [5, 6, 10, 12, 15, 27-31], RO operational strategies [11, 25, 32-34], scale/fouling monitoring capability [11, 15, 18, 25, 35], integrated and self-adaptive UF and RO technology [36], novel RO concentrate desupersaturation and salt harvesting process [9, 10, 20, 21, 26, 37, 38], and unique control and optimization methods [39-41] that have been laboratory and field tested and can resolve the challenges of sustainable drainage water treatment and reuse. Given the accumulated knowledgebase from the above previous efforts, the UCLA team is now in a unique position to further develop and demonstrate (through the proposed project), *for the first time*, a practical technology for effective, high recovery RO desalting of challenging (particularly in the San Joaquin Valley) agricultural drainage water with concentrate salt harvesting.

In the subsections below, the scientific merit and hypothesis of the research work to be conducted in the proposed project is presented, followed by a discussion of the PDD drainage water characteristics, mineral scaling potential, and concentrate salt harvesting potential. The UCLA team's overall integrated approach to achieving high recovery desalination is then presented. This is followed by detailed description of new and unique methods that will be integrated, refined, and field demonstrated in the project, along with basic supporting data from previous and ongoing studies.

4.1 Scientific Merit & Hypothesis

The proposed project will serve to advance and field demonstrate the scientific knowledge and engineering technology required for design and scale-up of autonomous multistep RO-desalination with integrated salt harvesting (AMRO-DISH) under challenging conditions of drainage water treatment. Specifically, the proposed project will, *for the first time*, provide field-validated methodologies and optimization framework for applying online membrane mineral scaling detection (via direct membrane surface imaging) to control and optimize RO desalination operation in real-time, under variable feed water salinity and membrane scaling potential. It is hypothesized that such methodologies will enable engineering and scale-up of high recovery RO desalination processes that can: a) maintain optimal operation surpassing the limit imposed by mineral scaling, b) effectively mitigate membrane mineral scaling, c) minimize antiscalant dosage, d) robustly adapt to changing feed water conditions, and e) effectively treat primary RO concentrate to enable high recovery RO desalting while also facilitating salt harvesting.

To realize potential benefits of drainage water treatment (e.g., drainage volume reduction, production of potable-grade water, harvesting of valuable concentrate salts), the proposed project will advance a novel concept of continuous chemically-enhanced seeded precipitation (CCESP) to the continuous, steady state process. In the AMRO-DISH approach, RO concentrate desupersaturation via CCESP enables not only further water recovery from the desupersaturated RO concentrate, but also continuous harvesting of RO concentrate salts (e.g., primarily gypsum). It is hypothesized that a CCESP process for RO concentrate treatment can be realized via a system of two sequential continuous reactor units:

a) A chemical precipitation reactor unit (i.e., partial lime softening) where alkaline-induced $CaCO_3$ precipitation and flocculation enable antiscalant scavenging,
b) A moving bed reactor unit where reduced residual antiscalants allows for mineral seeds (e.g., calcium sulfate or calcium phosphate) crystal growth with favorable kinetics for RO concentrate desupersaturation.

Testing the above hypothesis will involve development fundamental information regarding antiscalant-$CaCO_3$ precipitative removal (via adsorption and inclusion) in a continuous chemical precipitation system, as well as acquiring field data and modeling crystal growth kinetics in a continuous, moving bed reactor. The resulting CCESP design and operation principles will then provide the necessary knowledgebase for effective integration with RO desalting, as well as engineering and scale-up of the CCESP process.

4.2 Materials & Methods

4.2.1 Drainage Water Source Composition and Salt Harvesting Potential

Field development and long-term demonstration of high recovery desalination with concentrate salt harvesting will utilize subsurface agricultural drainage water from Tile Sump No. 3 (TS-3) at the Panoche Drainage District (PDD) treatment site. Recent water quality analysis (over a 4-month period) demonstrate that desalination of this source water is very challenging due to high and variable drainage water salinity (16,660-19,080 mg/L) and mineral scaling potential (primarily by gypsum, with gypsum saturation index range of 0.87-1.45). Major ions include sulfate (38-40%wt), sodium (26-28%wt), chloride (23-24%wt), and calcium (3-6%wt). Desalination of PDD TS-3 water for drinking water production will also need to address several contaminants, including nitrate, selenium, and boron. Both nitrate (173-191 mg/L) and selenium (0.428-0.526) are significantly above CDPH drinking water maximum contaminant limit (MCL) of 45 mg/L and 0.01 mg/L, respectively. Boron is present at 53.9-100 mg/L, which is above the CDPH notification limit (NL) of 1 mg/l.

***Table 4.1**. Recent water quality data of agricultural drainage water from PDD Tile Sump No. 3.*

Analyte	7/24/2014	7/29/2014	9/23/2014	11/4/2014
Turbidity (NTU)	1.17	<1	<1 NTU	<1 NTU
pH	7.42	7.38	7.7 pH	7.7
Total Dissolved Solids (mgl/L)	17,620	18,170	19,080	16,660
Total Organic Carbon (mgl/L)	9.4	10.4	13.4	13.9
Total Alkalinity (mgl/L as $CaCO_3$)	358	366	414	343
Dissolved Aluminum (mgl/L)	<0.1	<0.1	<0.2	<0.2
Dissolved Barium (mg/L)	<0.05	<0.05	<0.1	<0.1
Dissolved Boron (mgl/L)	100	58.7	65.8	53.9
Dissolved Calcium (mgl/L)	975	620	544	514
Dissolved Chloride (mgl/L)	4,086	4,354	4,641	4,051
Dissolved Magnesium (mgl/L)	676	434	412	382
Dissolved Nitrate (mgl/L)	178	191	187	173
Dissolved Potassium (mgl/L)	8.09	10.8	10.8	42.8
Dissolved Selenium (mgl/L)	0.463	0.489	0.526	0.428
Dissolved Silica (mgl/L)	20.7	42.46	45	43.2
Dissolved Strontium (mg/L)	9.28	10.2	9.84	13.7
Dissolved Sodium (mgl/L)	4,520	4,980	5,310	4,540
Dissolved Sulfate (mgl/L)	6,493	6,977	7,566	6,555
Mineral Scaling Potential	**7/24/2014**	**7/29/2014**	**9/23/2014**	**11/4/2014**
Calcium Carbonate Sat. Index	8.7	6.8	6.9	5.9
Gypsum Saturation Index	1.45	1.04	0.94	0.87
Strontium Sulfate Saturation Index	0.74	0.89	0.97	1.22
Barium Sulfate Saturation Index	<8.6	<7.8	<16	<16
Silica Saturation Index	0.18	0.36	0.37	0.36

**Saturation Index = $IAP/K_{sp,x}$ = Ion Activity Product/Solubility Product of mineral salt x.*

Thermodynamic solubility analysis (via previously developed methods [10, 12, 21, 29]) based on TS-3 water quality data in **Table 4.1** revealed high potential for harvesting high purity concentrate salts from PDD drainage concentrate. The analysis indicate that gypsum (91-97 % wt.) and calcium carbonate (3-7%wt) are the most thermodynamically stable solids that can readily be precipitated from the drainage concentrate. For example, from TS-3 drainage water concentrated at a factor of 3.3 (which can be generated via RO desalination at a water recovery of 70%), up to about 5.8-13.2 metric tons of valuable salts can be readily harvested (via precipitation) per acre-foot of drainage water concentrate, depending on the target mineral salt saturation level in the drainage water (**Table. 4.1**).

4.2.2 High Recovery Desalination via Autonomous Multistep RO Desalination with Integrated Concentrate Salt Harvesting (AMRO-DISH)

The UCLA team approach to high water recovery desalination of inland brackish water (including agricultural drainage water) is based on a continuous multi-step RO process that integrates intermediate concentrate desupersaturation and salt harvesting with primary and secondary RO desalting (AMRO-DISH; **Fig. 4.1**). In this process, feed water is desalted in a primary RO (PRO) desalination step, operated near the maximum achievable water recovery level (i.e., up to 70-75% or higher for PDD drainage water feed) as limited by mineral salt supersaturation levels and antiscalant effectiveness. The generated PRO concentrate is directed through a process of continuous chemical enhanced seeded precipitation (CCESP), where residual antiscalant is removed, PRO concentrate is desupersaturated, and concentrate salts are harvested (primarily gypsum for PDD drainage water concentrate). Subsequent process of secondary RO (SRO) desalting of desupersaturated PRO concentrate (from the CCESP system) allows for further water recovery (with make-up antiscalant dosing), thereby enhancing the overall desalination water recovery (up to 90% or higher for PDD drainage water) and minimizing the residual drainage concentrate volume. It is noted (although not shown in **Fig. 4.1)** that a

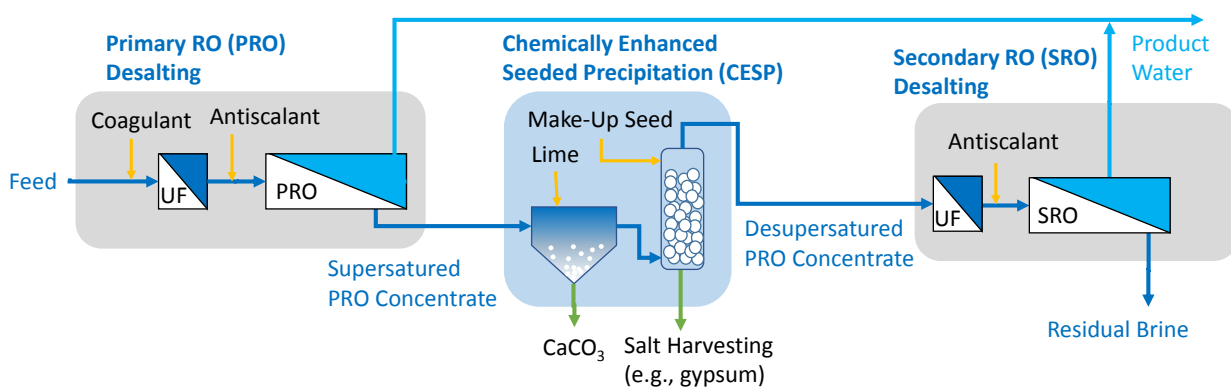


***Figure 4.1**. Process diagram of autonomous multistep RO desalination with integrated salt harvesting (AMRO-DISH).*

portion of the SRO concentrate can be recycled into the CCESP system to increase salt harvesting productivity and to further enhance SRO water recovery. Additionally, the final, residual SRO brine can be processed in a separate CCESP system. This could serve for additional salt harvesting, but more importantly for concentrate stabilization (i.e., to avoid mineral salt precipitation/scaling in downstream piping and/or vessels) prior to final processing (i.e., selenium reduction/removal, solidification via evaporation, etc.).

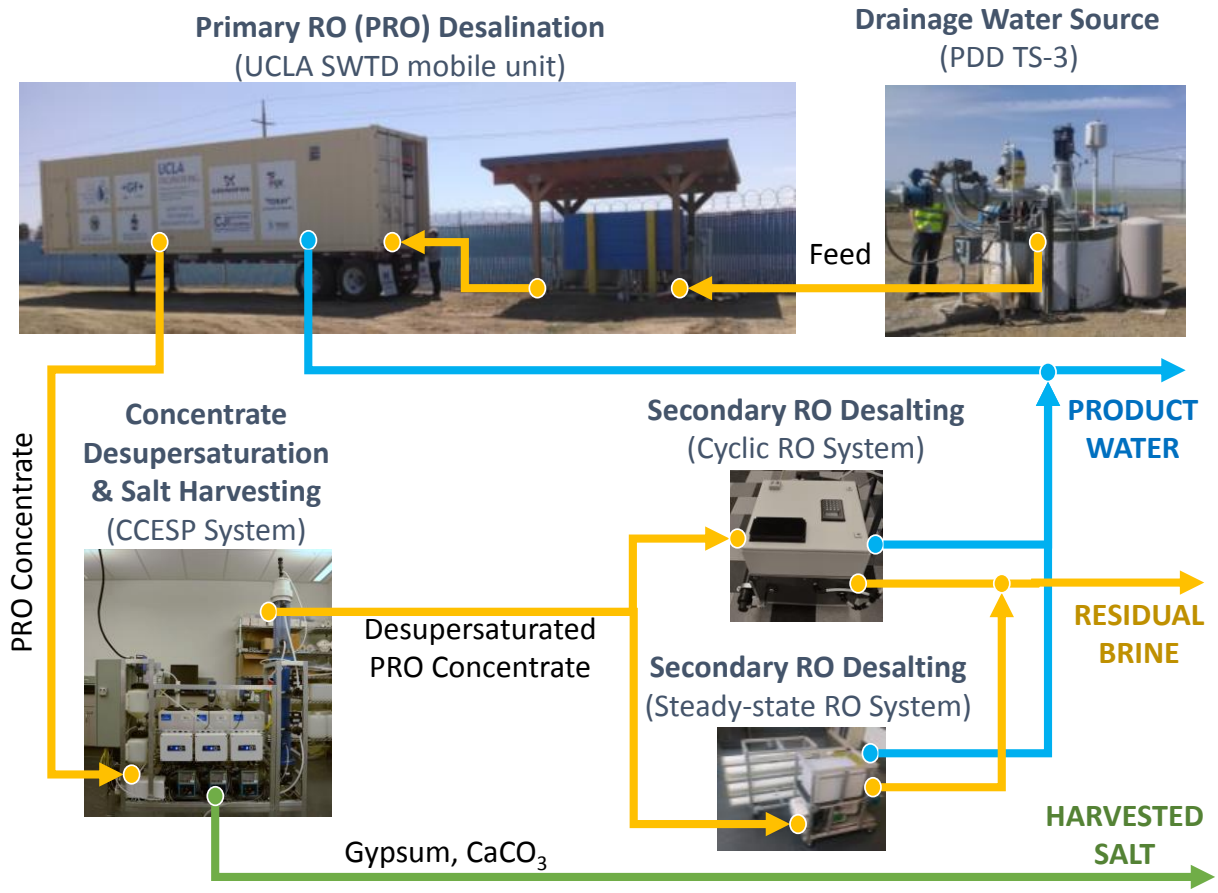


***Figure 4.2**. Proposed implementation of field demonstration of autonomous multistep RO desalination with integrated salt harvesting (AMRO-DISH) at the Panoche Drainage District treatment site.*

Field development and demonstration of the AMRO-DISH process for drainage water treatment will be implemented through the integration of existing UCLA equipment (to be provided as in-kind contributions), field-deployed at the PDD treatment site. As illustrated in **Fig. 4.2**, the AMRO-DISH plant will integrate existing UCLA Smart Water Treatment and Desalination (SWTD) unit with UCLA CCESP and secondary RO desalting systems. The SWTD unit is currently operating at PDD treatment site, receiving sand-filtered subsurface agricultural drainage water from PDD tile sump no. 3 (TS-3). RO concentrate from UCLA SWTD unit will be directed to the

UCLA CCESP system for concentrate desupersaturation and salt harvesting. The UCLA CCESP system, currently at the UCLA WaTeR center laboratory, is ready for immediate field deployment. Based on thermodynamic solubility analysis of PDD drainage water (see **Section 4.1.1**) and previous bench-scale field testing [20], gypsum (>98% purity) will be the primary mineral salt product from CCESP salt harvesting. The desupersaturated PRO concentrate from the CCESP system will be further desalted (post solids removal) in a secondary RO system; two existing RO units are available for secondary RO desalting (see **Section 6.3.2**). Product and concentrate streams from all of the above field equipment will be recombined prior to discharge into RP-1 agricultural ditch (see **Section 2.2.4**), which is owned and operated by PDD and is covered by existing PDD CEQA and NEPA permits.

4.2.3 MeMo-Enabled Self-Adaptive RO Desalination to Maximize RO Water Recovery

In the deploying the AMRO-DISH approach for drainage water management, the RO desalting steps serve to: a) produce product water for water reuse, b) generate the necessary thermodynamic force (i.e., supersaturation) for salt harvesting (via CCESP), and c) reduce the volume of residual drainage water for final processing and disposal. These critical RO desalting functions are optimized to achieve the maximum feasible PRO and SRO water recovery levels. The water recovery limits are variable as they are governed by a variety of factors, including: a) adequacy of RO feed pretreatment (in removing particulates and colloids), b) RO retentate mineral supersaturation levels (i.e., driving force for mineral scaling, and c) antiscalant treatment effectiveness (in retarding membrane mineral scaling), all of which are dependent on feed water quality. As a consequence, high recovery RO desalting can only be accomplished with an operation/system that can self-adapt to drainage water quality, which varies seasonally and can be affected by local agricultural irrigation and drainage management activities. Accordingly, the proposed project will serve to refine, advance, and field demonstrate novel, self-adaptive RO desalting operation and control methodologies that are necessary for achieving high recovery desalting under high and variable feed water salinity and mineral scaling potential.

4.2.3.1 Advanced architecture for real-time process monitoring & feedback control

The UCLA WaTeR center's approach to achieving self-adaptive high recovery RO (RO) desalting is based on an advanced architecture for real-time process monitoring and feedback control (**Fig. 4.3-4.4**). A unique and enabling aspect of this architecture is the utilization of direct membrane surface imaging via UCLA membrane monitor (MeMo) for real-time detection and monitoring of mineral scaling, which is then used to direct RO system optimization and control. Online data from MeMo and other process sensors (pressure, flow, conductivity, temperature) are integrated and analyzed along with operator specifications (i.e., target water production) in a model-based controller and optimizer (MCO) module. Based on analyzed data, MCO algorithms predicting RO operation and water recovery limit are utilized to determine the necessary

operational set-points (i.e., pressure, flow, antiscalant dose) for maximizing RO water recovery. Using these set-points, feed pump, valve, and metering pump controllers in the MCO direct the appropriate signals to the associated process actuators to make the necessary process adjustments. Through a feedback mechanism, any disturbances to the RO process (e.g., changes in feed water quality, membrane scaling potential, temperature, etc.) detected by the process sensors are handled in real time by the MCO via the appropriate adjustments to process actuators.

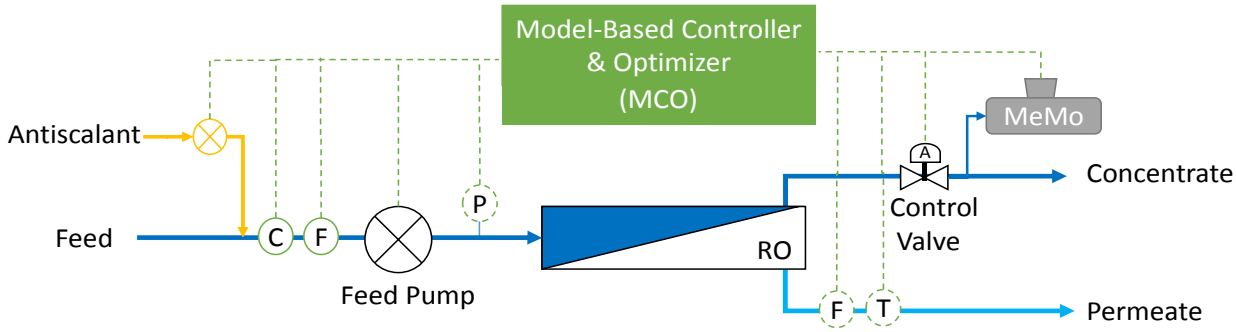


Figure 4.3. *Schematic of process monitoring and feedback control for self-adaptive high recovery RO operation.*

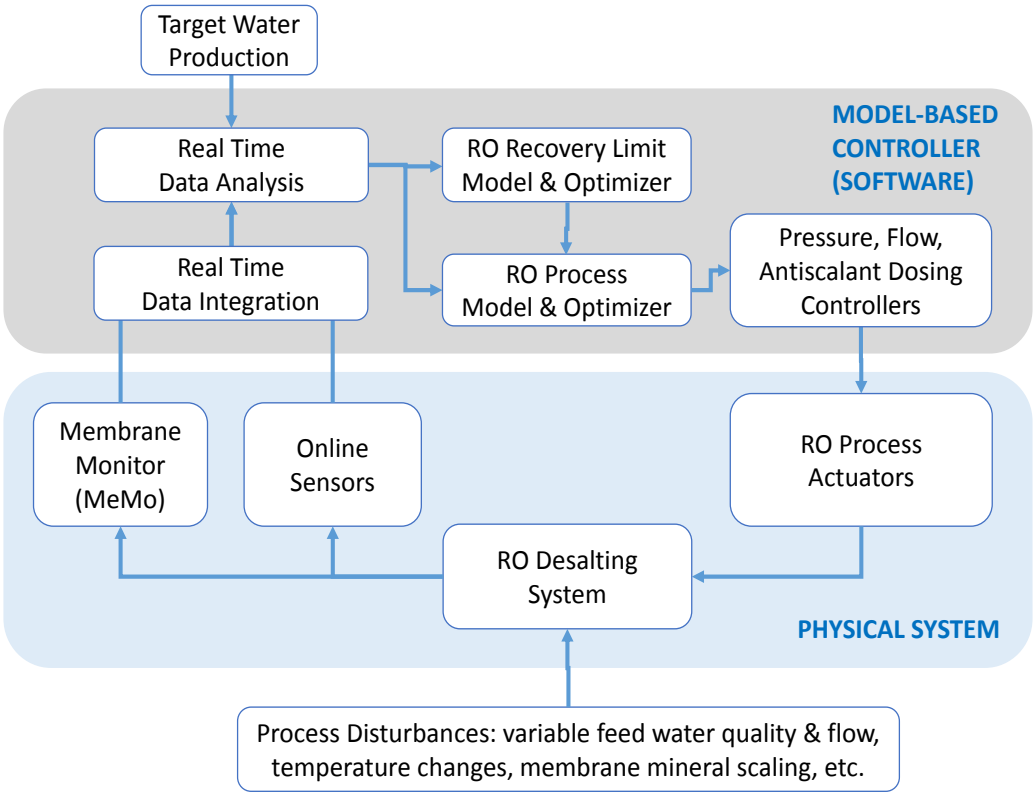


Figure 4.4. *Process monitoring and feedback control architecture for self-adaptive high recovery RO operation.*

Previous and ongoing foundational studies provided support to the feasibility of the proposed process monitoring and control architecture (**Fig. 4.4**). For example, a model-based controller currently implemented at the UCLA SWTD unit already demonstrated the controller's capability in handling significant variability in feed water salinity. As shown in **Fig. 4.5**, the UCLA SWTD unit model-based controller correctly predicted and adjusted first and second stage RO pressures in maintaining RO production and water during a period of significant water salinity variations (by ~5,000 mg/L TDS) caused by a rain event. In a previous study conducted at PDD Drainage Point 25 (DP-25) field test site [42], MeMo was successfully utilized for rapid optimization of antiscalant dosage (**Fig. 4.6**a) and estimation of water recovery limits (**Fig. 4.6b**). In a more recent study, MeMo automated mineral scale detection and monitoring capabilities were field demonstrated in the UCLA SWTD unit. MeMo was able to automatically detect the occurrence of gypsum scaling (**Fig. 4.7a**), as well as to track the time evolution of gypsum scale surface coverage on the membrane surface (**Fig. 4.7b**). It is therefore expected that, with refinement and optimization, the proposed study will be able to implement and field demonstrate the proposed process monitoring and control architecture (**Fig. 4.4**) for enabling self-adaptive RO operations near water recovery limits.

