OPPORTUNITIES FOR WATER TECHNOLOGY INNOVATION IN THE SAN JOAQUIN VALLEY

Assessing the potential for new approaches to address regional water challenges

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ACKNOWLEDGMENTS

This report was inspired by the San Joaquin Valley Water Innovation Workshop, held in Fresno, CA (February, 2024) to discuss the potential for next-generation advanced water technology to be applied in the San Joaquin Valley. Diverse stakeholders, including water users, technical experts, community NGOs, regulators, and water managers gathered to discuss emerging options and shared their knowledge and expertise of the local conditions to help inform the development and application of technologies that can offer benefits for agriculture, Valley communities, and other water needs. (See Appendix for a list of workshop participants.)

The research team would like to thank and acknowledge the National Alliance for Water Innovation (NAWI) and the California State Water Resources Control Board for providing funding for this effort. We also thank the many San Joaquin Valley (SJV) community organizations, agricultural businesses, technical experts, and water regulators who participated in discussions that informed this report. Without the hard work of California's diverse stakeholders to consider management and use of the state's limited water resources, and the willingness of these same stakeholders to collaborate on innovative, co-beneficial solutions to California's immense water challenges, this report would not have been possible.

We extend our special thanks to members of the Steering Committee for the February 2024 San Joaquin Valley Water Innovation Workshop, including Dr. Isaya Kisekka, Dr. Karl Longley, Toni Pezzetti, and Jessi Snyder, whose insights and dedicated support made this report possible.

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DISCLAIMER

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FOREWORD:
A LETTER FROM THE STEERING COMMITTEE

The challenge of accumulating salts in groundwater and soils rarely makes national headlines, but in many agricultural regions of the American West, it is becoming as significant a challenge as scarce water supplies. This concern is particularly urgent in the perennially water-scarce San Joaquin Valley (SJV) – one of the most productive agricultural regions in the world. Coveted water resources have defined the region since its gold rush inception, when “first in time, first in line” and “use it or lose it” principles fueled the consumption of water resources and the growth of California’s cities, industries, and agriculture at the expense of ecosystems and communities that had not (yet) made claims on the state’s waters.[2] As water supplies become more scarce in the SJV, they are increasingly susceptible to rising salt concentrations from agricultural, municipal, industrial, or natural sources. These salts build up in soils over time, reducing the overall arability and value of SJV land.[3]

California’s legacy system of water management and regulation was not designed to address the challenges of today’s warming climate, which has introduced the hottest and driest conditions observed in modern history. Under current conditions, researchers estimate that more than half a million acres of SJV farmland may need to be laid fallow by 2040 to relieve the region’s over-drafted aquifers.[4] Aridification is expected to continue to stress local and regional water resources into the foreseeable future. There is no silver bullet to prepare the SJV for a drier future. Instead, a holistic blend of interventions—including expedited regulatory reform, nature-based solutions, and advanced water treatment technology (such as desalination)—must be explored to mitigate future harms to communities and businesses in the SJV and similar regions. To design and implement an effective suite of solutions, including adaptive, fit-for-purpose water treatment technologies, leaders must collaborate with local and regional stakeholders and integrate their deep understanding of regional conditions, the Valley’s unique challenges, geographic characteristics, and community needs.

In February 2024, the National Alliance for Water Innovation (NAWI) and researchers at the University of California, Berkeley (UC Berkeley) convened a workshop of stakeholders to inform the design of locally-appropriate water solutions and advanced water technologies in the SJV. Participants included water users, technical experts, regulators, water managers, and representatives of community organizations.

Focusing on the SJV’s specific regional needs, this report offers a place-based exploration of how existing strategies can work with emerging advanced water technologies and critical regulatory and programmatic actions to create co-benefits for growers and rural communities in the SJV. It offers considerations for the design of desalination and other advanced water technology systems and explores the financial and regulatory commitments that are necessary for success.

As community members, advocates, and researchers, we were honored to support the preparation and facilitation of this workshop and look forward to continuing this important discussion with the diverse stakeholders who are critical to developing lasting solutions. We hope the report is supportive of your endeavors and strongly encourages other leaders in the field to invest in the ideas and solutions presented here.

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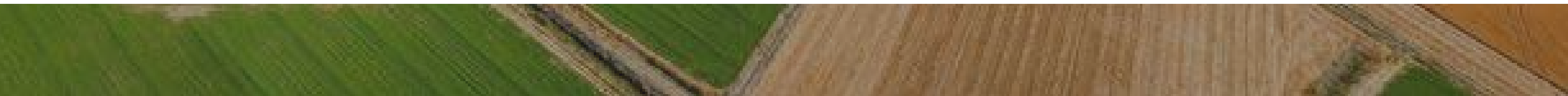

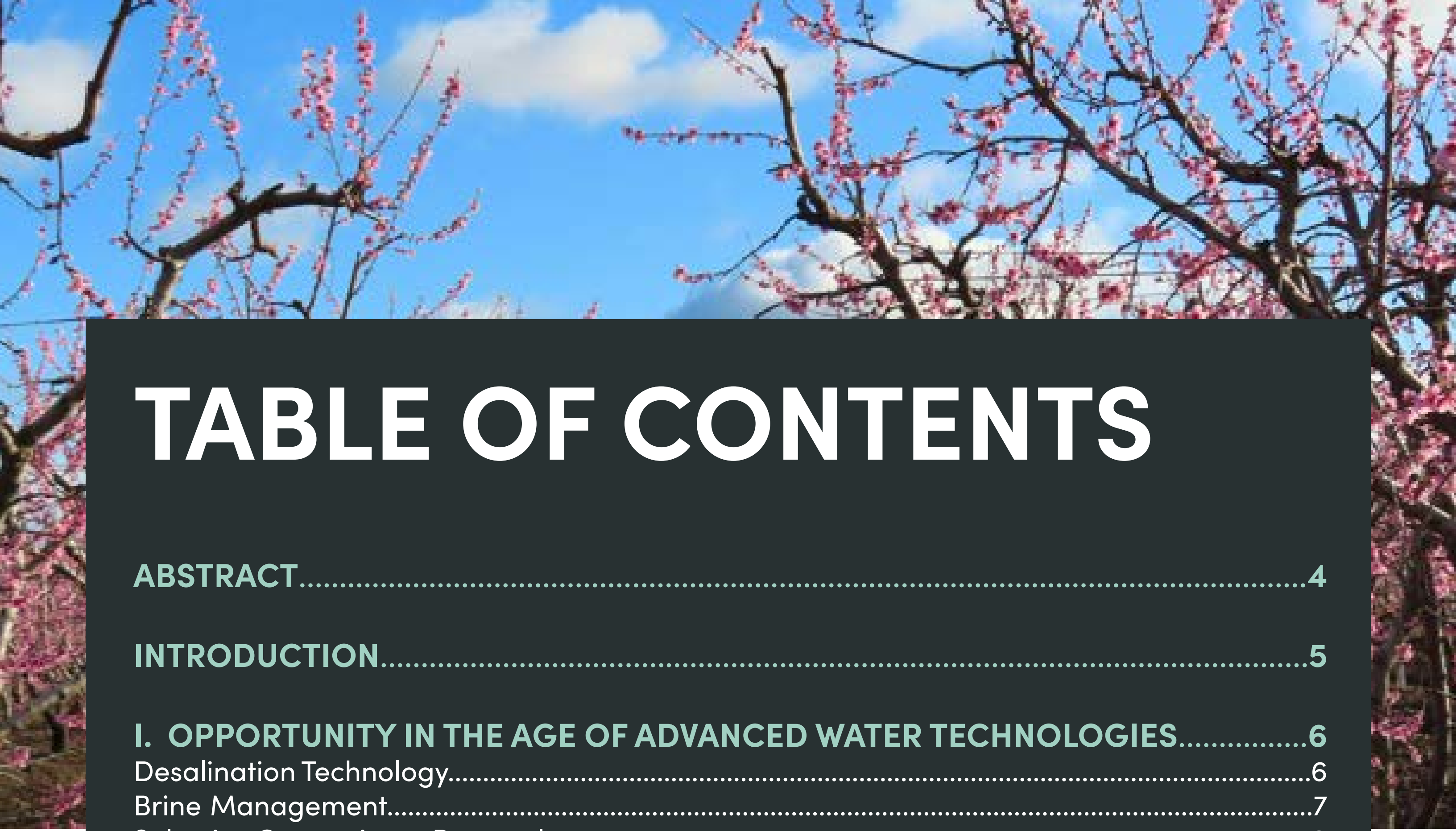

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ABSTRACT

The San Joaquin Valley (SJV) faces a significant water challenge due to a mismatch between water demand and available water resources, which is compounded by contamination of water supplies with nitrate, pesticides and other chemicals used in agricultural and industrial activities, along with the accumulation of salts in soils and groundwater. Although efforts to improve water use efficiency, coupled with changes in agricultural practices, may help bring water demand down to more sustainable levels, advanced water technologies could play a larger role in helping the region adapt to its water challenges. Innovative water technologies are undergoing rapid improvements in performance and reductions in cost, which could make them more viable for agricultural and rural applications. Informed by a workshop involving water managers, researchers, farmers, and community organizations who are familiar with the region, this report addresses the potential for employing these technologies in concert with changes in policies and optimization of existing water resource management tools. It also identifies areas of uncertainty and offers suggestions for advancing the use of advanced water technologies to address the SJV's current and future needs.

