June 2026

Managing Salinity in a Changing Delta

Insights from Collaborative Workshops

Delta Science Program

DELTA STEWARDSHIP COUNCIL

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Disclaimer

Executive Summary

Overview

The Salinity Management Workshop series brought together hundreds of interested participants to learn from one another and explore strategies for managing salinity intrusion in the face of accelerating climate change. Below are the three overarching management needs that emerged from the workshops and how the Council is working to address them.

Management Need 1: A Holistic, Systems Approach to Adaptively Managing Salinity

Through this workshop series, participants built upon existing hydrodynamic frameworks to develop a new conceptual model that includes the connections between social, ecological, and technological elements and associated trade-offs. We recommend the use and expansion of this conceptual model to address the most pressing knowledge gaps and foster an interconnected understanding of salinity management. This will require additional social science capacity and funding, which is already being supported by a number of Council efforts including the Delta Residents Survey, the Delta Research Awards, and the Bay-Delta Social Science Community of Practice.

Management Need 2: Inclusive Collaboration and Coordination Across Regions, Sectors, and Disciplines

Factors across California impact salinity dynamics in the Delta, and vice versa. Workshop participants highlighted that many groups directly impacted by salinity management actions are not adequately represented in decision-making spaces, including Tribes, in-Delta residents, and environmental justice communities across California that rely on Delta water. Addressing these gaps requires dedication to meaningfully engage with diverse groups across the state, which is supported by the Council's Tribal and Environmental Justice Issue paper.

Management Need 3: Flexible Modeling Approaches to Assess Trade-offs and Track Metrics that are Meaningful to Society

Support for novel modeling approaches will allow for more flexible, efficient, and accurate modeling research. As part of this workshop series, the Council funded the development of a new modeling approach that others can use and build upon to explore salinity outcomes. Integrating new modeling approaches can be supported by multiple efforts including the modeling Collaboratory currently being piloted by the Council, and the related COEQWAL and Just Transitions in the Delta efforts led by University of California and focused on salinity management.

This workshop series demonstrated how agencies can open dialogue to make adaptive management processes more transparent by bringing together participants with diverse interests to share knowledge, improve collective understanding of complex issues, and create opportunities for further collaboration.

Inspiration for a Salinity Management Workshop Series

The Sacramento-San Joaquin Delta (Delta) is the most significant water hub in California, providing water to more than 27 million Californians and supporting communities, farms, and industries within and outside the region. The Delta also provides critical habitat for more than 750 plant and animal species, many of which are endangered. The Delta's watershed covers approximately 40 percent of California, where extended droughts and sea level rise are expected to worsen with climate change, increasing the potential for intrusion of salty ocean water into the Delta through the San Francisco Bay. Salinity intrusion into the Delta's waterways increases salt in ground and surface waters, threatening water quality and availability for human uses (e.g., drinking water, irrigation) and ecosystem health (e.g., species tolerances). Historically, the distribution of salinity in the estuary fluctuated significantly between and across years, but today's salinity distribution in the Delta depends on hydrology, bathymetry (underwater topography), freshwater reservoir releases, and physical infrastructure that prevents saltwater intrusion. Given the uncertainties surrounding climate change and the risks to current infrastructure, managing Delta surface water salinity to meet diverse needs requires adaptive approaches across institutional and regional boundaries.

The Delta needs long-term, feasible approaches to salinity management that support both a high-quality water supply and a healthy Delta ecosystem. To help address these evolving challenges, the Council's Delta Science Program (DSP) hosted a series of Salinity Management workshops from 2022 to 2024 with three primary goals:

1. **Build a shared understanding** of the range of issues associated with ocean salt intrusion in the Delta and different **salinity management tools and strategies** that could be used in response to sustained and recurring drought conditions and other climate change impacts.

2. Identify **knowledge gaps** and scenario-based modeling work to evaluate **socioeconomic and ecological impacts and trade-offs** of different salinity management tools and strategies.
3. Support the development of **collaborative adaptive management** approaches to salinity management.

Workshop Approach

The Salinity Management Workshop series, led by the DSP, featured online public workshops, working group meetings, and support for developing a more efficient modeling approach to discern salinity responses to changes in Delta geometry, such as tidal wetland restoration or physical flow barriers. Speakers and panelists included representatives from state and federal agencies, Tribes, agriculture, community groups, public water agencies, and recreational users. Participatory workshops provided hundreds of attendees with opportunities to actively engage, share their perspectives, learn from one another, and inform the development of the workshop series. Participants also provided feedback to inform a pilot research project using the CalSim water resources planning modeling framework, which is widely used by agencies to understand the effects of water infrastructure operations on salinity in the Delta. While well-attended, workshop participation was dominated mainly by staff from various local, state, and federal agencies, with a small portion of participants from Tribes, agricultural groups, recreational groups, community-based organizations, and residents.

Lessons Learned About Salinity Management

The workshop series focused on saltwater intrusion and the challenges of controlling salinity under climate change. It also highlighted available actions for managing salinity and their associated trade-offs. Three broad management needs emerged from the Workshop Series:

1. A Holistic, Systems Approach to Adaptively Managing Salinity

Throughout the workshop series, participants discussed the complex and interconnected nature of salinity management in the Delta. From the watershed to the ocean, interconnected dynamics unfold across space, time, and disciplinary dimensions (Figure 1). This complexity makes it difficult to develop strategies that achieve desired outcomes while avoiding unintended consequences. To address this complexity, workshop participants worked together to build conceptual models of salinity management, explicitly demonstrating a wide range of potential direct and indirect trade-offs associated with different management actions (Figure 1).

For example, workshop participants discussed converting certain islands into managed wetlands with control gates as a salinity management strategy. Aside from the primary benefit of controlling salinity, participants noted potential benefits such as carbon storage, bird habitat, and recreation. However, participants also pointed out that gate operations could facilitate the spread of certain invasive species, which could then impact fish populations important to agency conservation efforts and recreational fishing communities. Thus, planning additional invasive species control could be a key component of such a scenario to minimize undesirable consequences. Understanding related systemic connections and their impacts can improve adaptive management planning and associated monitoring needs.

2. Inclusive Collaboration and Coordination Across Regions, Sectors, and Disciplines

Factors across California impact decisions that influence Delta salinity dynamics, and vice versa. While the system is interconnected, it is managed by diverse and sometimes fragmented organizations. Effectively representing diverse priorities and minimizing negative impacts requires detailed understanding of interactions across scales from local to statewide, and effective collaboration and coordination to balance needs and impacts. Workshop participants highlighted that many groups, whose perspectives are not adequately represented at the decision-making table, stand to be directly impacted by salinity management actions. These groups include Tribes, in-Delta residents, and environmental justice (EJ) communities from across California that rely on Delta water. This emphasizes the importance of deliberately incorporating more representation and transparency into decision-making processes. To support this, interdisciplinary research can meaningfully engage affected communities whose perspectives have historically been less considered in water management decisions.