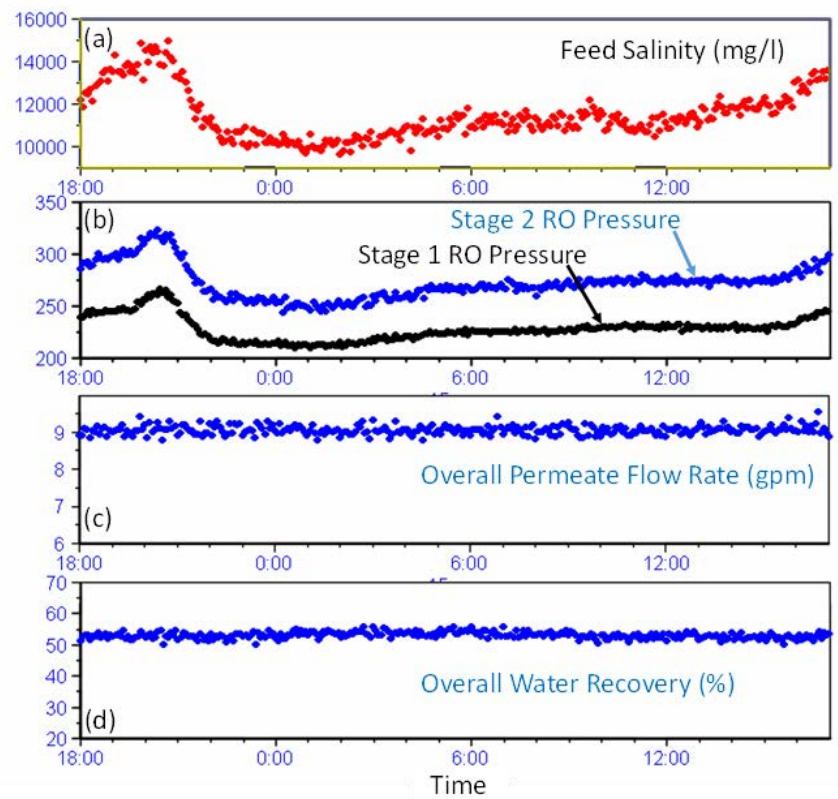


***Figure 4.5**. Feed salinity, RO feed pressures, overall permeate flow rate, and overall water recovery in the UCLA SWTD unit during a rain event (December 14-15, 2014).*

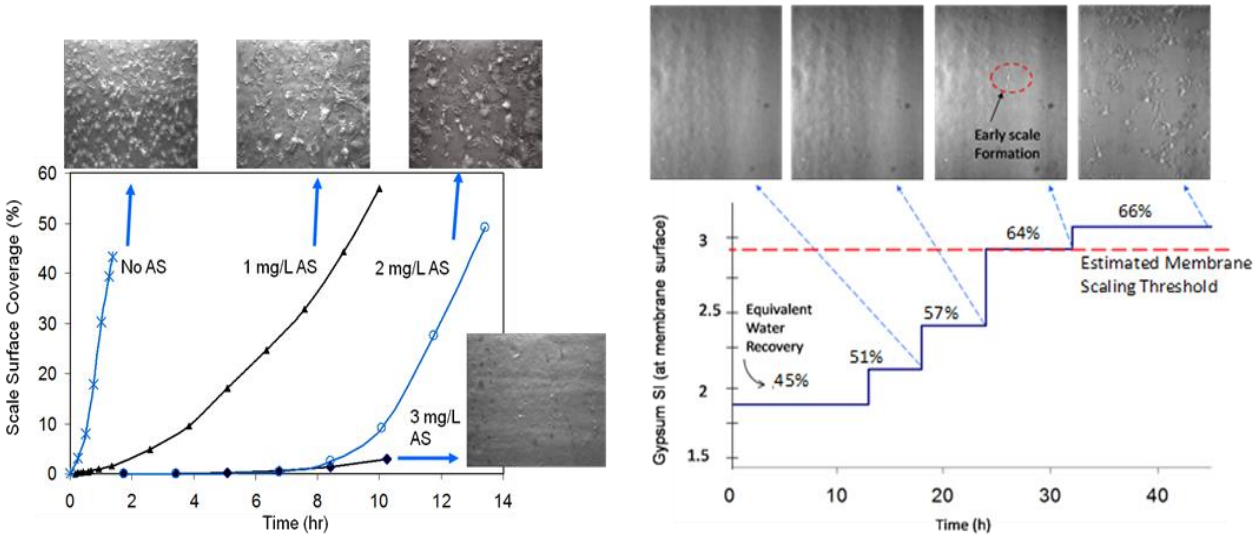


Figure 4.6. *(a) Impact of antiscalant dosage on the time evolution of surface mineral scale coverage of RO membranes during MeMo operation with antiscalant treatment. Equivalent RO process recovery: 66% [42]; (b) Membrane surface images take during AD water desalting using MeMo at successively increasing gypsum saturation index near the membrane surface and the corresponding equivalent water recovery. Antiscalant dose: 3 ppm [42].*

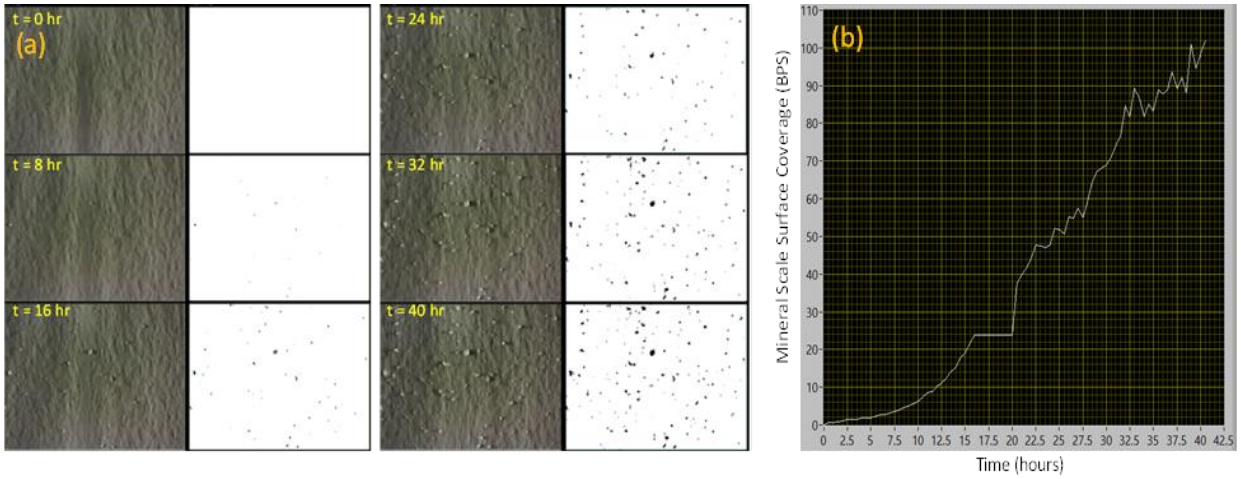


Figure 4.7. *Automated online (a) membrane image analysis and (b) tracking of gypsum mineral scale coverage in a MeMo standalone operation using ultra filtered PDD TS-3 drainage water (TDS~17,000). Equivalent RO recovery: 50%; no antiscalant. Fractional mineral scale surface coverage over the membrane surface area is expressed in basis point unit, in which 1 BPS = 1/10,000 = 0.01 % area scaled).*

4.2.3.2 Importance of RO feed pretreatment

In developing self-adaptive high recovery RO operation, RO feed pretreatment in the UCLA SWTD unit will be optimized to ensure minimal chemical usage (e.g., coagulant) and water loss (i.e., due to filter cleaning/backwashing operations). The SWTD unit utilizes feed pretreatment train (**Fig. 4.8**) consisting of centrifugal separator, inline coagulation, screen filtration (300 μm), and ultrafiltration (0.02 μm) for removal of particulates and colloids and microorganisms (i.e., bacteria). Previous and ongoing foundational studies have shown that effective removal of particulates and colloids is a critical prerequisite for effective mitigation of membrane mineral scaling. For example, a recent MeMo study compared mineral scaling potential of raw (unfiltered) and ultrafiltered source water in the UCLA SWTD unit at PDD. With minimal feed pretreatment and no antisalant, deposition of particulates promoted rapid formation of mineral scaling (primarily gypsum) within 12 hours RO operation (**Fig. 4.9**). With ultrafiltration, reduction of particulates significantly reduced rate of mineral scale formation on the membrane surface, even in the absence of antiscalant dosing (**Fig. 4.10**).

In the proposed field demonstration, it is anticipated that, with the proposed monitoring and control architecture and optimal RO feed pretreatment, self-adaptive PRO operations up to water recovery of 70-75% or higher would be feasible. A recent study in the UCLA SWTD unit has already indicated that 60% recovery is feasible with general-purpose antiscalant (BWA Flocon 260) at a modest dose of 4 ppm (**Fig. 4.11**). The use of high performance antiscalants (BWA Flocon 135) is currently being investigated at the UCLA SWTD unit, which should enable one to reach higher water recovery and provide important baseline information for the proposed project. At the projected 70-75% recovery levels, target water recovery of 40-67% for SRO desalting would be sufficient for achieving overall AMRO-DISH water recovery levels of up to 90% or higher.

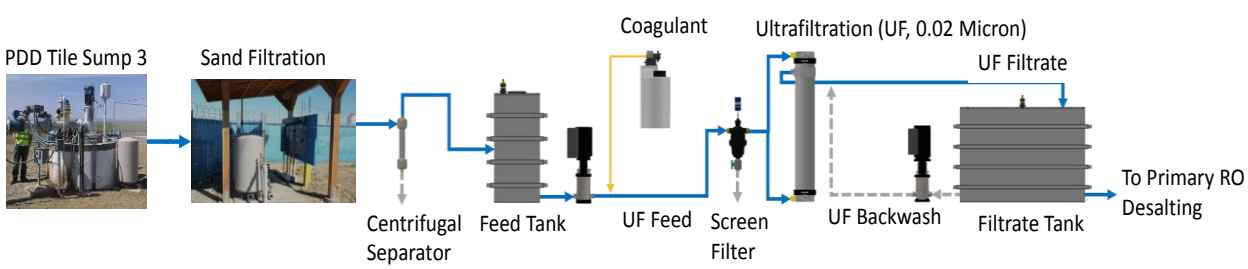


***Figure 4.8**. RO feed pretreatment train in the UCLA Smart Water Treatment & Desalination unit.*

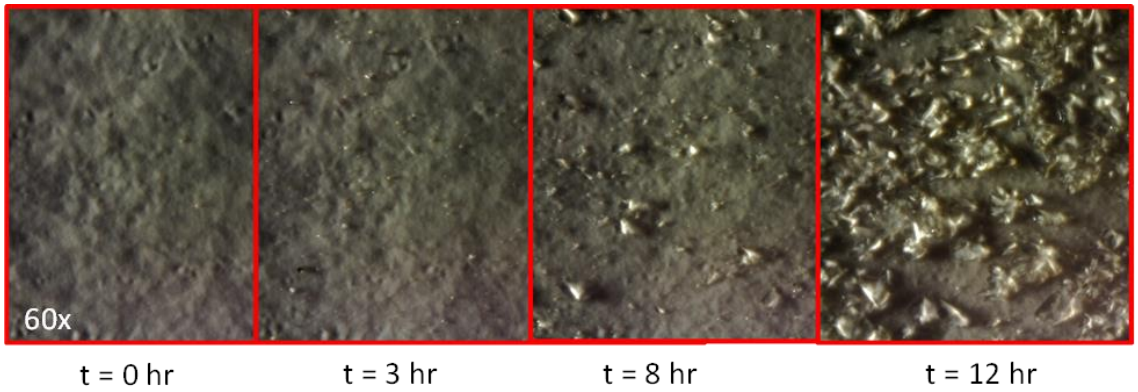


Figure 4.9. *Evaluation of mineral scaling potential (gypsum) via MeMo using raw (unfiltered) Panoche (CA) source water (TDS~17,000). Equivalent RO recovery: 50%; no antiscalant.*

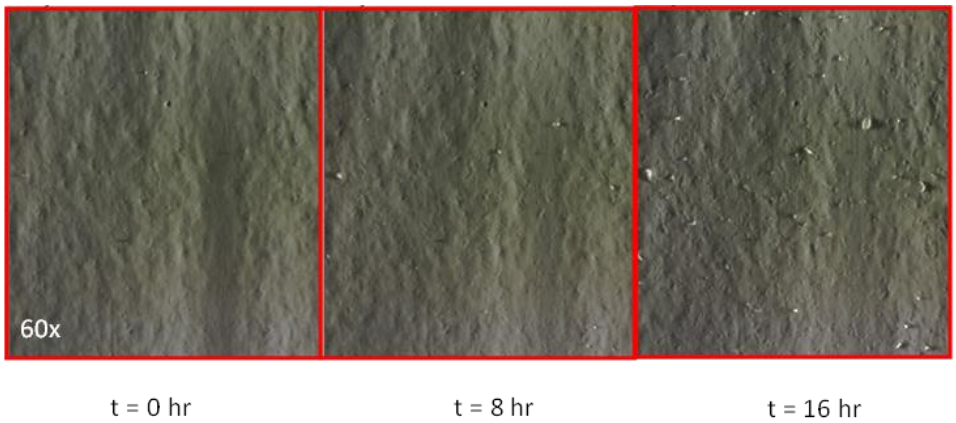


Figure 4.10. *Evaluation of mineral scaling potential (gypsum) via MeMo using ultrafiltered Panoche (CA) source water (TDS~17,000). Equivalent RO recovery: 50%; no antiscalant.*

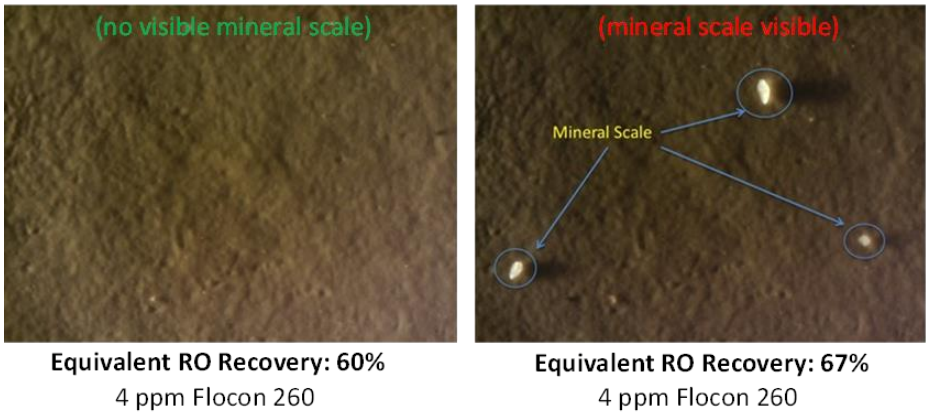


Figure 4.11. *Assessment of RO recovery limit via MeMo operation using RO concentrate from RO desalination of ultrafiltered PDD TS-3 drainage water. Flocon 260 antiscalant. Images were taken at the end 18 hour of MeMo operation.*

4.2.3.3 RO Process Configuration

It is noted that the RO system in the UCLA SWTD unit can be readily configured (using automated valves) for either single- or two-pass RO operation (**Fig. 4.12**); the latter allows for production of higher quality permeate by desalting first-pass RO permeate in a second-pass RO step. In demonstrating self-adaptive RO operation, the need for two-pass RO operation will be determined based on actual RO permeate quality versus target water quality (as will be assessed by both UCLA and PDD). Recent data from two-pass RO operation of the UCLA SWTD unit indicate that first pass RO can produce high quality product water that meets CDPH MCL of nitrate (<45 mg/l) and selenium (<0.01 ppm). Moderate level overall boron rejection of 81% was achievable via two-pass RO, without pH adjustment of the first-pass permeate. Given that RO membrane rejection of Boron is governed by pH [43], meeting CDPH boron notification limit of 1 mg/L may require two-pass RO operation with pH adjustment of first-pass RO permeate to alkaline conditions prior to second-pass desalting.

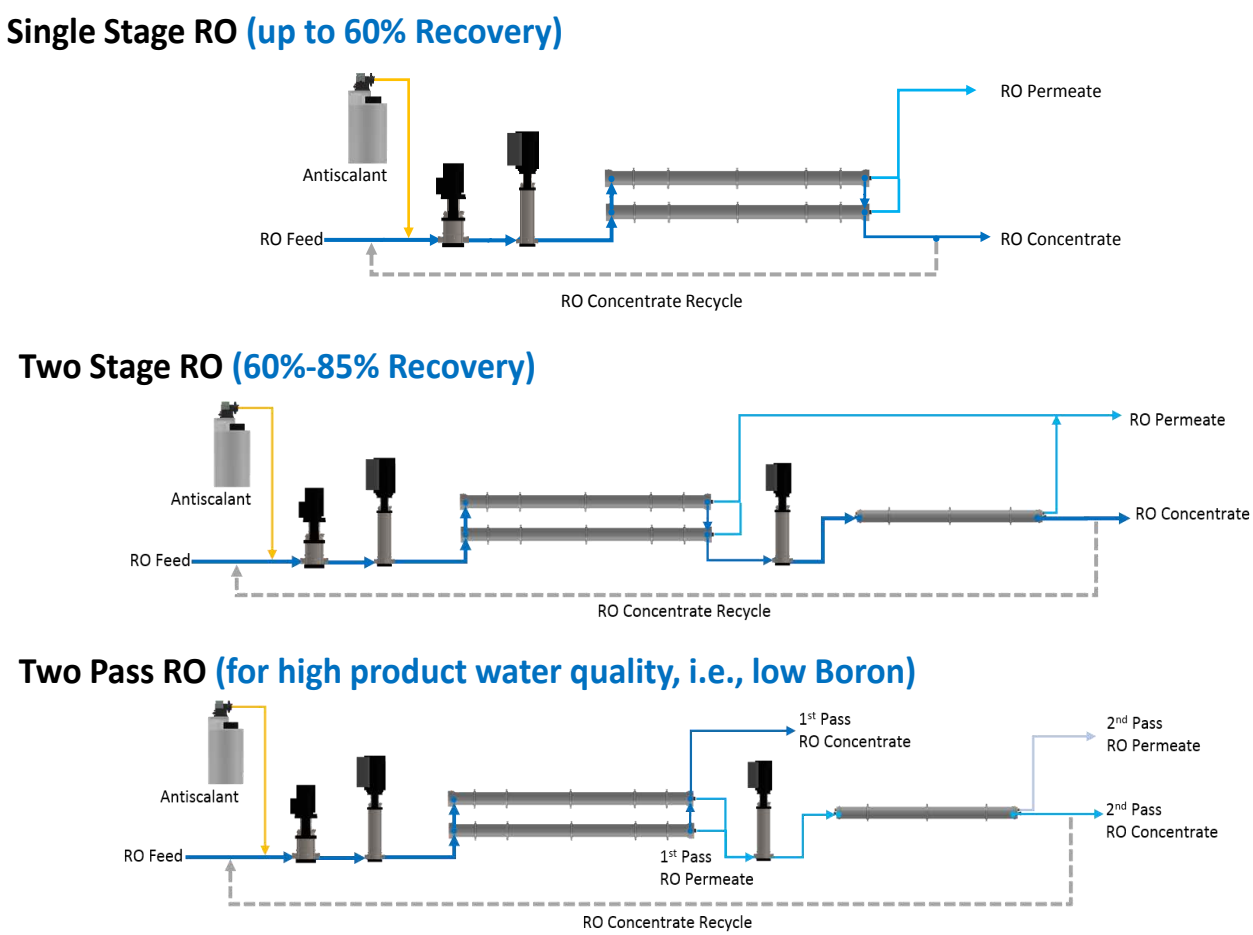


***Figure 4.12**. Feasible RO configurations in the UCLA SWTD unit.*

***Table 4.2**. Water quality data from UCLA SWTD unit operation in two-pass RO mode.*

Constituent	Raw Water	1st Pass RO Permeate	2nd Pass RO Permeate
Turbidity	<1 NTU	<1 NTU	<1 NTU
pH	7.7	6.8	5.8 pH
Total Dissolved Solids (mgl/L)	16,660	167	29
Total Organic Carbon (mgl/L)	13.9	1.4	1.3
Total Alkalinity (mgl/L as $CaCO_3$)	343	18	4
Dissolved Aluminum (mgl/L)	<0.2	<0.01	<0.01
Dissolved Boron (mgl/L)	53.9	24.1	10.4
Dissolved Calcium (mgl/L)	514	<1	<1
Dissolved Chloride (mgl/L)	4,051	40	5.2
Dissolved Magnesium (mgl/L)	382	<1	<1
Dissolved Nitrate (mgl/L)	173	11	0.245
Dissolved Potassium (mgl/L)	42.8	<0.5	0.555
Dissolved Selenium (mgl/L)	0.428	< 0.001	< 0.001
Total Silica (mgl/L)	43.2	0.421	0.216
Dissolved Sodium (mgl/L)	4,540	38.9	7
Dissolved Sulfate (mgl/L)	6,555	7.311	6.2

4.2.4 Novel CCESP Process for Concentrate Desupersaturation and Salt Harvesting

The proposed project will serve to advance and field demonstrate continuous CESP (CCESP) as scalable unit operation for continuous, steady-state RO concentrate desupersaturation and salt harvesting. The technology is now at a critical junction in which: (a) the feasibility of the batch CESP process has been established both in the laboratory and in the field, and (b) an evaluation platform of continuous CESP (CCESP) equipment has been developed, constructed, and ready for research use (e.g., **Fig. 4.2**). The CCESP process [21] is based on the finding that a sequential combination of chemical and seeded precipitation can balance chemical use with favorable precipitation kinetics in the demineralization of antiscalant-containing RO concentrate [21]. CCESP processing of primary RO concentrate overcomes the precipitation retardation action of antiscalants that are commonly present in the desalination concentrate. In general, the supersaturation level of RO concentrate, with respect to a mineral scalant *x*, is assessed in terms of a thermodynamic saturation index, $SIx=IAP/K_{sp,x}$, where IAP is the ion activity product and $K_{sp,x}$ is the solubility product for the mineral salt *x* (where *x* is the mineral salt of concern such as *c*: calcium carbonate (as calcite) or *g*: gypsum). As illustrated in the example shown in **Fig. 4.13,** for the case of gypsum-supersaturated RO concentrate, concentrate desupersaturation via CESP involves two sequential steps. In the first CESP step, alkaline pretreatment is initiated by dosing with an alkaline chemical in order to elevate the RO concentrate pH and deprotonate bicarbonate ions present in the concentrate, thereby elevating the RO concentrate supersaturation index (SIc) with respect to calcite. This step induces rapid nucleation and growth of $CaCO_3$ particles, leading to concomitant scavenging of antiscalants by these $CaCO_3$ particles [21, 26]. The second CESP step (i.e., seeded precipitation) is initiated by inoculating the alkaline-pretreated RO concentrate with mineral seed crystals (**Fig. 4.13**) in order to induce $CaSO_4$ precipitation. The overall CESP process minimizes dissolved residual antiscalant concentration to enable effective concentrate desupersaturation via $CaSO_4$ precipitation. CESP has the important benefit of consuming alkaline chemicals only to the minimal extent required for dissolved antiscalant removal by precipitated $CaCO_3$, without introducing chemical constituents foreign to typical RO concentrate solution matrices [21]. The above approach should also be effective in dealing with other recalcitrant scalants (e.g., calcium phosphate and barium phosphate) where in the mineral seeding step the appropriate seed crystals are utilized.

Previous foundational CESP studies have focused on batch precipitation experiments using synthetic and field concentrate of PDD agricultural drainage water. These studies have established process proof-of-concept [21], elucidated the mechanisms of antiscalant removal by precipitated $CaCO_3$ [26], assessed sustained seeded precipitation with mineral crystal seed recycling [20], verified feasibility with field RO concentrate [20], and evaluate potential economic benefits [20]. A continuous CESP (CCESP) process concept was recently proposed and its operational merits evaluated based on numerical process simulations [37] of the process that

integrates chemical precipitation reactor unit (i.e., partial lime softening) with a moving bed reactor (**Fig. 4.14**). This initial work has led the design and construction of a pilot-scale CCESP to be field deployed in the proposed project.

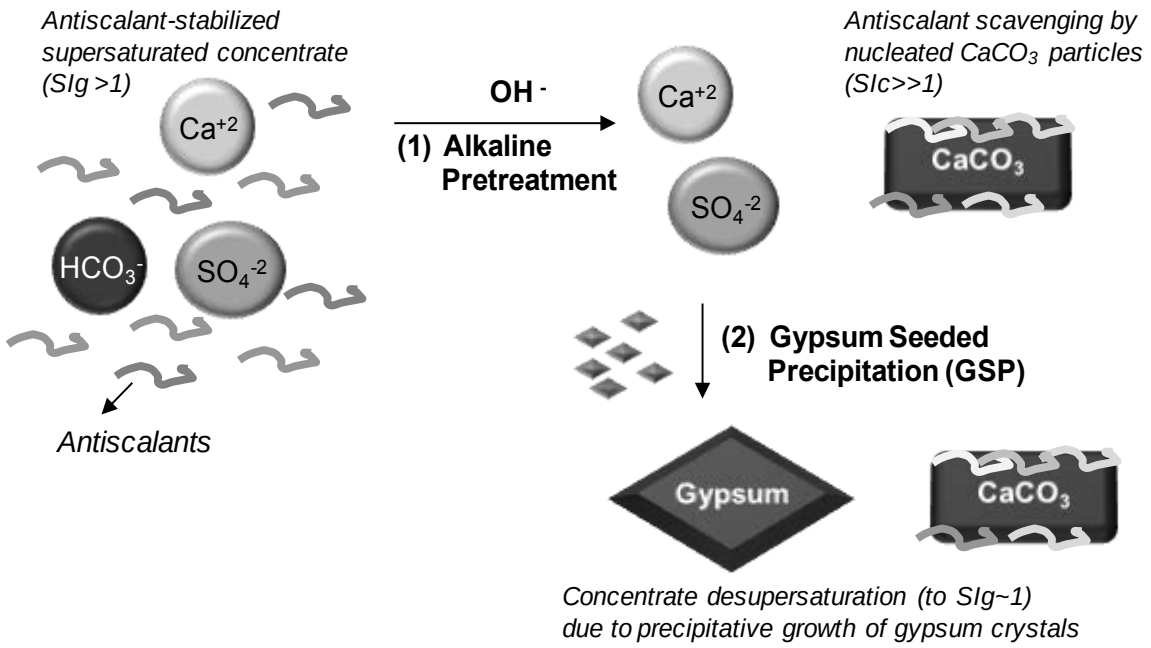


Figure 4.13. *Mechanisms antiscalant removal and concentrate desupersaturation in chemically-enhanced seeded precipitation (CESP) in antiscalant-containing RO concentrate of high gypsum scaling potential [4].*

In the continuous CESP process (**Fig. 4.14**), the PRO concentrate undergoes partial lime treatment in a series of rapid mixing and flocculation reactors. Next, $CaCO_3$ solids are separated from the lime-treated PRO concentrate (i.e., centrifugal separation) prior to seeded precipitation to desupersaturate the primary RO (PRO) concentrate with respect to the limiting mineral scalant, thereby enabling secondary (SRO) desalination to enhance water recovery (see **Fig. 4.1**). The seeded precipitation step is performed in a vertical moving bed reactor to maximize the driving force for seeded precipitation and minimize the reactor volume required for a given extent of reaction (**Fig. 4.14**). The solid particles in the moving bed reactor provide the reactive surface area for heterogeneous precipitation, thereby resulting in desupersaturation of the lime-treated PRO concentrate. As particles grow via precipitation they are gradually purged from the reactor and replaced with fresh mineral seeds in order to maintain a steady-state particle size distribution and total specific surface area within the reactor. The performance of the moving bed reactor for concentrate desupersaturation is expected to depend on a variety of factors, including solids fraction in the reactor, solids bed height, solids purge rate, and solids make-up rate [37]. In order to maintain a constant level of performance (i.e., final mineral salt saturation

level or extent of precipitation reaction) in the seeded precipitation step of CESP, the available active surface area must be preserved by effectively preventing antiscalant poisoning (via upstream antiscalant removal) and via periodic charging with make-up seed crystals. Based on preliminary process modeling and simulations, it was determined that a CCESP moving bed reactor is a feasible approach [37] and the recently constructed CCESP unit will be available for use in the proposed project.