After identifying examples of advanced water technologies that are of greatest potential relevance to the SJV, we present the institutional context that determines how growers, cities and rural residents obtain, pay for, and plan for future water needs. We identify three distinct-but-overlapping challenges affecting the SJV: (1) securing a reliable supply of high-quality water for growing high-value crops; (2) realizing the human right to water in communities facing widespread contamination and falling groundwater levels; and (3) developing a long-term strategy for salt management. Although an ecosystem of water users, government agencies, political leaders, researchers, entrepreneurs, and community advocates are already working on policy reforms and ways of encouraging investment in the SJV's water future, progress is challenging because most of the current solutions that appear to be tractable require compromises that threaten the SJV's economic and public health.

Brackish water desalination is presented as an example of a technology with the potential to contribute to the solution of all three water challenges. We describe ways in which the deployment of small-scale modular desalination systems might gradually spread from a tool that serves some of the most water-stressed parts of the region to an approach that could help the broader community realize its shared goals. We identify technology bottlenecks, such as managing the brines produced by the desalination process, as well as regulatory, institutional, and social challenges to pursuing this and other advanced water technologies. Finally, we offer recommendations for next steps to gain additional insight into the potential for advanced water technologies to be part of a broader set of tools for responding to the region's water challenges.

Although our efforts focused on the SJV, the insights and recommendations in this report can contribute to assessments of the role of advanced water technologies in other water-stressed regions that face similar challenges with respect to the competing needs of irrigated agriculture, cities, and rural communities.

INTRODUCTION

As water technologies become more affordable, they are attracting greater attention as potential solutions for a more diverse range of applications.[5] Although advanced water technologies are no panacea, they may offer vital contributions to the "solutions toolbox" needed to support water-stressed areas around the world in adapting to drier conditions. As experts explore ways to apply these technologies in a wider range of communities, multi-stakeholder dialogues can provide insight into community needs, concerns, and potential institutional barriers to technology adoption.

This report uses California's San Joaquin Valley (hereafter referred to as the "SJV" or "the Valley") as a case study for developing water management strategies with the local context and unique regional concerns in mind. It was informed by a February 2024 convening of water managers, researchers, community leaders, and a range of water users from the region to analyze factors influencing the potential of advanced water technology applications. It combines insights shared during the workshop with research and perspectives of academics, technology developers, and other leading thinkers involved in SJV water technology development. It aims to provide critical regional context, as well as recommendations for further research, policy and financing considerations, and opportunities to optimize other, existing tools for managing water in the SJV.

While the findings and recommendations included here are focused on the SJV, this work contributes to an important national and global conversation about the potential for emerging technologies to be applied to other water-stressed regions. It is intended to inform researchers, entrepreneurs, and water service providers of approaches to best serve the needs of the SJV and similar communities.

The results of this effort are presented in three sections:

I. **Opportunity in the Age of Advanced Water Technologies** introduces the relevant types of advanced water technologies for SJV communities. For those with little prior knowledge of these technologies, this section offers context for understanding the capabilities and level of maturity of these advanced water technologies.
II. **Considerations for Place-Based Design** details the SJV-specific challenges and needs that inform the design and implementation of the region's water management strategies.
III. **Building a Sustainable Water Future in the San Joaquin Valley** sets forth strategic considerations for the research, policy, financial and other actions needed to support successful implementation of these technologies.

A PLACE-BASED ANALYSIS IN AMERICA'S AGRICULTURAL CAPITAL

This report examines the applicability of advanced water technologies within California's San Joaquin Valley, one of America's most productive agricultural regions. Located within the southern two-thirds of the Central Valley region, the SJV is home to the nation's top three agricultural counties. While agricultural production has defined many of the SJV's local communities and fueled its vibrant economy, the Valley's remarkable output has come at a price.

The SJV's communities and agricultural industry face a multitude of water-related challenges. Limited and variable surface water supplies have increased reliance on groundwater resources for agriculture, which has greatly depleted the area's groundwater aquifers. Agriculture, industry, and municipal water uses have increased concentrations of a variety of contaminants in the SJV's soils, groundwater, and surface waters, including salts, nitrates, and pesticides like dibromochloropropane (DBCP). These growing stressors on already limited water supplies have accelerated the exploration of innovative water solutions and prompted water technology innovators to evaluate whether emerging solutions can be adapted for application to the SJV's circumstances.

I. OPPORTUNITY IN THE AGE OF ADVANCED WATER TECHNOLOGIES

Following a trend set by solar panels, information technology, and other innovations, advanced water treatment technologies—once prohibitively costly—are becoming less expensive and increasingly effective in addressing water quantity and quality challenges (including salinization and the selective removal of contaminants that pose risks to human health and wildlife) in a variety of settings. This section reviews several advanced water technology categories, key terms, and related considerations. It is not a comprehensive list of available advanced water technologies, but a list of strategies highlighted by experts and participants in the February 2024 workshop as potentially relevant for the SJV.

DESALINATION TECHNOLOGY

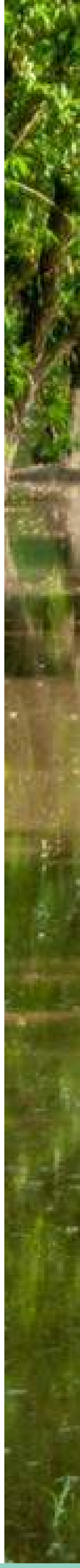
Desalination is the process of removing salts and other constituents from seawater, brackish groundwater, and any other water source. Ongoing innovations in desalination technology were one of the drivers for and a primary focus of the February 2024 workshop to discuss technology applications within the SJV. Today, desalination systems supply water to communities, farms, and industries worldwide using three approaches:[6]

Membrane-based technologies rely upon the ability of a thin layer of material (usually a synthetic polymer), referred to as a membrane, to selectively remove salts and other contaminants from water. The most common process is referred to as reverse osmosis (RO) because it relies upon the application of high pressure to reverse the osmotic gradient, which forces water to pass across the membrane from the salty solution to create water that is nearly salt-free. In the United States, RO is the most popular approach to desalination, accounting for over 75% of the nation's treatment capacity.

Thermal technologies employ heat to separate water from salts. Although various technological innovations involving pressurization of the water have made this process more efficient than the distillation systems that have been used for over a hundred years, modern systems still require a significant amount of energy. As a result, thermal processes have become less popular over the last few decades.

Electrochemical technologies, such as electrodialysis and capacitive deionization, employ electric fields to separate salts from water. These technologies are typically less efficient for seawater desalination than they are for the treatment of brackish groundwater and other waters with lower salt content. Because they are less mature, these technologies may have more potential for improvement than reverse osmosis, especially for application to brackish waters.

The majority of the desalinated water produced worldwide relies upon seawater as a source, and the product it yields is most commonly used for municipal or industrial purposes. However, technological advancements in desalination are leading to more diverse uses. Desalination of brackish groundwater, in particular, is becoming an increasingly common option for both industrial and municipal water supplies [see Figure 1].[7] As one example, California's Eastern Municipal Water District (EMWD) employs a brackish groundwater desalination plant using RO treatment to deliver 14 million gallons of water to more than 30,000 households each day.[8] More recently,



interest has been increasing in applying these technologies for agricultural applications, as described in NAWI's 2021 research roadmap for agricultural applications of water technologies.[9] Ongoing work at the United Nations Food and Agriculture Organization (FAO) is supporting sharing of information about the opportunities and challenges of using desalinated water in agriculture.[10] Early work suggests that desalinated water is of high quality and can have a less negative impact on soils and crops, in comparison with direct use of brackish water, and that brackish water desalination is more suitable for agricultural production than seawater desalination.[11] Desalination is also being used for agricultural applications outside of the United States. For example, growers in Spain are demonstrating the feasibility of brackish groundwater desalination applications, with over 20% of Spain's desalinated brackish groundwater used for agricultural irrigation.[12]

Fig. 1: Although "desalination" often conjures images of large coastal treatment plants, in 2020, inland desalination of brackish groundwater already accounted for a significant share of California's desalination facilities, as shown above.[13]

BRINE MANAGEMENT

Technologies for removing salt from water (i.e., desalination) are widely available. In contrast, the management of the brines produced by desalination (and other treatment technologies, such as ion exchange for nitrate removal) is a less mature field. In many cases, salty water is simply released back into the environment, with limited evaluation of its potential impacts. For inland regions where the dilution of brines in coastal outfalls is not an option, development and application of advanced water technology will depend on technological innovation to lower costs of safely managing brines. Brine management strategies typically include a combination of volume reduction, valorization (i.e., resource recovery), and disposal.