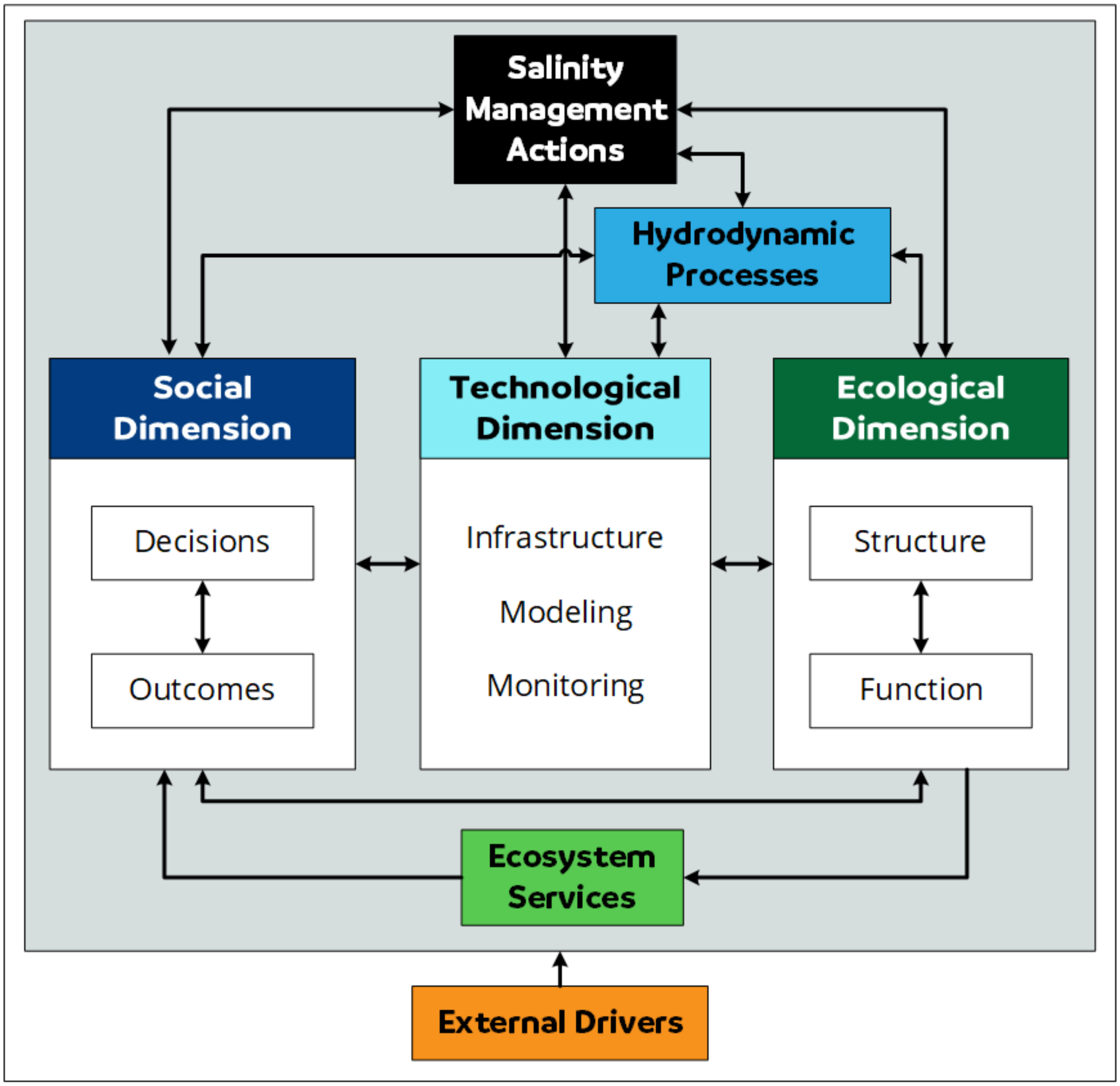

Figure 1: A simplified conceptual model of salinity management developed by workshop participants. See the full text for a more detailed version.

3. Flexible Modeling Approaches to Assess Trade-offs and Track Metrics that are Meaningful to Society

Modeling is essential for decision-making in water management. However, existing modeling tools often inadequately consider social dimensions of salinity management, despite the integral role people play in managing salinity and its impacts on communities across California. To address this disconnect, the workshop showcased how tools and approaches, such as participatory scenario development and improving existing models, can fundamentally transform modeling and establish more widespread support for proposed actions. Participatory approaches to model development, such as the Franks Tract Futures effort, are responsive to feedback, explicitly incorporate trade-offs, and highlight issues that matter most to communities, which can improve the credibility and legitimacy of proposed salinity management actions. Additionally, improved functionality of existing models can increase the range of scenarios that can be quantitatively modeled.

As part of the DSP-funded pilot modeling project, the modeling team developed an updated approach for modeling inputs to be used in CalSim, enabling more in-depth exploration and evaluation of a wider range of scenarios involving sea level rise and land-use changes, including tidal restoration. For more information on the status of their project, check out the Delta Science Tracker (project #53501) or email AdaptiveManagement@deltacouncil.ca.gov.

Introduction

The Delta is the central hub for much of California's water supply, routing water from upstream watersheds and reservoirs to communities, farms, and industries in and outside the region. It is also a complex tidal system where freshwater management interacts dynamically with marine-based salinity, which is pushed inland and upstream by tides from the Pacific Ocean (Herbert et al., 2015). Under current and future conditions, the region faces substantial challenges to managing salinity including extreme precipitation variability (Dettinger 2016); severe, multi-year droughts (Williams et al. 2020); and anticipated sea-level rise (Chua and Xu 2014). These conditions put immense pressure on water management systems and require innovative approaches to salinity management.

The intrusion of salt into the Delta can have far-reaching impacts, including, but not limited to, disrupting wildlife and ecosystems, compromising water quality and availability for urban and agricultural users, damaging crops, and impeding water pumping operations. These concerns, among others, underscore the importance of anticipatory, creative, science-based modeling and planning for managing salinity, a recurring theme across the region's climate adaptation strategy, Delta Adapts (Council, 2025a).

Workshop Goals

As climate change continues to unfold, the Delta needs long-term, feasible approaches to salinity management that maximize benefits while minimizing negative impacts on affected ecosystems, individuals, communities, and organizations. To help address these evolving challenges, the DSP hosted a series of Salinity Management workshops from 2022 to 2024 with three primary goals:

1. **Build a shared understanding** of the range of issues associated with ocean salt intrusion in the Delta and different **salinity management tools and strategies** that could be used in response to sustained and recurring drought conditions and other climate change impacts.
2. Identify **knowledge gaps** and scenario-based modeling work to evaluate **socioeconomic and ecological impacts and trade-offs** of different salinity management tools and strategies.
3. Support the development of **collaborative adaptive management** approaches to salinity management.

Workshop Approach

These workshops were designed to support adaptive management (Figure 2) of salinity in the Delta to maximize water supply reliability, support a healthy Delta ecosystem, and minimize harm to people and other species. Adaptive management is defined in the Delta Reform Act as a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specific objectives (Wat. Code, § 85052). Three phases – "*Plan*," "*Do*," and "*Evaluate and Respond*" – iteratively guide adaptive management in the Delta. This workshop series was more specifically focused on supporting the *"Plan"* phase. The workshop also focused solely on managing ocean salt intrusion, rather than other forms of salinity that impact the Delta.

To ensure the events were relevant to science and water management priorities in the Delta, workshop planning was informed by interdisciplinary experts from various government agencies, water contractors, and universities.

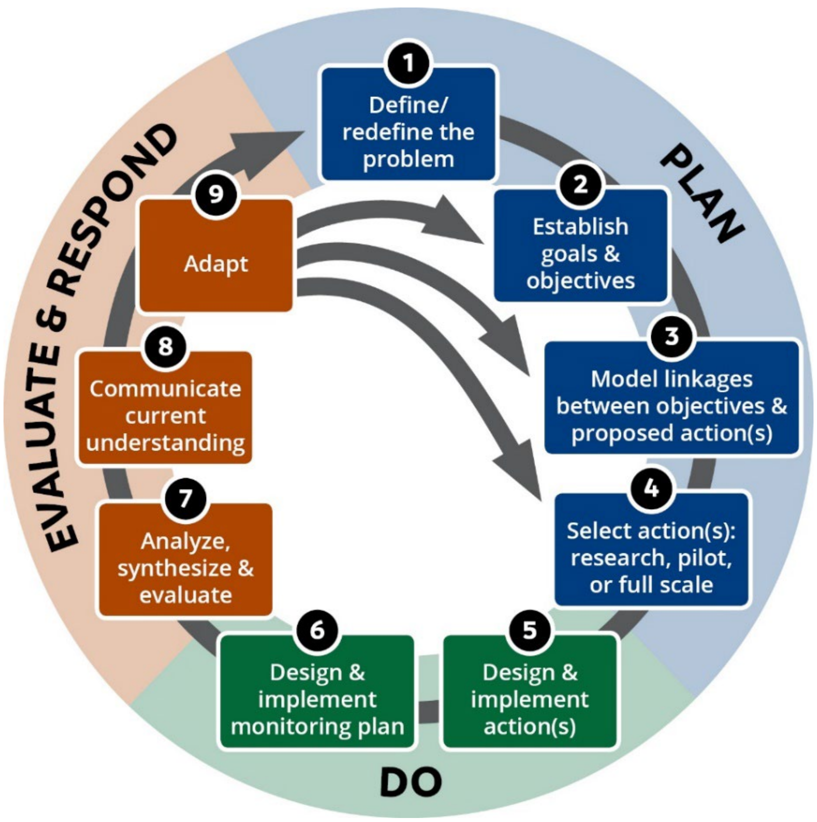

Figure 2: A Nine-step Adaptive Management Framework. The different shading represents the three distinct phases of adaptive management (Plan, Do, and Evaluate & Respond), and the boxes represent the nine steps. Adaptive management is often applied at the individual project level, but it can also be applied on a programmatic scale and can involve coordination across many different entities.

The workshops were multi-day online events featuring presentations, panel discussions, and small group conversations. The first workshop (April 2022) framed the challenge of future salinity management. In response to feedback from the first workshop, the Council through the DSP, funded a hydrodynamic modeling research project to pilot new methods for projecting future salinity scenarios. The DSP then hosted two focused working groups to discuss the social dimensions of salinity management, guiding the direction of the workshop series and future social science research. The second workshop (March 2024) compared modeling outputs, elicited discussion on trade-offs between management strategies, and identified partners needed for a long-term collaborative adaptive management framework for salinity. For more information on the workshops, refer to Appendix A.