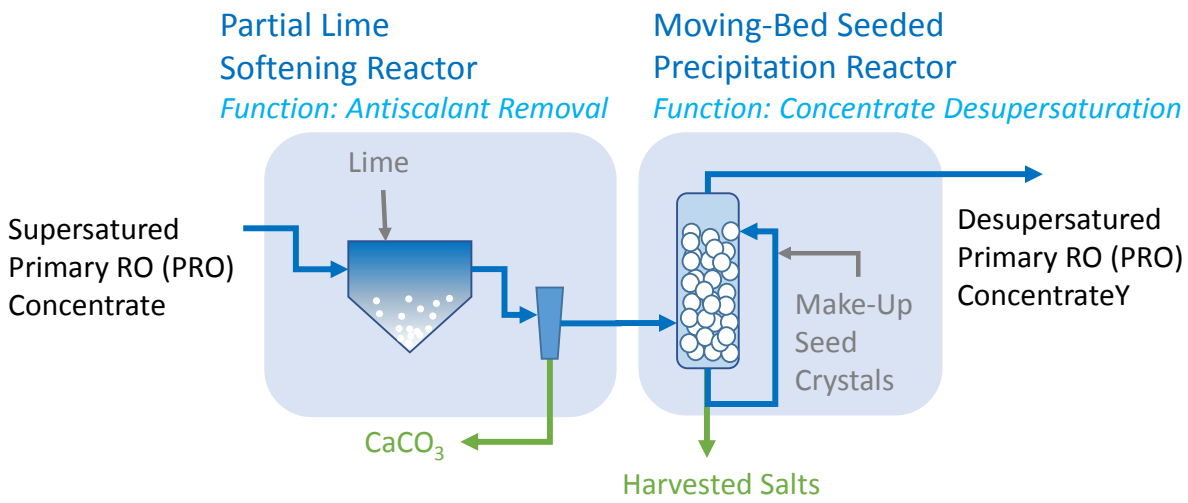


Figure 4.14. *Schematic of a proposed continuous CESP (CCESP) process illustrating pretreatment via lime-induced $CaCO_3$ precipitation for AS removal prior to RO concentrate desupersaturation via seeded precipitation with recycling of solids in a moving bed reaction [37].*

In order to develop principles for effective design and operation of the CCESP process, two critical knowledge gaps must be addressed. First, fundamental knowledge of the antiscalant scavenging process in a continuous, steady-state chemical precipitation softening proces stage of CCESP is needed, particulary for determining alkaline dose and residence time requirements of chemical rapid mixing and flocculation. Previous studies of RO concentrate precipitation softening have elucidated the interactions of antiscalants with precipitated $CaCO_3$ in RO concentrate, but are limited to batch systems [26, 44, 45]. These studies have shown that $CaCO_3$ precipitation is retarded during precipitation softening [44, 45], but in turn also lead to significant antiscalant scavenging [26] (via surface adsorption and inclusion by precipitating crystals) that is central to the CESP process. It was also shown that knowledge of crystal growth kinetics in moving bed reactor is critical for determining the impacts of residual antiscalants and process requirements for purging of crystal seed purging and make-up for steady-state operation.

Previous work on preliminary evaluation of CCESP process feasibility [37] yielded encouraging results, demonstrating the feasibility of sustained production of gypsum and thus feasibility of concentrate salt harvesting. The feasibility assessment was performed via a series of batch multi-

cycle seeded precipitation experiments with solids recycling (**Fig. 2.4**). Removal of antiscalant (AS) carry-over via lime-induced $CaCO_3$ precipitation prior to seeding was found to prevent poisoning of the seed crystals during CESP over multiple cycles. The kinetic rate constant for seeded precipitation subsequent to lime pretreatment (0.25 g/L lime) for AS removal was found to reach a constant value of 12.9 L^2/m^2-mol-min after the first cycle of CESP; the rate of precipitation was maintained over multiple subsequent cycles with solids recycling. The rate constant for CESP with 0.25 g/L lime (12.9 L^2/m^2-mol-min) was only slightly lower (4%) than that observed for seeded precipitation without AS dosing (13.5 L^2/m^2-mol-min) indicating that seed poisoning by AS was prevented. Furthermore, indirect measurements of AS concentration based on the determined seeded precipitation rate constants showed that the AS concentration was reduced by 95% via lime-induced $CaCO_3$ precipitation prior to seeding. These results provide evidence that the rate of seeded crystal precipitation could be sustained in a continuous CESP process provided that there is sufficient lime pretreatment for residual antiscalant removal.

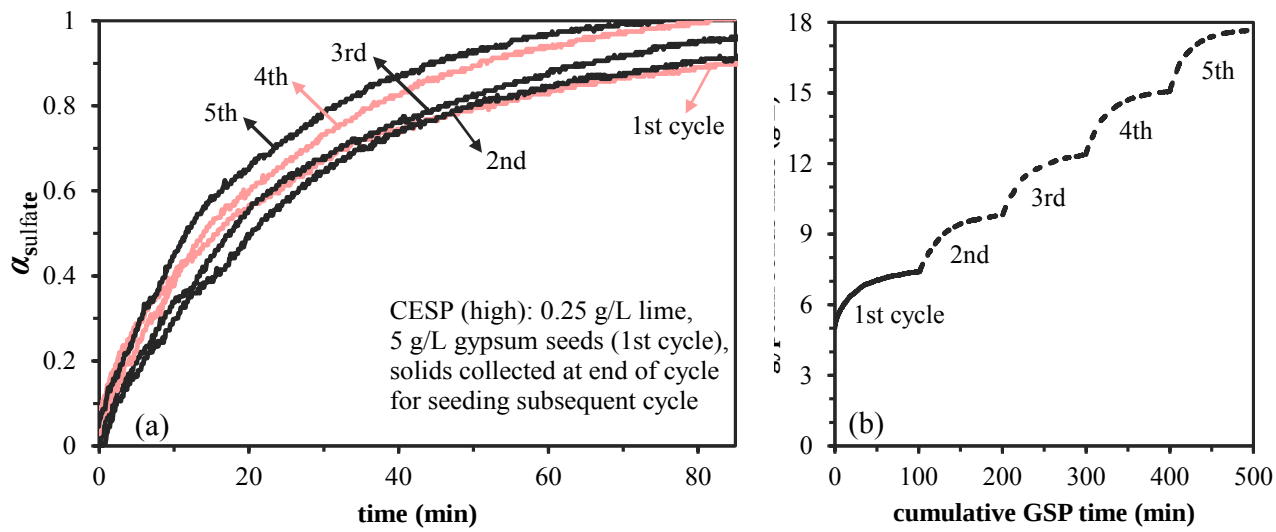


Figure 2.4. *Sulfate extent of reaction (a) and gypsum solids mass (b) in model PRO concentrate (SIg = 2.5) subsequent to 0.25 g/L lime treatment (not shown) during five batch cycles of CESP with 5 g/L gypsum seeds to induce gypsum precipitation in the 1st batch cycle followed by recycled solids in the remaining batch cycles [37]. GSP: gypsum seeded precipitation.*

5. Task Breakdown

5.1 Project Tasks Overview

The proposed project tasks will include six field demonstration/development tasks (**Tasks 1-6**) and a reporting task (**Task 7**), organized based on the components of the AMRO-DISH process (**Fig. 5.1**). **Tasks 1-3**, to be completed in **Year 1** with a total budget of $253,819 (DWR funds plus in-kind), will focus on: a) achieving technical readiness of CCESP for concentrate salt-harvesting (**Milestone 1**), and b) optimizing self-adaptive primary RO desalination operation with concentrate salt harvesting (**Milestone 2**). **Tasks 4-6**, to be conducted in **Year 2** with a total budget of $264,255 focuses on demonstrating long-term treatment and cost performance (**Milestone 3**), including demonstration of secondary RO desalting and treatment cost analysis.

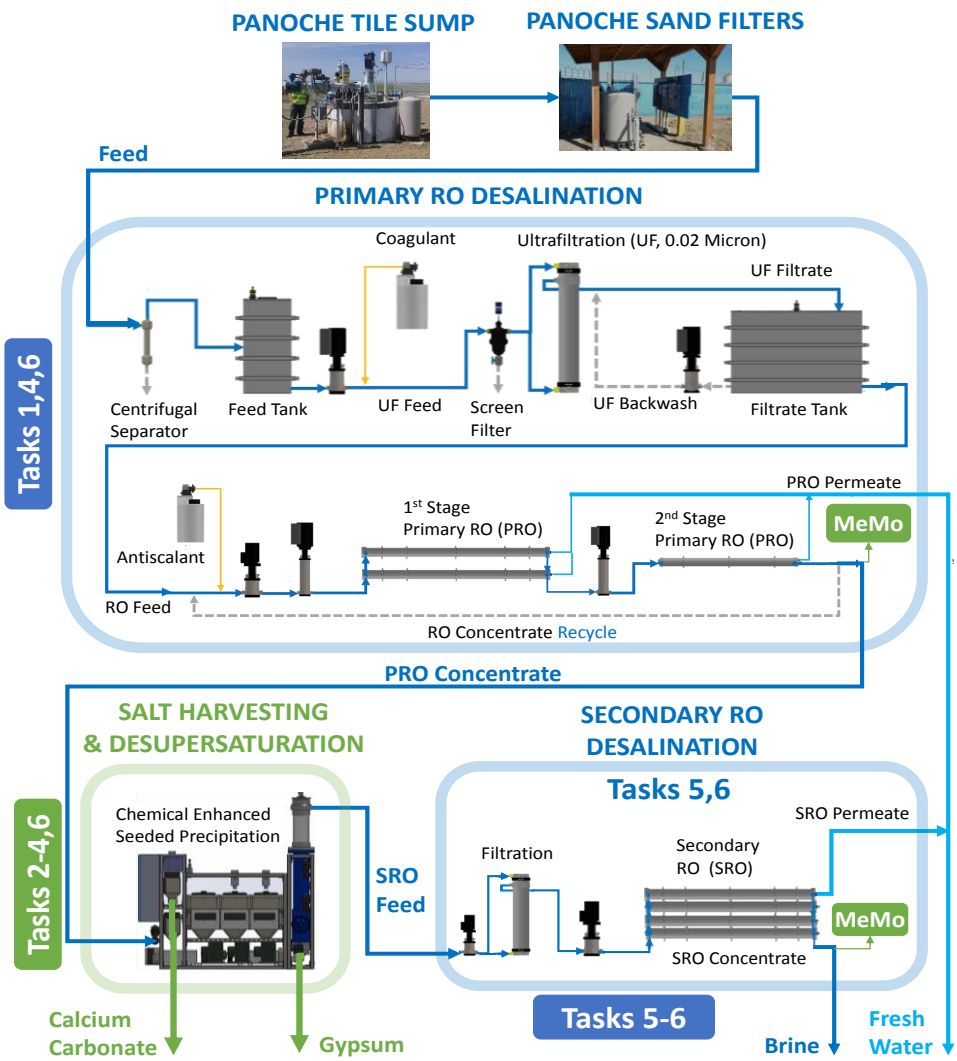


***Figure 5.1**. Components of the AMRO-DISH process.*

All major equipment that will be required for field development and demonstration of the AMRO-DISH process (**Fig. 5.1**) will be ready and available for the project as in-kind. In addition to in-kind services from field personnel of Panoche Drainage District, about 20 person months of UCLA personnel effort (to be funded via the grant) will be committed for accomplishing the proposed project tasks. Task breakdown are provided in the following sections (**Sections 5.3-5.9**), which include brief overview of task status, budget, and schedule. The detailed budget for each task and the respective cost basis are provided in the Budget section in **Tables 7.2-7.5** and **Section 7.2**, respectively. Cost documentations are given in the **Appendix** in **Section 11**. Detailed schedule of project tasks are provided in **Tables 8.1-8.2** in the **Project Schedule** section of this proposal.

5.2 Expected Results and Outcomes

It is expected that the primary project result will be a field validation of the long-term technical and cost performance of the AMRO-DISH approach (**Fig. 5.1**) for self-adaptive, high recovery desalination of agricultural drainage water with concentrate salt harvesting. Important outcomes of the project will include:

- Development and demonstration of methodologies and process models that are necessary for operating primary and secondary RO desalting self-adaptively at high water recovery levels, while effectively mitigating membrane mineral scaling.
- Field data and experience that will provide the necessary technical knowledge for continuous harvesting of concentrate salts via the CCESP process.
- Process cost models that will be developed will allow economic cost analysis of the scaled-up of the AMRO-DISH process for sustainable on-farm drainage water treatment.

Dissemination and documentation of project results will include:

- Communication of project progress to project stakeholders via regular project progress reports and review meetings.
- Documented of all project results in the final technical project report.
- Dissemination of research results via preparation and submission of research articles to peer-reviewed journals and scientific conference presentations (AIChE, AWWA, AMTA, and NAMS conferences).
- Documentation of project research methodologies and results in student theses/dissertations, which undergo rigorous evaluations by University committees.

A key project outcome will be the demonstration (and resolution of uncertainties) that long-term implementation of high recovery desalination of agricultural drainage water along with integrated concentrate salt harvesting are both technically feasible and cost effective. Drainage water desalination via the AMRO-DISH approach will produce potable water at an overall water recovery levels of up to 90% or higher, reduce drainage water volume (by up to 90% or higher), and generate usable/valuable concentrate salts (e.g., gypsum, $CaCO_3$). Such generation of value

products and reduction of RO residual volumes will provide measurable offset of the costs of desalination and residual management (i.e., brine disposal). It is anticipated that drainage water desalination via the AMRO-DISH approach will become an important, practical strategy for achieving sustainable drainage water management.

5.3 Task 1: Optimize Primary RO (PRO) Desalting for High Recovery Self-Adaptive Operation

TASK 1 OVERVIEW

Performance Target & Measure

Successful completion of Task 1 will enable self-adaptive operation of primary RO desalination of PDD agricultural drainage water at recovery levels of 70-75% or higher, while effectively mitigating membrane mineral scaling. Existing data already indicate that up to 60% and possibly higher water recovery should be achievable (see **Section 4.2.3**). Process optimization is expected to enable further water recovery enhancements.

Milestone Achievement

Completion of this task is a partial requirement for achieving **Project Milestone 2**, optimal self-adaptive primary RO desalination with concentrate salt harvesting.

Task Status: Ready to proceed immediately upon project approval.

The UCLA Smart water treatment and desalination (SWTD) unit, serving as the primary RO (PRO) for the AMRO-DISH plant, is fully commissioned and operational at the PDD treatment site. Optimization of self-adaptive high recovery operation can begin immediately upon project approval to proceed.

Task Schedule: 6/15/2015-6/30/2016

Salaries & Benefits: $ 23,981 (3.8 person months)

The task budget includes salaries and benefits for project management and guidance by the principal investigator and field work conducted by a Graduate Student Researcher (GSR 1). GSR 1 will conduct the study both on site and via remote operation of the SWTD unit.

Other Direct Costs: $ 34,558

Direct costs for this task include field study supplies, field site expenses, and mandatory fees (GSR fee remission). Field supplies for demonstrating high recovery primary RO desalination include coagulant, antiscalants, and cleaning chemicals (e.g., acid/base). Field site expenses will cover bimonthly field site visits by GSR 1.

In-Kind Contributions: $88,729

In-kind contributions for this task include: (a) use of UCLA SWTD unit for conducting field demonstration of primary RO (PRO) desalting, (b) use of UCLA membrane monitor (MeMo) for real-time detection of mineral scaling, and (c) use of field infrastructure at the Panoche Drainage District treatment site that includes the cost of electricity for the SWDT unit.

The UCLA WaTeR center's approach to achieving self-adaptive high recovery primary RO (PRO) desalting that is free of mineral scaling, is based on an optimization framework for online assessments and establishing set points of RO water recovery limits, coupled with model-based feedback process control of RO desalting. The optimization framework relies on UCLA membrane monitoring (MeMo) technology for real-time membrane mineral scale detection. In **Task 1**, the optimization framework will be refined and integrated with model-based process control to enable high recovery self-adaptive PRO operations. Building on existing UCLA work, the framework will be field demonstrated using the UCLA SWTD unit, currently operating at the PDD drainage water treatment site. Successful completion of this task along with **Task 3** will signify the achievement of **Project Milestone 2**. **Task 1** is composed of three subtasks:

Subtask 1.1. Optimize RO feed pretreatment operations (3.5 months)

Previous UCLA studies at PDD have demonstrated effective removal of particulates and colloids as a critical prerequisite for effective mitigation of membrane mineral scaling; the presence of particulates and colloids in PRO feed has been shown to promote and exacerbate membrane mineral scaling (see Section 4.2.3 and [15]). The water recovery level is therefore also governed by the effectiveness of ultrafiltration (UF) backwashing operations and inline coagulation for controlling UF membrane fouling. In this subtask, the PRO feed pretreatment train will be further optimized with respect to the UF backwashing operations, as well as coagulant dosage. Building on previous UCLA work in Port Hueneme [36] and current effort at PDD (**Section 4.2.3.2**), ultrafiltration membrane fouling will be systematically assessed over a range of operating conditions (coagulant dosage, UF filtration duration, UF backwash duration, UF backwash flux). The field data will be utilized to develop a controller that will be implemented for real-time optimization of UF operations. It is anticipated that pretreatment of the PRO feed will reach 95-98% water recovery; UF water recovery of 97% is already achievable in the current UCLA SWTD unit operation.

Subtask 1.2. Refine RO process model of primary RO desalting (4 months)

In the current UCLA SWTD unit, a model-based control approach is utilized for operating the primary RO desalting system. The process model determines (in real-time) the optimal RO pressure and flow set points for achieving a desired level of water productivity and recovery levels, based on real-time information from flow, pressure, and conductivity sensors. This approach allows the PRO system to maintain optimality, while autonomously adapt to variable feed water salinity. In order to enable self-adaptive PRO operation near the maximum water recovery limit, an optimization framework for online assessments of RO water recovery limits will be integrated into the existing RO process model.

In developing the optimization framework (see **Section 4.2.3.1**), a water recovery limit algorithm will first be established using field data, correlating water recovery limit with antiscalant dosage (for a select number of antiscalant type). The field data will be generated with the aid of the field-deployed UCLA membrane monitoring (MeMo) system; MeMo allows for early detection of membrane mineral scaling via direct membrane surface imaging and automated online image analysis. Specifically, the PRO desalting system will be operated under a range of water recovery levels and antiscalant treatment conditions. For each specific set of PRO operating conditions, MeMo will be utilized for identifying the associated water recovery limit. Subsequently, methods will be developed for automated (self-adaptive) RO operational adjustments toward process optimality, based on real-time MeMo sensor data analysis and real-time establishment (via process models) of water recovery limits.

Subtask 1.3. Demonstrate self-adaptive high recovery operation of PRO desalting (5 months)

In this subtask, the RO process controller will be implemented into the PRO monitoring and control system. The ability of the monitoring and control system in identifying and driving system operation near the PRO water recovery limit will be demonstrated and further refined. For this purpose, the PRO desalting system will be operated under variety of challenge conditions. For example, blending of the incoming high salinity drainage water (10,000-20,000 mg/L from PDD tile-sump 3) with lower salinity feed water maybe done in order to simulate rapid changes in feed water quality. At the PDD treatment site, lower salinity agricultural runoff (~3000 mg/L TDS) is available from the RP-1 agricultural ditch. Assessments will be conducted to demonstrate the robustness of the approach, with each assessment involving 2-3 weeks of continuous PRO operation. It is anticipated that the proposed optimization framework will enable self-adaptive PRO operation with water recovery levels reaching 70-75% or higher. It is noted that, in demonstrating self-adaptive RO operation, the need for two-pass RO operation for enhanced Boron removal will be determined (by UCLA and PDD) based on actual RO permeate quality versus target water quality.

5.4 TASK 2: EVALUATE CCESP CONC. SALT HARVESTING PROCESS REQUIREMENTS

TASK 2 OVERVIEW

Performance Target & Measure

Effective removal of antiscalants (>90%) from the PRO concentrate will be demonstrated in the pilot continuous CESP process, thereby allowing effective concentrate desupersaturation and concentrate salt harvesting. Feasibility of near complete removal of antiscalants is supported by results from previous bench-scale batch CESP evaluations ([26], see **Section 4.2.4**).

Milestone

Completion of this task is the requirement of meeting **Project Milestone 1**, technical readiness of CCESP for concentrate salt-harvesting.

Task Status: Ready to proceed immediately upon project approval.

The UCLA CCESP system is fully constructed and ready for field deployment.

Task Schedule: 6/15/2015-12/31/2015

Salaries & Benefits: $ 17,388 (3 person months)

Task 2 will include budget support for salaries and benefits associated with project management and guidance by the principal investigators and field work conducted on-site by a Graduate Student Researcher (GSR 2).

Other Direct Costs: $ 16,983

Direct costs for **Task 2** include field study supplies, field site expenses, and mandatory fees (GSR fee remission). A container will be acquired for the CCESP system at the field test site, as well as piping connections and hardware to integrate the CCESP system with the UCLA SWTD unit. Chemicals to be used for this task will include lime and gypsum seeds. Field site expenses will cover field site visits by GSR 2 for conducting the field demonstration.

In-Kind Contribution: $7,956

In-kind contribution for **Task 2** is primarily the use of UCLA CCESP system which will be interfaced with the SWTD.

The UCLA-developed continuous chemical enhanced seeded precipitation (CCESP) process for concentrate salt harvesting involves an initial step of partial lime softening for antiscalant removal from primary RO concentrate. This critical step enables the subsequent step of concentrate desupersaturation and salt harvesting via crystal seeding in moving bed reactor. The primary objective of **Task 2** is to evaluate the CCESP process requirements for continuous antiscalant scavenging to enable effective concentrate desupersaturation and concentrate salt harvesting. Building on extensive UCLA studies on the CESP process, **Task 2** represents the crucial translational development toward achieving and demonstrating the continuous CESP (CCESP) process. Thus, **Project Milestone 1** will be achieved with the completion of **Task 2**.

Subtask 2.1. Deploy CCESP system at field test site (1.5 months)

The UCLA CCESP system, to be provided as in-kind for the proposed project, will be field deployed at the PDD field test site. For this purpose, a container (10-ft) will be acquired in the proposed project in order to house the CCESP system at the PDD field test site. Electrical connections (110 VAC) with the UCLA SWTD unit will provide the necessary electrical power for operating the CCESP system. The CCESP monitoring and control system will be interfaced with the UCLA SWTD unit for supervisory monitoring and control, which will enable remote access of the CCESP system (i.e., from UCLA). Primary RO concentrate will be provided from the UCLA SWTD RO unit via flexible piping connections. Desupersaturated concentrate from the CCESP system will be pumped and handled by the UCLA SWTD unit's stream and waste management system. Preliminary tests will be conducted to ensure field operational readiness.

Subtask 2.2. Determine CCESP process conditions for effective antiscalant removal (3 months)

Process requirements for antiscalant removal via partial lime softening will be determined in this subtask. This includes evaluation of the requirements of alkaline (e.g., lime) dosing, rapid mixing, and flocculation in the CCESP partial lime softening step. Experimental evaluations will be conducted using primary RO concentrate from the UCLA SWTD PRO unit. The UCLA CCESP system is equipped with separate rapid mixing and flocculation tanks, with solids liquid separation accomplished via a centrifugal separator. Coupled with multi-electrolyte solubility analysis and stirred-tank reactor modelling, the impact of alkaline dose levels, rapid mixing duration, and flocculation duration on the extents of mineral salt precipitation and associated antiscalant removal will be quantified at various process steady states. For this purpose, various analytical methods will be employed, including online calcium measurement via calcium ion-selective electrode, pH, organic carbon. Periodic sulfate concentration measurements will be done via ICP-MS as confirmation of calcium sulfate precipitation. Particle size analysis via electrical zone sensing and/or dynamic light scattering will be conducted to evaluate the particle size distribution of the precipitated mineral salts (expected to be primarily $CaCO_3$ in this first CCESP stage) in the flocculation tank and the precipitation softening reactor effluent, as well as in the centrifugal separator solids purge stream. Using experimental data, an operational process model and/or correlation will be developed to characterize the kinetics of precipitation in the first CCESP stage that focuses on antiscalant removal. This will be used to quantify /optimize antiscalant removal, while minimizing alkaline dose requirements.

Subtask 2.3. Demonstrate effective concentrate desupersaturation via CCESP (2 months)

The purpose of this subtask is to demonstrate that effective continuous concentrate desupersaturation via crystal seeding is indeed enhanced with near complete removal of antiscalants (>90%) from the primary RO concentrate. The level of concentrate desupersaturation, as quantified by calcium removal in the CCESP moving bed reactor, will be

compared between PRO concentrate with and without antiscalant removal. The moving bed reactor will be operated at various bed heights in order to determine the minimum amount of initial seed crystals that would be required to achieve near complete concentrate desupersaturation (gypsum saturation index ~1). Bed height increase due to crystal growth will be quantified, which will demonstrate technical readiness for concentrate salt harvesting.

5.5 TASK 3: OPTIMIZE CCESP OPERATION FOR EFFICIENT CONCENTRATE SALT HARVESTING

TASK 3 OVERVIEW

Performance Target & Measure

This task goal is to demonstrate sustained production of mineral salt solids (expected to consist of primary gypsum of >98% purity, [20]) in the continuous CESP process during RO concentrate treatment. Previous bench-scale batch CESP process demonstrated sustained production of mineral salt crystals is feasible (**Section 4.2.4**; [37]).

Milestone

Completion of this task is a partial requirement of meeting **Project Milestone 2**, optimal self-adaptive primary RO desalination with concentrate salt harvesting.

Task Status: Ready to proceed after **Task 2** without additional infrastructure.

Task Schedule: 1/2/2016-6/30/2016

Salaries & Benefits: $ 17,388 (3 person months)

The task budget will provide support for salaries and benefits associated with project management and guidance by principal investigators and field work conducted by a Graduate Student Researcher (GSR 2).

Other Direct Costs: $ 14,483

Direct costs for this task include field study supplies, field site expenses, and mandatory fees (e.g., GSR fee remission). Chemicals to be used for this task will include lime and gypsum seeds. Field site expenses will cover field site visits by GSR 2 for conducting the field demonstration.