Volume reduction: Volume reduction aims to minimize the volume of brine, thereby reducing the cost of transport and disposal. Zero Liquid Discharge (ZLD) describes strategies that remove all water from the brine to produce solid salts; Minimum Liquid Discharge (MLD), a less energy intensive process, produces a much smaller volume of brine than what is produced in the desalination process. Technologies used in both of these strategies, such as high-pressure reverse osmosis and vapor compression distillation, are costly and energy intensive.[14,15] As a result, most current applications of these technologies are limited to industrial brines. Emerging technologies, such as solvent-based extraction that can achieve brine concentration or salt crystallization, have the potential to lower the costs of MLD and ZLD.[16] Land-based strategies, such as the use of evaporation ponds[17] or the application of brines to salt-tolerant crops,[18] offer lower-cost alternatives but require large land areas and careful management to mitigate environmental risks, such as wildlife exposure to toxic salts.

Valorization: The recovery of marketable resources from brine offers an opportunity to turn waste into beneficial products and to offset the costs of brine management. Technologies are being developed to extract specific components from brines, such as calcium, magnesium, potassium, and sulfate, which are commonly used in fertilizers.[19] Additionally, other commodity chemicals like caustic, sulfuric acid, and chlorine can be recovered and utilized in industrial processes. Valorization is attractive because it can reduce transportation costs and dependency on imported materials. It also can create new markets for brine-derived products, potentially contributing to the sustainability of agricultural and industrial operations.

Disposal: Despite progress being made on brine volume reduction and valorization, the management of residual waste remains a critical challenge. Presently, landfilling of solid salts is often the most cost-effective option, provided that concentrations of toxic elements are low enough to avoid hazardous waste classification. However, scaling up landfilling operations may require dedicated facilities designed to prevent leaching into groundwater, and landfilling may not be a long-term sustainable solution, considering the quantities of salt that might be generated in a region like the SJV. Another disposal method is deep well injection, where brine is stored in subsurface geological layers isolated from water supplies. While effective in some regions, the feasibility of this approach depends on the availability of suitable injection sites. Even in inland regions, pipelines can be built to transport brine to coastal areas for disposal in the ocean, though this strategy comes with high costs and potential environmental impacts.

THE SAN JOAQUIN VALLEY: A HISTORY OF WATER INNOVATION

With SJV agricultural commodities flowing to global markets, a dynamic population, and a shifting climate, the SJV is constantly evolving and has long been at the forefront of global trends to adapt, innovate, and grow. This region, and much of California, has pioneered the deployment of water-efficient irrigation technologies[20] and offered testing grounds for advanced water treatment technologies.

Federal government investments in water technologies in the 1960s led to a variety of research projects and breakthroughs in water innovation. Notably, Sydney Loeb and Srinivasa Sourirajan led an effort at the University of California Los Angeles (UCLA) to develop the modern reverse osmosis membranes now used in desalination.[21] The first major application of these advanced water technologies took place in the SJV town of Coalinga. Subsequent advancements paved the way for the first cost-competitive seawater desalination solution in coastal California, the Middle East, Australia, and other parts of the world.



SELECTIVE CONTAMINANT REMOVAL

Although salt contamination is a critical issue in the SJV, as well as many other parts of the world, other advanced water treatment technologies that complement desalination are being used to address a wide array of contaminants that compromise water quality. A range of technologies can be used to remove contaminants for drinking water, irrigation water, and/or to lower the costs of brine disposal (e.g., by removing contaminants that would lead to the classification of the wastes as hazardous).[22] Advanced technologies that can effectively separate contaminants also have the potential to valorize what would otherwise be waste products, subsidizing the cost of treatment and shifting the region towards a circular economy. Common strategies for selective contaminant removal include:

Biological treatment: Bioreactors use microbes to remove contaminants like selenium (a toxic element) from irrigation water, capturing it in a solid form that is easier to manage. The Bureau of Reclamation and other entities have attempted to pair biological treatment with RO membranes to address selenium contamination, which has been the subject of concern in irrigation drainage water in the SJV for several decades.[23] [24]

Electrochemical treatment: NAWI is developing alternatives to biological contaminant removal that rely upon electrochemical treatment to remove contaminants, such as selenium and arsenic. These approaches can be less expensive, easier to operate in modular configurations, and more robust when faced with changing water conditions or flow rates than biological treatment.

Organic contaminant oxidation: California communities in which drinking water is contaminated with organic chemicals (e.g., DBCP, 1,4-dioxane) sometimes employ oxidative treatment (e.g., ultraviolet light and hydrogen peroxide) to degrade organic chemicals.

Activated carbon treatment: Passing water that is contaminated with organic compounds through cartridges packed with activated carbon, a substance similar to charcoal, or other types of high-surface-area materials, can remove organic contaminants. These cartridges can be installed at drinking water treatment plants, at groundwater wells, or in homes (e.g., under the sink).

Ion exchange: Like activated carbon adsorption, ion exchange employs cartridges packed with resins that are designed to remove charged ions. They can be used to remove contaminants like nitrate (a substance that is sometimes leached from farms) or hexavalent chromium (a naturally occurring ion that is sometimes found in groundwater at unsafe concentrations).

MODULARITY AND AUTONOMY

Innovative design and operations of treatment plants are lowering costs and increasing advanced water technology applications. Modularity is the process of converting product manufacturing from tailored applications to standardized approaches. Autonomy refers to the ability of advanced water technologies to operate without constant oversight from a trained, onsite operator. Historically, advanced treatment technologies like reverse osmosis (RO) required detailed engineering designs and constant operator support to function effectively. Today, modular designs have made it possible to produce compact, point-of-use (POU) and point-of-entry (POE) systems, such as under-sink RO units that require minimal maintenance and no operator oversight. At the same time, breakthroughs in autonomy—using sensors, actuators, computing tools, and machine learning—are enabling increasingly sophisticated water treatment systems to operate independently, further reducing the need for operator intervention. By leveraging standardized, modular designs and eliminating the reliance on costly onsite operators, these advancements pave the way for small-scale, decentralized systems to become cost-effective and widely accessible.

PLACE-BASED SOLUTION: UCLA'S SMART INTEGRATED MEMBRANE SYSTEM (SIMS)

Modular and decentralized approaches to water treatment have successfully addressed sub-regional water challenges on an as-needed basis. UCLA's Smart Integrated Membrane System (SIMS), for example, is a portable desalination plant that employs reverse osmosis to treat roughly 25,000 gallons of clean water per day. This technology has already been deployed to mitigate high levels of salt and calcium sulfate in the farmlands of the SJV's Panoche Water District and Drainage District and to treat nitrate-contaminated, saline drinking water for disadvantaged communities in the Salinas Valley.

SIMS addresses several critical needs in the SJV by offering an automated, remotely-operable solution that reduces the burden on individual growers and communities to manage system operation. While broadband access is a prerequisite and remains a limitation in some areas, SIMS' scalability makes it a promising option for water treatment in under-resourced communities. If adopted widely, SIMS or similar systems could lay the groundwork for regionally managed, distributed water treatment solutions.

Despite its promise, SIMS also underscores the persistent challenge of brine management in the San Joaquin Valley. During its deployment in Panoche, the system discharged its brine stream into pre-existing infrastructure that is not available throughout the SJV. In the Salinas Valley, brine was managed via discharge into the communities' septic systems, a solution that required years of engagement with regulators. While the UCLA team is optimistic that a similar general permit waiver could be approved in the SJV, this approach would likely only be viable for small, septic-dependent communities in the SJV. Moreover, while locally effective, this method does not address the broader issue of salinity accumulation across the Valley, highlighting the need for scalable, region-wide strategies to manage brine and mitigate long-term salinity impacts.

II. CONSIDERATIONS FOR PLACE-BASED DESIGN

Designing for the conditions of a specific location or region is essential to ensuring adoption and successful, long-term technology operation. For water innovation to be practical and effective, it must consider the local context, including institutional factors, and geographic attributes and constraints. Additionally, understanding the needs, challenges, and opportunities of the local community and water users is critical to designing robust solutions that will have broad support. The following section addresses the local conditions in the SJV that can provide insight into the design and potential application of advanced water technologies. A similar place-based assessment of community needs, geography, geology, institutions, contaminants, water rights, and other factors is necessary before applying these technologies in other locations. While a one-size-fits-all technical solution does not exist, the challenges and enabling conditions discussed in the SJV can provide insights into applications elsewhere. In other words, the communities that pioneer these systems will make it easier for communities that follow them to tailor advanced water technologies to meet a new set of local needs.