In this report, we summarize the wide range of content shared during presentations and small-group exercises at the Workshop Series to identify the most pressing barriers to and opportunities for developing a collaborative adaptive management approach shared by participants. Across the workshop, three primary management needs emerged:

1. **A holistic, systems approach to adaptively manage salinity;**
2. **Inclusive collaboration and coordination across regions, sectors, and disciplines;** and
3. **Flexible modeling approaches to assess trade-offs and track metrics that are meaningful to society.**

This summary paper highlights the discussion from workshop speakers and participants, describes the processes used throughout this workshop series to address them, and summarizes key findings. This synthesis grounds the summaries and findings with reference to relevant science. The following summaries and conclusions represent perspectives shared across the workshop series, but do not necessarily reflect the views of the Delta Stewardship Council and do not supersede any Council publications.

All listed affiliations reflect the affiliations at the time of the event and may have changed since then.

Management Need 1: A Holistic, Systems Approach to Adaptively Manage Salinity

Wide-ranging Concerns About the Impacts of Salinity and Salinity Management

Salinity intrusion impacts the beneficial uses of Delta water across the state, a fact well recognized by workshop speakers and participants. With increased sea level rise, changing precipitation patterns, and drought resulting from climate change, salinity intrusion is expected to increase in both frequency and magnitude. Sea level rise pushes ocean water further into the Delta, which means that water managers must release more freshwater to maintain the hydraulic salinity barrier needed to keep salt out. At the same time, extended droughts limit the availability of water, thereby reducing the amount of freshwater available to maintain salinity levels. These interacting stressors will require enhancing existing management actions and developing new ones.

Workshop panelists emphasized that saltwater intrusion into the Delta causes direct economic harm locally and throughout the watershed. Panelists shared that increased salinity can damage infrastructure, reduce water quality for agricultural use, degrade the quality of drinking water for communities in the Delta and regions reliant on exports, and disturb the range of suitable habitat for various plants and animals. For Tribes, salinity affects the quality and abundance of traditional materials (e.g., tule reeds, which require low salinity water) and impedes the ability to connect with elders, ancestors, and ancestral places. It could also impact recreational fishing, causing economic losses in local fisheries, marinas, and other fishing-related industries. Furthermore, panelists shared that EJ communities are disproportionately burdened by increased salinity, including impacts on subsistence farmers, thousands of farm workers, small drinking water systems, and the municipal water supplies for Antioch, Stockton, and the Contra Costa Water District.

There are many actions that are or could be used to manage salinity. For example, salty water can be redirected through strategically placed wetland restoration or physical barriers, such as operable gates or temporary rock dams. Regulatory mandates can restrict water use, potentially leading to reduced exports and increased freshwater flows through the Delta. Reservoir releases can be timed to enhance the freshwater buffer, protecting water quality conditions to meet standards.

Each of these salinity management actions have trade-offs, a significant theme of the workshop series (see Section 1.2). For example, constructing physical barriers to limit salinity intrusion may benefit water for agricultural use, but would obstruct recreational boaters and potentially the recreational boating economy. Additionally, while barriers can strategically protect certain areas from salinity, they may also worsen salinity conditions elsewhere, emphasizing that benefits and costs associated with salinity management decisions can be uneven across the Delta.

Workshop participants emphasized the need to keep EJ communities in mind when considering these trade-offs. Workshop participants were concerned, for example, that Harmful Algal Blooms (HABs) could be a by-product of salinity management actions and negatively impact EJ communities. HABs are triggered by a combination of environmental factors, including water temperature and residence time. There is concern that salinity management actions, such as building a salinity barrier, could increase residence time and create more favorable conditions for HABs. Therefore, salinity management strategies should consider the interplay between different costs (e.g., HABs) and benefits (e.g., enhanced salinity management) in tandem.

Freshwater supports EJ communities both in the Delta and in export regions, so it is important to craft holistic approaches that benefit the most users while minimizing significant adverse impacts. Participants emphasized that this approach may require decision-makers to design salinity management strategies that consider indirect effects and associated trade-offs, and identify complementary actions and policies necessary to maintain and improve human well-being. Untangling these complex relationships is challenging but essential to an equitable adaptive management approach to salinity.

Water management strategies like reservoir releases alone may not be sufficient for meeting basic water quality standards, especially during periods of water scarcity. Changes to the Delta landscape, such as strategic tidal wetland restoration, could help redirect salinity; however, existing modeling tools to understand these potential implications are limited. Furthermore, improved understanding of how individual actions interact and affect different components of the Delta water system could support more strategic solutions. This underscores the need for diverse forms of monitoring to track the effects of multiple types of actions, but identifying the right metrics to track can be a challenge due to limited resources. Participants suggested that linking monitored and modeled metrics in the beneficial uses of Delta water and associated cultural values is one way to promote socially relevant monitoring. Participants emphasized that strong conceptual models, which clearly connect salinity management actions, metrics, and values, are essential tools for enabling adaptive management. More social science can help explore the breadth of values and concerns of those impacted by salinity management and develop conceptual models accordingly.

Conceptual Model Development

As a preliminary step towards developing a holistic adaptive management approach, workshop participants collaboratively built conceptual models. Groups built on established hydrodynamic models (i.e., Figure 3) and incorporated a broader range of social and ecological impacts of salinity management to demonstrate the complex interactions of strategies across sectors.

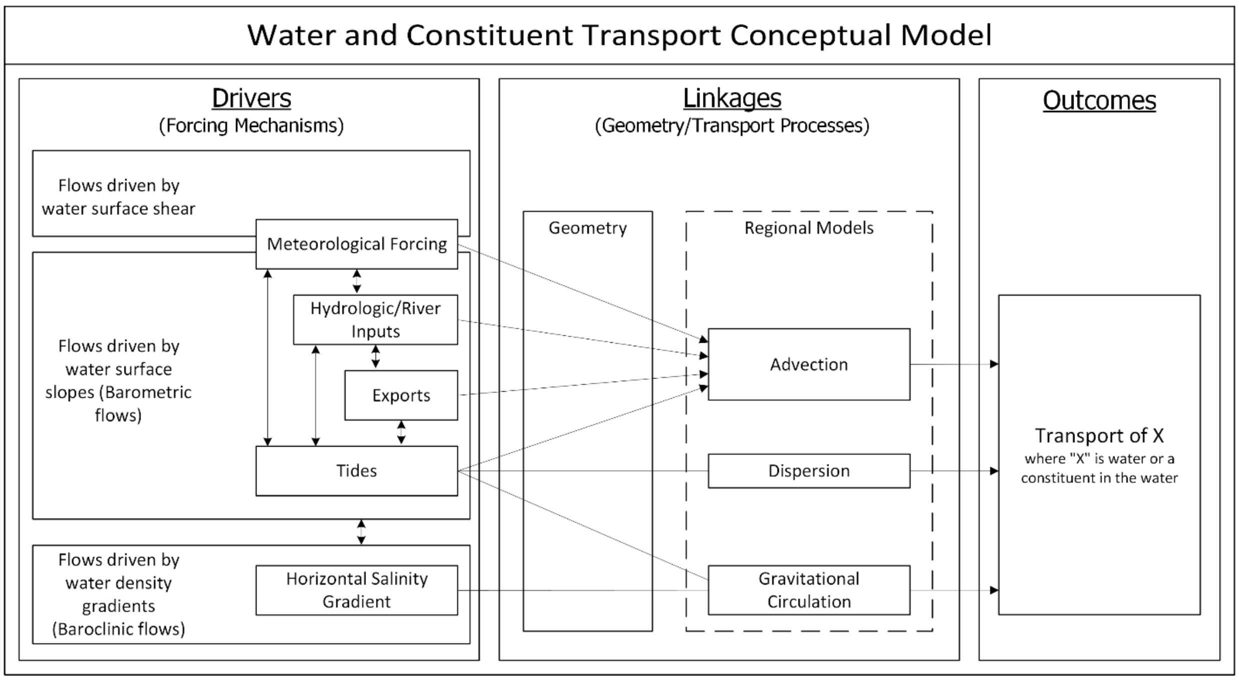

Figure 3: A conceptual model of the major hydrodynamic drivers and linkages associated with water and constituent transport in the San Francisco Bay and the Delta. Adapted from CALFED's 2007 Delta Regional Ecosystem Restoration Implementation Plan Hydrodynamics Conceptual Model.

Conceptual models can distill relationships between social, environmental, and infrastructural systems into simplified representations (Fischenich, 2008; Levin et al., 2016; Zador et al., 2017). By visualizing connections between components, conceptual models can help direct research, highlight research gaps, and develop management strategies (Harvey et al., 2016; Zador et al., 2017). Conceptual models are an essential component of the Delta Plan adaptive management process, illustrating how proposed actions relate to project objectives (Delta Plan Appendix C).

Specifically, conceptual models can map the connections between actions, metrics, and values that are important to different groups of people. Conceptual models have been developed for various components of the Delta ecosystem, including the effects of tidal restoration on fish (Sherman et al., 2017) and sedimentation processes (Schoellhamer et al., 2012). When conceptual models are created in collaboration with interested parties, they can become even more relevant to the challenges and concerns of those within the system, making them more effective as tools for decision-making and communication (Rosellon-Druker et al., 2019).