In-Kind Contribution: $7,956

In-kind contribution for this task is primarily the use of UCLA CCESP system.

High-purity gypsum will be the primary salt that will be harvested from concentrate generated by primary RO desalination (via the SWTD unit) of PDD agricultural drainage water. This task will focus on optimizing and demonstrating the CCESP process for efficient gypsum salt harvesting. This would necessitate sustained gypsum production in the CCESP moving bed reactor. **Milestone 2** will be achieved upon successful completion of this task along with **Task 1**.

Subtask 3.1. Develop gypsum growth kinetics model for CCESP (4 months)

In order to optimize the CCESP process for continuous concentrate salt harvesting, the crystal growth kinetics in a continuous, moving bed seeded precipitation reactor will be elucidated. This understanding is crucial for determining the reactor requirements for solids purging (i.e., production) and seed crystal make-up to enable steady-state reactor operation for concentrate salt harvesting. A foundational CCESP study ([37]) has indicated that the extent of concentrate desupersaturation (as quantified by the reduction in the limiting ion concentration of the precipitating mineral salt) is dependent on various factors, including solids fraction in the reactor, solids bed height, solids purge rate, and solids make-up rate in the steady-state operation of seeded precipitation (see **Section 4.2.4**). Thus, using the CCESP system, the seeded precipitation process will be systematically characterized with respect to the above factors. Using the PRO concentrate from the UCLA SWTD unit, the moving bed reactor will be operated at various steady states. Calcium ion removal (which is indicative of the extent of precipitation reaction) will be measured using calcium ion-selective electrode. Analysis of particle size distribution will be done via electrical zone sensing in order to quantify the extents of precipitation and particle aggregation [21]. Based on field data, a process model of the moving bed reactor will be developed and refined. It is expected that the process model will enable rational reactor design of the CCESP process, identification of process operational requirements, as well as systematic process optimization.

Subtask 3.2. Optimize gypsum solids harvesting operations (2 months)

Gypsum solids harvesting operations of the CCESP moving bed reactor will be optimized. With the aid of the process model from Subtask 3.1, the optimal solids fraction in the reactor, solids bed height, solids purge rate, and solids make-up rate will be determined and validated. The ability to maintain steady-state production of gypsum solids will be demonstrated. SEM imaging will be conducted to characterize the morphology of the produced gypsum solids, which may provide an indication of the level interactions of antiscalants and crystal seed (i.e. antiscalant poisoning) and the extent of particle aggregation [9, 26]. Purity of the harvested salts will be analyzed via solids digestion and subsequent ICP-MS elemental analysis.

5.6 Task 4: Demonstrate Continuous High Recovery PRO Desalting with Concentrate Salt Harvesting

TASK 4 OVERVIEW

Performance Target & Measure

This task will focus on demonstration of a self-adaptive operation of primary RO desalting, integrated with continuous concentrate salt harvesting over a period of 6-9 months. Target performance includes primary RO recovery levels of up to 70-75% and sustained production of mineral salts (primarily gypsum solids of ~ 98% purity and higher).

Milestone

Completion of this task is a partial requirement of meeting **Project Milestone 3**, demonstrated long-term operation and treatment cost performance.

Task Status: Ready to proceed after **Tasks 1-3** with no additional infrastructure.

Task Schedule: 7/1/2016-4/30/2017

Salaries & Benefits: $ 24,840 (4.4 person months)

The task budget is for salaries and benefits associated with project management and guidance by the principal investigator and on-site field work by GSR 1 and GSR 2.

Other Direct Costs: $ 41,037

Direct costs for this task include field study supplies, field site expenses, and mandatory fees (GSR fee remission). Chemicals for long-term demonstration of RO desalting include coagulant and antiscalants. Chemicals for concentrate salt harvesting include lime and seed crystals. Miscellaneous chemicals (for periodic cleaning/disinfection) include acid, base, chlorine, and sodium metabisulfite. Field site expenses also include field site visits by GSR 1 and GSR 2.

In-Kind Contribution: $96,754

In-kind contributions for this task are primarily the use of: (a) UCLA Smart Water Treatment and Desalination RO unit, serving as the primary RO (PRO), for conducting the field demonstration, (b) use of UCLA membrane monitor (MeMo) for real-time detection of mineral scaling, (c) use of UCLA CCESP system for concentrate salt harvesting, and (d) use of field infrastructure at the Panoche Drainage District treatment site including cost of electrical power consumption.

The objective of this **Task 4** is to demonstrate long-term performance of self-adaptive high recovery primary RO desalination with concentrate salt harvesting using the SWTD unit integrated with the CCESP system. Completion of this task along with **Tasks 5-6** will enable the achievements of **Project Milestone 3: demonstrated long-term operation and treatment Cost performance**.

Subtask 4.1. Demonstrate long-term self-adaptive PRO desalting with concentrate salt harvesting (9 months)

The UCLA SWTD unit, integrated with the CCESP system, will be operated continuously over an extended time period of 6-9 months. This task will assess (and optimize as needed) the long-term effectiveness of the MeMo-enabled optimization framework in enabling robust primary RO operation near the water recovery limit. Additionally, an assessment will be undertaken of the long-term performance of the CCESP process in continuously producing high-purity gypsum salt from the primary RO concentrate of the UCLA SWTD unit. Real-time sensor data will be recorded and analyzed online to provide real-time process performance information. All data will be operator-accessible via an on-site interface and remotely via the web. Although significant biofouling is not expected (based on previous experience at PDD), preparations will be made to deal with episodes of high biofouling potential including disinfection of process vessels and piping. It is noted that UF with inline coagulation is highly effective in removing bacteria and thus will contribute to minimizing biofouling in the RO train. An online operator and maintenance log will be kept of all field work, including refill of consumables (chemicals, cartridge filters), inspection of equipment condition, sensor recalibration, membrane system clean-in-place, and the staff hours. The operator and maintenance logs will serve to identify long-term operator and maintenance requirements for cost analysis. At the end of this task, the long-term technical feasibility of self-adaptive primary RO desalting (at water recovery levels 70-75% or higher) with concentrate salt harvesting will be established, which along with completion of **Tasks 5-6** will signify the final project milestone of demonstrated long-term operational and treatment cost performance.

Subtasks 4.2 Collect samples and obtain water quality and solids purity data (Quarterly)

Periodic water samples (at least quarterly) will be taken from the RO feed, RO concentrate, and RO permeate of the UCLA SWTD unit. Samples will also be collected from the desupersaturated RO concentrate exiting the CCESP moving-bed reactor (see **Fig. 4.14**), as well as from the gypsum solids produced by the reactor. Analysis will primarily be done at the UCLA ICP-MS facility for elemental analysis, as well as at the UCLA WaTeR center laboratory for TOC and particle size analysis. Additional analysis may be performed as deemed necessary.

Subtask 4.3. Perform membrane autopsy (1 month)

This task will verify complete suppression of membrane mineral scaling in the UCLA SWTD unit during the long-term demonstration period. Lead and tail RO elements will be removed for autopsy at the UCLA WaTeR center laboratory. Membrane autopsy will include visual inspection of the membrane element, optical analysis, and SEM-EDS analysis of membrane samples.

5.7 Task 5: Demonstrate Enhanced High Recovery Desalting via Secondary RO of Desupersaturated Primary RO Concentrate

TASK 5 OVERVIEW

Performance Target & Measure

This task aims to demonstrate secondary RO desalting of desupersaturated primary RO concentrate that will allow the achievement of overall desalination water recovery of up to 90% or higher. Previous process analysis have shown that water recovery of up to 93% is theoretically achievable v [20].

Milestone

Completion of this task is a partial requirement of meeting **Project Milestone 3**, demonstrated long-term operation and treatment cost performance.

Task Status: Ready to proceed in parallel with **Task 4**.

Task Schedule: 9/1/2016-4/30/2017

Salaries & Benefits: $ 22,790 (4 person months)

The task budget will provide support for salaries and benefits associated with project management and guidance by the principal investigators and field work conducted by GSR 2. The task will be conducted on-site, as well as remotely from UCLA (via remote control capabilities).

Other Direct Costs: $ 22,629

Direct costs for this task include field study supplies, field site expenses, and mandatory fees (GSR fee remission). Field study supplies are primarily antiscalants, which are dosed continuously during secondary RO desalting. Field site expenses will cover field site visits by GSR 2 for conducting the field demonstration.

In-Kind Contribution: $13,798

In-kind contribution for this task is primarily the use of UCLA Cyclic RO and Mini RO systems for secondary RO desalting of desupersaturated primary RO concentrate.

Task 5 will focus on demonstrating enhanced water recovery through secondary RO desalting of desupersaturated primary RO concentrate. In order to demonstrate secondary RO (SRO) desalting, desupersaturated primary RO concentrate from the CCESP system will be desalted using the UCLA cyclic RO system and/or UCLA mini RO system, both of which will be provided as in-kind. This task is divided into the following subtasks:

Subtask 5.1. Integrate a small-scale RO system for SRO desalting (1 month)

The UCLA cyclic system and/or UCLA mini RO system, both of which will be available for this task, will be field deployed. They will be connected and interfaced with the CCESP system though the UCLA SWTD unit supervisory monitoring and control system. Preliminary tests will be

conducted to verify synced operability of SRO desalting with CCESP concentrate desupersaturation.

Subtask 5.2. Assess maximum achievable water recovery enhancement (2 month)

The maximum achievable water recovery in secondary RO desalting will be assessed with the aid of UCLA MeMo, following the approach of **Task 1**. This will include optimization of make-up antiscalant dosage. Given target PRO water recovery levels of 70-75% or higher, target water recovery levels of at 40-67% or higher for SRO desalting would be sufficient for achieving overall AMRO-DISH water recovery levels of up to 90% or higher. The high salinity (50,000-80,000 mgl/L) and thus high osmotic pressure of the PRO concentrate, however, may necessitate the use of high permeability RO/NF membranes in order to keep SRO operation within the pressure limit (<1000 psi). Previous analysis indicated that water recovery levels of up to 93% for desalting PDD agricultural drainage are achievable with standard brackish/sea water RO membranes [20].

Subtask 5.3. Demonstrate continuous secondary RO operation (4 months)

The optimized secondary RO process will be continuously operated over a period of 3-4 months in order to demonstrate long-term performance. MeMo will be utilized to enable self-adaptive operation. Operation and maintenance logs will be kept to document operational requirements of SRO desalting. Periodic water samples (at least monthly) will be taken from the SRO feed, concentrate, and permeate.

Subtask 5.4. Perform membrane autopsy (1 month)

To verify effective membrane mineral scaling mitigation, lead and tail RO elements from SRO desalting will be removed for autopsy analysis at UCLA after the end of the demonstration period. Membrane autopsy will include visual inspection of the membrane element, optical analysis, and SEM-EDS analysis of membrane samples.

5.8 Task 6: Develop an Economic Process Cost Model based on Field Data

TASK 6 OVERVIEW

Performance Target & Measure

This task focus is to demonstrate the long-term cost performance of AMRO-DISH. The cost model to be developed in the task will enable assessments of process economics of a full-scale AMRO-DISH plant.

Milestone

Completion of this task is a partial requirement of meeting **Project Milestone 3**, demonstrated long-term operation and treatment cost performance.

Task Status: Ready to proceed in parallel with **Tasks 4-5**.

Task Schedule: 1/2/2017-4/30/2017

Salaries & Benefits: $ 9,047 (1.2 person months)

The task budget will provide salary support for the principal investigators and graduate student researchers for developing the process cost model and performing cost analysis.

Other Direct Costs: $ 3,046

Other direct costs for this task are primarily the GSR remission fee benefits.

In-Kind Contribution: $2,880

The principal investigator (Y. Cohen) will contribute time as in-kind.

Subtask 6.1. Collect cost data and organize relevant field operational data (2 months)

Based on equipment requirements of PRO, CCESP, and SRO, capital cost data will be compiled. Operating cost will be determined based real-time data on chemical dosing (e.g., antiscalant, coagulant, lime, gypsum seed), electrical power usage, as well as information from operation and maintenance logs (e.g., system cleaning, staff hours, consumables).

Subtask 6.2. Develop process cost model and perform cost analysis (2 months)

A process cost model will be developed to enable cost analysis of the AMRO-DISH process scale-up, as well as to evaluate cost performance. The process cost model will be implemented in a simple cost analysis tool (e.g., spreadsheet tool). The cost analysis tool will enable economic process analysis for on-farm drainage water treatment, reuse, and residual volume reduction. This will include evaluation of the potential of potable water and concentrate salt production to offset desalination treatment cost, including residual management (i.e., brine disposal).

5.9 TASK 7. PROJECT REPORTING & INVOICING

TASK 7 SUMMARY
Performance Measure/Target Timely submissions of all project deliverables, including reports and invoices per project schedule in **Tables 8.1-8.2**. **Task Status:** Ready to proceed in the first project quarter. **Task Schedule:** Quarterly Progress Report, Biannual Project Review Meetings, Final and Post-Completion Reports toward the end of project period. **Salaries & Benefits**: $ 6,150 (0.4 person months) The task budget will provide partial salary support the Principal Investigators for preparation, review, and submission of quarterly progress reports and final technical report. Financial reporting and post-completion report will be covered by indirect cost.

Task 7 is designed to ensure completion and timely submission of all project deliverables, which include quarterly progress reports, final technical report, post-completion report, and invoicing. This task will cover report preparation and review, as well as communication with DWR staff (including responding to DWR staff comments and questions). Biannual project meetings will be held with PDD and DWR staff for periodic review of project progress, direction, and plans, as well as to seek input on project matters.

6. Qualifications and Project Management

6.1 Personnel Qualifications, Roles, and Responsibilities

The qualifications, roles, and responsibilities of project personnel are described in the following sections, with biographical sketches of the key personnel given in **Section 6.2**. Roles and responsibilities of UCLA and PDD personnel are summarized in **Tables 6.1-6.2**.

6.1.1 Key Personnel

Dr. Yoram Cohen (Project Director (PD) and Principal Investigator (PI)), Professor of Chemical & Biomolecular Engineering and Director of the Water Technology Research Center at the University of California, Los Angeles (UCLA), will serve as the Project Director (PD) and Project Principal Investigator (PI). As a project director, Dr. Cohen will be responsible for execution of the grant and any of its amendments, as well as successful completion of all project tasks (Tasks 1-7). He will be responsible for reviewing and approving all project deliverables and invoices, as well as ensuring their timely submissions. As a Principal Investigator, Dr. Cohen be responsible for providing general guidance on the technical and scientific direction of the project, maintaining and promoting collaborations with project partners and industry affiliates, as well as developing general strategies for implementation of project tasks to meet project goal and objectives

Professor Yoram Cohen received his doctoral degree in Chemical Engineering from the University of Delaware. He has been on the faculty of the Department of Chemical and Biomolecular Engineering at the University of California, Los Angeles (UCLA) since 1981. Dr. Cohen has been actively involved in fundamental and applied research in the area of membrane-based separation, desalination, and reuse technologies for more than 35 years. He has been involved in directing and consulting various field demonstration projects, including field demonstration of novel UF-RO desalination system at US Naval Base Port Hueneme, high recovery desalination with intermediate precipitation in collaboration with Metropolitan Water District of Southern California, real-time membrane monitoring in collaboration with PDD, Orange County Water District, and pilot-scale RO desalination in collaboration with PDD. Dr. Cohen has over 250 publications and several patents in water technology, nanotechnology, separations processes, transport phenomena, polymer science, and environmental engineering, in addition to three environmental volumes. He is the founder and director of the Water Technology Research Center and the Center for Environmental Risk Reduction and a founding member of the UCLA/NSF Center for the Environmental Implications of Nanotechnology (CEIN). Dr. Cohen is an adjunct professor at Ben-Gurion University and a member of the International Advisory Committee to the Stephen and Nancy Grand Water Research Institute at the Technion. He was a visiting professor at the Technion (1987-1988), at Universitat Rovira i Virgili (2006) and a distinguished visiting professor at Victoria University (2006). Dr. Cohen is a UCLA Luskin Scholar

and a recipient of the 2008 Ann C. Rosenfield Community Partnership Prize in recognition of his environmental research. He received the 2003 Lawrence K. Cecil award in Environmental Chemical Engineering from the AIChE, as well as the AIChE Outstanding Paper Award (1997).

Dr. Anditya Rahardianto (Project Manager (PM) and Co-Principal Investigator (Co-PI)), Assistant Researcher at the at the UCLA Water Technology Research Center & UCLA Institute of the Environment will serve as Project Manager responsible for managing the project schedule and budget and for preparing project reports and final documentation. Dr. Rahardianto will work closely with the project team members to track project progress, manage project resources, as well as coordinate with personnel from California DWR, Panoche Drainage District, and industry partners (Tasks 1-7). He will be responsible for preparing and submitting all project deliverables upon approval from the Project Director. As a Co-Principal Investigator, Dr. Rahardianto will contribute toward the technical and scientific direction of the project and be responsible for overseeing and guiding day-to-day implementation of project tasks.

Dr. Rahardianto received his B.S. degree from the University of Wisconsin-Madison and his Ph.D. degree from UCLA, both in Chemical Engineering. He has served as a researcher, project team coordinator, and lead engineer for various major projects over the last ten years in water treatment, seawater and brackish water desalination and water reuse, including the development, design, construction, and field deployment of prototype monitoring devices and advanced desalination systems. He was the UCLA project manager and lead engineer responsible for developing and designing the UCLA Smart Desalination unit, as well as overseeing its construction and field deployment. Dr. Rahardianto also coordinated field deployment and demonstration of a novel UF-RO system at the US Naval Base Ventura County. Over the past 10 years, Dr. Rahardianto has developed significant expertise in high recovery desalination of brackish water (including subsurface agricultural drainage water) and desalination concentrate treatment, co-authoring 9 scientific papers on the subject matter. His doctoral dissertation entitled “High Recovery Desalting of Brackish Water” formed the basis of the technology to be field-demonstrated in the proposed project (i.e., chemical enhanced seeded precipitation). In collaboration with Metropolitan Water District of Southern California, he co-wrote the early papers on the subject of intermediate chemical demineralization as an approach for attaining high recovery in brackish water desalination. Dr. Rahardianto has published over twenty scientific papers and book chapters on water desalination, membrane monitoring and characterization.

6.1.2 Day-to-Day Project Personnel

Two Graduate Student Researchers (GSR) will be involved in the project and work with the Project Manager on day-to-day implementation of project tasks both on-site and remotely from UCLA. The first graduate student (GSR 1) will be responsible for demonstrating and refining self-adaptive high recovery operation of the UCLA desalination unit with real-time membrane monitoring (Tasks 1 and 4). GSR 2 will be responsible for demonstrating and refining concentrate

salt harvesting using the UCLA CCESP system (Tasks 2-4). GSR 2 will also be responsible for demonstrating secondary RO desalting for enhancing product water recovery (Task 5). Both of the graduate students, as guided by the PI and Co-PI, will contribute in the development of process models for optimizing the process (Tasks 1-3), as well as the development of economic model for the treatment process (Task 6). Both GSRs will be responsible for developing and writing experimental procedures and methodologies, analyzing experimental results, and generating graphs and tables for project reporting. Undergraduate students will also participate in the proposed project as in-kind through the UCLA Student Research Program (SRP).

***Table 6.1**. List of UCLA personnel for the proposed project.*

UCLA PERSONNEL			
Name & Contact	**Roles**	**Responsibilities**	**Tasks**
Dr. Yoram Cohen P: (310) 825-8766 E: yoram@ucla.edu	Project Director, Principal Investigator	Execution of grant agreement and amendments, review and approval of project deliverables and invoices, overall guidance on project direction	1-7
Dr. Anditya Rahardianto P: (310) 948-7773 E: andi@ucla.edu	Project Manager, Co-Principal Investigator	Day-to-day project and budget management, interfacing with project partners, tracking and assigning project tasks, contribute to overall project direction, prepare/submit deliverables	1-7
Flora O'Brien P: 310-206-0807 F: 310-943-1654 E: flora.obrien@ research.ucla.edu	Authorized Representative	General grant administration, approval of all grant agreements and amendments as an Authorized Representative	7
Miguel Perez P: 310-825-1203 E: miguel@seas.ucla.edu	Fund Manager	Tracking of fund, purchasing, coordinate with UCLA EFM office for invoicing and financial reporting	7
Graduate Student 1 & 2 TBD	Project Personnel	Conducting field work on developing and demonstrating self-adaptive primary RO desalination; Developing methodologies, analyzing and summarizing results.	1,4,6
Graduate Student 2 TBD	Project Personnel	Conducting field work on developing and demonstrating concentrate salt harvesting and secondary RO desalination; Developing methodologies, analyzing and summarizing results.	2-6

6.1.3 Partnership with Panoche Drainage District

Partnership with Panoche Drainage District (see support letter in **Section 1.2**) will provide the necessary field infrastructure for conducting the proposed project, including provision of secure space, drainage water supply, electricity, waste management, and field personnel support. Panoche Drainage District, which serves approximately 44,000 acres, focuses in drainage management efforts that are part of a regional Westside Integrated Water Resources Plan. The plan includes coordination of drain water supplies, partnerships to avoid conflicts with farms and wetlands, saline management of groundwater supplies and practices that address selenium, salt, boron and dissolved oxygen in water resources. Panoche Drainage District (PDD), represented by Dennis Falaschi (General Manager) and Chris Linneman (Consultant), will contribute to the direction of the proposed project through regular meeting with the UCLA team. The Project Manager will closely coordinate with PDD personnel (Betty Lindeman and Jeff Moore) to ensure that Tasks 1-6 will operate in accordance to all relevant environmental and safety guidelines. PDD will also help in reviewing project results and providing recommendations in order to ensure consistency of project efforts with overall drainage water management efforts in the region.

***Table 6.2**. List of Panoche Drainage District personnel for the proposed project.*

PANOCHE DRAINAGE DISTRICT PERSONNEL			
Name & Contact	**Role**	**Responsibility**	**Tasks**
Dennis Falaschi, P: 209-364-6136 E: dfalaschi@aol.com	PDD General Manager	Oversee collaboration with UCLA	1-6
J. Christopher Linneman, P.E. P: 559-582-9237 E: linneman@summerseng.com	Consultant to PDD	Oversee UCLA collaboration, assist in reviewing project results and recommendations	1-6
Betty Lindeman, P: 209-364-6136 E: blindeman@panochewd.org	PDD field personnel	Provide field support	1-6
Jeff Moore, P: 209-829-9133 E: jmoore@panochewd.org	PDD field personnel	Provide field support	1-6

6.1.4 Grant Administration and Financial Management.

Grant administration will be handled by the UCLA Office of Contract and Grants, with Flora O'Brien serving as the designated UCLA Authorized Representative for the proposed project. As a Senior Grants Analyst, she is responsible for administering grant awards and will be the main contact for all administrative matters of the proposed project grant. Financial management including accounting, invoicing, financial reporting, and auditing will be handled by the UCLA Extramural Fund Management (EFM) Office and coordinated by Miguel Perez, the finance manager at the UCLA Department of Chemical and Biomolecular Engineering.

6.2 Key Personnel Biographical Sketch

Yoram Cohen, Ph.D.

Professor, UCLA Chemical & Biomolecular Engineering Department

420 Westwood Plaza, 5531 Boelter Hall, Los Angeles, CA 90095-1592

Email: yoram@ucla.edu; Web: www.watercenter.ucla.edu; Tel.: (310) 825-8766

Professional Preparation

University of Toronto, Chemical Engineering, B.A.Sc. (1975), M.A.Sc. (1977)
University of Delaware, Chemical Engineering, Ph.D. (1981)

Appointments

1991 - Present Professor, Chemical Engineering Department, UCLA
2012 - Present Professor, UCLA Institute of the Environment and Sustainability
2005 - Present Director, Water Technology Research Center (UCLA)
1995 - 2008 Director, Center for Environmental Risk Reduction (UCLA)
2008 - Present Adjunct Professor, Ben-Gurion University
1995 - 1996 Vice-Chair, Department of Chemical Engineering, UCLA
1992 - Present Affiliate Faculty, UCLA Env. Science and Engineering Program
2007 - Present Member, California NanoScience Institute
2008 - Present Member, UCLA/NSF Center for Env. Implications of Nanotechnology
1994 - Visiting Professor, Universitat Rovira i Virgili, Spain
1987 -1992 Director, UCLA/EPA National Center for Intermedia Transport Research
1981- 1999 Assistant (1981-1985) & Associate (1986-1990) Professor, Chemical Engr. Dept., UCLA

Awards, Honors, and Distinction

- Fellow of the American Institute of Chemical Engineers (Elected 2009)
- UCLA Luskin scholar (2009 - present)
- Ann C. Rosenfield Distinguished Community Partnership Prize (2008)
- Distinguished Visiting Professor (2006, Victoria University, Australia
- Member, Blue Ribbon Committee, Metropolitan Water District of Southern CA (2010-2011)
- 2012 California Governor's Green Chemistry Award to the UCLA Center for Environmental
- Implications of Nanotechnology (Dr. Cohen is Co-PI and CO-founder of the CEIN)
- Distinguished Visiting Lecturer, Ben-Gurion Univ., July/August 2012
- Chair, AIChE Separations Division, 2008 (Vice Chair, 2006-2007)
- AIChE, Lawrence K. Cecil Award in Environmental Chemical Engineering (2003)

- Outstanding Research Paper (1997 & 2008), AIChE Separations Division
- Board Member, North American Membrane Society, 2004-2007
- Member, Int. Sci. Advisory Committee, Water Res. Center, Israel Inst. Technol. (2004-2007)
- Lady Davis Fellow, Technion, Israel (1987-1988; 1995)
- Del Amo Research Fellowship (1994-1995)
- Chair, AIChE Env. Division, 2002 (Vice-Chair, 2000-2001)
- Member, National Res. Council Board on Environ. Studies and Toxicology (1989-1992)
- Associate Editor, J. Exposure Analysis & Env. Epidemiology (1991- 1994)
- Member, USEPA Science Advisory Board, 1987-1990
- Recognition for Community Service for the Protection of Public Health
- County of Los Angeles Commendation, 2008 - recognition of service to Los Angeles County
- California Senate Certificate of Recognition, 2008 – contributing to legislation to protect public health; Certificate of Special Congressional Recognition (US) for service to the community (2008)

Research Interests and Expertise

Environmental transport of nanoparticles, exposure and risk analyses, cognitive systems for process analysis, machine learning of physicochemical properties and toxicity (chemicals and nanoparticles), nanoinformatics, membrane science and technology, sorption processes, water decontamination, development of high efficiency NF/RO membranes, membrane process optimization and control, water treatment systems.