INSTITUTIONAL AND REGULATORY ENVIRONMENT

Water management in the SJV takes place within a complex institutional and regulatory landscape. A water rights regime established over a century ago governs access to surface water supplies, while groundwater governance is a rapidly evolving field. Water users in the SJV may be subject to oversight from a host of different entities, including city and county governments, irrigation districts, groundwater sustainability agencies (GSAs), salt and nitrate management zones, drainage districts, and water quality coalitions associated with the Irrigated Lands Regulatory Program (ILRP), among others. While these entities often overlap geographically, their boundaries rarely align, contributing to the hyper-localized nature of water management in the region and complicating efforts to implement integrated, regional solutions. While a comprehensive review of this landscape is beyond the scope of this report,[25] this section highlights the illustrative policies, programs, and initiatives that were cited as relevant to the design and application of innovative water technologies during the workshop preparation and discussions.

THE HUMAN RIGHT TO WATER

With Assembly Bill (AB) 685 in 2012, California recognized the human right to water through state law, acknowledging that "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."[26] While efforts to make good on this promise are still under development, more than one million Californians still face water insecurity. Investments, such as the Safe and Affordable Funding for Equity and Resilience (SAFER) program, have committed millions of dollars to accelerate the progress of providing safe and affordable drinking water and achieving the vision set out in AB 685.[27]

THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA)

In 2014, California enacted the Sustainable Groundwater Management Act (SGMA) to strengthen local management and monitoring of groundwater basins critical to the state's water needs. The legislation established a framework for state-wide groundwater resource protection to ensure a sustainable water supply. SGMA required water users to develop plans for achieving sustainable groundwater levels by the early 2040s. Most water users are planning to employ a mix of two approaches:

Reductions in water use: Identifying more efficient ways to use water, shifting to less water-intensive crops, and, in some cases, taking farmland out of production, can lead to substantial water savings. According to the Public Policy Institute of California (PPIC), SGMA will require the fallowing of at least 10% of the SJV's irrigated farmland (more than 500,000 acres) by 2040.[28]

Restoration of depleted groundwater supplies: Managed aquifer recharge[29]—the process of replenishing groundwater resources by enhancing the infiltration of rainwater or by using imported water to recharge—can reverse much of the historic groundwater depletion.

SGMA prompted local agencies to form local groundwater management organizations called Groundwater Sustainability Agencies (GSAs). These bodies are responsible for developing and implementing groundwater sustainability plans (GSPs) tailored to sub-regional conditions.[30] The GSPs (which, in 2024, are being adopted, approved or disapproved by the State, and implemented) may accelerate land fallowing and investments in recharge infrastructure, or create new opportunities for investments in advanced water technologies. While SGMA's decentralized approach allows policymakers to tailor the selection and implementation of water technologies to a regional context, the introduction of GSAs and corresponding GSPs within the landscape of existing California water regulations has complicated the regulatory process. Many workshop participants lamented the increasing reporting and compliance costs faced by municipal water utilities, farmers, and other SJV water users under SGMA.

CENTRAL VALLEY SALINITY ALTERNATIVES FOR LONG-TERM SUSTAINABILITY (CV-SALTS)

The Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) program, established in 2006, is a collaborative effort to address the challenges of salt and nitrate accumulation in California's Central Valley. Its mission is to protect water quality, restore groundwater, and ensure safe drinking water for communities while supporting agricultural and economic sustainability. Operating on both immediate and long-term timescales, CV-SALTS has developed the Salt and Nitrate Management Plan (SNMP) and the Salt and Nitrate Control Program, providing a framework for near-term solutions and planning for sustainable resource management over decades.[31]

NON-GOVERNMENTAL SUPPORT FOR WATER IN THE SJV

In addition to the entities implementing specific programs and/or supporting specific user groups, there are numerous non-governmental organizations (NGOs) and other entities working on solutions to the water challenges facing the SJV. NGOs play a crucial role in water management and often serve as intermediaries between government agencies and water users; advocating for underrepresented interests; filling gaps in expertise, decision-making, and planning; and providing education and training.

Providing technical assistance: Organizations like Self-Help Enterprises[32] and the Community Water Center[33] assist small communities that have contaminated drinking water supplies by offering technical expertise, assisting with infrastructure planning, and connecting them with funding opportunities to improve water systems.

Facilitating research and policy development: Research institutes, such as the Public Policy Institute of California (PPIC), provide data-driven insights and recommendations on water governance, including strategies for groundwater sustainability, salinity management, and equitable water access.

Advocating for marginalized communities: NGOs work to amplify the voices of disadvantaged communities that are disproportionately affected by water scarcity and contamination, ensuring that the concerns of these communities are represented in policy discussions at local, state, and federal levels.

Supporting sustainable agriculture: Organizations such as Sustainable Conservation collaborate with farmers to promote best practices for groundwater recharge, irrigation efficiency, and nutrient management, helping balance agricultural productivity with environmental sustainability.

Engaging in advocacy and lobbying: NGOs across various sectors actively participate in advocacy and lobbying efforts, influencing legislation and policies that address critical water issues, from drinking water quality standards to large-scale infrastructure projects.

Promoting multi-benefit solutions: Environmental organizations like the Environmental Defense Fund build coalitions to support initiatives like the Multi-Benefit Land Repurposing Program (MLRP),[34] which integrates water conservation, habitat restoration, and community resilience into regional land-use planning.

Educating and empowering stakeholders: Through workshops, training programs, and outreach, NGOs equip water users, community leaders, and policymakers with the knowledge and tools needed to engage in informed water management and decision-making.

Within the patchwork of agencies, stakeholder coalitions, NGOs, and community groups pursuing their visions for a sustainable future in the SJV, formal pathways of cross-sector collaboration across groups that are focused on agriculture, low-income rural communities, and long-term planning are limited. GSAs are starting to create opportunities for critical interaction among stakeholder groups on a very localized scale. To advance a sustainable future in the SJV, governing agencies and bodies at the state and local levels will need to work together to develop sustainable, holistic, and implementable solutions.

PHYSICAL AND CLIMATIC CONDITIONS

The unique characteristics of any region must be accounted for in the solution-building process. Key characteristics of the SJV include:

Climate variability and climate change: Like other water-stressed regions, the SJV suffers from the impacts of human-induced climate change. In recent decades, climate change has exacerbated water shortages, spurred more frequent and extreme flood or drought events, and (in some areas) degraded water quality.[35] Furthermore, the region is experiencing increasingly erratic weather patterns. SJV leaders are exploring technologies to support farmers and communities, with an eye toward adapting to a future where a changing climate is likely to have a greater effect on many aspects of the region's economy and daily life.[36]

Increasing salt and nitrate contamination: The intensification of agricultural activities (including large dairy operations and a range of efforts to increase yield per acre), industrial activities, and urban development have significantly increased the levels of salts, nitrates, and other contaminants in San Joaquin Valley soils, groundwater, and surface water. Elevated concentrations of salts and contaminants can make many water resources unusable for agriculture and unsuitable for drinking or bathing. As a result of groundwater use, exacerbated by an increasing frequency of droughts and higher evaporation rates, the SJV increasingly represents a "closed basin"—with water either exiting through evaporation or infiltrating into groundwater.[37] [38] Diminishing outflows of water increases the concentration of salts and other contaminants in dwindling groundwater supplies. Rising soil salinity is already leading to billions of dollars in lost revenue, and experts predict that farming will become less viable as salinity in soil and water supplies rises in the next several decades.[39]

Sub-regional variations: Exploration of water solutions in the SJV is complicated by stark sub-regional differences between the east and west sides of the basin. With notably more arid conditions and lower soil permeability, the SJV's western region is more prone to salinization and waterlogging[40] than the eastern SJV.

COMMUNITY CHALLENGES AND NEEDS

The SJV's water-related challenges are exacerbated by a host of underlying social challenges, including poverty and income disparities. While advanced water technologies cannot resolve these societal issues, a deeper awareness of the selection, design, siting, and implementation of technological solutions can avoid compounding a community's existing challenges. As such, this section details more of the local context as it relates to both agricultural water and community drinking water.

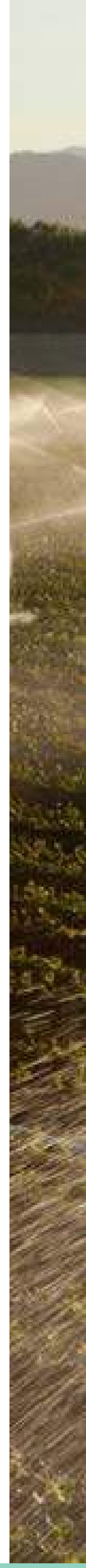
LOCAL CONSIDERATIONS FOR AGRICULTURAL WATER

Farming and related industries that produce a variety of agricultural commodities—including wine, stone fruit and citrus, tree nuts, vegetables, dairy products, and beef—account for about 14% of the SJV's GDP and employ nearly one-fifth of the region's workforce.[41] Despite their economic importance, the region's farms face significant irrigation water supply challenges. The Public Policy Institute of California (PPIC) estimated that "combined impacts of SGMA, climate change, and environmental regulations could cause a 20 percent reduction in water availability for valley agriculture" by the year 2040. The SJV also faces increasing labor costs and labor shortages, development pressure, and competition with other agricultural regions. These changing local conditions all require farmers and agricultural communities to adapt their practices.