At the workshop, breakout groups built upon previous efforts, specifically CALFED's Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) hydrodynamics conceptual model (Figure 3). The DRERIP hydrodynamic conceptual model served as a scaffold from which the breakout groups expanded to identify direct and indirect effects of salinity management actions on salinity dynamics, people, ecosystems, and infrastructure. Discussion focused on three types of actions: (1) nature-based solutions (NBS), (2) policy solutions, or (3) infrastructure. DSP staff collected, synthesized, and combined the individual conceptual models into a simplified conceptual model. For more details on the methods, please see Appendix A.

A Collaboratively Developed Conceptual Model of Salinity Management and Potential Trade-offs

Taken together, the combined conceptual model (Figure 4) built on participant contributions shows a highly complex web of components and their interactions. This complexity underscores the need to consider both the direct, designed impacts of a salinity management action and its indirect and unintended consequences. These impacts can create trade-offs affecting human communities, non-human species, and critical infrastructure (Table 1). Participants identified a wide range of ecosystem services – the benefits people get from nature (MA, 2005) – that they thought could be impacted by salinity management. By explicitly considering the interactions between these dimensions, decision-makers can help avoid unintended consequences and even create synergies to simultaneously meet salinity objectives and provide a more robust suite of ecosystem services. A more complete picture of the Delta as one complex, interconnected system could provide more productive outcomes in the long term (Culberson, 2024).

One strategy, managed wetlands with control gates, exemplifies the complexity that participants described. While participants recognized potential benefits such as carbon storage and bird habitat (and associated recreational ecosystem services), they were also concerned about potential adverse outcomes. For example, could the gate operations allow certain invasive species to spread more easily? If so, it could have adverse downstream effects on fish habitat, which is often a target outcome for agencies and a boon to recreational fishing communities. This intersection of human, environmental, and infrastructure impacts demonstrates the value of adopting a social-ecological-technological systems (SETS) approach to managing the Delta, thereby enhancing the delivery of ecosystem services (McPhearson et al., 2022).

A common thread throughout the conversations was the need to understand spatially specific impacts of management actions. Conceptual models are useful for illustrating how a system works or is believed to work; however, they do not always consider specifics. In the context of tidal wetland restoration or temporary rock dams, for example, location matters a lot for salinity effects. The nature or magnitude of a relationship represented in the conceptual model could differ depending on the location or community in focus. Furthermore, the strategies to help mitigate or supplement local impacts would differ depending on the spatial context. For example, participants discussed that small agricultural businesses could be more impacted by tiered water prices and up-front costs associated with a mandate to increase water efficiency far more than big agricultural businesses, highlighting an important equity issue that must be addressed. As part of the exercise, workshop participants also explicitly discussed possible benefits and costs associated with different strategies (Table 1).

It is also important to note that some actions participants discussed could have direct impacts on salinity, while others have an indirect relationship with salinity, or could change the way we interact with salinity. For example, one group discussed "flooded agriculture to control subsidence" as a salinity management action, because they thought that the reduced strain from subsidence reversal would decrease the likelihood of levee failure and associated salinity intrusion in certain locations. This further highlights the complexity of managing for salinity and how a better understanding of intertwined system dynamics could enable more effective management actions.

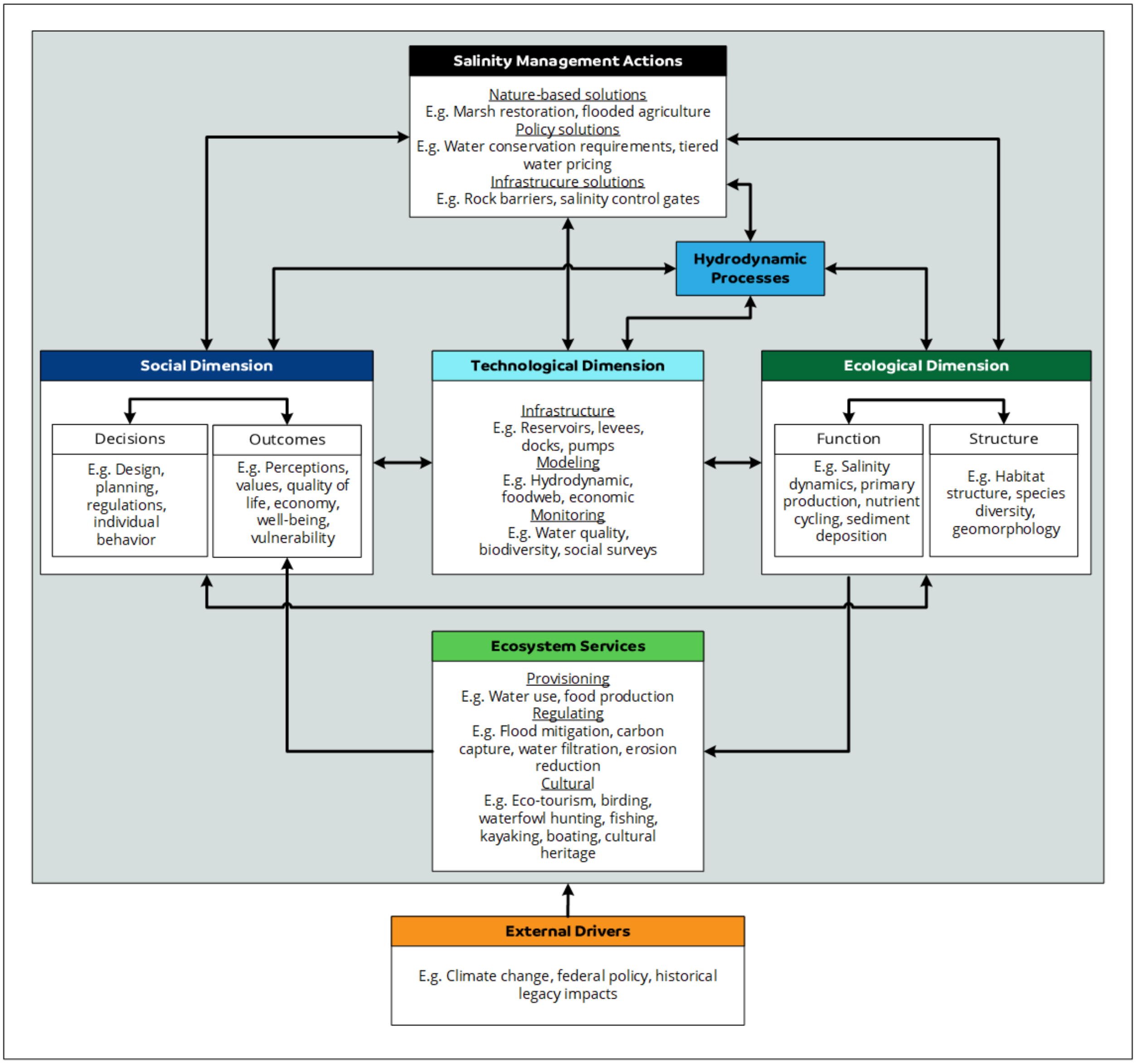

Figure 4: The combined conceptual model of salinity management, based on workshop participant collaboration. The "hydrodynamic processes" box represents the DRERIP hydrodynamics model (Figure 3), which participants built upon. Other conceptual models can also be nested within this one to gain a deeper understanding of nuances relevant to specific objectives. The majority of specifics listed in this conceptual model came from workshop participants during the conceptual model-building exercise, while a few specifics came from other discussions during the workshops. Monitoring, for example, did not come up in the conceptual model breakout groups, but it was discussed in detail during other sessions and fits well within the "Technological" dimension. Arrows indicate perceived causal relationships between the different components of the conceptual model, showing how workshop participants thought that various components affected other system components.