Professional Societies

- American Institute of Chemical Engineers (AIChE)
- American Chemical Society (ACS)
- American Water Works Association (AWWA)
- American Membrane Technology Association (AMTA)
- North American Membrane Society (NAMS)

Research Products

Dr. Cohen has published more than 250 research papers and book chapters and presented more than 400 papers and 140 invited seminars.

Five Products Most Closely Related to the Proposed Project

1. Y. Cohen, B. McCool, A. Rahardianto, M.-m. Kim, J. Faria, Membrane Desalination of Agricultural Drainage Water, in: A.C. Chang, D. Brawer Silva (Eds.) Salinity and Drainage in San Joaquin Valley, California, Springer Netherlands, 2014, pp. 303-342.

2. B.C. McCool, A. Rahardianto, J.I. Faria, Y. Cohen, Evaluation of chemically-enhanced seeded precipitation of RO concentrate for high recovery desalting of high salinity brackish water, Desalination, 317 (2013) 116-126.
3. J. Thompson, A. Rahardianto, H. Gu, M. Uchymiak, A. Bartman, M. Hedrick, D. Lara, J. Cooper, J. Faria, P.D. Christofides, Rapid field assessment of RO desalination of brackish agricultural drainage water, Water Res, 47 (2013) 2649-2660.
4. B.C. McCool, A. Rahardianto, Y. Cohen, Antiscalant removal in accelerated desupersaturation of RO concentrate via chemically-enhanced seeded precipitation (CESP), Water Res, 46 (2012) 4261-4271.
5. A. Rahardianto, B.C. McCool, Y. Cohen, Accelerated desupersaturation of reverse osmosis concentrate by chemically-enhanced seeded precipitation, Desalination, 264 (2010) 256-267.

Five Other Significant Products

1. Pascual, X., H. Gu, A. Bartman, R. Zhu, A. Rahardianto, J. Giralt, R. Rallo, P. D. Christofides, Y. Cohen, "Fault Detection and Isolation in Spiral-Wound RO Desalination," Ind. Eng. Chem. Res., 53 (2014) 3257–3271.
2. Gao, L., A. Rahardianto, H. Gu, P. D. Christofides, and Y. Cohen, "Energy-Optimal Control of RO Desalination," I&EC, 53 (2014) 7409–7420.
3. Sagiv, A., A. Zhu, P. Christofides, Y. Cohen, R. Semiat, "Analysis of Forward Osmosis Desalination via Two-Dimensional FEM Model," J. Membrane Sci., 464 (2014) 161–172.
4. Gu, H., A. R. Bartman, M. Uchymiak, P. D. Christofides and Y. Cohen, "Self-Adaptive Cyclic Feed Flow Reversal Operation of Reverse Osmosis Desalination," Desalination, 308 (2013) 63-72.
5. J. Thompson, N. Lin, E. Lyster, R. Arbel, T. Knoell, J. Gilron, Y. Cohen, RO membrane mineral scaling in the presence of a biofilm, J. Membrane Sci., 415–416 (2012) 181-191.

Synergistic Activities

- Pioneered multimedia approach to environmental impact assessment; developed educational & commercial software;
- Developed new courses in membrane technology, pollution prevention and env. assessment;
- Contributed to community understanding of environmental contamination through Federal and State review and advisory committees & superfund site assessments;
- Developed membranes and membrane-based processes for water desalination and pervaporation; (5) Established and directed three major academic research centers over a period of 30 years (The EPA National Center for Intermedia Transport research; The UCLA Center for Environmental Risk Reduction and the UCLA Water Technology Research Center).

Anditya Rahardianto, Ph.D.

Assistant Researcher, UCLA Chemical & Biomolecular Engineering Department

420 Westwood Plaza, 5531 Boelter Hall, Los Angeles, CA 90095-1592

Email: andi@ucla.edu; Web: www.watercenter.ucla.edu; Tel.: (310) 948-7773

Professional Preparation

2009 - Ph.D, Chemical Engineering, University of California, Los Angeles
2001 - B.S., Chemical Engineering, University of Wisconsin - Madison

Appointments

- Assistant Researcher, Chemical and Biomolecular Engineering Department, UCLA (4/2014-Present)
- Assistant Researcher, Institute of the Environment & Sustainability, UCLA (4/2014-Present)
- Postdoctoral Scholar & Lecturer, Chemical Engineering Department, UCLA (2011-3/2014)
- Staff Research Associate, Water Technology Research Center, UCLA (2008-2009, 2010-2011)
- Process Development Scientist, Envirosoft Corporation, Los Angeles, CA (2009-2010)
- Graduate Student Researcher, Chemical Engineering Department, UCLA (2003-2008)
- Process Engineering Co-op, Uniqema, Chicago, IL (2000)

Research Products

Journal articles: 20, Book chapters: 2, Patent applications: 2, Conference abstracts/proceedings: 25+, Citations: 592, h-index: 14
Publication List: http://scholar.google.com/citations?user=Hve13rQAAAAJ&hl=en

Five Products Related to Proposal

1. B.C. McCool, A. Rahardianto, J.I. Faria, Y. Cohen, Evaluation of chemically-enhanced seeded precipitation of RO concentrate for high recovery desalting of high salinity brackish water, Desalination, 317 (2013) 116-126.
2. J. Thompson, A. Rahardianto, H. Gu, M. Uchymiak, A. Bartman, M. Hedrick, D. Lara, J. Cooper, J. Faria, P.D. Christofides, Rapid field assessment of RO desalination of brackish agricultural drainage water, Water Res, 47 (2013) 2649-2660.
3. B.C. McCool, A. Rahardianto, Y. Cohen, Antiscalant removal in accelerated desupersaturation of RO concentrate via chemically-enhanced seeded precipitation (CESP), Water Res, 46 (2012) 4261-4271.
4. A. Rahardianto, B.C. McCool, Y. Cohen, Accelerated desupersaturation of reverse osmosis concentrate Precipitation, Desalination 264 (2010) 256-267.
5. Y. Cohen, B. McCool, A. Rahardianto, M.-m. Kim, J. Faria, Membrane Desalination of Agricultural Drainage Water, in: A.C. Chang, D. Brawer Silva (Eds.) Salinity and Drainage in San Joaquin Valley, California, Springer Netherlands, 2014, pp. 303-341.

Five Other Significant Products

1. L. Gao, A. Rahardianto, H. Gu, P. Christofides, Y. Cohen, Energy-Optimal Control of RO Desalination, Ind. Eng. Chem. Res. 53 (2014) 7409.
2. X. Pascual, H. Gu, A. Bartman, A. Zhu, A. Rahardianto, J. Giralt, R. Rallo, P. Christofides, Y. Cohen, Fault Detection and Isolation in Spiral-Wound RO Desalination Plant, Ind. Eng. Chem. Res. 53 (2014) 3257
3. C.J. Gabelich, M.D. Williams, A. Rahardianto, J.C. Franklin, Y. Cohen, High-recovery reverse osmosis desalination using intermediate chemical demineralization, Journal of Membrane Science, 301 (2007) 131-141.
4. A. Rahardianto, J. Gao, C.J. Gabelich, M.D. Williams, Y. Cohen, High recovery membrane desalting of low-salinity brackish water: Integration of accelerated precipitation softening with membrane RO, Journal of Membrane Science, 289 (2007) 123-137.
5. A. Rahardianto, W.-Y. Shih, R.-W. Lee, Y. Cohen, Diagnostic characterization of gypsum scale formation and control in RO membrane desalination of brackish water, Journal of Membrane Science, 279 (2006) 655-668.

Synergistic Activities

Interests & Expertise:

- Fundamentals of Membrane-Based Separations
- High Recovery Brackish Water Desalination
- Desalination Concentrate Treatment and Salt Harvesting
- Development and Design of Water Treatment and Desalination Systems
- Process Control of Membrane-Based Separations Systems
- Cyber-infrastructure of Distributed Water Systems
- Real-Time Monitoring of Membrane Fouling/Mineral Scaling
- Rea-Time Monitoring of Membrane Integrity

Research Interests:

My main interests are in research, development, and application of novel, advanced process, materials, and systems technologies for desalination and water purification, including water systems cyber-infrastructure & decision support tools. Recently, my work has focused on a new, emerging concept of smart water systems for distributed water treatment for municipal, agricultural, and industrial applications, as well as for remote/disadvantaged communities. This concept targets the crucial need for upgrading the nation's aging centralized water infrastructure, as well as for augmenting dwindling fresh water supplies with new potable water production from alternative water sources (seawater, brackish groundwater, and contaminated water).

Peer Reviews of International Journals:

Environmental Science & Technology, Journal of Membrane Science, Desalination, Water Research, Chemical Engineering Science

6.3 INSTITUTIONAL CAPACITY

The University of California Los Angeles (UCLA) primary purpose as a public research university is "the creation, dissemination, preservation, and application of knowledge for the betterment of global society". UCLA consistently ranks among the top five universities and colleges in total research and development spending. UCLA has a long tradition of research in water technology, including being the first (in 1959) to demonstrate reverse osmosis (RO) as a practical process. The UCLA Water Technology Research (WaTeR) Center (www.watercenter.ucla.edu) is continuing this tradition, advancing water technologies through science-based innovation, technology evaluation, advanced education, and rapid information dissemination. The UCLA WaTeR Center has extensive experience in multidisciplinary research and field demonstration projects. The Center has carried out numerous projects in collaboration with industry and water agencies, including projects with the US Office of Naval Research, California DWR, Panoche Drainage District, US Bureau of Reclamation, US Environmental Protection Agency, Metropolitan Water District of Southern California (MWD), as well as various water foundations (e.g., WateReuse, NWRI, AWWA) and industry sponsors. Recent WaTeR Center research efforts have led to the development of novel RO process scaling and fouling monitoring approaches; new class of surface nano-structured fouling/scaling resistant membranes; new high recovery/near-zero liquid discharge desalination processes; advanced monitoring, optimization, and control of membrane processes; smart integrated membrane system for industrial wastewater treatment and for shipboard seawater desalination; and smart mobile water treatment and desalination unit.

6.3.1 Field Facility

In partnership with Panoche Drainage District and industry affiliates (Georg Fischer, Grundfos Pumps Corporation, CJI Process Systems, Inge/BASF, Toray Membrane USA and BWA Water Additives), a ready-to-use field facility will be available as in-kind for conducting the proposed project. The field facility includes a fully deployed mobile, containerized desalination unit with 30 gallon/minute feed capacity (**Fig. 6.1**). The UCLA desalination mobile unit is fully automated and is equipped with:

- self-cleaning centrifugal separator and screen filters for particle removal (>300 micron),
- an inline chemical coagulation system,
- an advanced multi-bore ultrafiltration system for fine particle and colloid removal (>0.02 micron),
- an RO system (with 4" RO elements) reconfigurable to single- and two-stage operations, as well as two-pass operations,
- a feed (150 gal.) tank, reconfigurable to a chemical cleaning tank,
- UF filtrate and RO permeate collection tanks (400 gal. each),
- high performance multi-stage centrifugal pumps with variable frequency drive,
- fully automated flow and pressure controls with electrically actuated valves,
- chemical dosing systems for coagulant, pH adjustment, antiscalants, chemical cleaning

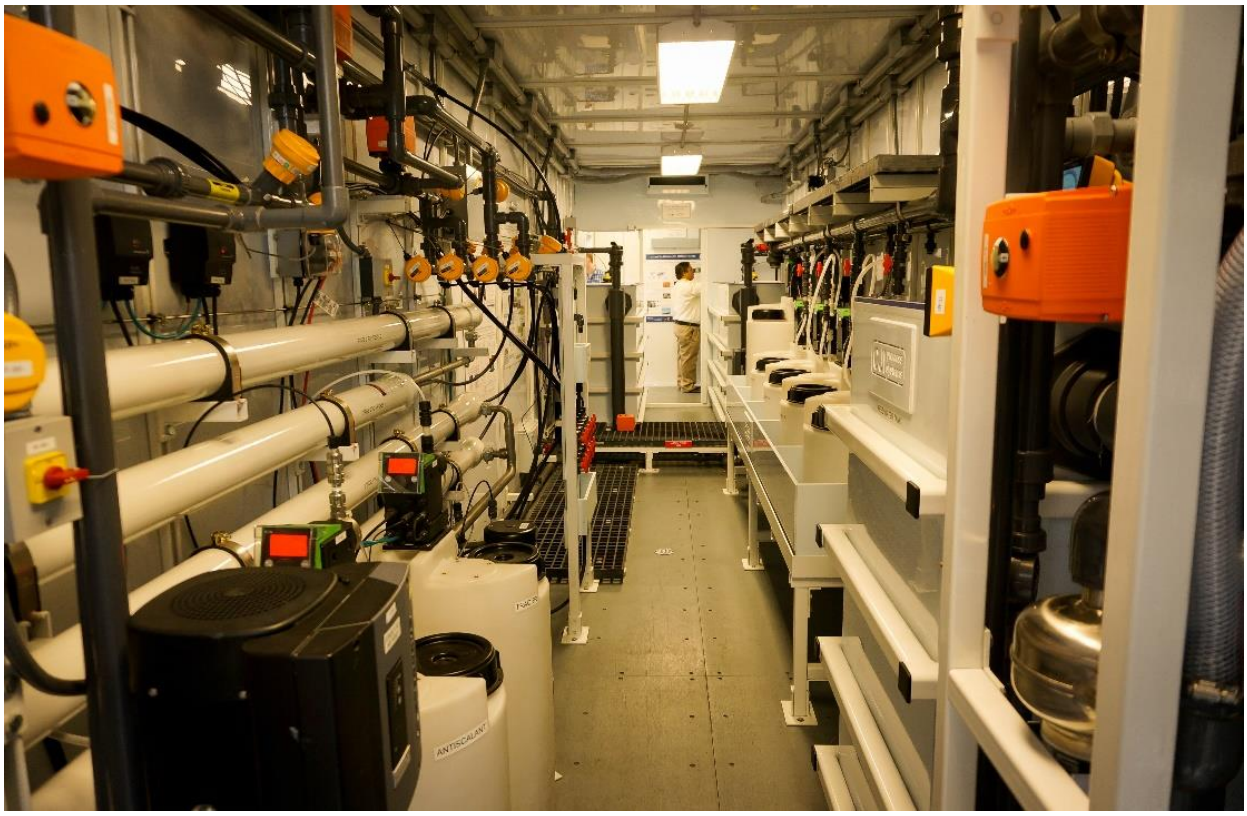


Figure 6.1. *UCLA smart water treatment and desalination mobile unit, field deployed at Panoche Drainage District Treatment site near Firebaugh, CA.*

- a full suite of online sensors for flow, pressure, pH, ORP, temperature, energy consumption, valve positions, and turbidity
- centralized electrical distribution panel
- advanced control system with embedded computing for plant monitoring and autonomous control
- 4G wireless internet connection, enabling full remote control of plant operation
- a separate operator room with touch-panel plant controls
- air conditioning and exhaust fans
- stream sampling points

Figure 6.2. *Field infrastructure at Panoche Drainage District treatment site, supporting operation of the UCLA desalination mobile unit. PDD RP-1 irrigation ditch is covered under existing PDD CEQA and NEPA permits.*

The UCLA mobile desalination unit is currently deployed inside a secure 6000 ft^2 test area at the Panoche Drainage District (PDD) treatment site (see **Figs. 2.1, 1.5 and 2.6** in **Section 2**). Continuous drainage water supply (15,000-20,000 mgl/L TDS) is available from PDD Tile Sump No. 3 (**Fig. 6.2**), which is equipped with a submersible pump that is capable of delivering 35-40 gallon/minute of drainage water to the UCLA desalination unit. A sand filter and hydro-pneumatic tanks (**Fig. 6.2**) are also available at the test area for pre-filtration of the drainage water prior to entering the UCLA desalination unit. RO unit process stream discharge is directed to the RP-1 agricultural ditch (**Fig. 6.2**), which is owned and operated by PDD and is covered by existing CEQA and NEPA permits. The UCLA desalination unit is already fully operational at the PDD treatment site, capable of desalting drainage water (17,000 mg/L TDS) up to a water recovery of 60% (**Fig. 6.3**). It is anticipated that further process optimization under the proposed project will allow primary RO operation up to 70-75% recovery.

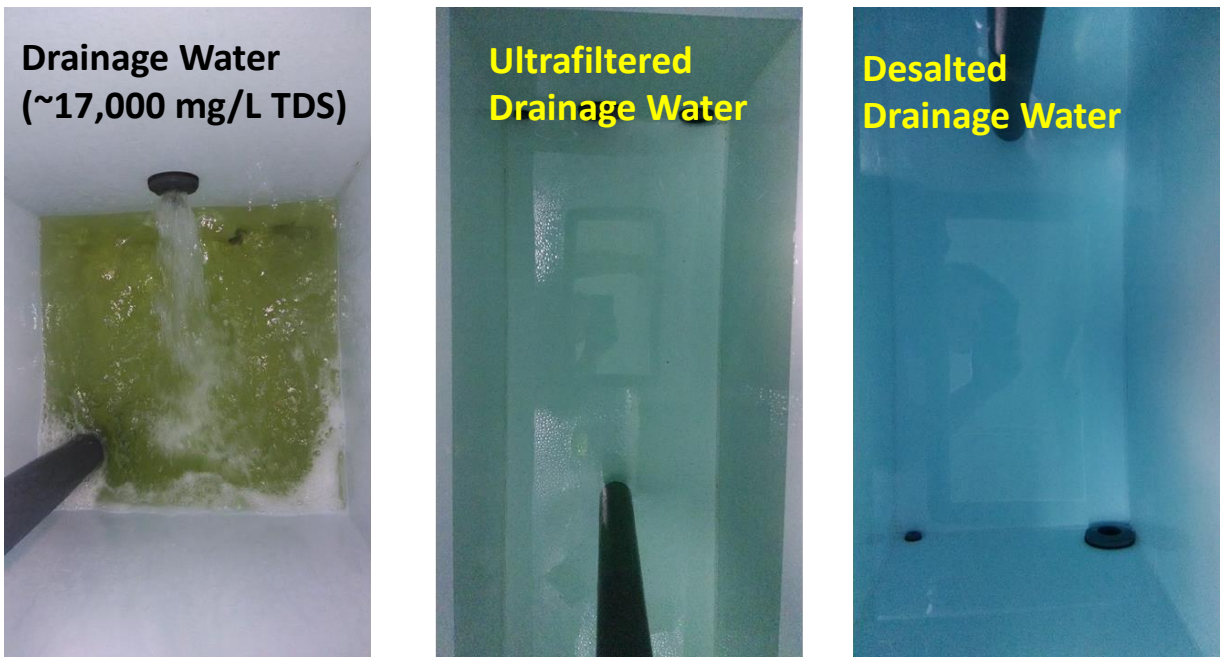


Figure 6.3. *Images of drainage water treated at the UCLA mobile desalination unit. Source water: PDD tiles sump 3.*

6.3.2 Other Specialized Equipment for Field Deployment

The following specialized equipment will be field deployed and utilized in the proposed project as in-kind:

1. ***Novel Membrane Monitoring Systems***

   Two novel membrane monitoring systems will be available for use in the proposed project. The UCLA ***Membrane Monitor (MeMo)*** is a novel platform for real time monitoring of

membrane fouling and scaling (**Fig.6.4a**). MeMo is currently interfaced with the RO system in the UCLA mobile desalination unit. MeMo, with automated image analysis, allows for real-time tracking of membrane mineral scaling, enabling feed-back control of the RO system in order to ensure effective mitigation of membrane mineral scaling. The ***Pulse Injection Membrane Integrity Monitor (PIMIM)*** system, which will be deployed in the mobile unit in January 2015, is a novel real-time and on-line membrane integrity monitoring system was developed specifically for monitoring RO/NF plants and is capable of demonstrating greater than 4 log removal detection.

Figure. 6.4*. (a) UCLA novel membrane monitor (MeMo) for real-time detection of membrane fouling and mineral scaling. (b) UCLA continuous chemical enhanced seeded precipitation system for concentrate salt harvesting*

2. *Concentrate Salt Harvesting System*

A Continuous Chemically-Enhanced Seeded Precipitation (CCESP) System will be available for use as in-kind in the proposed project for concentrate salt harvesting (**Fig. 6.4.b**). The CCESP system is currently at the UCLA WaTeR center laboratory and will be field deployed and integrated with the UCLA desalination unit for the proposed project. This system was recently

designed and constructed using equipment grant received from the UC Discovery program. With a feed capacity range of 0.05-0.5 gal/minute, the system consisted of three main integrated units: a) rapid mixing reactor, b) flocculation unit with centrifugal separator, and c) a vertical, moving bed reactor. The system has programmable embedded computing for automated monitoring and control process flow rates and directions, as well process solids handling. A sampling cell was developed to enable online measurements of pH, temperature, and calcium ion activity.

3. *Systems for Secondary RO desalination*

Two systems are available for secondary RO desalting of the desupersaturated concentrate from the concentrate harvesting system. The **UCLA cyclic RO system** (**Fig. 6.5a**) is a low energy, DC-powered RO system capable of treating water with a wide range of salinity (contaminated/brackish water to seawater). This small pilot system is very flexible, capable of operating optimally at variable water recovery from 10% to 90%. Designed for emergency and portable applications, the UCLA cyclic RO system has a production capacity of 400 gallon/day with capabilities for remote monitoring and control via high-speed wireless connectivity. The **UCLA mini RO system** (**Fig. 6.5b**) is fully-instrumented modular RO system, designed for high pressure RO applications. Capable of treating up to 6,500 gallon/day of feed water, the system is equipped with 6 x 2.5" RO elements and a high pressure pump (up to 1000 psi) with variable frequency drive, along with a suite of online sensors (including a dedicated MeMo). The system can operate with concentrate recycling in order to achieve high recovery levels (up to 85%). The UCLA mini RO system is slated to be completed in January 2015.

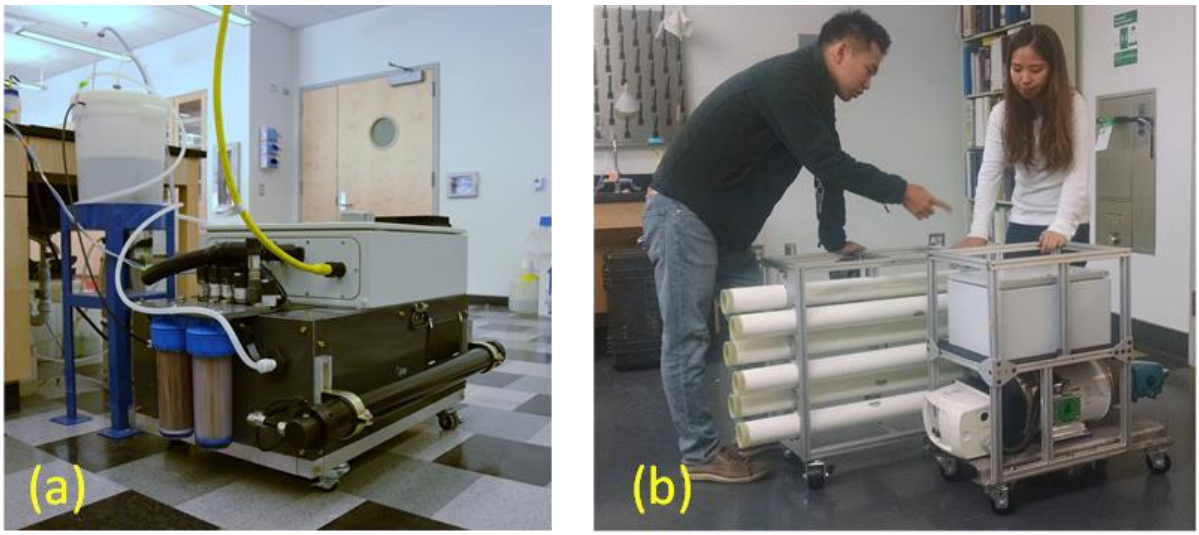
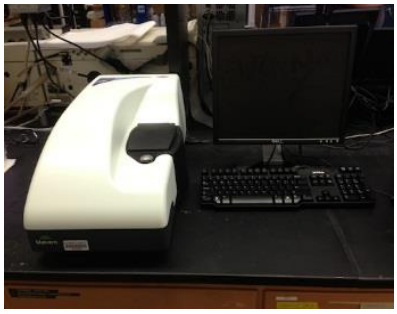


***Figure. 6.5**. (a) UCLA novel cyclic RO system. (b) UCLA mini RO system.*

6.3.3 General Laboratory Facility

The proposed project will benefit from direct access to water quality laboratory at the UCLA Water Technology Research (WaTeR) center, as well as analytical instruments at various UCLA shared facilities. The WaTeR Center dedicated water technology laboratories (>3,000 ft^2 lab space) are located at UCLA School of Engineering & Applied Sciences. The UCLA WaTeR Center dedicated water technology laboratories and test facility are equipped with advanced capabilities for development, optimization and testing of membrane process systems membrane characterization, and water quality analysis (http://watercenter.ucla.edu). Various equipment and analytical instruments are available at the WaTeR center to support the proposed project, particularly the following equipment:

1. Particle Size Analysis Instrumentation



Particle analysis will be important for characterizing particles generated or grown during the CCESP process. Instruments for particle analysis based on electrical sensing zone analysis and dynamic light scattering are available at the WaTeR center laboratory. The Beckman Coulter Multisizer 3 Coulter Counter Particle Analyzer is used for quantifying particle number, volume, mass, and surface area size distributions in one measurement via the Coulter principle (i.e., electrical sensing zone method). The overall sizing range is 0.4 µm to 1,200 µm. The Malvern Zetasizer Nano S90 can measure particle sizes in the range of 0.3nm to 5 µm and molecular weight measurements down to 9,800Da via a 90 degree scattering laser with a wavelength of 633nm. Both instruments are available for dedicated use for the project. If needed, additional instruments for particle size analysis are also available at the UCLA Molecular Instrumentation Center at hourly rate basis.