Challenges and Needs for Agricultural Water

Regulatory compliance: Growers in the SJV face an increasingly complex regulatory landscape. Navigating the intricate web of regulations—imposed by the Department of Water Resources, the Central Valley Regional Water Quality Control Board, and others, many of which are not directly related to water (e.g., pesticide management)—demands significant staff time and resources from farmers.

The struggle to preserve small farms: While many factors have contributed to the corporate consolidation of agriculture in recent decades, including market access, financing mechanisms, agronomic sophistication, and distribution capacity, there is a prevailing belief that today's regulatory environment is hostile to small-scale farming operations.[42] Many SJV stakeholders feel strongly that small farmers should have a continued role in the Valley's future. Many advocate for regulatory reforms to right-size compliance requirements for small farmers, alongside capacity-building initiatives to



help farmers navigate regulatory systems efficiently and/or platforms for collectively managing and complying with regulations.

Volume and reliability of water supplies: The demand for irrigation water for agricultural crops fluctuates significantly over the course of the year. Generally, SJV farms require high volumes intermittently, depending on growing cycles, which results in inconsistent demand. While some farms are transitioning their crops and farming practices to adapt to increasing water scarcity, farmers often have great difficulty securing an ample volume of irrigation water at the right time. Due to water shortages throughout the SJV, there is still an inherent challenge in supplying large volumes of water to widely dispersed users.

Financial pressure: Farmers in the SJV are increasingly caught in a financial squeeze, facing rising costs of inputs (labor, materials, and water) on one side and declining farmland values on the other. Many attribute this land devaluation to SGMA-related uncertainties in groundwater availability and unpredictable access to surface water, which reduce the appeal of agricultural land for buyers.[43] This dual pressure complicates farmers' ability to sell their properties, limits the value of land as collateral for loans, and strains small rural communities through reduced property tax revenues.

LOCAL CONSIDERATIONS FOR DRINKING WATER

Access to clean, affordable drinking water is essential for the 4.3 million residents of the SJV, yet many communities in the region face persistent water quality, quantity, and affordability challenges. Hundreds of thousands of SJV residents rely on water systems that have received violations for exceeding maximum contaminant levels (MCLs), with nitrates, arsenic, and DBCP among the most common contaminants. Small, rural communities are disproportionately affected, and many residents depend on private wells that may be contaminated but remain largely unmonitored. The combined pressures of groundwater overdraft, climate change-induced drought, and a legacy of agricultural and industrial pollution have led to significant drinking water insecurity. While state programs like the Safe and Affordable Funding for Equity and Resilience (SAFER) initiative aim to address these issues, the resources they provide fall short as drinking water supplies are increasingly requiring more (and more complicated) treatment.

Challenges and Needs for Drinking Water

Community capacity: Within the SJV, large municipal water providers have substantial operating resources and are typically able to provide safe drinking water to their constituents. In contrast, many small and low-income communities lack the technical, managerial, and financial (TMF) capacity to maintain adequate water quality, making them more vulnerable to water quality violations.[44] NGOs like Self-Help Enterprises play a critical role in bridging this capacity gap, providing technical assistance and helping small communities navigate drinking water challenges and solutions. State agencies and NGOs frequently recommend consolidation with a larger water system over installing standalone treatment solutions. However, this approach can conflict with communities' desires to maintain local control and autonomy over their water supply.

Financial barriers and funding gaps: Most funding for drinking water infrastructure is allocated as upfront capital for new projects, with limited support for ongoing operation and maintenance (O&M) costs. This places the financial burden of O&M—covering labor, energy, and materials—on consumers through their water bills. While the SAFER program has introduced some provisions for ongoing maintenance, California lacks a statewide rate assistance program to



help low-income households afford their water bills. Water systems using advanced treatment technologies often face high operating costs due to labor and energy demands, making them financially unsustainable for small or under-resourced communities. Proposition 218 ("Right to Vote on Taxes Act") further constrains public utilities by prohibiting cross-subsidies for system upgrades and operations and requiring ratepayer approval for rate increases. When residents already struggle to pay their water bills, there is often strong resistance to costly new water projects that could push rates even higher.

Technical and operational challenges: Water systems that rely on advanced treatment technologies require qualified operators, but these specialized professionals are costly and in short supply. Retention of water system operators is also a challenge, since urban utilities can offer higher salaries than small SJV communities can afford. To address these operational gaps, many stakeholders, including some workshop participants, support the creation of a regional utility district to manage and operate small community water systems. Some advanced treatment technologies also introduce waste/brine management challenges. For example, ion exchange systems, often considered the gold standard for nitrate treatment, produce a brine waste stream that must be properly handled. Due to cost and disposal challenges, this technology is rarely used in the SJV, leaving communities with few viable treatment options.

Public mistrust: Researchers have documented significant public mistrust of the institutions responsible for managing SJV water supplies, with focus group participants citing anecdotal evidence of irritants in tap water, uncertainty regarding the age and condition of pipes, and frustrating interactions with water companies.[45] This mistrust extends to Point-of-Use (POU) and Point-of-Entry (POE) treatment systems, as a major barrier to adoption. Residents are uncomfortable with outsiders on their property or in their homes for system installation and maintenance. These concerns further complicate efforts to implement decentralized water treatment solutions in affected communities.

Water systems that serve both farms and residential communities face similar operating limitations in SJV's rural, remote areas. Affordable and reliable access to labor, energy, broadband internet, and materials—attributes that are critical for many advanced water technology solutions—may be a barrier to these small communities.[46] The shortage of a trained workforce capable of maintaining and operating small-scale advanced water systems is an additional challenge in the SJV. Taking these complex and intertwined challenges into account in the design of technology, systems, and infrastructure is critical to a sustainable water future in the SJV.

III. BUILDING A SUSTAINABLE WATER FUTURE IN THE SAN JOAQUIN VALLEY

Like many water-stressed communities, the SJV faces a complex set of challenges. Once the challenges and needs of the region are thoroughly understood, a common vision for the future and an integrated strategy can be used to identify and evaluate solutions. A range of resources and tools will be needed, including but not limited to advanced water technologies.

A TOOLBOX APPROACH

Implementing comprehensive water management strategies in the SJV will require multiple tools. An array of existing and potential future strategies, infrastructure solutions, and practices are needed to comprehensively manage a sustainable water supply, including:

- **Ensuring adequate flood management for wet years** to minimize damage to communities
- **Stormwater recharge and groundwater banking** to manage floodwaters and develop mechanisms to retain water in wet years, which then provides water resources for drought years
- **Region-wide freshwater pipelines** to transport freshwater, including desalinated water, over long distances
- **Repurposing agricultural land** for solar development, water-limited cropping, habitat restoration, recharge basins, and water-efficient new housing. As many as half a million acres of land may need to be fallowed and repurposed in a "best-case-scenario" for the SJV[47]
- **Real-time management** to remove salts from the Valley by discharging brine seasonally or during higher surface water events

The following section offers considerations for designing advanced water technology solutions appropriate for the SJV's water challenges. Following an overview of specific design criteria and strategies for brackish groundwater desalination, brine management, and distributed delivery mechanisms with potential for success in the SJV, this section addresses critical provisions for the successful implementation of desalination systems and other advanced water technology strategies in the SJV, including sustainable financing, capacity-building, regulatory and institutional support, and community engagement.

DESIGN CONSIDERATIONS FOR ADVANCED WATER TECHNOLOGIES IN THE SJV

Innovations that lower costs and improve performance have made advanced water technologies (including desalination) that were once thought to be relevant only to municipal water supply and high-value industrial operations viable for a wider range of applications, including agriculture. Many technologies are still undergoing development that will continue to improve performance and lower costs. Thus, we anticipate that technologies that appear to be out of reach for SJV water users today may become more attractive in the next decades.

This section explores key criteria and other considerations that need to be factored into the designs for advanced water technology across three contexts: community water supplies, irrigation supplies, and Valley-wide salinity management. February 2024 workshop participants cited several characteristics that would render desalination technologies suitable for the SJV's geography and community needs. Ongoing dialogue is necessary to further refine these design criteria for specific applications of advanced water technologies.

CENTRALIZATION VERSUS DISTRIBUTED SYSTEMS

Coastal seawater desalination plants, which serve densely populated areas, are a well-established model in California. However, this approach is less suitable for many parts of the SJV, where farms, businesses, and homes are widely dispersed and have diverse needs for water volume and quality. By rethinking system scale and distribution, advanced water technologies can be more effectively adapted to meet the region's varied and decentralized water demands.