Table 1: Possible benefits and costs associated with different salinity management actions identified by workshop participants. Strategies are grouped by their major SETS dimension, but there are interdependencies between all three dimensions for all strategies. The social dimension (S) includes management, science, policy, economics, governance, and cultural norms and values. The ecological dimension (E) includes climate, weather, biodiversity, as well as ecosystem structure and function. The technological dimension (T) encompasses physical infrastructure, such as dams and levees, as well as cyber infrastructure and technologies, including modeling, data integration platforms, and visualization platforms, that facilitate decision-making (Markolf et al., 2018; McPhearson et al., 2022). ***As noted elsewhere in this document, the workshop had a limited range of perspectives represented; therefore, the perceived benefits and costs presented in this table are not exhaustive and are not presented as definitive facts.***

Possible Salinity Management Strategy	Primary Dimension (S, E, or T)	Possible Benefits Perceived by Workshop Participants	Possible Costs Perceived by Workshop Participants
Restructuring water rights and contracts, with particular focus on priorities during times of shortage	S	• Could streamline tracking of water availability, supply, and demand, which could help California's drought response • Could support more equitable allocation for human health and safety • Restructured framework before drought could aid advanced planning	• The process of restructuring water rights could be extensive and challenging • Could disproportionately impact areas deemed "less important" during drier times
Tiered water pricing	S	• Could encourage additional water conservation	• Could make water unaffordable for disadvantaged communities • Could deprioritize small agriculture in favor of large corporations • Could limit development in areas from which water is being transferred

Possible Salinity Management Strategy	Primary Dimension (S, E, or T)	Possible Benefits Perceived by Workshop Participants	Possible Costs Perceived by Workshop Participants
Water conservation requirements for agriculture	S	• Could allow increased instream flow • Could allow flood flows to be stored on agricultural land for use in the dry season	• Could increase food costs due to lower agricultural production • Could create overwhelming or impractical start-up and ongoing operational costs for small agriculture operations
Temporary urgency change petitions	S	• Could provide “experiment” years where flows are reduced to see ecosystem impacts	• May not fix long-term salinity problems
Flooded agriculture to control subsidence	E	• Could help maintain agricultural heritage and economy • Could decrease pressure on levees • Could be wildlife friendly	• Could increase costs of field preparation • Could include costs specialized equipment to make it most efficient
Floodplain expansion	E	• Could reduce flood risk • Could increase intermittent freshwater habitat • Could increase groundwater recharge during the flooded period • Could support riparian vegetation growth	• Could increase costs to develop/maintain setback levees • Could release accumulated toxins in soil from legacy uses • Could lead to loss of agricultural land • Draining could strand fish • Could raise water temperatures to the detriment of fish

Possible Salinity Management Strategy	Primary Dimension (S, E, or T)	Possible Benefits Perceived by Workshop Participants	Possible Costs Perceived by Workshop Participants
Managed wetlands with control gates	E, T	• Could enhanced long-term viability of duck clubs • Could increase flexibility to manage habitat, primary productivity, and invasive species • Could increase habitat for salt marsh harvest mouse • Could provide pulses of organic materials during flood into the food web	• Could increase risk of wetland drowning due to sea-level rise • Could increase levee maintenance costs • Could increase invasive species • Could be less accessible to fish • Could increase crayfish and mosquitofish populations • Could require ongoing operations and maintenance costs
Wetland restoration as natural salinity barriers	E	• Could increase flood protection • Could reverse subsidence • Could increase habitat and ecosystem function for fish and wildlife • Could enhance eco-tourism • Could capture carbon • Could increase erosion protection • Could support water purification • Could decrease tidal mixing, depending on location • Could reduce soil loss • Could aid in meeting acreage commitments (for agencies)	• Could increase long-term management costs to continue receiving benefits • Could increase mercury mobilization • Could increase tidal mixing and lead to negative salinity impacts, depending on location • Could reduce local government tax base • Could reduce tidal range of established upstream marsh • Could increase carbon loading • Could increase mosquito habitat • Could increase invasive species • Could lead to loss of terrestrial habitat, including

Possible Salinity Management Strategy	Primary Dimension (S, E, or T)	Possible Benefits Perceived by Workshop Participants	Possible Costs Perceived by Workshop Participants
		• Could enhance recreation	for protected species like the salt marsh harvest mouse • Could be limited by cost of land • Could lead to competition between sites • Could be limited by lack of funds for long-term maintenance, including for invasive species • Could cause potential drinking water quality issues for downstream users • Could be limited by slow and costly permitting process • Could create negative socioeconomic impacts on agriculture
Carryover storage	T	• Could reduce uncertainty in planning for extended drought	• Could reduce beneficial high environmental flows • Could reduce the volume of water available to export
Holistic modeling to inform long-term planning	T	• Could use a full watershed model to assess actions, individually and in conjunction, to understand impacts • Could be used to gain consensus • Could be used to look beyond the Delta	• Could have limitations such as the inability to make predictions at the decadal scale without high uncertainties, which render the usability of such models impractical for planning purposes

Possible Salinity Management Strategy	Primary Dimension (S, E, or T)	Possible Benefits Perceived by Workshop Participants	Possible Costs Perceived by Workshop Participants
Planned retreat	T, S	• Could be more resilient under future climate conditions	• Could lead to economic losses • Could lead to displacement of people • Could be inequitable with who is pressured to retreat, the timeline of retreat, and potential payouts

California's system of water rights is central to the way water is managed in the State, and workshop participants discussed the concept of restructuring the water rights system as a way of enhancing salinity management. Participants acknowledged that accomplishing this would be challenging given that water rights and priorities are embedded in the California Constitution and State laws. Although California's water system was conceived and built to convey surplus water to dry areas, if the system cannot protect both the Delta and superior water rights while supplying dry areas with what they need, participants felt that something will likely need to change. However, participants did not expand on what exactly that could mean.

It is worth noting that workshop attendees did not fully represent all relevant water user groups and perspectives. For instance, agriculture appeared in multiple groups' conceptual models, but no farmers were present. The same can be said for Tribes and disadvantaged communities – although these groups are represented in the conceptual models, there was little representation among workshop participants. Most workshop participants came from various local, state, and federal government agencies. Despite missing some key perspectives in the workshop, the co-produced models demonstrate a wide range of impacts across various sectors. For salinity management actions to be successful, they should be taken in conjunction with other actions to prevent or mitigate adverse outcomes – especially those that would impact already disadvantaged communities. This underscores the importance of open venues and events for sharing information across groups so that concerns of diverse groups are made clear.

Management Need 2: Inclusive Collaboration and Coordination Across Regions, Sectors, and Disciplines

Workshop participants emphasized that managing salinity in the Delta is a statewide issue. Upstream decisions about reservoir operations affect the timing and quantity of freshwater that flows into the Delta. In-Delta actions, such as restoration and control gates, influence how salinity spreads in the Delta. South of the Delta, demand for water and annual export allocations affect how much water flows from the Delta to support agricultural and urban uses, within constraints on pumping from the Federal and California Endangered Species Acts, and D-1641, the State Water Board Decision governing Delta flow and related water operations. These are just a handful of example decisions across the state that can impact salinity dynamics in the Delta. These interconnected systems and decisions are managed by diverse and sometimes fragmented organizations and institutions, which requires ongoing coordination that cuts across geographic boundaries.

Detailed local knowledge of the people, ecosystems, and infrastructure that stand to be impacted by various decisions can help support thoughtful coordination. Robust biophysical monitoring and other data are essential for tracking how the system responds to various changes; however, it is also critically important to expand the scope of social science research on the values, priorities, and well-being of the diverse communities impacted by salinity management. Transdisciplinary approaches that bring scientists, managers, Tribes, and community members together can guide collaborations where local context and systems are represented. This can help identify gaps in representation, making coordination smoother and minimizing negative trade-offs. Ensuring that salinity management is designed and implemented effectively requires a holistic approach that engages the people whom salinity management actions will most impact.

Actor Mapping Exercise

To support this more holistic approach, workshop participants identified groups impacted by salinity management by co-producing actor maps. Actor maps are tools for visually identifying groups that are impacted by a particular topic (in this case, salinity management) and the degree to which they are directly impacted (Gopal and Clarke, 2015). For more details on the exercise, see Appendix A.

During this exercise, participants arranged the groups they identified based on how directly or indirectly they felt those groups were impacted by salinity management. Then, participants shared whether they felt each group had their perspectives adequately represented at the salinity management decision-making table to help identify potential priorities for future engagement. (Figure 5).