2. Organic Carbon Analyzer

A central component of the proposed project will be in quantifying antiscalant removal in the partial precipitation softening stage of CCESP. For this purpose, an organic carbon analyzer is available at the WaTeR center for dedicated use. The Aurora 1030D is equipped to perform both heated persulfate wet oxidation and high temperature combustion techniques on the same instrument. Both wet oxidation and

combustion modes process aqueous samples for analysis of the total organic carbon (TOC), total inorganic carbon (TIC), and non-purgeable organic carbon (NPOC) content of the samples. The detection range for the persulfate wet oxidation method is between 2 ppb to 30,000 ppm of organic carbon; while the detection range for the combustion method is 100 ppb - 30,000 ppm of organic carbon. The Aurora 1030D Dual Oxidation Mode TOC Analyzer is equipped with the 1088 Rotary Autosampler.

3. Batch Precipitation System

A Batch Precipitation System is available for the project to conduct bench-scale experiments for understanding the kinetics of CESP process. The system consisted of batch reactor cells and on-line pH and calcium ion probes. The adjustable agitator enables a wide range of mixing from rapid to slow gentle mixing. Real time measurement of pH and calcium activity is accomplished via a computerized system.

Various advanced equipment are available through shared instrumentation facilities at UCLA campus, including shared facilities at the California NanoSystems Institute (http://www1.cnsi.ucla.edu/staticpages/facilities). The following instruments and analytical services are also available at hourly or service basis in support of membrane autopsy and water quality analysis work in the proposed project:

1. *Scanning Electron Microscopy with Elemental Analysis*

The UCLA Molecular Instrumentation Center provides instrumentation access to scanning electron microscopy (JEOL JSM-6700F FE-SEM) with Energy-dispersive X-ray spectroscopy (http://www.mic.ucla.edu), which will be utilized for membrane autopsy in the proposed project. The UCLA inductively coupled plasma-mass spectrometer.

2. *Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) Facility*

The UCLA ICP-MS facility (http://ehs.ph.ucla.edu/news/icp-ms-facility-ehs), hosted by the UCLA School of Public Health, provides analytical services for elemental analysis of water samples at a nominal fee. The ICP-MS facility will be utilized in the proposed project for analysis of water quality, as well as assessment of solid purity.

6.3.4 Computational Facility and Software

The project will have direct use of a dedicated computational facility (directed by the PI) consisting of high performance servers, four high-end workstations and two in-house computational clusters. The main computational cluster is comprised of 22 computation nodes with 240 CPUs, 536 GB RAM, and 51 TB of storage capacity. The Linux based cluster is built with the Rocks Cluster, using the Oracle Grid Engine batch-queuing system. The cluster is managed

and its performance monitored continuously via an array of open source infrastructure monitoring utilities such as Ganglia, Nagios, OpenIPMI, etc. Various compilers (e.g. C, C++, Python) as well as computing environments (e.g. MATLAB, R, Java) are also running on the cluster. The cluster includes backup equipment and web-based applications for high volume data storage and management. The collaboration and data management (CDM) server hosts research group sites, as well as a Data Repository site for the sharing of files/data among internal and external groups. The site allows individual users and groups to build their own sub-sites for data storage with appropriate security measures. There is a protocol for document (data and metadata) submission/uploading (to the Data Repository) with an advanced search and report generation.

Available at the WaTeR center, the following licensed software will utilized for the project:

- NI Labview will be utilized for developing custom real-time monitoring and control of the in support of the project.
- OLI Stream Analyzer will be utilized for multi-electrolyte thermodynamic analysis, which is important for characterizing precipitation driving force of the various CCESP process streams. The software enables single- and multiple-point equilibrium calculations for trend analysis for temperature, pressure, pH and composition effects of complex multi-electrolyte systems.

6.4 Project Management and Communication Plan

6.4.1 Management Structure and Personnel Time Allocation

The project management structure for the proposed project is shown in **Fig. 6.6**. Project management will be the responsibility of the project director (PD), Dr. Yoram Cohen, assisted by the project manager (PM), Dr. Anditya Rahardianto. All matter related to grant administration will be handled by the UCLA Office of Contracts and Grants, with Flora O'Brien as the designated Authorized Representative. Financial accounting, reporting, and invoicing will be handled by the UCLA Extramural Fund Management (EFM) office and will be coordinated by Miguel Perez, the fund manager. Two graduate student researchers (GSR) will work on various aspects of the project and will report directly to the PD with day-to-day supervision by the PM.

In order to ensure the attainment of project goal and objectives within the two-year project timeline, each project task will be assigned specific personnel with sufficient personnel time to be allocated for each project tasks, as summarized in **Table 6.2**. A total of 9.9 person months will be allocated in each year, with Task 1-3 to be conducted in parallel in Year 1 and Tasks 4-6 to be conducted in parallel in Year 2. The PD will be responsible for general management of each task. The PM will be taking day-to-day responsibility in coordinating direct and support personnel to ensure timely completion of each project tasks.

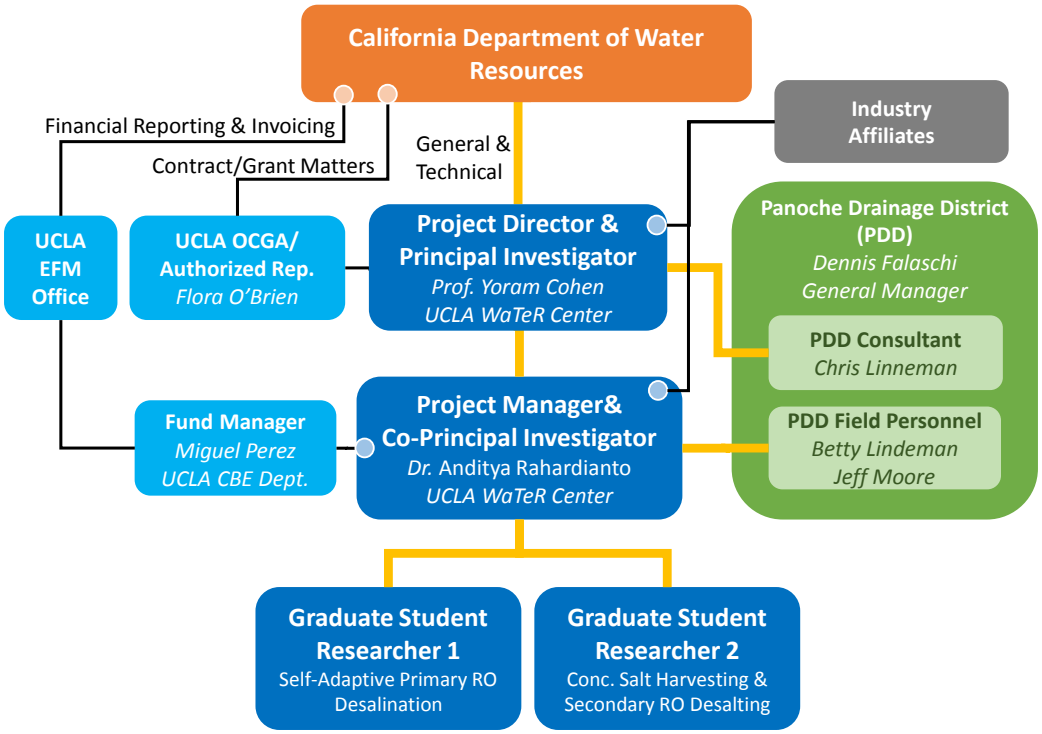


Figure 6.6. *Project management structure of the proposed project.*

Table 6.2*. Summary of task duration and personnel time allocations for the proposed project. Note that Tasks 2 and 3 are in parallel with Task 1, while task 5 and 6 in parallel with Task 4.*

YEAR	TASK	TASK DESCRIPTION	DURATION (MONTHS)	PERSONNEL TIME (PERSON MONTHS)	DIRECT PERSONNEL	SUPPORT
Year 1	1	Optimize Primary RO (PRO) Desalting	12.5	3.8	PD, PM, GSR 1	PDD
	2	Evaluate CCEP Salt Harvesting Process Requirements	6.5	3.0	PD, PM, GSR 2	PDD
	3	Optimize CCESP for Efficient Concentrate Salt Harvesting	6	3.0	PD, PM, GSR 2	PDD
Year 2	4	Demonstrate PRO Desalting with Conc. Salt Harvesting	10	4.4	PD, PM, GSR 1, GSR 2	PDD
	5	Demonstrate Enhanced High Recovery Desalting	8	4.0	PD, PM, GSR 2	PDD
	6	Develop an Economic Process Cost Model	4	1.2	PD, PM, GSR 1, GSR 2	PDD
Year 1-2	7	Project Reporting & Invoicing	Quarterly	0.4	PD, PM	Fund Manager, UCLA EFM

PD: Project Director, PM: Project Manager, GSR: Graduate Student Researcher, PDD: Panoche Drainage District, EFM: Extramural Fund Management Office

6.4.2 Maintenance of Partnerships and Collaborations

Continual engagement of project partners and collaborators are paramount to the success of the proposed project. In order to ensure that the project overall direction is consistent with the Drainage Reuse Grant Program priorities and Panoche's drainage management plan, the PD will be responsible in maintain regular communication with California DWR and Panoche Drainage District (as represented by PDD Consultant). This will be formally facilitated through quarterly technical progress reporting and bi-annual project review meetings. The PD will also continue to engage the WaTeR center's industry affiliates in fostering mutually beneficial collaboration, through existing consortium, which will benefit the proposed project. The PM will work closely with PDD field personnel through direct engagements and weekly briefings to ensure that the proposed project's field operations will be consistent with PDD daily drainage reuse activities. The PM will coordinate with PDD field personnel in maintaining consistent drainage water supply for and handling of residuals from the AMRO-DISH plant.

6.4.3 Internal Communication and Reporting

The UCLA team project implement a project management and communication plan that will feature:

- Frequent and clear communications among team members, as well as with key staff, to help identify issues early, enabling resolution before issues grow;
- Control of the schedule by developing a baseline schedule, regularly evaluating progress with task leaders, and resolving schedule variations;
- Regular monitoring of project costs, including bi-weekly review of expenditures; and
- Implementation of quality control overseen by senior personnel, including project team meetings and internal quality control reviews.

In facilitating the above, project task management and internal data sharing and reporting will be handled with the aid of Asana web application, which is currently already being implemented at UCLA WaTeR center. Asana is a web-based application for the effective collaboration of teams that enables users to plan and manage projects and tasks online, as well as sharing data and reports. The team will have daily briefings to discuss daily plans and issues, as well as weekly project review meetings to ensure continual project progress toward objectives and goal. Because of the distance between field site and UCLA, some meeting will be conducted only via the aide of Skype. In managing the project's budget and expenditure, the PM will have regular weekly briefings with the UCLA fund manager, who is responsible for tracking expenditures using UCLA accounting and fund management system.

6.4.4 Data Management and Sharing

Data to be generated in the proposed project include acquired data from online sensors in the AMRO-DISH plant, manually-collected experimental data and logs, and water quality data

from water quality laboratory. All data will be retained at existing UCLA WaTeR center data center, which feature the following attributes:

- Used as a central site for storing all data produced by the project team
- Arranged with only one level deep navigation with the use of metadata
- Web-based access to various functions such as editing/viewing file metadata properties or version controls for check-in and check-out of files.
- Details of search reports can be developed based on metadata information
- Automated workflow for review and acceptance of uploaded data files
- Security
- Authentication and authorization

A website is currently being developed to enable streaming of live data from the AMRO-DISH plant. It is anticipated that the website will be available by proposed project start data. The website will facilitate in sharing of live plant data with the project team, as well as project collaborators.

7. Project Budget and Justification

7.1 Budget Summary

The total project budget for the proposed two-year project is $ 518,074, with a proposed period of performance starting from June 15, 2015 to June 14, 2017. In meeting this budget, $300,000 (58%) is requested from CA DWR Drainage Reuse Grant Program, which will cover salaries and fringe benefits for UCLA project personnel, field study supplies, field site expenses, UCLA fees and indirect cost. In-kind contributions valued at $218,074 (42%) will include in-kind efforts by the Principal Investigator, as well as use of UCLA specialized field equipment and facility (including the UCLA mobile desalination unit) and Panoche Drainage District field infrastructure (e.g., secure space, drainage water supply, electricity, waste management, and field personnel support). A summary of project budget, organized by task and funding source is given in **Table. 7.1**. Detailed project budget by task are given in **Table 7.2** for Year 1 and **Table 7.3** for Year 2. Detailed project budget from DWR funds, organized by budget item is given in **Table 7.4**, along with details of the cost basis. Details on the value of in-kind contributions and their calculation basis are summarized in **Table. 7.5**. Budget justification are described in **Section 2**, with relevant cost documentation given in the Appendix in **Section 11**.

Table 7.1. *Summary of Project Budget. Period of Performance: 6/15/2015-6/14/2017.*

TASK	TASK DESCRIPTION	DWR FUNDS	INKIND	TOTAL BUDGET
1	Optimize Primary RO (PRO) Desalting for High Recovery Self-Adaptive Operation	$ 69,183	$ 88,729	$ 157,912
2	Evaluate CCEP Salt Harvesting Process Requirements	$ 40,968	$ 7,956	$ 48,925
3	Optimize CCESP Operation for Efficient Concentrate Salt Harvesting	$ 37,843	$ 7,956	$ 45,800
4	Demonstrate Continuous High Recovery PRO Desalting with Conc. Salt Harvesting	$ 77,562	$ 96,754	$ 174,317
5	Demonstrate Enhanced High Recovery Desalting via Secondary RO of Desupersaturated RO Concentrate	$ 53,932	$ 13,798	$ 67,730
6	Develop an Economic Process Cost Model based on Field Data	$ 14,361	$ 2,880	$ 17,241
7	Project Reporting & Invoicing	$ 6,150	$ -	$ 6,150
TOTAL		**$ 300,000** (58%)	**$ 218,074** (42%)	**$ 518,074**

Table 7.2. *Detailed Project Budget by Task for* ***Year 1*** *(6/15/2015-6/30/2016).*

TASK	TASK DESCRIPTION	CA DWR FUNDS					INKIND CONTRIBUTION			TOTAL COST (YEAR 1)
		Person Months	Salaries & Benefits	Other Direct Costs	Indirect Cost	Total DWR Funds (Year 1)	Salaries & Benefits	Infra-structure	Total Inkind (Year 1)	
1	**Optimize Primary RO (PRO) Desalting for High Recovery Self-Adaptive Operation**	**3.8**	**$ 23,981**	**$ 34,558**	**$ 10,644**	**$ 69,183**	$ 7,544	$ 81,185	**$ 88,729**	**$ 157,912**
1.1	Optimize RO feed pretreatment operations	1.1	$ 6,770	$ 9,756	$ 3,005	$ 19,532	$ 2,130	$ 22,920	$ 25,050	$ 44,582
1.2	Refine RO process model of primary RO desalting	1.2	$ 7,720	$ 11,124	$ 3,426	$ 22,270	$ 2,428	$ 26,133	$ 28,562	$ 50,832
1.4	Demonstrate self-adaptive high recovery operation of primary RO desalting	1.5	$ 9,491	$ 13,677	$ 4,213	$ 27,381	$ 2,986	$ 32,131	$ 35,117	$ 62,498
2	**Evaluate CCESP Salt Harvesting Process Requirements**	**3.0**	**$ 17,388**	**$ 16,983**	**$ 6,597**	**$ 40,968**	$ 3,772	$ 4,184	**$ 7,956**	**$ 48,925**
2.1	Deploy CCESP system at field test site	0.7	$ 4,060	$ 5,882	$ 1,540	$ 11,482	$ 881	$ 977	$ 1,858	$ 13,340
2.2	Determine CCESP process conditions for effective antiscalant removal	1.4	$ 8,032	$ 6,690	$ 3,048	$ 17,770	$ 1,742	$ 1,933	$ 3,675	$ 21,445
2.3	Demonstrate effective concentrate desupersaturation	0.9	$ 5,296	$ 4,411	$ 2,009	$ 11,716	$ 1,149	$ 1,274	$ 2,423	$ 14,139
3	**Optimize CCESP Operation for Efficient Concentrate Salt Harvesting**	**3.0**	**$ 17,388**	**$ 14,483**	**$ 5,972**	**$ 37,843**	$ 3,772	$ 4,184	**$ 7,956**	**$ 45,800**
3.1	Develop gypsum growth kinetics model for CCESP	2.1	$ 12,406	$ 10,333	$ 4,261	$ 27,001	$ 2,691	$ 2,985	$ 5,677	$ 32,678
3.2	Optimize gypsum solids harvesting operations	0.9	$ 4,982	$ 4,149	$ 1,711	$ 10,843	$ 1,081	$ 1,199	$ 2,280	$ 13,122
7	**Project Reporting & Invoicing**	**0.09**	**$ 946**	**$ -**	**$ 237**	**$ 1,183**	$ -	$ -	**$ -**	**$ 1,183**
7.1	Prepare and Submit Progress Reports & Invoicing	0.09	$ 946	0	$ 237	$ 1,183	$ -	$ -	$ -	$ 1,183
TOTAL COST (YEAR 1)		9.9	$ 59,704	$ 66,023	$ 23,450	**$ 149,178**	$ 15,088	$ 89,553	**$ 104,641**	**$253,819**

Table 7.3. *Detailed Project Budget by Task for* ***Year 2*** *(7/1/2016-6/14/2017).*

TASK	TASK DESCRIPTION	CA DWR FUNDS					INKIND CONTRIBUTION			TOTAL COST (YEAR 2)
		Person Months	Salaries & Benefits	Other Direct Costs	Indirect Cost	Total DWR Funds (Year 2)	Salaries & Benefits	Infra-structure	Total Inkind (Year 2)	
4	**Demonstrate Continuous High Recovery PRO Desalting with Conc. Salt Harvesting**	**4.4**	**$ 24,840**	**$ 41,037**	**$ 11,686**	**$ 77,562**	$ 7,201	$ 89,553	**$ 96,754**	**$ 174,317**
4.1	Demonstrate long-term self-adaptive PRO desalting with conc. salt harvesting	3.1	$ 17,745	$ 29,317	$ 8,348	$ 55,410	$ 5,144	$ 63,976	$ 69,121	$ 124,531
4.2	Collect samples and obtain water quality and solids purity data	0.75	$ 4,257	$ 7,032	$ 2,003	$ 13,291	$ 1,234	$ 15,346	$ 16,580	$ 29,871
4.3	Perform membrane autopsy	0.5	$ 2,838	$ 4,688	$ 1,335	$ 8,861	$ 823	$ 10,231	$ 11,053	$ 19,914
5	**Demonstrate Enhanced High Recovery Desalting via Secondary RO of Desupersaturated RO Conc.**	**4.0**	**$ 22,790**	**$ 22,629**	**$ 8,513**	**$ 53,932**	$ 5,761	$ 8,037	**$ 13,798**	**$ 67,730**
5.1	Integrate a small-scale RO system for SRO desalting	0.5	$ 2,681	$ 2,662	$ 1,001	$ 6,345	$ 678	$ 946	$ 1,623	$ 7,968
5.2	Assess maximum achievable water recovery enhancement	1.0	$ 5,745	$ 5,705	$ 2,146	$ 13,596	$ 1,452	$ 2,026	$ 3,478	$ 17,075
5.3	Demonstrate continuous SRO operation	2.0	$ 11,491	$ 11,410	$ 4,292	$ 27,193	$ 2,905	$ 4,052	$ 6,957	$ 34,150
5.4	Perform membrane autopsy	0.5	$ 2,873	$ 2,852	$ 1,073	$ 6,798				
6	**Develop an Economic Process Cost Model based on Field Data**	**1.2**	**$ 9,047**	**$ 3,046**	**$ 2,268**	**$ 14,361**	$ 2,880	$ -	**$ 2,880**	**$ 17,241**
6.1	Collect cost data and organize relevant field operational data	0.6	$ 4,523	$ 1,523	$ 1,134	$ 7,180	$ 1,440	$ -	$ 1,440	$ 8,621
6.2	Develop process cost model and perform cost analysis	0.6	$ 4,523	$ 1,523	$ 1,134	$ 7,180	$ 1,440	$ -	$ 1,440	$ 8,621
7	**Project Reporting & Invoicing**	**0.35**	**$ 3,974**	**$ -**	**$ 993**	**$ 4,967**	$ -	$ -	**$ -**	**$ 4,967**
7.1	Prepare & Submit Progress Reports & Invoicing	0.07	$ 745	$ -	$ 186	$ 931	$ -	$ -	$ -	$ 931
7.2	Prepare & Submit Final Report	0.26	$ 2,980	$ -	$ 745	$ 3,725	$ -	$ -	$ -	$ 3,725
7.3	Submit Post Completion Report & Invoicing	0.02	$ 248	$ -	$ 62	$ 310	$ -	$ -	$ -	$ 310
TOTAL COST (YEAR 2)		9.9	$ 60,650	$ 66,712	$ 23,460	**$ 150,822**	$ 15,842	$ 97,590	**$ 113,433**	**$ 264,255**

***Table 7.4**. Detailed Project Budget for the Requested California DWR Funding, Organized by Budget Item.*

BUDGET ITEM	COST BASIS		BUDGET ESTIMATE		
SALARIES & BENEFITS			***YEAR 1***	***YEAR 2***	***TOTAL***
Salaries	**Annual Appointment**	**Monthly Rate[1]**			
Y. Cohen (PI)	2.08%	$20,156	$ 5,291	$ 5,555	$ 10,846
A. Rahardianto (Co-PI)	12.5%	$ 5,567	$ 8,768	$ 9,206	$ 17,973
Grad. Student Res. 1 (GSR)	25%	$ 4,913	$ 14,739	$ 14,739	$ 29,478
GSR 2	43%	$ 4,913	$ 25,351	$ 25,351	$ 50,702
Total Salaries			**$ 54,148**	**$ 54,851**	**$ 109,000**
Fringe Benefits	**Rate**	**Effective Rate**			
Y. Cohen (PI)	12.70%	12.70%	$ 672	$ 706	$ 1,377
A. Rahardianto (Co-PI)	47.82%	47.82%	$ 4,192	$ 4,402	$ 8,594
GSR 1	1.3% Academic Yr, 3% Summer	1.73%	$ 254	$ 254	$ 508
GSR 2	1.3% Academic Yr, 3% Summer	1.73%	$ 437	$ 437	$ 875
Total Benefits			**$ 5,556**	**$ 5,799**	**$ 11,355**
Total Salaries & Benefits			**$ 59,704**	**$ 60,650**	**$ 120,355**
OTHER DIRECT COSTS			***YEAR 1***	***YEAR 2***	***TOTAL***
Field Study Supplies	**Description of Items:**				
Chemicals	Antiscalants, coagulant, gypsum, lime, acid/base		$ 10,046	$ 10,046	$ 20,091
System Parts	CCESP system container, piping, hardware, tools		$ 3,500	$ 1,000	$ 4,500
Consumables	Filters, RO elements, general supplies		$ 550	$ 1,750	$ 2,300
Analytical Services	Analysis kits, water quality, SEM-EDS		$ 2,000	$ 2,600	$ 4,600
Miscellaneous	Field internet/software subscriptions, contingencies		$ 1,230	$ 1,022	$ 2,252
Field Site Expenses	***Visits/Year (UCLA- Panoche, RT):***	**22**			
Transportation	Cost/visit (@ $0.56/mi x 530 mi. RT):	$ 291.20	$ 6,406	$ 6,406	$ 12,813
Lodging	Nightly Rate (2 nights/visit):	$ 90.00	$ 3,960	$ 3,960	$ 7,920
Subsistence	Daily Rate (2 persons, 3 days/visit)	$ 46.00	$ 6,072	$ 6,072	$ 12,144
GSR Fee Remission[2]	**2 GSRs**	**Annual Rate/Student $ 15,203.10**	$ 31,927	$ 33,523	$ 65,449
Tech. Infrastructure Fee[3]	**Person Mo./Yr.: 9.66**	**Rate: $ 34.46**	$ 333	$ 333	$ 666
Total Other Direct Costs			**$ 66,023**	**$ 66,712**	**$ 132,735**
Total Direct Cost (TDC)			**$ 125,728**	**$ 127,362**	**$ 253,090**
INDIRECT COST					
Modified TDC (MTDC)[4]	**Year 1: $ 93,801**	**Year 2: $ 93,840**	***YEAR 1***	***YEAR 2***	***TOTAL***
Total Indirect Cost	**Rate: 25%**	**of MTDC**	**$ 23,450**	**$ 23,460**	**$ 46,910**
TOTAL BUDGET REQUESTED FROM CA DWR			***YEAR 1***	***YEAR 2***	***TOTAL***
			$ 149,178	**$ 150,822**	**$ 300,000**

1. Salaries for PI&Co-PI are based on 2014 rate with 5% adjustment for cost-of-living escalation.
2. Fee to cover in-state registration for graduate student researchers (GSR) employed at 25% or higher.
3. Fee to cover telecommunication and internet usage at UCLA campus.
4. Basis for calculation of indirect cost is total direct cost less GSR fee remission.