Brackish water desalination for agriculture: In some regions of the SJV, particularly on the west side, desalination may allow growers to use brackish groundwater that would otherwise be too salty for irrigation or to extend the use of degraded once-fresh groundwater supplies.[48] While growers generally prefer control over their own resources and may favor highly distributed, farm-scale systems, smaller systems do not benefit from economies of scale and are often more expensive on a per-unit basis. Large, well-resourced farms may therefore benefit from installation of their own desalination systems, while groups of neighboring smaller farms could collaborate by connecting multiple wells that share a single desalination system. However, current irrigation practices, which involve high flow rates for short periods according to the growing season, pose challenges for implementing brackish water desalination: sizing systems to match irrigation flow demand would result in much higher upfront costs, while sizing a smaller system designed for continuous operation would require significant storage capacity. For growers in irrigation districts, a district-operated local desalination system could leverage existing infrastructure to store and distribute desalinated groundwater, making it more accessible and affordable for smaller, less-resourced farms.

Distributed design alternatives for communities and homes: Mobile units, point-of-use (POU) water treatment (under-the-sink), and point-of-entry (POE) systems (at the entry to a home or business) employ small reverse osmosis cartridges, ion exchange, granular activated carbon, or absorptive media to remove salts, nitrate, chemicals, and other contaminants from drinking water. Research efforts, including those led by NAWI, seek to improve the performance, affordability, and energy efficiency of these small-scale treatment systems while reducing reliance on external maintenance. Other emerging approaches, such as electrochemical treatment and modular, container-based desalination systems, offer potential solutions for businesses or communities with financial means to treat brackish or contaminated groundwater at shared wells. While distributed treatment infrastructure is and will continue to be necessary for homes and communities in the SJV, many workshop participants stressed the institutional and governance challenges of decentralized systems and highlighted the benefits of more centralized management, operation, and governance. Questions related to the appropriate scale of advanced water treatment systems will remain important as NAWI and others seek out the early adopters and plan for technologies that are suitable for the later stages of technology diffusion.

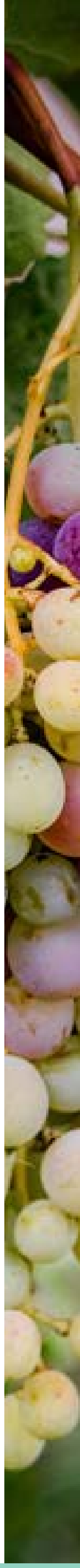
FINANCIAL VIABILITY AND AFFORDABILITY

While cost and affordability of treatment technologies is a crucial factor across the board, water systems' affordability depends on the context.

Agricultural affordability and business models: In agriculture, affordability is a question of whether growers can continue to make a profit while using desalinated water. In February 2024, workshop participants indicated that for agricultural applications, the cost of producing desalinated water becomes attractive as it lowers closer to $800 per acre-foot, a range familiar to growers of high-value or permanent crops during dry periods. For context, desalination technologies available in 2024 are often capable of producing water at a cost between $600 and $1,200 an acre-foot, with the range determined in large part by the approach used for brine management and disposal. However, farmers are often hesitant to invest in expensive systems outright due to climate variability, since they are unlikely to use desalinated water during wet years. Flexible business models, such as leasing, rental, or water purchase agreements, may be more appealing than outright purchase.

Operational affordability in community water systems: For community water systems, long-term affordability hinges on keeping operating costs low enough to ensure continued use in low-income communities, even if initial capital costs are higher: while funding programs often finance the installation of treatment systems, they rarely cover ongoing operational expenditures, leaving communities to shoulder these recurring costs.

Financing salt removal and value recovery: When considering long-term salt management, the key metric may be the cost of removing salts from the Valley rather than the cost per unit of water produced. Financial viability will depend on equitable funding and financing structures that determine who pays and how costs are distributed. Affordability can also be enhanced through valorization, in which constituents of the brines are converted into marketable commodities (e.g., fertilizers) to partially offset project operating costs. Achieving this outcome requires investment in research, market development, and processing infrastructure. Integrated strategies combining treatment technologies, brine disposal, and sustainable practices will be critical to ensuring both affordability and regulatory compliance.



OPERATIONAL REQUIREMENTS

Desalination systems for the SJV need to be as simple as possible to operate, incorporating features like autonomous operation to eliminate the need for constant onsite supervision.

Local labor and regional operation for communities: For community water systems, workshop participants described the importance of employing local labor whenever possible. They also raised the potential for a regional utility district model, in which communities could share operators to achieve economies of scale and ensure access to skilled labor without sacrificing the safe operation of their systems.

Reducing operational burdens and managing intermittency for growers: Growers noted that they already manage too many roles and responsibilities and do not want to also learn how to run a desalination system. This concern demonstrates the need for systems that are either simple enough for anyone to use—akin to a washing machine—or supported by business models in which technology providers handle operations. Desalination systems for agriculture also need to be able to handle intermittency on multiple timescales, since systems would likely only operate in dry years and during the irrigation season.

STRATEGIES FOR BRINE MANAGEMENT IN THE SJV

Advanced water technologies cannot be implemented sustainably in the SJV without also advancing options for brine management. Workshop participants highlighted the complexity of the brine management challenge and the need for solutions that do not trade one problem for another. Without a viable solution for handling brine, many promising water treatment technologies remain impractical and could complicate the salinity challenges over time or result in significant financial burdens on local communities. For example, small-scale desalination for agriculture is nearing (and in some cases, has reached) economic viability, but brine disposal remains an unsolved problem. Similarly, while ion exchange effectively treats nitrate contamination in drinking water, it is rarely deployed in the SJV because the lack of cost-effective brine disposal options puts an economic burden on communities that outweighs the benefits of the technology.

Limitations of current brine disposal strategies: Existing strategies for brine disposal in the SJV offer limited scalability and significant tradeoffs. Land-based strategies, such as evaporation ponds or applying brine to salt-tolerant crops, have long been used in the SJV, and may become more viable as SGMA is expected to take some farmland out of production. However, these strategies require significant land area and careful management to avoid environmental impacts, such as wildlife exposure to toxic salts (e.g., selenium) or contamination of nearby groundwater. A successful regulatory approach from the Central Coast may offer a model for small communities in the SJV: after years of effort, a discharge waiver now allows small volumes of brine to be disposed of in community septic systems. While this could work for some small communities in the SJV, it is not scalable for the larger brine volumes produced by agriculture or municipal systems, nor does it address basin-wide salt accumulation. Out-of-basin disposal options (e.g., a pipeline transporting brine to San Francisco Bay) have also been discussed, though some workshop participants view this path as unrealistic due to its enormous cost—estimated at over $8 billion—and likely permitting and political hurdles. A more flexible approach might be a "virtual brine line," which would involve transporting highly concentrated brine slurries by truck or rail to coastal regions for discharge. While this option decreases the direct costs of a pipeline, a careful cost-benefit analysis would be needed to fully estimate indirect costs and risks.

A case for regional brine management: While advances in brine treatment technologies are ongoing, they remain costly, operationally demanding, and technologically complex. It is therefore unlikely that decentralized solutions for brine concentration and valorization will develop quickly enough to support the widespread adoption of small-scale desalination systems. A more feasible approach may involve regional brine management, in which brine from distributed small-scale systems can be aggregated. Regional facilities would allow economies of scale, enabling more cost-effective brine concentration, valorization, and disposal. Successful deployment of valorization technologies in particular can support a long-term vision of sustainable agriculture and circular economies in the SJV.[49] This approach could provide small-scale systems with a feasible disposal pathway while also leveraging regional resources to address the Valley's broader salt management issues.

Balancing in-basin and out-of-basin disposal: Workshop participants emphasized the need to carefully weigh the sustainability of in-basin versus out-of-basin brine disposal options. In-basin strategies, such as evaporation ponds or landfilling, offer localized solutions but must address challenges related to land availability, environmental risks, and salt accumulation. Out-of-basin options, like a brine pipeline or a virtual brine line, remove salts from the SJV entirely but are costly and raise environmental concerns for receiving areas and transport impacts.

Moving forward, participants agreed that brine management strategies must be both technically and economically sustainable while protecting the Valley's long-term soil and water health. Addressing regulatory constraints on brine disposal will also be critical, especially for smaller systems that lack clear discharge pathways. Ultimately, brine management solutions need to balance local feasibility with the broader goal of maintaining the Valley's agricultural, environmental, and economic viability.

FINANCING A STATE-WIDE STRATEGY FOR BRINE MANAGEMENT

Concentrated brines from desalination systems are a burdensome liability to communities and water managers throughout California. Local stakeholders shoulder the cost of brine waste disposal, and long-term storage can result in compounding impacts of salt accumulation in coastal waters and community water sources. Recognizing the magnitude of the brine management challenge for many communities and growers throughout California, there is a compelling case for state leadership to finance and develop a suite of strategies for:

Resource recovery and reuse: Conducted at-scale, the recovery and reuse and/or sale of salts and other critical minerals in brine water could offset the costs of advanced water technology in the SJV and beyond.