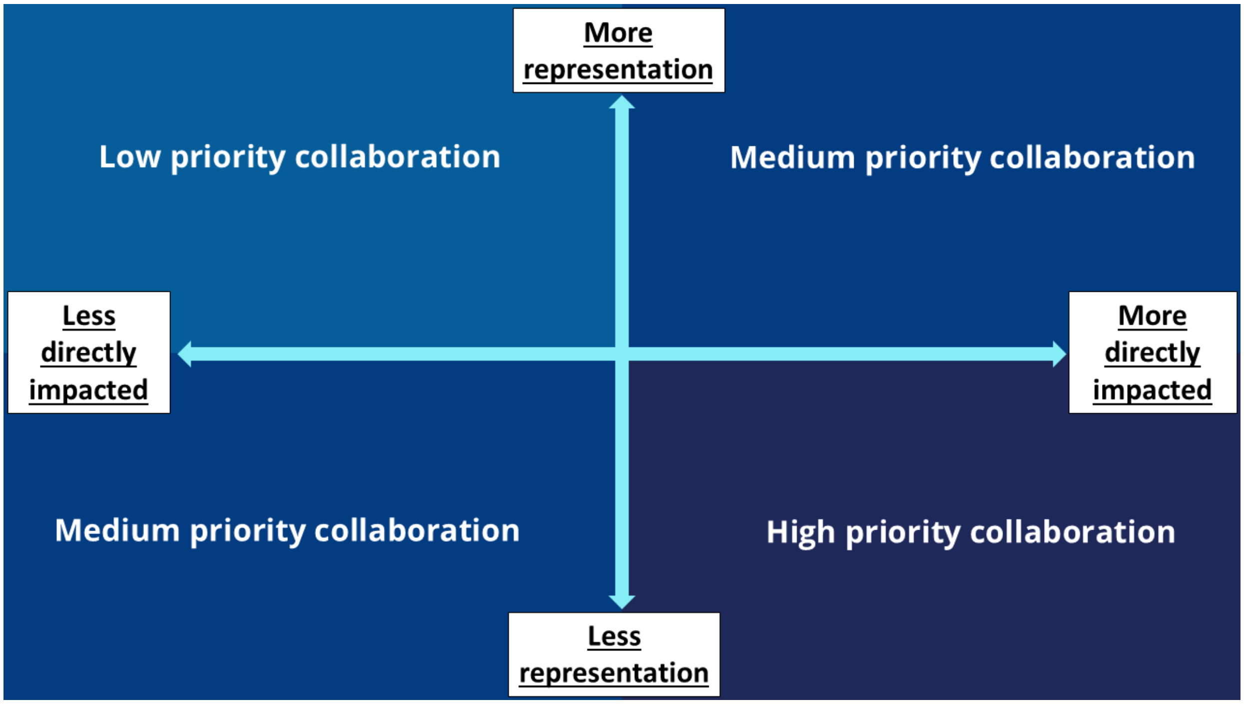

Figure 5: A template for how actor mapping data could be used to identify potential collaborators, based on how directly impacted a group or individual is and how well they are currently represented at the decision-making table for a particular topic. This could be applied to specific projects or at a higher programmatic level.

Tribal communities were a primary focus of this conversation. All breakout groups that specifically identified Tribal communities and interests highlighted that these groups had less representation, despite being directly impacted by salinity management. This is a recurring issue in Delta governance, where Tribes continue to be intentionally or unintentionally excluded from decision-making processes that directly affect them, thereby exacerbating the impact of historical injustices (Council, 2025b). While there are existing requirements for state and local agencies to consult with Tribes (such as AB 52 as a part of the California Environmental Quality Act), participants felt that future efforts could make more effort to meaningfully engage with and represent Tribal perspectives.

Environmental advocacy organizations, in-Delta communities, and recreational groups were also highlighted as having less representation, despite being directly impacted by salinity management. Further, participants noted that the diverse parties driving and impacted by salinity management decisions are geographically spread across California and may benefit from increased communication. These points underscore the potential benefits of expanding the range of perspectives, input, and collaborations in salinity decision-making spaces. Despite these potential benefits, participants noted the limited space at the decision-making table for diverse perspectives under current conditions, which limits the system's ability to adapt to diverse needs and values.

Advancing community-based collaborative science is one way to build equity into adaptive management approaches, ensuring that societal values and concerns are centered throughout the process. More open and collaborative science and decision-making opportunities can not only enhance the effectiveness of management strategies but also increase transparency and trust, thereby further enhancing the ability to collaborate and coordinate in the future. These perspectives shared during the workshop are consistent with the findings and recommendations from the Tribal and Environmental Justice Issues in the Sacramento-San Joaquin Delta white paper (Council, 2025b).

Management Need 3: Flexible Modeling Approaches to Assess Trade-offs and Track Metrics that are Meaningful to Society

Well-designed models can provide information that is robust, accurate, and transparent to inform decision-making. Modelling assesses the potential impacts of actions before they are implemented to identify potential effects on people, ecosystems, and infrastructure. As discussed in the workshop, hydrodynamic modeling is time- and resource-intensive, which limits the number of scenarios that can be modeled and questions that can be answered. Predominant modeling tools used by decision-makers are not always accessible to resource-limited groups or particularly flexible for testing multiple scenarios. Thus, there is a need for more efficient and accessible modeling approaches to inform adaptive management.

One way to develop more trust and transparency around modeling is to connect modelers with interested parties. At the workshops, DSP facilitated active dialog between modelers and participants to develop trust in modeling processes and guide the direction of the modeling pilot project (Appendix B). The workshops gave an opportunity to participants who are not normally at the table to engage with modelers and provide feedback on what to model and how to present results. Another way to develop trust and transparency is through participatory modeling approaches, where impacted groups take part in designing possible management actions that are then modeled. An example of this process discussed at the workshops is the Franks Tract Futures project, an iterative, participatory modeling approach to provide equitable, multi-benefit outcomes. Through a co-design process, Franks Tract Futures brought local communities into the planning process for modeling scenarios to create a design that would manage salinity intrusion, create habitat, and maintain recreational and cultural benefits. This approach improved project design and built trust in the modeling process. Another example of participatory modeling, as discussed at the workshops, being applied to salinity management is the Just Transitions in the Delta project. This project examines salinity management at a higher level, co-producing scenarios that model larger-scale approaches to managing salinity, with the goal of modeling trade-offs associated with different management scenarios. These participatory approaches enable modeling projects to track and evaluate metrics that matter most to people, allowing them to understand trade-offs and inform more effective and equitable decisions.

Feedback and Ideas for Modeling

Modeling tools that accurately forecast expected conditions support management actions and inform future investments and adaptation strategies. For example, workshop participants discussed how improved forecasting models could help managers plan the timing of reservoir releases along longer time horizons, enhancing the adaptive capacity of the system. New modeling technologies can enhance managers' ability to dynamically manage the system, both in real-time and on a long-term basis.

Workshop participants were asked to share the hydrodynamic metrics they were most interested in seeing visualized and explain why. This knowledge can help modelers develop tools and visualizations that inform a variety of interested partners. Participants most frequently selected salinity, residence time, net flow, mean high water, mean low water, and mean tide level as the hydrodynamic metrics they were most interested in seeing visualized to accompany modeling results (Table 2). Generally, workshop participants thought that heat maps, particle flow animations, and time series were effective methods for visualizing hydrodynamic data, particularly when they highlighted specific locations of interest and context for the values displayed.

As part of the DSP-funded pilot modeling project, the modeling team developed a more efficient approach to evaluate the impacts of future Delta conditions on water supply and salinity management. This new approach integrates high-resolution, multidimensional hydrodynamic models to simulate transport processes under different scenarios, which can then be used in CalSim. This will enable more in-depth exploration and evaluation of a wider range of possible scenarios, with a particular focus on sea level rise and large-scale changes to the landscape, such as restoration. Feedback from workshop participants helped direct the modeling project, and members from the modeling team attended the workshops to get feedback and learn from participants. For more details on this project, see Appendix B.

Table 2: Priority metrics for modeling hydrodynamic impacts of geometric changes in the Delta identified by participants. These are the metrics that workshop participants expressed the most interest in during a breakout discussion about hydrodynamic modeling. As noted elsewhere in the document, certain groups were not well represented among workshop participants, and this should not be considered an exhaustive list.

Hydrodynamic metric	Improves understanding of..
Salinity	• Species tolerance, including fish, clams, wetland vegetation, and submerged aquatic vegetation • Habitat assemblages, especially in low salinity zones, wetland, and wildlife resources in Suisun Marsh • Salinity changes at compliance locations for operations • Seasonal changes related to D-1641 • South Delta, where water quality standards are often exceeded
Residence time	• HABs, primary productivity, and where invasive weeds may thrive • Impacts to native fish within tidal restoration sites
Net flow	• Fish survival, reproduction, and abundance • Drought impacts
Mean high water	• Frequency and duration of wetland inundation • Vegetation communities and key habitats for at-risk species • The distribution of high water
Mean low water	• Fish passage • Availability of refuge to small/juvenile fish • Depth and navigation in the South Delta
Mean tide level	• Tidal restoration sites and vegetation growth • Marsh drowning under sea-level rise • Points of diversion

Participants were also asked to identify research questions and topic areas for future salinity modeling researchers to pursue.

Specific questions included:

- What is the minimum amount of water needed to meet existing salinity standards without changing Delta geometry?
- How would increasing habitat restoration change freshwater supply?
- What is the impact of the Suisun Marsh salinity control gates in different scenarios?
- How do flow actions and non-flow actions affect salinity management, and what are the synergies between them?

Other questions and topics were broader, with participants wanting modelers to explore more fundamental questions about the Delta to help better understand the impacts of various salinity management strategies. For example, extreme weather events are more likely under climate change scenarios, so participants emphasized the importance of modeling stress tests to identify potential weak points in the system, especially where they may exacerbate existing vulnerabilities to EJ communities and critical infrastructure. Similarly, participants were interested in modelers conducting sensitivity studies using CalSim to better understand the Delta's sensitivity to change and pinpoint the most important variables for various hydrodynamic outputs.