***Table 7.5**. In-kind Contributions.*

INKIND CONTRIBUTION ITEM	BASIS		ESTIMATED VALUE		
			YEAR 1	*YEAR 2*	*TOTAL*
Salaries, Benefits, Indirect (@25%)	Appointment	Montly Rate			
Y. Cohen	4%	$ 31,932	$ 15,088	$ 15,842	$ 30,930
Specialized Equipment Usage	Amortization/Yr	Purpose			
UCLA Smart Desalination System	$ 53,432	Primary RO	$ 53,432	$ 53,432	$ 106,864
UCLA Membrane Monitor Unit	$ 2,753	Primary RO	$ 2,753	$ 2,753	$ 5,505
UCLA Continuous CESP System	$ 8,368	Salt Harvesting	$ 8,368	$ 8,368	$ 16,737
UCLA Mini RO System	$ 6,462	Secondary RO	$ -	$ 6,462	$ 6,462
UCLA Cyclic RO System	$ 1,575	Secondary RO	$ -	$ 1,575	$ 1,575
Field Infrastructure Support					
Panoche Drainage District	$ 25,000		$ 25,000	$ 25,000	$ 50,000
TOTAL INKIND CONTRIBUTIONS			**$ 104,641**	**$ 113,433**	**$ 218,074**

7.2 BUDGET JUSTIFICATION

7.2.1 Personnel and Benefits Costs

All salaries and wages (**Table 7.4**) are calculated using current UCLA academic and staff salary scales. A 5% cost of living increase per year is estimated for all senior personnel salaries. Benefits rates are estimated based on actual or composite benefits rates established by the University of California, Office of the President. The benefits rates are listed in **Table 7.4**.

Dr. Yoram Cohen (PI), Professor in the UCLA Department of Chemical & Biomolecular Engineering, will serve as Project Director and Principal Investigator with responsibilities as outlined in **Section 6.1**, with time allocation per task included in **Table 6.2**. Salary support of ¼ Summer months per year (**Table 7.4**) is requested from DWR funds. Dr. Cohen will contribute 5% of his time during the academic year (equivalent to 4% annually) as in-kind (**Table 7.5**).

Dr. Anditya Rahardianto (Co-PI), Assistant Researcher in the Department of Chemical & Biomolecular Engineering, will serve as Project Manager and Co-Principal Investigator with responsibilities as outlined in **Section 6.1**, with time allocation per task included in **Table 6.2**. For his proposed effort, partial salary support for 1.5 months per year (equivalent to 12.5% annually) is requested from DWR funds.

Two **Graduate Student Researchers (GSR)** will be involved in the proposed project with duties and time allocation as described in **Section 6.1** and **Table 6.2**. GSR 1 will be employed at 25% annually, focusing on PRO desalination. Given that the UCLA SWTD system is already operational, GSR 1 appointment at 25% will be sufficient for optimizing and demonstrating the process. GSR 2, who will focus in both concentrate salt harvesting and secondary RO desalting, will be employed at 49% during the school year and 25% during the summer months (equivalent to 43% annually). The higher appointment of GSR 2 is needed in order to account for time in setting up and commissioning the concentrate salt harvesting and secondary RO desalting field equipment.

7.2.2 Field Study Supplies

Field study supplies required to conduct the tasks for the proposed project include chemicals, system parts, consumables, analytical services, and miscellaneous supplies as detailed in the Task Breakdown in **Section 4**. The estimated costs for each category of field study supplies are detailed in **Table 7.6**, along with cost basis. The costs of field study supplies are estimated based on cost documentations given in **Section 11.5**. Major costs are anticipated to be coagulant and antiscalant, which will be continuously dosed for demonstrating high recovery RO desalting. The dosages are estimated based on maximum dosing requirements. It is anticipated that actual costs would be lower as coagulant and antiscalant dosages will be optimized. Miscellaneous chemicals (for cleaning or pH adjustments) include acid/base, chlorine, and sodium metabisulfite.

***Table 7.6**. List of field study supplies and estimated costs.*

CHEMICALS	TASKS	Unit	Est. Price	Qty. Yr. 1	Qty. Yr. 2	Cost. Yr. 1	Cost. Yr. 2	Documentation
Antiscalant	1,4,5	55 gal drum	2343	1	1	$ 2,343	$ 2,343	Web Price
Coagulant	1,4,5	2 x 55 gal drums	1006	6	6	$ 6,036	$ 6,036	Quote
Ultrafine Gypsum	2-4	5 x 51 lbs	271.71	2	2	$ 543	$ 543	Quote
Hydrated Lime	2-4	50 lbs	87.31	10	10	$ 873	$ 873	Web Price
Miscellanous Chemicals	1-5	set	250	1	1	$ 250	$ 250	Estimated
TOTAL CHEMICALS						**$ 10,046**	**$ 10,046**	
SYSTEM PARTS		**Unit**	**Est. Price**	**Qty. Yr. 1**	**Qty. Yr. 2**	**Cost. Yr. 1**	**Cost. Yr. 2**	**Documentation**
CESP Container, 10 FT	2	each	2500	1	0	$ 2,500	$ -	Web
Piping, hardware, tools	1-5	set	1000	1	1	$ 1,000	$ 1,000	Estimated
TOTAL SYSTEM PARTS						**$ 3,500**	**$ 1,000**	
CONSUMABLES		**Unit**	**Est. Price**	**Qty. Yr. 1**	**Qty. Yr. 2**	**Cost. Yr. 1**	**Cost. Yr. 2**	**Documentation**
RO Membranes	4,5	each	300	0	4	$ -	$ 1,200	Web Price
Filters	1,4,5	each	150	2	2	$ 300	$ 300	Quote
General Supplies	1-5	set	250	1	1	$ 250	$ 250	Estimated
TOTAL CONSUMABLES						**$ 550**	**$ 1,750**	
ANALYTICAL SERVICES		**Unit**	**Est. Price**	**Qty. Yr. 1**	**Qty. Yr. 2**	**Cost. Yr. 1**	**Cost. Yr. 2**	**Documentation**
WQ Analysis	1-5	sample	150	8	12	$ 1,200	$ 1,800	UCLA rate
SEM-EDS	4-5	hourly	50	6	6	$ 300	$ 300	UCLA rate
WQ Analysis Kits	1-5	set	500	1	1	$ 500	$ 500	Estimated
TOTAL ANALYTICAL SERVICES						**$ 2,000**	**$ 2,600**	
MISCELLANEOUS		**Unit**	**Est. Price**	**Qty. Yr. 1**	**Qty. Yr. 2**	**Cost. Yr. 1**	**Cost. Yr. 2**	**Documentation**
Field Internet Subs.	1-5	monthly	30	12	12	$ 360	$ 360	Current rate
Software Subscription	1-5	yearly	500	1	1	$ 500	$ 500	Current rate
Contingencies	1-5					$ 370	$ 162	Estimated
TOTAL MISCELLANEOUS SUPPLIES						**$ 1,230**	**$ 1,022**	
TOTAL FIELD SUPPLIES						**$ 17,326**	**$ 16,418**	

7.2.3 Field Site Expenses

Field site expenses (**Table 7.4**) include transportation, lodging, and subsistence for two personnel for regular periodic visits (bimonthly) to field test site to conduct the proposed study. It is anticipated that 22 visits per year will be required to conduct the proposed study, with each visit lasting three working days. Each visit will be conducted via personal vehicles, with an anticipated roundtrip transportation distance of 530 miles per visit between UCLA campus, Panoche drainage district treatment site (11000 N. Russell Ave, Firebaugh, CA), and lodging location in Los Banos, CA. The anticipated cost per visit ($747) is estimated based on the allowable reimbursement rates specified by the California Department of Human Resources (http://www.calhr.ca.gov/employees/pages/travel-reimbursements.aspx):

- Personal vehicle mileage reimbursement: 56 cents/mile for 530 miles roundtrip per visit (shared ride), totaling $291/visit
- Lodging: up to $90 per night (shared double room) for two nights, totaling $180/visit.
- Subsistence: $46 per person ($7 breakfast, $11 lunch, $23 dinner, $5 incidentals) for two personnel for three days, totaling $276 per visit.

7.2.4 Fees and Indirect Cost

The **graduate student researcher (GSR) fee remission** benefit (**Table 7.4**; see **Section 11.1** for cost documentation) is assessed for each graduate student employed greater than 25% during the academic year. GSR fee remission benefit covers in-state tuition, student services fee and health insurance for the GSR. The GSR remission fee is calculated based on 2014-2015 academic year rate with 5% yearly adjustment. Based on the current rate of $15,203, the GSR fee remission is estimated as $15,963 (2015-2016 academic year) and $16,761 (2016-2017 academic year) per GSR. Two GSRs will be covered in the proposed project.

The mandatory **technology infrastructure fee** (**Table 7.4**; see **Section 11.2** for cost documentation) is assessed monthly for campus communication services (internet, email systems, etc.) on the basis of a monthly accounting of actual usage data. These costs are charged as direct costs and are not recovered as indirect costs. The charge is $34.46/person-month, pro-rated. It is anticipated this expense will cost this project $333 annually (9.66 person months x $34.46, at which the PI's (Y. Cohen) summer employment's is excluded).

The **indirect cost** for the proposed project (**Table 7.4**; see **Section 11.3** for cost documentation), which covers general facilities and administrative (F&A) costs, is based on the established University of California rate for agreements with California state agencies (UC Office of the President indirect cost rate exception no. 03R-135), which applies a rate of 25% on the Modified Total Direct Cost (MTDC) base. For the proposed project, MTDC is calculated from the total direct cost minus mandatory graduate student fee remissions. The base (MTDC) used to calculate indirect cost for each year is: Year 1 - $93,801, Year 2 - $93,840.

7.2.5 In-Kind Contributions

In-kind contribution include 5% of time of the Principal Investigator (PI, Prof. Y. Cohen) during the academic year, valued at $30,930 throughout the project period. The value of this in-kind contribution is estimated based on the PI actual salary, benefits, and indirect cost, plus 5% yearly adjustment for cost-of-living escalation (**Table 7.5**).

Use of specialized equipment for field deployment during the proposed study is based on the respective equipment yearly amortization value. The annual amortization value, as detailed in the Appendix in **Section 11.4**, is calculated based on the cost of system fabrication, amortized over a 10-year lifetime with a 5% yearly discount rate.

Field infrastructure support provided by Panoche Drainage District is valued at about $50,000 for two years, per Panoche support letter provided in **Section 1.2.**

8. Project Schedule

8.1 Summary of Project Schedule

The proposed project is scheduled to be completed within a time frame of two years, with a proposed period of performance of June 15, 2015 to June 14, 2017. The project schedule is detailed in **Table 8.1** for the first year and **Table 8.2** for the second year, which contain the timeline and dependencies for each project task, the project milestones, and the due dates of all project reports and project review meetings. As indicated in the project schedule Tasks 1-3 are conducted in parallel in Year 1, building on each other to enable achievements of the first and second milestones. Tasks 4-6 are conducted in parallel in Year 2, with their completion signified by the achievement of the final milestone and thus the project goal. The Project Director and the Project Manager will implement project tasks per the scheduled plans. If any adjustments to the project schedule will be needed for completing project tasks, all efforts will be exhausted to ensure overall project completion within the two-year project timeframe.

8.2 Readiness to Proceed

The proposed project is ready to proceed by the proposed project start date of June 15, 2015, when it is anticipated that funding will be available should the proposed project is approved. The basis for readiness-to-proceed includes:

1. Field infrastructure is already in place at Panoche Drainage District for conducting the proposed project, including a secure space, electricity, drainage water supply, waste management, and personnel support.
2. The UCLA mobile desalination unit (SWTD) is already commissioned and fully operating, with waste discharge handled by existing Panoche drainage water management infrastructure. It is anticipated that no additional permitting will be required for CEQA and NEPA compliance.
3. All specialized equipment for concentrate salt harvesting and secondary RO desalination are ready for use. The CCESP system is currently at UCLA and can be immediately field deployed by the proposed start date. The UCLA cyclic RO system is already operational and can be field deployed at any time. The UCLA mini RO system is slated to be completed in January 2015 and therefore will be field deployable by the project start date.
4. The PD/PI and PM/Co-PI are ready to commit to the proposed project per the time allocation specified in **Table 6.2**. Existing graduate students are also available to conduct the proposed project. Involvement of additional students will be assessed as per project requirements and budget constraints.

***Table 8.1**. Project Schedule for Year 1 (June 15, 2015- June 30, 2016).*

TASK	TASK DESCRIPTION	START	END	Q1	Q2	Q3	Q4
1	**Optimize Primary RO (PRO) Desalting for High Recovery Self-Adaptive Operation**	**6/15/2015**	**6/30/2016**				M2
1.1	Optimize RO feed pretreatment operations	6/15/2015	9/30/2015				
1.2	Refine RO process model of primary RO desalting	10/1/2015	1/31/2016				
1.3	Demonstrate self-adaptive high recovery operation of primary RO desalting	2/1/2016	6/30/2016				
2	**Evaluate CCEP Salt Harvesting Process Requirements**	**6/15/2015**	**12/31/2015**		M1		
2.1	Deploy CCESP system at field test site	6/15/2015	7/31/2015				
2.2	Determine CCESP process conditions for effective antiscalant removal	8/1/2015	10/31/2015				
2.3	Demonstrate effective concentrate desupersaturation	11/1/2015	12/31/2015				
3	**Optimize CCESP Operation for Efficient Concentrate Salt Harvesting**	**1/2/2016**	**6/30/2016**				M2
3.1	Develop gypsum growth kinetics model for CCESP	1/2/2016	4/30/2016				Task 5
3.2	Optimize gypsum solids harvesting operations	5/1/2016	6/30/2016				
7	**Project Reporting & Invoicing**	**DUE DATE**					Task 6
7.1	Quarter 1 Progress Report & Invoicing	10/6/2015					
	Quarter 2 Progress Report & Invoicing	1/7/2016					
	Quarter 3 Progress Report & Invoicing	4/7/2016					
	Quarter 4 Progress Report & Invoicing	7/7/2016					
7.4	Project Review Meetings 1 & 2	1/4/2016	7/4/2016				

MILESTONE 1 (M1): Technical Readiness of CCESP for Concentrate Salt-Harvesting

MILESTONE 2 (M2): Optimal Self-Adaptive Primary RO Desalination with Concentrate Salt Harvesting

***Table 8.2**. Project Schedule for Year 2 (July 1, 2016- June 14, 2017).*

TASK	TASK DESCRIPTION	START	END	Q5	Q6	Q7	Q8
4	**Demonstrate Continuous High Recovery PRO Desalting with Conc. Salt Harvesting**	**7/1/2016**	**4/30/2017**				M3
4.1	Demonstrate long-term self-adaptive PRO desalting with conc. salt harvesting	7/1/2016	3/31/2017				
4.2	Collect samples and obtain water quality and solids purity data	9/1/2016	3/31/2017				
4.3	Perform membrane autopsy	4/1/2017	4/30/2017				
5	**Demonstrate Enhanced High Recovery Desalting via Secondary RO (SRO) of Desupersaturated RO Concentrate**	**9/1/2016**	**4/30/2017**				M3
5.1	Integrate a small-scale RO system for SRO desalting	9/1/2016	9/30/2016				
5.2	Assess maximum achievable water recovery enhancement	10/1/2016	11/30/2016				
5.3	Demonstrate continuous SRO operation	12/1/2016	3/31/2017				
5.4	Perform membrane autopsy	4/1/2017	4/30/2017				
6	**Develop an Economic Process Cost Model based on Field Data**	**1/2/2017**	**4/30/2017**				M3
6.1	Collect cost data and organize relevant field operational data	1/2/2017	2/28/2017				
6.2	Develop process cost model and perform cost analysis	3/1/2017	4/30/2017				
7	**Project Reporting & Invoicing**	**DUE DATE**					
7.1	Quarter 5 Progress Report & Invoicing	10/7/2016					
	Quarter 6 Progress Report & Invoicing	1/6/2017					
	Quarter 7 Progress Report & Invoicing	4/7/2017					
7.2	Final Technical Report	5/31/2017					
7.3	Post Completion Report & Invoicing	6/14/2017					
7.4	Project Review Meetings 3 & 4	1/3/2017	5/2/2017				
MILESTONE 3 (M3): Demonstrated Long-Term Operation and Treatment Cost Performance							

9. Project Deliverables

Project deliverables include:

1. **Quarterly Progress Report & Invoicing** (due within 7 days after the end of quarters 1-7)

Quarterly progress report will be submitted to the designated DWR program manager as per the project schedule **Table 8.1-8.2**. The progress report will summarize the work conducted and the final status of each project tasks during the reporting period, highlight project accomplishments, discuss project challenges and problem-mitigation strategies taken, as well as updated project plans for the following quarter. The quarterly progress report will also summarize discussions with project partners and CA DWR based on project review meetings. Quarterly financial reports and invoicing will be submitted by the UCLA EFM office.

2. **Final Technical Report** (due 5/31/2017)

The Final Technical Report will be prepared and submitted to the designated DWR program manager by May 31, 2017, which is one month after the anticipated completion of all project tasks (April 30, 2017) per the project schedule in **Table 8.2**. The final report will include:

a) Discussion of project accomplishments with respect to DWR Drainage Reuse program priorities.
b) Field data from online sensors demonstrating the long-term performance of self-adaptive high recovery desalination with concentrate harvesting.
c) Analytical data indicating water quality of relevant RO process streams and harvested concentrate salt composition, as well as membrane autopsy results.
d) Description of process models and analysis results for optimizing high recovery RO desalination processes and concentrate salt harvesting via the CCESP process.
e) Description economic process cost model and analysis results for assessing process-scale up of high recovery desalination with concentrate salt harvesting.

The Final Technical Report will be organized as follows:

a) Executive Summary, summarizing project objectives, findings, and recommendations.
b) Introduction, summarizing project motivation, goal and objectives, scientific merit, project hypothesis, and relation to the DWR Drainage Reuse Program priorities.
c) Summary of Project Approach, detailing project tasks and methodologies.
d) Results and Discussion, detailing and discussing project results
e) Conclusion, Recommendations, and Appendix

3. **Post-Completion Report & Invoicing** (due 6/14/2017)

A Post-Completion report will be submitted, summarizing grant funding account close-out and final financial report. Final invoice will be submitted as part of the close-out procedure.

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[45] L.F. Greenlee, F. Testa, D.F. Lawler, B.D. Freeman, P. Moulin, Effect of antiscalants on precipitation of an RO concentrate: metals precipitated and particle characteristics for several water compositions, Water Research, 44 (2010) 2672-2684.

11. APPENDIX

11.1 GRADUATE STUDENT RESEARCHER FEE REMISSION BENEFIT

Source: https://grad.ucla.edu/gss/library/1415remissionsgsr.pdf

UCLA GRADUATE DIVISION

2014-2015 GRADUATE STUDENT RESEARCHER FEE REMISSION BENEFITS (3276)

TOTAL COST OF EDUCATION (CA Residents or Registered AB540)				
DESCRIPTION	ANNUAL RATES	QUARTERLY RATES		
		FALL	WINTER	SPRING
Tuition and Fees for continuing students[1]	**$15,582.09**	**$5,195.03**	**$5,194.03**	**$5,193.03**
TOTAL FEE REMISSION BENEFTIS FOR RESIDENTS EMPLOYED AT 25% TIME OR MORE				
Fee Remission I - Tuition	$11,220.00	$3,740.00	$3,740.00	$3,740.00
Fee Remission II – Student Services Fee	$972.00	$324.00	$324.00	$324.00
Health Insurance	$3,011.10	$1,003.70	$1,003.70	$1,003.70
Total	**$15,203.10**	**$5,067.70**	**$5,067.70**	**$5,067.70**
TOTAL BALANCE TO BE PAID BY THE STUDENT				
Continuing student only	$378.99	$127.33	$126.33	$125.33
New Entering PhD students only	$478.99	$227.33	$126.33	$125.33
New Entering Master's students only	$458.99	$207.33	$126.33	$125.33

TOTAL COST OF EDUCATION (Non-Residents)				
DESCRIPTION	ANNUAL RATES	QUARTERLY RATES		
		FALL	WINTER	SPRING
Tuition and Fees for continuing students[1]	$15,582.09	$5,195.03	$5,194.03	$5,193.03
Total Non-Resident Supplemental Tuition (NRST)	$15,102.00	$5,034.00	$5,034.00	$5,034.00
Total	**$30,684.09**	**$10,229.03**	**$10,228.03**	**$10,227.03**

11.2 Technology Infrastructure Fee

Source: https://www.it.ucla.edu/support/billing-questions/2014-2015-billing-rates-and-structure-annoucement

2014/2015 BILLING RATES AND STRUCTURE ANNOUCEMENT

Home | Support | Billing Questions | 2014/2015 Billing Rates and Structure Annoucement

The purpose of this communication is to share with you updates to the Information Technology Services (IT Services) FY 2014/15 rates effective July 1, 2014.

IT Services' FY 2014/15 budget proposal and recommended recharge rates have been approved by the Policy Committee on Sales and Service Activities and Service Enterprises (POSSSE).

As in prior years, voice and technology infrastructure fee components (TIF) will be billed separately. The voice access rate, which is directly linked to the cost of providing dial tone and includes all calling features except for voicemail remains unchanged at $17.54.

The TIF, which is based upon full time equivalent employee (FTE), will decrease from $35.42 to $34.46. This decrease includes a one-time credit to the campus of $9.84 per FTE, or a monthly credit of $.82 per FTE. This one-time credit represents the return of a prior year surplus in TIF due to an increase in the number of actual campus FTE compared to the budgeted FTE. Without this credit, the rate would have been $35.28 for FY 2014/15.

Except for pass-through sales, all other direct-billed rates will remain unchanged from FY 2013/14 rates.

To find a rate for a specific product or service, please refer to the Products & Services Catalog available at: https://www.it.ucla.edu/network-phone-tv/products-services.

You may also contact me at x44438 or cjordan@it.ucla.edu if you have any questions regarding these changes.

Constance Jordan
Associate Director of Administration
Information Technology Service

Product & Service Descriptions	FY 12/13 Approved Rates	FY 13/14 Approved Rates	FY 14/15 Approved Rates
Technology Infrastructure Fee (TIF)	$38.41	$35.42	$34.46

11.3 INDIRECT COST RATE

Source: http://www.ucop.edu/raohome/cgmemos/03-02.htm

University of California
Office of the President

Senior Vice President—
Business and Finance

Costing Policy & Analysis
Research Administration Office

Memo
Operating Guidance
No. 03-02
May 9, 2003

CONTRACT AND GRANT OFFICERS
VICE CHANCELLORS--ADMINISTRATION

Subject: Cancellation of Two Indirect Cost Rate Exceptions

The Office of the President Research Administration Office (RAO) maintains a database of all approved individual and
class indirect cost rate exceptions. On an annual basis, after the final fiscal year report of systemwide contract and grant
activity is distributed, we review all the class exceptions and delete those for sponsors from which the Univers has not received any awards in 4 to 5 years. We then distribute a revised list of class waivers to your office.

We do not usually inform campuses of deleted class exceptions which are based on the fact that the University has not received awards from the sponsor in the past 4 to 5 years. However, we are informing you in this Operating
Guidance Memo of two newly deleted class exceptions, 93R-058, Federal Agencies – Intergovernmental Personnel
Agreements, and 85R-086, State Resources Agencies, because the University is continuing to receive awards from these sponsors, but these indirect cost rate exceptions are no longer applicable to them.

Implementation Date:

The change in indirect cost rates for proposals and awards which should be implemented in any new proposals being
prepared under these sponsors' programs within 10 working days of your office's receipt of this memo. Any proposals which were submitted before this date that reflect the rates on the canceled waivers can be accepted with those rates.

Intergovernmental Personnel Agreements:

Indirect cost rate exception no. 93R-058, Federal Agencies – Intergovernmental Personnel Agreements, was deleted last month, based on a new directive from the Department of Defense. (Copy attached.)
The Intergovernmental Personnel Act (IPA) Mobility Program allows university faculty and staff to have temporary assignments with federal agencies. The federal Office of Personnel Management has overall authority for setting the rules for IPAs, which had included language that prohibited or greatly restrict payment of indirect costs on IPAs.

The attached January 28, 2003 memo from the Department of Defense, Director of Defense Procurement and Acquisition Policy, instructs DOD agencies to provide reimbursement of indirect costs in IPAs. Contracting Officers are instructed to pay indirect costs on future IPAs and to consider

modifying existing IPA agreements to allow for indirect cost payment. The memo also indicates the Office of Personnel Management is revising its guidance for all agencies to clarify that indirect costs are reimbursable on IPAs and that "reimbursement of such costs should be determined by the agency the enters into the agreement." To date, OPM has not made this clarification in its guidance to all agencies. However, while we have no "track record" yet of what rate any agency will determine is reimbursable, campuses should now include the off-campus, other sponsored activity rate in IPA budgets.

State Resources Agencies:

In 1985, the Division of Agriculture and Natural Resources (DANR) requested that all awards to the University from the State Department of Food and Agriculture (CDFA) and the State Resources Agencies be accepted with a 10% indirect cost rate. (No. 85R-086) The rate was approved only for non-federal funds. At the time, the DANR Vice President cited the State's direct funding of that Division as providing additional support that could justify the lower rate for these State agencies only. Federal indirect cost rates for research were under 40%. Since this exception was approved, most campus federal indirect cost rates for research have risen to over 50%. What was defined as "State Resources Agencies"changed significantly with the establishment of the State Environmental Protection Agency (EPA), causing continued confusion and conflict between campuses and State agencies over whether this exception applied to them. The additional State support for DANR does not reach to campuses which now have the vast majority of agreements with State Resources Agencies and EPA. As an added complication, agencies did not limit their application of this rate to only State funds, which caused on-going delays and misunderstandings in budget negotiations.

Section 8752 of the *State Administrative Manual* reminds State agencies that State policy obligates them "to recover full costs whenever goods or services are provided for others." "Full costs" includes "a fair share of indirect costs." As such, the University needs to recover "a fair share" of its indirect costs while working with State agencies to reduce these costs and the administrative burden incurred under State agreements.