Brine transport and storage: An integrated plan for leveraging new and existing infrastructure to transport and store extracted materials is necessary for effective brine disposal.

Integrated surface and groundwater management: Planning is essential for shifting stream flows, irrigation needs, drinking water supplies, floodwater management, aquifer recharge, etc.

Grower support: State-wide strategies to partner with growers in designing solutions that ensure the viability of SJV agriculture is critical to SJV economic development and national food security.

ACTION KEY:
- Regulatory
- Financial
- Technology
- Community

SJV BRINE MANAGEMENT ACTION PLAN

Participants in the February 2024 workshop discussed the importance of developing a long-term plan for brine management in order to achieve a vision of sustainability for the SJV. They emphasized the value of efforts underway, including the CV-SALTS Prioritization and Optimization (P&O) Study,[50] which is developing a long-term plan for managing and controlling salt accumulation throughout the Central Valley. Water users, government agencies, political leaders, researchers, and community advocates all have roles to play, and a coordinated plan that integrates their efforts will maximize impact. Workshop participants brainstormed illustrative examples of the actions needed by diverse players at key points in a long-term timeline. These ideas, many of which align with CV-SALTS' existing plans, are presented below.

YEAR 1

- Assess technology needs, including ZLD, contaminant removal and constituent recovery, modular/flexible treatment
- Conduct study to estimate real cost (true cost accounting) of comprehensive brine management strategy
- Complete CV-SALTS study to characterize salt conditions across SJV
- Develop pilot salt management demonstration area on west side of SJV utilizing drainage water
- Study brine transport options: export concentrated brine (hazardous and nonhazardous) and in-valley brine transport to salt management areas(s)
- Launch SJV technology incubator and business accelerator
- Pilot salt concentration technologies to reduce volume, including evaporation without open ponds
- Study costs, legal constraints and technical needs for brine line to transport concentrated waste
- Conduct study to identify options for concentrating brine and managing residual
- Complete permit for demonstration salt management area
- Conduct study to assess incentives and subsidies for effective salt management in SJV
- Conduct study on potential for revenue positive valorization of brine
- Engage in ongoing dialogue with entities to define design criteria for specific applications
- Pilot brine collection and management infrastructure: collect west-side salts at centralized management area
- Pilot advanced resource recovery facility to valorize constituents from brine
- Develop floodwater management strategy

YEAR 10

- Establish "One Water for Salt" institutional mechanism for managing selenium across surface water, groundwater, and other entities
- Initiate Basin Plan Amendment
- Create Valley-wide workforce development strategy for operation of facilities
- Complete scientific proof of concept for treating brine
- Complete proof of concept at demonstration salt management area
- Complete CV-SALTS Prioritization & Optimization Study

YEAR 15

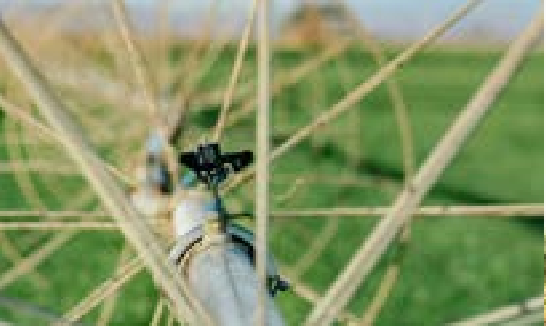
- Treat brackish groundwater for use
- Expand to multiple salt consolidation collection sites
- Implement incentives for salt collection
- Establish institutional body for integrated salinity management
- Establish a basin-wide permit for brine management

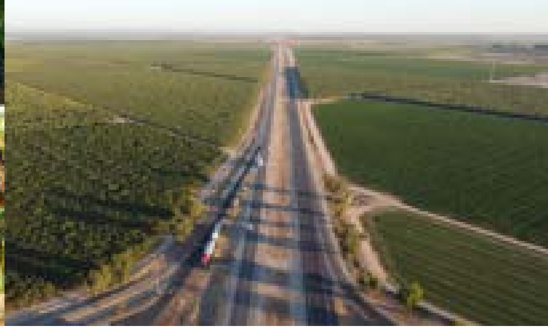
YEAR 20

- Establish a legislative model for long-term funding salt management and wastewater treatment requirements
- Complete concentrated Brine Residue Transport system
- Complete full-scale resource recovery facility

YEAR 40

- Vibrant communities
- Prosperous agricultural sector, supporting SJV economy and food supply for California and the country
- Access to consistent, affordable, and safe water supplies with sufficient volumes for agriculture and community development
- Effective management of brines to extract valuable materials (e.g., gypsum, fertilizers, fresh water) and minimize impacts from contaminants





OVERCOMING BARRIERS TO INNOVATIVE TECHNOLOGY ADOPTION

By some accounts, technological innovation and research is the "easy" stage of the water challenge. Creating the enabling environment to support the acceptance, implementation, and operation of advanced water technologies is, by many measures, the more formidable challenge. Furthermore, new technologies require a longer path to scale, compared to tested, conventional water management options. To pave the way for the adoption of advanced water technologies in the SJV, participants in the February 2024 workshop emphasized the importance of:

- Financing, economic development, and capacity building
- Building enabling regulatory conditions and institutional support
- Facilitating community engagement and partnership with local leaders

FINANCING, ECONOMIC DEVELOPMENT, AND CAPACITY BUILDING

One of the most cited impediments to implementing viable water and salt management solutions in the SJV is funding. Funding is critical to success, not only for research and development of emerging technologies, but also for long-term operations and maintenance financing. Examples of financial needs raised by workshop participants included:

- Financing mechanisms for operations and maintenance of small water systems
- Investment in the permitting, piloting, operations, and scaling of salt management areas for local disposal
- Financial incentives to support growers and other water users in the SJV to:
    - Enact practices to reduce the concentration of salts
    - Facilitate effective brine management on farms
    - Monitor and address groundwater salinity

An assessment of the true cost of a comprehensive salinity management strategy—from treatment to disposal of residue—can further define opportunities for advanced technologies. An assessment is costly, but this research can illuminate important information for lawmakers, agencies, and all stakeholders who want to contribute to a comprehensive, successful strategy.

A study funded by a mission-related agency, such as the California Department of Water Resources (DWR)—that includes financial needs, available funding, regulatory reforms, trade-offs, and other factors—could determine the feasibility of incorporating at-scale advanced water technologies into the SJV's water management strategy. CV-SALTS is engaged in some of this work already and may present a mechanism for pursuing additional opportunities for financing critical infrastructure and incentives.

BUILDING ENABLING REGULATORY CONDITIONS AND INSTITUTIONAL SUPPORT

Workshop participants stressed the challenge of complying with existing regulations. Numerous federal and state agencies and civil society initiatives have jurisdiction over related issues: CV-SALTS, SGMA, the Environmental Protection Agency (EPA), State Water Resources Control Board (SWRCB), and the CA Natural Resources Agency (which houses the Department of Water Resources), whose responsibility includes climate adaptation and resilient infrastructure. These represent a complex web of authorities and resources relevant to scaling advanced water solutions. Future initiatives that expand the mandate of existing management entities, rather than creating new ones, may avoid exacerbating this institutional complexity.

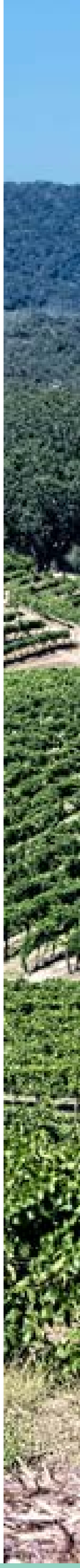
The SJV's size and landscape diversity also demand new types of institutional controls to address salinity management. Surface water entities, groundwater entities, and various user groups can work together to tailor solutions that address unique local needs. Groundwater Sustainability Agencies (GSAs) are well positioned to implement decentralized approaches while other interests explore centralized solutions. A valley-wide management strategy involving regional and state agencies and (potentially) new institutional bodies could attract more resources, create economies of scale, and open more solutions beyond those available locally. Solutions that allow for both local leadership and implementation controls, along with regional, valley-wide solutions and resources, are essential.

COMMUNITY ENGAGEMENT AND LOCAL LEADERSHIP

Effective data aggregation, communication, outreach, and community engagement will help develop public support for effective water and salinity management. Generating opportunities for collaboration across stakeholder groups can improve understanding of the local context and tap local expertise. The State Department of Water Resources (considered "friendlier" than other government agencies by many within the SJV) could serve as a hub for information sharing, research, convening, and community engagement. Elements of a communications and outreach strategy may include:

- Communication tools and maps that clearly convey the regional concentration of contaminants to SJV residents and describe available resources to address them.
- An SJV-wide map of contaminant concentrations to support farmers, local water managers, and technology developers, in efforts to develop integrated solutions.