Conclusions

Adaptive Management Implications

Helping support the development of a collaborative adaptive management approach for salinity management was a major overarching goal of the workshop series. Workshop activities were designed primarily to support the "Plan" phase of adaptive management, but lessons and methods from the series can also be applied to inform the "Do" and "Evaluate and Respond" phases (Table 3). While a comprehensive adaptive management approach will be a long-term effort, there is a strong need for the enhanced collaboration needs identified by the workshop in the near-term to successfully address salinity intrusion and its impacts on statewide water supply, the Delta ecosystem, and the millions of people impacted. As is clear from this workshop, the concerns and goals surrounding salinity management are far-reaching – touching on social, ecological, and technological dimensions in the Delta and across the state. To adaptively manage this complex issue in a holistic way that meaningfully addresses diverse priorities goes beyond the scope of any one group, requiring collaborative progress across groups simultaneously pursuing their own specific missions.

The conceptual model developed by workshop participants can inform the design of a holistic approach for adaptively managing salinity in the Delta. It is clear from the conceptual model how interconnected the system is and how the effects of salinity management have the potential to influence social, ecological, and technological dimensions.

Currently, actions that directly and indirectly impact salinity are not necessarily coordinated as part of a collaborative salinity strategy. A holistic adaptive management strategy for salinity should consider discrete actions as part an interconnected system for managing salinity and its effects. For example, a tidal wetland restoration project is likely to focus primarily on providing habitat for protected species, but the cumulative impacts of the project on salinity dynamics should be considered. If such a project is implemented, what else might need to be done in conjunction to ensure salinity objectives and other social needs are met? The conceptual model that workshop participants developed together can serve as a starting point for refining the details of a cohesive and collaborative approach to adaptively managing salinity.

Table 3: How the Salinity Management Workshop Series laid the groundwork for a collaborative adaptive management approach for salinity. The "Plan" phase is represented by steps 1-4, the "Do" phase by steps 5-6, and the "Evaluate and Respond" phase by steps 7-9.

Adaptive Management Step	How this workshop series supported each step…
1. Define/ redefine the problem	A wide range of workshop participants shared concerns about salinity intrusion and emphasized the importance of maintaining beneficial uses of Delta water.
2. Set goals & objectives	Workshop participants with diverse interests shared their desire to manage salinity holistically, allowing the Delta ecosystem and communities across California to thrive.
3. Model linkages between objectives and proposed action(s)	Workshop participants collaboratively developed a conceptual model of salinity management (Figure 4), illustrating the complexity of the topic and the potential linkages between actions and a diverse range of outcomes. The Council also funded a pilot project to enhance the process of modeling the effects of management actions.
4. Select action(s): research, pilot, or full scale	Participants discussed the pros and cons associated with a wide range of possible salinity management actions (Table 1), which could help inform decisions on future actions.
5. Design and implement action(s)	Discussion and presentations provided an improved understanding of the concerns surrounding various salinity management actions to consider when designing implementation.
6. Design and implement a monitoring plan	The collaboratively built conceptual model can help design monitoring programs to track metrics across relevant system dimensions and guide directed research to fill knowledge gaps.
7. Analyze, synthesize, and evaluate	Ecosystem services identified in the conceptual model exercise can help scientists and managers determine which outcomes to evaluate. At the same time, hydrodynamic metrics of interest (Table 2) can assist modelers in crafting visualizations that resonate with their target audiences. The DSP funded pilot project developed an enhanced technique that enables more efficient estimation of scenario impacts in CalSim.
8. Communicate current understanding	Piloted tools (like actor mapping) that can be used to craft communication strategies to ensure relevant parties are informed, and approaches (like the workshops themselves) for interested parties to discuss new information and share lessons.
9. Adapt	Workshop outcomes provided context and tools to help guide adaptation in more equitable ways to minimize trade-offs and support vibrant communities across California.

While it may not be technically feasible at this moment to model all the interconnected dimensions outlined in the conceptual model simultaneously, a modular framework that links specialized models through consistent data and boundary conditions could be one approach. Critically, some components of the system already have strong, vetted conceptual models (e.g., food webs or hydrodynamics), while others do not (e.g., out of Delta impacts and social dimensions). Thus, additional work to collaboratively develop these less represented conceptual models would be important for this modular approach.

Barriers and Opportunities for Collaborative Adaptive Management

This workshop highlighted the role that salinity plays in social dimensions across the state and emphasized the importance of creating a more equitable balance for all Californians. While lessons from this workshop series can help inform future collaborative adaptive management efforts, there are still barriers to overcome. Rigid regulatory frameworks and policies can limit the types of strategies and methods that managers and scientists can utilize, especially on short timelines. Another recurring theme from participants was concern that the structure of decision-making power in the Delta is uneven, with a strong top-down dynamic driving major decisions. Despite the presence of many collaborative groups in the Delta, attendees emphasized that these groups often lack actual decision-making power and can be siloed and exclusionary, all of which can create mistrust and limit their effectiveness.

Even when convening organizations attempt to bring more partners into collaborative groups, participants felt that institutional support and resources to engage with external partners, such as community groups and Tribes, were limited. Further, when additional perspectives are incorporated, conflicting interests and priorities across diverse individuals and groups from across the state may intensify. This creates challenges for navigating the competing interests and politics inherent in decision-making, and thus necessitates establishing meaningful and ongoing collaboration, which in turn may increase demands on groups with limited capacity.

To overcome these challenges, workshop participants discussed alternative approaches for building a collaborative adaptive management approach. Participants thought that agencies could enhance the transparency and collaborative nature of the various working groups that they lead. This could help agencies consciously address frameworks of power and improve outreach, making collaborative groups and forums more productive and meaningful for a wider range of attendees. Participants felt that more inclusive and holistic approaches could also inform new collaborative groups and forums, like a government-commissioned working group that has decision-making authority with diverse membership, a community engagement taskforce, a Collaboratory with a structured decision-making nexus, or an open forum where people could share their knowledge of the Delta. Participants also thought that reevaluating policies, such as the X2 standards, and expanding initiatives like the Cutting the Green Tape initiative could help facilitate more effective collaboration and experimentation. Using these new approaches to enhance existing groups and collaborations while developing new structures and processes could support long-term success for adaptive management.

Closing Thoughts

The Salinity Management Workshop series brought together interested partners to address one of the most pressing, existential issues facing the Delta: salinity intrusion. Through open dialogue and a variety of participatory approaches, the workshop provided the structure for diverse participants to come together, share perspectives, and learn from one another. Through this collaborative forum, we learned that a systems approach could help manage salinity in a way that is both effective and equitable.

Salinity management affects the entire state, and operationalizing that idea into an adaptive management framework demands a foundational knowledge of how social, ecological, and technological dimensions across the state interact across time and space. To do this means extensive collaboration and coordination beyond business as usual. It means going beyond existing biophysical monitoring, modeling, and research and greatly expanding the scope of social science to better understand who is impacted by salinity management and what their values and priorities are. It means engaging in coproduction, recognizing and incorporating the expertise and values of Tribes and community members into management priorities and decisions. It also means developing science-based modeling tools that are flexible and able to represent the complex, interwoven, social-ecological-technological systems to accurately and transparently represent the trade-offs that matter most to people.

These are not small tasks. Accomplishing them may require monumental investments and fundamentally reevaluating the institutional norms that guide decision-making today. However, by leveraging and enhancing our relationships, leaning into each other's strengths, and creatively harnessing the tools at our disposal, we can adapt and thrive in the face of the challenges that lie before us.

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Glossary

Term	Definition
Adaptive management	A framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives (23 CCR Section 5001).
Advection	The movement of some dissolved material suspended in fluid. In the context of this report, this refers to the movement of dissolved salt in water.
CALFED	This was a consortium of state and federal agencies, including management and regulatory authorities in the San Francisco Bay-Delta, to coordinate water and environmental planning in the region.
CalSim	CalSim is a water resources planning model, jointly developed by the California Department of Water Resources (DWR) and the California Great Basin Region of the U.S. Bureau of Reclamation (Reclamation), to simulate operations of the State Water Project (SWP) and the Central Valley Project (CVP) and much of the water resources infrastructure in the Central Valley of California and the Sacramento-San Joaquin Delta region.
Carryover storage	This refers to unused allocated water from one season that is stored in a reservoir for use in a following season.
D-1641	State Water Resources Control Board Water Right Decision 1641. D-1641 is a water rights decision to implement water quality objectives set by the Bay-Delta Water Quality Control Plan by assigning responsibility to specific water rights holders.