As a result of these factors, RAO, in consultation with the Vice President – DANR, has determined that the exception for State Resources Agencies should be ended. The continuation of a 10% rate for CDFA only is linked to the University's support as a land grant institution and the additional funding received for this role. However, the continuation of this rate for CDFA, as reiterated by the Vice President – DANR, is based on CDFA "practices that minimize administrative costs to the University, that is, contractual terms and conditions which are standard, consistent with University policies and include no extraordinary reporting or documentation. We also understand (and want CDFA to be so informed) that this blanket exception applies only to non-federally funded awards from CDFA."

Many State programs apply unsubstantiated rates which have no basis in statute or formal regulations to their University agreements. At the same time, State contracts with private institutions, commercial companies, and federal laboratories accept their approved federal rates which are several times higher than the University's rates. With the growing complexity of issues in contract negotiations and invoicing with State agencies, the University can no longer afford this across- the-board reduced overhead rate. At the same time, the University recognizes its unique role as the research entity for the State and its support from the State. Thus, the University has begun applying a minimum rate of 25% of modified total direct costs (MTDC) on State agreements, a rate which is about half of the University's federally approved research rates.

RAO has already arrived at agreement with several State agencies for this more equitable indirect cost reimbursement rate, closer to 25%. The University has also made this 25% MTDC rate applicable to federal flow-through funds as well in order to simplify the application of indirect costs on State agreements.

Unless a State agency program has a published indirect cost policy stated in a funding announcement or federal regulation applicable to federal flow-through funds, campuses may use a 25% MTDC rate in State proposal budgets and not have to continue to request multiple individual indirect cost rate exceptions for State agencies.

In conjunction with these changes, RAO will continue to work with DANR and CDFA on the continued use of standard terms and conditions in our agreements. In addition, RAO will continue to communicate with
the State Resources Agencies and State EPA about what has necessitated this change in policy.

Refer: Samuela A. Evans

(510) 987-9849

samuela.evans@ucop.edu

Subject: 08

Organization: S-001, S-097, S-105, S-210

David F. Mears
Director, Research Administration

Attachment
DOD IPA Memorandum (pdf)

Cc: Vice President Gomes, DANR
Director Nation, DANR

USE INDIRECT COST RATE EXCEPTION NO. 03R-135 AND 05R-049

11.4 In-Kind Contribution: Use of Specialized Equipment

***Table 11.1**. Total value of equipment and their annual amortized value. Amortization is based on 10-year life time with 5% annual discount rate.*

Equipment	Purpose	Fabrication Cost	Total Value	Amortized Value/Yr
Smart Desalination System	**Primary RO**		$ 412,589	$ 53,432
Cash		$ 80,000		
Cost-Share/Inkind		$ 332,589		
Membrane Monitor Unit	Primary RO monitoring	$ 21,255	$ 21,255	$ 2,753
Continuous CESP System	Salt Harvesting	$ 64,619	$ 64,619	$ 8,368
Mini RO System	Secondary RO	$ 49,900	$ 49,900	$ 6,462
Cyclic RO System	Secondary RO	$ 12,160	$ 12,160	$ 1,575
Total			$ 560,523	$ 72,590

UCLA Smart Water Purification & Desalination Unit: Value from Cash Component

FAB NO. 1300112

FABRICATION REQUEST

To: Equipment Management

Administration Contact / Fund Manager Miguel Perez_____ Ext 51203_____

Department _Chemical & Biomolecular Engineering_____

Funding Agency _U.S. Bureau of Reclamation_ Award No. R11AC81533_____

Fund No.22727 Account No. 442531 CC _CY_ Department No. _0130 Org No._4130_____

Location: Bldg. Boelter Hall___, Room 5651_____, Mail Code _159210_____

Estimated Value. $80,000_____, Estimated Completion Date _10/31_____, 2013_____

Upon Completion of the fabrication. Title will vest initially with:

☒ University ☐ Government ☐ Deliverable to Agency

Quantity / Description / Function

Quantity:__1_____

Description:_Water filtration and desalination system._____

Function:__ A containerized water filtration and desalination system, utilizing a reverse osmosis (RO) process with ultrafiltration (UF) feed pretreatment. The system will be housed in a 40 ft ISO container and will have feed water capacity of up to 30 gallons/minute. This containerized UF-RO desalination will be custom-fabricated based on UCLA's system design and specifications.

Prepared by:_Miguel Perez_____ Date _2/6_____, 2013__

Yoram Cohen
Principal Investigator

Department Authorization

Equipment Management Approval:_____ Date 3/7, 2013

UCLA Smart Water Purification & Desalination Unit: Value from Cost-Share Component

UCLA Cost Sharing Contribution Report

Reversion Period: Subject to the Terms of Award

I. AWARD INFORMATION									Fund Number	22727
1. Principal Investigator	Yoram Cohen				2. Department	Chemical and Biomolecular Engineering				
3. Project Title	Pilot-Scale Evaluation of High Recovery Desalination				4. Sponsor	U.S. DOI/Bureau of Reclamation				
5. Award Amount (Inception to date)	$ 199,809.00	6. Award No.	R11AC81533		7. Frequency (check one)	Quarterly	X	Semi		
						Annual		Final		
8. Project Start Date	09/29/11	9. Project End Date		10/31/14	10. Budget Start Date	09/29/11	11. Budget End Date		10/31/14	

II. COST SHARING INFORMATION							
A. Commitments				B. Contributions			
12. This Period	$ -	13. All Periods	$ 453,315.00	14. This Period	$ 332,589.39	15. All Periods	$ 427,651.04
IMPORTANT: Attach the spreadsheets showing the detail line item per FAU supporting this report							

16. Salary Contributions

Employee Name	FAU Charged	Non-Federal Gross Salaries	Cost Contribution %	Cost Contribution Amount
John Thompson	442531-CY-18306	$ 3,353.80	100.00%	$ 3,353.80
		$ -		$ -
		$ -		$ -
		$ -		$ -
		$ -		$ -
TOTAL SALARY CONTRIBUTIONS				$ 3,353.80

17. Benefit Contributions

Employee Name	FAU Charged	Non-Federal Employee Benefits	Cost Contribution %	Cost Contribution Amount
John Thompson	442531-CY-18306	$ 84.19	100.00%	$ 84.19
0		$ -		$ -
		$ -		$ -
		$ -		$ -
		$ -		$ -
TOTAL BENEFIT CONTRIBUTIONS				$ 84.19

18. Other Contributions (including in-kind)

Description	FAU Charged	Reference No./PO Number	Cost Contribution %	Cost Contribution Amount
Inge Gmbh/BASF	402530-1A-19900		100.00%	$ 10,000.00
Grundfos	402530-1B-19900		100.00%	$ 25,000.00
GF			100.00%	$ 73,657.00
CJI Process Systems			100.00%	$ 98,500.00
Panoche/Fund 20624			100.00%	$ 125,432.39
				$ -
				$ -
				$ -
				$ -
TOTAL OTHER CONTRIBUTIONS				$ 332,589.39

19. I certify that the above costs represent cost contributions of the grantee (as interpreted in grantee regulations) to the expense of conducting research under this Federal grant during the period shown, and that these costs have not been and will not be additional as grantee contributions with respect to any other grant or period. Details substantiating this summary report of costs are available for audit.

Principal Investigator's Signature: Yoram Cohen

Date: January 30, 2014

SUMMARY (for this reporting period):		
20. Total Payroll Contributions (Direct Cost only)	$	3,438
21. Total Other Contributions (Direct Cost only)	$	332,589
22. Total Direct Costs Subject to F&A	$	-
23. F&A Rate		0.0%
24. Total F&A	$	-
25. Total Cost Share Contribution	$	336,027

rev. apr2410

Membrane Monitor Unit

FAB NO. 12000 99

FABRICATION REQUEST

To: Equipment Management

Administration Contact / Fund Manager Miguel Perez Ext 51203

Department Chemical & Biomolecular Engineering 4130

Funding Agency US Bureau of Reclamation Award No. R11AC81533

Fund No.22727 Account No. 442531 CC CY Department No. 0130 Org No.

Location: Bldg. Boelter, Room 5651 Mail Code 159210

Estimated Value. $21,255, Estimated Completion Date 4/30, 2013

Upon Completion of the fabrication. Title will vest initially with:

☒ University ☐ Government ☐ Deliverable to Agency

Quantity / Description / Function

Quantity: 1

Description: SIMS Membrane Monitor Unit

Function: An analytical system for direct online observation of membrane mineral scaling

Prepared by: Miguel Perez Date 10/2, 2012

Principal Investigator Department Authorization 10/12/12

Yoram Cohen

Equipment Management Approval: Date 10/3, 2012

Continuous CESP System (for Concentrate Salt Harvesting)

FAB NO. 1200/00

FABRICATION REQUEST

To: Equipment Management

Administration Contact / Fund Manager Miguel Perez_____ Ext 51203_____

Department Chemical & Biomolecular Engineering_____ 4130

Funding Agency UC Discovery___ Award No. 212946_____

Fund No.09593_ Account No. 522531 CC _CY Department No. 0130____ Org No._____

Location: Bldg. Boelter____, Room _5651_____, Mail Code _159210_____

Estimated Value. $64,619___, Estimated Completion Date 8/31_____, 2013____

Upon Completion of the fabrication. Title will vest initially with:

☑ University ☐ Government ☐ Deliverable to Agency

Quantity / Description / Function

Quantity:_1_____

Description:_Continuous CESP System_____

Function:_A bench-scale precipitation reactor unit for RO concentrate treatment_

Prepared by:_Miguel Perez_____ Date 10/2_____, 2012____

Principal Investigator

Department Authorization

Equipment Management Approval: _____ Date 10/3, 2012

UCLA Mini RO System

FAB NO. 140168

UCLA FABRICATION REQUEST
(To be completed by Department Administration)

Fabrication requests must meet the following conditions:

- Has an estimated cost of $5,000 or more
- Is freestanding
- Department personnel build at least some of the asset
- **Upon completion, will be placed into service for one year or longer, will remain at UC, UC will retain title, and the finished product will be a one-of-a-kind item**
- **Will not be deliverable to the sponsor**
- Is not available on the open market
- Typically parts will be from multiple vendors and/or via multiple purchase orders
- Labor with a recharge rate will be included in the item value. The actual expense for departmental administration labor will not be included in the equipment's value
- All Purchase Orders should reflect the FAB Number in the Project Field of the FAU
- All FAB expenses should post to either 9600 or 9610 object codes

Department Contact / Fund Manager: Miguel Perez — Ext: 512.03
Department: Chemical Engineering — Department No. 0130
Funding Agency: EPRI — Sponsor Award No. 00-10001128
Fund No. 57395 — Account No. 442531 — CC: CY — Custody Code. 4130
Fab Location: Bldg. Boelter — Room: 5651 — Mail Code: 159210
Qty: 1 — Estimated Value: 49,900 — Estimated Completion Date: 1/31/17
To be delivered to agency? Yes [ ] No [X] — Final Location of Equipment: U.C.L.A.
Upon Completion title will vest initially with: UCLA: [X] Agency: [ ]
Description: Self-Adaptive FFR RO System
Function: Enabling FFR operation with maxfed flow rate of 4 GPM.
Prepared by: Miguel Perez — Date: 7/25/14
Dept. Authorization Name: [signature] — Dept. Signature: 7/25/14
CFS Approval: [signature] — Date: 7/28/14

**Please attach any additional descriptive information or pictures to support this form

UCLA Cyclic RO System

FAB NO. 130137

FABRICATION REQUEST

To: Equipment Management

Administration Contact / Fund Manager _Miguel Perez___ Ext __51203_____

Department Chemical Engineering_____

Funding Agency _US Bureau of Reclamation__ Award No. _R13AC80025_____

Fund No.22387__ Account No. 442531 CC _CY Department No. 0130___ Org No._____

Location: Bldg. _Boelter Hall_____, Room _5651_____, Mail Code _159210_____

Estimated Value. $12,160_____, Estimated Completion Date _9/18_____, 2014_____

Upon Completion of the fabrication. Title will vest initially with:

☒ University ☐ Government ☐ Deliverable to Agency

Quantity / Description / Function

Quantity: 1

Description:_Laboratory Cyclic RO Unit_____.

Function:_Small-scale 300 gal/day reverse osmosis desalination system with cyclic operatonal capabilities_____

Prepared by:_Miguel Perez_____ Date _10/15_____, 2013_____

_Yoram Cohen_____
Principal Investigator

Department Authorization

Equipment Management Approval: Date Oct 16, 2013

11.5 Field Supplies Cost Documentation

Coagulant

Qemi International, Inc.
800 Rockmead Dr Ste 100
Kingwood TX 77339-2197
United States
http://www.qemi.com

Quotation

Customer No.	Date	Quote #
42064	7/29/2014	QT-410887

Bill To
Yoram Cohen
UCLA- School of Engineering
420 Westwood Plaza
Boelter Hall, RM 5819
Los Angeles CA 90095
United States

Ship To
Han Gu
Water Technology Research Laboratory
PolySepResearch Laboratory
Department of Chemical and Biomolecular Engineering
University of California, Los Angeles
Los Angeles CA 90095
United States

Customer Ref#	Availability.	Entered By.	Payment Terms
email req	1 week	Sherina Q Anderson	Payment in Advance

Expires	Shipment Terms.	Ship Via.	Product Price Point.	Currency
8/28/2014	FOB: Los Angeles	Truck	Phoenix AZ	USA Dollar

Item	Description/Notes	Quantity	uom	Price	Amount
QEMIPAC 7580-N	Packaging: 2 x 600 lb drums (55 gallon drum)	1,200	LB	0.58	696.00
Inland Freight	freight including $75.00 lift gate charge	1	EA	310.00	310.00
			Total		$1,006.00

This Quotation is governed by and subject to Qemi International's General Terms and Conditions of Sale. Please go to www.qemi.com for details. Qemi International does not know of all of the uses to which its products may be utilized or the condition of use. Therefore, Qemi International makes no warranty concerning the fitness or suitability of the product for a particular use or purpose.

Antiscalants

www.water-rus.com/pret/chf.html

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December 9, 2014

Chemical Feed Systems

Antiscalant Chemicals

Can extend the life of the RO membranes in hard waters

- Lead time is Stock to 2 weeks.

Part Number	Manufacturer	Manufacturer's Model #	Form	Description / Scale Prevention	List Price 55 GAL
AF600	B.F. Goodrich	AF600	Liquid	CaSO4, for LSI less than 1.5 (NSF Approved)	1635
EL-4010	Calgon	EL-4010	Liquid	CaSO4, for LSI less than 1.5	1,582
EL-5600	Calgon	EL-5600	Liquid	CaSO3, for LSI less than 1.5	3,208
C-5	Calgon	C-5	Liquid	Iron	1,680
FL100	FMC	Flocon-100	Liquid	Inorganics	1,946
FL260	FMC	Flocon-260	Liquid	Iron	2,342
PGRO	Proffesional Water	Metaguard	Powder	Inorganics and Silica	2,695
PTP	King Lee	Pretreat Plus 0100	Powder	Inorganics	2,278
PTP-SC	King Lee	Pretreat Silica	Liquid	Silica	2,493
PTP-RO	King Lee	Protec RO	Powder	Inorganics	2,607
AF200	Argo Scientific	AF200	Liquid	CaSO4, for LSI less than 1.5	3,093

Gypsum Seeds

---------- Forwarded message ----------
From: **Ed Hackleman** <ed@usagypsum.com>
Date: Thu, Sep 4, 2014 at 9:00 AM
Subject: RE: [UCLA] Pulverized Gypsum Inquiry
To: Jack Lei <jacklei@ucla.edu>

Jack
I will give you a two options.

1. Your cost to purchase and ship 5 bags of Ultra-Fine Gypsum will be $271.70.
2. We will donate and ship the gypsum at no cost to you if you will provide us with copies of the results of your study.

Please let me know.

Ed Hackleman
USA Gypsum
1802 Texter Mountain Rd.
Reinholds, PA 17569
Ph 717-335-0379
Fax 717-335-2561
ed@usagypsum.com
www.usagypsum.com

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12/09/14 - 1 line

hydrated lime | FIND | CONTACT US | BOOKMARKS | ORDER HISTORY | CURRENT ORDER

Current Order

How can we improve? | Print | Forward | Save order | Delete order

About you

If you have ordered from this site before, we can retrieve your information.

User name or e-mail address

Password

LOG IN | CANCEL

Forgot your user name or password?

I am new to this website.

Products

Show line references

Purchase order (optional)

Line	Quantity	Product		Ships	Unit price	Total	Delete
1	1 each	3190K508	Hydrated Lime, 50 lbs.	today (from our Chicago warehouse) Need this sooner?	$87.31 each	87.31	
2							

ADD | ? | Paste products and quantities

Merchandise total $87.31

10-ft Container for CCESP field deployment

www.texasportablestorage.com/storage-containers-for-sale.php

TEXAS PORTABLE STORAGE

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STORAGE CONTAINERS FOR SALE

Due to high cost of steel, and a global shortage of portable storage containers, finding new and used storage containers for sale is harder than its ever been before. Many suppliers are only offering rentals due to the high price of purchasing storage containers. TexasPortableStorage.com can save you a ton of time by connecting you with the suppliers that are offering their units for sale. When purchasing used storage containers it is always a good idea to see them in person before you buy them, to make sure that they are in good condition. Containers are very durable and most of the time you can apply a fresh coat of paint or get new locks and your container will be just as good as new.

NEW AND USED STORAGE CONTAINER PRICES

Although prices are constantly fluctuating, here is what you can typically expect to pay for portable storage containers in Texas:

SIZE	TYPICAL PRICE
New 10 Ft. Storage Container	$2,000 - $3,500
Used 10 Ft. Storage Container	$1,000 - $2,500

GET PRICING

What Size Container?
- 40 Foot Storage Container
- 20 Foot Storage Container
- 10 Foot Storage Container

Your Zip Code

Get Pricing

TOP CITIES FOR TEXAS PORTABLE STORAGE

Abilene, Amarillo, Arlington, Austin, Beaumont, Fort Worth, Frisco, Garland, Grand Prairie, Houston, Mesquite, Midland, Odessa, Pasadena, Plano

RO Elements

www.thepurchaseadvantage.com/page/TPA/PROD/Toray_RO_Membranes/W2T431399

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Purchase advantage — 800-208-3554

Search products — Search — 0 Items in Cart

Reverse Osmosis Membranes | Water Quality Meters | UV Products | Filter Cartridges | ION Exchange Resin | Activated Carbon | Laboratory Products

Free Shipping On Most Items in Continental USA — We Ship to Over 200 Cour

Home > RO Membranes > Toray RO Membranes > Toray TM810, RO Membrane for Sea Water, 4 x 40, 1200GPD, 99.75% Rejection, 800psi

Toray TM810, RO Membrane for Sea Water, 40, 1200GPD, 99.75% Rejection, 800psi

Code: W2T431399

UOM: EACH

Shipping: Free Ground Shipping in the Domestic US

Prices are in: US$

Ships from: "Manufacturer"

Price: $279.99 as low as $237.99

Cartridge Filters

```
Harrington Industrial Plastics                    Quotation#   00554576
7003 Valjean Avenue                               Written:     JPW
Van Nuys CA 91406                                 Quote Date   04/10/14
818-780-5212                                      Expire Date  05/10/14
818-780-5037 Fax                                  Page         1 OF 1
                          Quotation

      083839                              Ship To:
      U C L A                             UCLA CHEMICAL ENGINEERING
                                          420 WESTWOOD PLAZA
      10920 WILSHIRE BLVD 5TH FLOOR       5531 BH
      LOS ANGELES, CA  90024              LOS ANGELES, CA  90095

Job:                                      RFQ# KEYSTONE FILTERS
==========================================================================
Contact: HAN GU                     Ship Via: UPS GROUND
Phone#: 310-206-1297          FOB / Delivery ARO: SHIPPING POINT
Fax: 310-206-2222                   Frt-Terms: CHRG INBOUND & OUTBOUND
==========================================================================
Product/Description                   Quantity      Price    U/M   Extension
--------------------------------------------------------------------------

*3099 FILTER PRODUCTS MISC                  4       143.50 EA       574.00
G08RN20JS KEYSTONE GIANT NANO
KEY FILTER 4.5"X20" SOE/222
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Analytical Services: ICP-MS at UCLA Facility

ICP-MS FACILITY AT UCLA

The UCLA inductively coupled plasma-mass spectrometer (ICP-MS) facility was created when a Shared Instrumentation Grant submitted by the Facility Director to the National Institutes of Environmental Health Sciences (NIEHS) was funded in 2003 for $284,867 to further the research of NIH and other federal agency research grantees at UCLA, the University of California, and other interested Universities, companies, and research organizations. Generous support from Dean Linda Rosenstock also was essential.

The award resulted in the acquisition of:

- An Agilent 7500c quadrupole ICP-MS with hydrogen/helium octopole collision cell to minimize argon and oxygen isobaric interferences, and equipped with automatic sampler introduction and with concentric and microflow nebulization. Isotope and isotope dilution techniques are also facilitated.
- An Agilent 1100 Liquid Chromatograph equipped with autosampler and LC-MS interface (atmospheric ionization/electrosp
- An Agilent 6890N gas chromatograph equipped with a parallel flame ionization detector and GC-MS interface
- An Agilent G1602A Capillary Electrophoresis system equipped with autosampler, variable wavelength ultraviolet-visible detector, and MS interface

Thus liquids can be analyzed via the 2 nebulization modes to obtain elemental content in a multielemental manner at parts per trillion concentrations for each sample. Chemical and biological speciation is also possible via the chromatographic introduction systems.

WHAT CAN BE ANALYZED?

❑ **ENVIRONMENTAL SAMPLES**

- Drinking, ground, sea, lake, and river waters
- Soils, dusts, and rocks
- Dust wipe samples
- Aerosol samples
- Turbid liquids
- Air samples (midget impinger or solid sorbent)
- Hazardous and solid wastes

❑ **BIOLOGICAL SAMPLES**

- Blood, plasma, saliva, and urine
- Tissues like organs
- Plant materials (vegetables/crops)
- Hair, skin, nails, teeth

❑ **FOODS**

- Liquids like beverages (sodas, wine, beer, supermarket drinking water)
- Solids like tea, coffee, fish, meats, market vegetables, food containers

❑ **RESEARCH & DEVELOPMENT MATERIALS**

- Semiconductor materials
- Nanotechnology solid substrates
- Engineering materials
- Metal alloys
- Organometallics
- Metallic parts

Collaboration and Chromatographic Analyses: Contact the Director

ORDERING INFORMATION AND PRICES (Cut this panel)

Elements to be Analyzed (Insert below or circle overleaf)_____
Elemental Sensitivity Desired
(Please indicate elements or ppt,ppb,ppm overleaf near circled element)
_____ppt (pg/mL);_____ppb (ng/mL)
_____ppm (µg/mL); All:_ppt _ppb_ppm
Report (please tick) as gram per __mL; __g (wet weight);__g(dry weight)

Payment Please complete a P39 form with the Full Accounting Unit (FAU) if UC
Payment Address: Please Provide Full details including E mail, Fax, Phone, Zip, Contact Person.

Fee for Service Prices (Nebulized Liquids)

Standard: $30 per element per sample for 1-5 elements (not machine ready); $15/element for 6-10 elements/sample; $10/element for 11-20 elements/sample; $8.50/element for 21-30 elements/sample. If machine-ready, multiply by 0.7.
Bulk Rates Per Element Per Sample For Many Samples Submitted At One Time: half-price for 100-500; one-third price for 500-999; quarter-price for 1000-1,500.
Turnaround Rates Per Element/Sample: Above, 10-day standard; 5-day, twice standard; 1 day, 4 times standard.
Chromatographic Analyses: $160/sample with the above bulk, multielement rates.

Analytical Services: SEM-EDS

UCLA MIC Molecular Instrumentation Center

607 Charles E. Young Drive, East
University of California, Los Angeles
Los Angeles, CA 90095-1569
http://www.mic.ucla.edu

Materials Characterization Lab

If your funding is managed in a department other than Chemistry and Biochemistry, please arrange to establish a chemistry account by contacting Arlette Silva (avs@chem.ucla.edu).

Once you have been given access, the account number that you provide will be charged an access fee every month. The current rate is $30/month/user. Access fees are only charged to a maximum of 5 users per Research Director. This charge is assessed whether or not you use the lab. Thus, you should notify us that your access should be removed if you no longer plan to use the lab. Please make sure that your research director is aware of this charge policy.

Additionally, usage of some of the instruments in the Materials lab will be recharged based on the amount of time they are used. The current rates for the recharged instruments are:

SEM	$50/hour
Sputterer	$18/hour
AFM	$10/hour
TGA	$13/hour
DSC	$13/hour
Light Scattering	$5/hour
SQUID	$150/day
XPS	$220/day
Consultation/training	$100/hour

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UCLA CHEMICAL & BIOMOLECULAR E
5531 BOELTER HALL 420 WES
LOS ANGELES, CA 90095-0001

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Sep 29 – Oct 28

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Data	$.00
Verizon Wireless' Surcharges and Other Charges & Credits	$.02
Taxes, Governmental Surcharges & Fees	$.00
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Total Charges Due by November 23, 2013 **$29.65**

Software Subscription

NATIONAL INSTRUMENTS

Quotation No.: 2025871

Anditya Rahardianto
University of California - Los Angeles
Chemical Engineering Offices (Boe
420 Westwood Plaza
LOS ANGELES, CA 90095
UNITED STATES

Quotation Date: 15-SEP-2014
Quote Valid Until: 15-OCT-2014
Phone: (310) 206 1297
Fax:
Contact No: 5577717

Quotation No. 2025871

Please indicate the above quote number when ordering for faster processing. Contact us at (800) 433-3488, or submit orders to orders@ni.com.

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783091-01	Panel Mount Accessory to easily mount and secure NI myRIO Standard Delivery time: 10 - 15 business days ARO. *Country of Origin: USA*	1	14.00		14.00
940015-01	Academic LabVIEW Standard Service Program [illegible] LABVIEW PREMIUM SUITE (1 USER)	1	411.80		411.80

UCLA WATER TECHNOLOGY RESEARCH CENTER

UCLA ENGINEERING
Henry Samueli School of Engineering and Applied Science

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