Thankfully, some of these efforts are already underway, though the resources are not always widely accessible. Collaboration is needed to capitalize on the available resources. Within the patchwork of agencies, stakeholder coalitions, NGOs, and community groups that are pursuing a sustainable future for the SJV, there are limited formal pathways for cross-sector collaboration that focus on agriculture, low-income rural communities, and long-term planning. GSAs are starting to create opportunities for critical interaction among stakeholder groups on a very localized scale. The February 2024 workshop reflected the value of dialogue among farmers, community water users, regulators, and others involved in water issues throughout the SJV. The range of interests and expertise illustrated why it is important to support multi-party collaboration. To advance a sustainable future in the SJV, governing agencies and bodies at the state and local levels will need to work together to develop sustainable, holistic, and implementable solutions.



CONCLUSIONS AND RECOMMENDATIONS

Technological advances, combined with changing environmental and economic conditions, have enabled advanced water technologies to help address more diverse water challenges in cities, industries, and a handful of agricultural communities worldwide. Innovative water technologies like desalination are undergoing rapid improvements in performance and reductions in cost, which could make them more viable for agricultural and rural applications in the SJV and similar regions of the US, where the combination of high-volume users and less dense populations creates challenging economics.

The February 2024 workshop offered an opportunity to examine the context of a specific population and to explore the potential for adoption of desalination and other innovative water technologies as part of a broader set of responses to regional water challenges. The workshop illuminated practical considerations, design criteria, and clear actions that can help inform and accelerate progress in the SJV. These insights can inform efforts in water-scarce communities throughout the country. The following summary highlights transferable insights and recommendations beyond technical design considerations.

1. **Local expertise is critical to successful technology design and implementation.**

The SJV offered an up-close look at the challenges faced by rural and agricultural communities. Diverse local, regional, and state experts bring knowledge that enhances understanding of both the challenges and local context, which can be used to help adapt innovative water technologies to a specific application. A robust understanding of local geography, contaminants, water rights, institutions, demographics, and community needs is critical to designing and implementing advanced water technologies. Furthermore, engaging a range of interests helps to ensure that the needs of all user groups are considered equitably. By exchanging ideas with local communities and exploring opportunities together, stakeholders are more likely to develop robust, co-beneficial, and lasting solutions that are supported and implementable. The workshop offered transferable insights but does not replace the value of site-specific community engagement as a best practice in the water technology development lifecycle.

2. **R&D alone is insufficient; an innovation ecosystem is needed.**

Water users, government agencies, political leaders, researchers, entrepreneurs, and community advocates need to work together to address policy reforms and institutional mechanisms that support technology innovation in the SJV and beyond. Research and development for advanced water technologies can only go so far without parallel efforts to address the financing, policy barriers and incentives, workforce development, and other enabling conditions that will help ensure that technologies are accepted, adopted, and safely operated. Partnerships with private industry could play a role in accelerating solutions by developing industrial uses for brine waste streams. For example, could sodium-ion battery manufacturers locate production facilities in the SJV?

3. Contributions from diverse players are needed.

A sustainable water future for the SJV will rely on many organizations, agencies, initiatives, and individuals. The workshop discussion highlighted some priority roles needed from specific organizations; we have itemized illustrative examples below. The list is not intended to be exhaustive.

NAWI and Technology Developers

- Continue to invest in technology innovation and development that helps address increasingly complex and emergent water challenges in water-stressed, rural, and agricultural communities.
- Continue efforts to develop modular and autonomous adaptations of water treatment technologies that will allow for increased flexibility to supply water in remote, water-stressed applications.
- Support efforts to address the enabling financial and regulatory conditions that will facilitate equitable implementation of advanced water technologies in the region.
- Design systems with low operating costs or systems that do not have to be operated continuously to be economical (e.g., can be "mothballed" during wet years to reduce operating costs and allow flexibility for increasingly erratic weather conditions).
- Develop autonomous systems that can be maintained by the workforce that exists in places like the SJV, which often lack the diverse and specialized skills available in larger population centers.
- Fund research to align future advanced water technology development with the needs of communities like the SJV. Engage existing coalitions, initiatives, and non-profit organizations to inform the further development of these technologies.
- Support collaborative community engagement in other regions of the country to expand understanding of the design characteristics in a wider range of applications.
- Work with state, regional, and local agencies to integrate advanced water technologies, including desalination, into the plans for long-term water sustainability.
- Advocate for the integration of place-based learning and authentic community engagement to inform the design and application of water technologies, in water-stressed regions of both the United States and abroad.

Policymakers

- Support home-grown and regionally-focused policy initiatives coming from groups like the SJV's GSAs and CV-SALTS.
- Harmonize existing regulations and ensure that any new regulations accompanying advanced water technologies do not exacerbate the already significant regulatory burden on communities and farmers in the SJV.
- Pursue options for public funding of major water development efforts, such as a region- or state-wide brine management strategy.

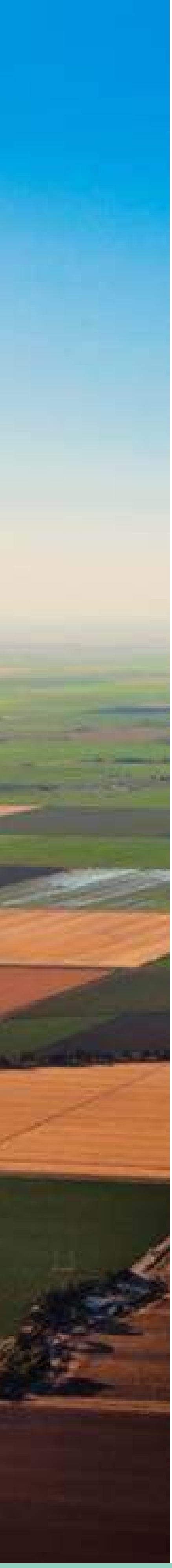
Groundwater Sustainability Agencies

- Integrate advanced water technologies, including desalination of brackish groundwater, into local groundwater sustainability plans.

California Department of Water Resources (DWR)

Relative to other agencies, DWR is widely trusted within the SJV. As such, they can play a critical role in supporting community engagement, education and co-design.

- Serve as a hub for information sharing, research, training, convening, and community engagement.
- Lead additional community outreach and education to support implementation of innovative water technologies at the individual and community levels.
- Support multi-stakeholder discussion forums.



- Help local residents and community leaders identify and understand best practices and integrate advanced water technologies into existing water management structures.

Local Academic Institutions

- Help build a trained workforce capable of maintaining and operating small-scale advanced water systems.
- Support the development of tools needed to assess local groundwater and soil conditions.
- Provide data sharing and extension services that target improved water and soil management alternatives.

4. Provide financing and leadership for a state-wide brine management strategy.

Some problems cannot be addressed effectively at the local level. Concentrated by-products from desalination systems are a burdensome challenge throughout California, and local jurisdictions lack the authority, resources, or political power to implement long-term solutions. Recognizing the magnitude of the brine management challenge in California, there is a compelling case for state and federal leadership to support research and development and to guide and finance strategies for:

- **Resource recovery and reuse:** Conducted at-scale, the recovery and reuse and/or sale of valuable commodities, like fertilizers and industrial chemicals, from brine could offset the costs of advanced water technology in the SJV and beyond.
- **Brine transport and storage:** An integrated plan for leveraging new and existing infrastructure to transport and/or safely store residual waste within the SJV is necessary for effective brine management.
- **Integrated surface and groundwater management:** Planning is essential for managing changing water availability, irrigation needs, drinking water supplies, floodwater management, aquifer recharge, etc.
- **Grower support:** State-wide strategies to partner with growers in designing solutions that ensure the viability of agriculture is critical to the economic development of many communities like those in the SJV and ensuring national food security.

5. A collaborative approach that involves the community is key to understanding the challenges to water management and developing implementable solutions.

This report illustrates the value of multi-stakeholder dialogue in the development of robust and implementable water resource strategies in communities like the SJV. The February 2024 workshop was an important step in an ongoing conversation about how to address complex challenges in the face of limited resources in the SJV, and it offers a model for reckoning with scarce water resources in other parts of the country. These conversations need to continue. Working together across user groups will allow communities to seek co-beneficial solutions while considering both equity and long-term sustainability of the region's economy. Having the right people at the table will help to ensure that one problem is not simply traded for another, or that the needs of one user do not come at the expense of another.

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ABOUT THE NATIONAL ALLIANCE FOR WATER INNOVATION (NAWI)

NAWI is a research program and public-private partnership supported by the U.S. Department of Energy (DOE) in partnership with the California Department of Water Resources and the California State Water Resources Control Board. NAWI brings together a world-class team of industry and academic partners to examine the critical technical barriers and research needed to radically lower the cost and energy of desalination. NAWI is led by the DOE's Lawrence Berkeley National Laboratory, in collaboration with National Energy Technology Laboratory, National Renewable Energy Laboratory, and Oak Ridge National Laboratory. It is funded by the Office of Energy Efficiency and Renewable Energy's Industrial Efficiency and Decarbonization Office.