Term	Definition
Delta Plan	The comprehensive, long term management plan for the Delta, adopted by the Delta Stewardship Council, to achieve the coequal goals of a reliable stateside water supply and a protected, restored Delta ecosystem in a manner that preserves the values of the Delta as a place (Cal. Wat. Code §§ 85001(c), 85054, 85059, and 85300).
Delta Reform Act	2009 Senate BillX7 1 (SBX7 1) passed by the California Legislature to create the Delta Stewardship Council and address water supply reliability and ecosystem health in the Sacramento-San Joaquin River Delta, (*see also* California Water Code § 85000 *et seq*.).
Dispersion	The process by which dissolved components mix.
Drought	Hydrologic conditions during a defined period, greater than one dry year, when precipitation and runoff are much less than average.
Environmental Justice (EJ)	The fair treatment and meaningful involvement of all people, regardless of race, culture, national origin, or income, in the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (CA Gov. Code, § 65040.12, subd. (e)).
Governance	The system in which decisions are made, which includes structures (e.g., governmental and non-governmental actors, organizations, forums), processes (e.g., participant interactions, decision-making), and laws, policies, and rules.
Gravitational circulation	This refers to the movement and mixing of water in an estuary, primarily driven by the density difference between seawater and freshwater from rivers.
Managed Wetland	Areas that are intentionally flooded and managed during specific seasonal periods.

Term	Definition
Meteorological forcing	This refers to the effect that various aspects of meteorology (e.g., precipitation and wind) have on hydrodynamics.
Net outflow	Generally, this refers to how much water flows out through a defined system after various water losses (e.g., evaporation and diversions).
Planned retreat	Purposeful and coordinated movement of people, buildings, or other infrastructure away from an area of high risk.
Residence time	The average length of time that an entity (water, in the context of this report) will remain in a defined area.
Salinity	This is the amount of salt dissolved in a body of water. It is a crucial water quality characteristic that impacts the use of water for municipal, industrial, agricultural, and fish and wildlife purposes.
Saltwater Intrusion	The movement of saline water into freshwater aquifers or waterways can lead to water quality degradation, including impacts on drinking water sources and other consequences.
Temporary Urgency Change Petition (TUCP)	A request for a temporary change to one or more water right requirements. Related to salinity management, TUCPs have been submitted by the DWR and the Bureau of Reclamation (owners and operators of the Central Valley Project and State Water Project) to change water right requirements included in D-1641.
Tiered water pricing	An approach to pricing water based on the amount of water used where up to a certain threshold, water used would be priced at one point, but once that point is exceeded, a new price would be charged. There can be many tiers, and typically the tiers get more expensive as more water is used.
Water right	A water right us a legal permission to use a reasonable amount of water for a beneficial purpose.

Term	Definition
Watershed	The entire region that drains into a river, river system, or other body of water. The watershed boundary separates waters flowing to different rivers, basins, or seas.
X2	The location in kilometers from the Golden Gate Bridge at which point water salinity is 2 parts per thousand of isohaline salt. This is used as a habitat indicator for the location of the low salinity zone, where freshwater transitions into brackish water. Fall X2 standards for September and October come from the United States Fish and Wildlife Service’s Delta Smelt Biological Opinion Fall X2 Action and California Department of Fish and Wildlife’s Incidental Take Permit to maintain the low salinity habitat at or less than 80km from the Golden Gate Bridge in the fall following wet and above normal water years.

Appendix A: Detailed Descriptions of Delta Stewardship Council Delta Science Program Salinity Management Workshops

The workshops were multi-day events that featured presentations, panel discussions, and small-group conversations. This first workshop (April 2022) framed the challenge of future salinity management. In response to feedback from the first workshop, the DSP funded a hydrodynamic modeling research project (Appendix B) to develop and test a methodology to more quickly and accurately evaluate future Delta salinity conditions under different management and climate scenarios. The DSP then hosted two focused working groups to discuss the social dimensions of salinity management, informing both the direction of the workshop series and future social science research. The second workshop (March 2024) compared modeling outputs, elicited discussion on trade-offs between management strategies, and identified partners needed for a long-term collaborative adaptive management framework for salinity. Below is a summary of the different sessions from the workshops.

All speaker and participant titles and affiliations reflect their status at the time of the event and may have since changed.

Workshop 1: April 2022

Day 1

Keynote presentation

The first workshop began with a keynote presentation from John Leahigh, the Water Operations Executive Manager for the State Water Project from DWR. He gave an overview of Delta salinity and relevant management tools, with a particular focus on the State Water Project and the Central Valley Project. He described how the Delta landscape has changed over time, the impact of these changes on hydrodynamics, and how managers regulate flow through three primary levers: dam releases, the Delta Cross Channel gates, and exports. He also emphasized the need for improved forecasting capabilities and adaptive strategies to guide water management in the face of rapid climate change.

Panel discussion: Social dimensions of salinity in the Delta

Panelists

Barbara Barrigan-Parilla, Restore the Delta
Lenora Clark, Save the California Delta Alliance; Pacific Inter-Club Yacht Association; Recreational Boaters of California
Jim Cox, Striped Bass Association
Bill Wells, California Delta Chambers & Visitors Bureau
Steve Mello, Mello Farms and Mello Locke Ranch; Reclamation District 563; North Delta Water Agency Board of Directors
Ivan Senock, Buena Vista Rancheria of Me-Wuk Indians

Moderator: Michelle Leinfelder-Miles, UC Cooperative Extension

Panelists discussed how drought, climate change, and associated impacts on Delta salinity are likely to affect human livelihoods, health, and recreation. The conversation covered a wide range of topics, including the impact of salinity on boating infrastructure, recreational fishing, subsistence farming, Tribal cultural resources, local water systems, and other related issues. Panelists discussed the need to meaningfully engage with communities that stand to be impacted by salinity management decisions to mitigate negative trade-offs and emphasized the desire for a more holistic approach to decision-making that allows for the creative use of available tools to serve all people better.

Panel discussion: Challenges, knowledge gaps, and needs for decision-support tools related to salinity management

Panelists

Tom Boardman, Westlands Water District
Dan Cayan, Scripps Institution of Oceanography
Chandra Chilmakuri, State Water Contractors
John Leahigh, Department of Water Resources
Diane Riddle, State Water Resources Control Board
Deanna Sereno, Contra Costa Water District
Andrew Schwarz, Department of Water Resources
Melinda Terry, North Delta Water Agency
Kristin White, US Bureau of Reclamation

Moderator: Michael George, Delta Water Master, State Water Resources Control Board

Panelists discussed primary goals, challenges, uncertainties, conflicts, and strategies for salinity management in the Delta from various water management perspectives. They agreed that the overall goal should be to find an equitable balance between the beneficial uses of Delta water; however, there are significant challenges to achieving this while navigating through competing interests and regulations, all while responding to changing environmental conditions. These rapidly changing conditions underscore the importance for managers to adopt new technologies and forecasting methods to reassess plans and regulations, informing long-term investments for a more resilient water future. Panelists also emphasized that it is essential not to become overly focused on the Delta when it comes to salinity management, because in-Delta water conditions are a result of statewide decisions. Instead, managers and scientists should consider the Delta, its watershed, and export regions together as one interconnected system.

Breakout group: Understanding diverse priorities and values around salinity management

These breakout groups featured facilitated discussions to understand the values and perspectives of workshop participants, learn from one another, and generate ideas on how better to understand the effects of different salinity management approaches. A key theme from the breakout groups was that salinity management can be beneficial or harmful, depending on how it is designed, balanced, and implemented. Participants shared that trade-offs between actions are not evenly distributed and that multiple values are at play, which must be understood to assess trade-offs accurately. Participants agreed that more social science is needed to explore these values, especially to understand effects on EJ communities.

Day 2

Presentation: Introduction to scenario modeling pilot exercise

The second day of the first workshop began with a presentation by Dr. Laurel Larsen, Delta Lead Scientist and Associate Professor at University of California Berkeley, to introduce scenario modeling exercises for piloting more flexible methods for understanding salinity management impacts and associated trade-offs. Pilot modeling exercises could 1) help modelers learn and improve methods through a small-scale project before moving onto a larger effort, 2) demonstrate the value in collaborative and forward-looking approaches while beginning to address management questions for future research, and; 3) kickstart a conversation about trade-offs apparent between different management strategies so that future, more robust modeling exercises could improve technical methods to reflect diverse societal priorities better.

Breakout group discussions: Scenario modeling pilot exercise

These breakout groups featured facilitated discussion about a possible pilot salinity management modeling exercise, to identify science, modeling, and communication needs alongside the major concerns, assumptions, and sources of uncertainty. Participants were most interested in a pilot modeling exercise that explored various restoration scenarios, including large-scale restoration and small, site-specific restoration projects, such as the Franks Tract Futures project. Baseline scenarios are crucial for modeling alongside other alternative scenarios to understand the long-term effects of action or inaction.

Panel discussion: Creating an adaptive management framework for managing salinity and understanding trade-offs of alternative approaches

Panelists

Eli Ateljevich, Department of Water Resources
Cory Copeland, Delta Stewardship Council
Mike Dettinger, Scripps Institution of Oceanography; Desert Research Institute
Rosemary Hartman, Department of Water Resources
Josué Medellín-Azuara, University of California, Merced
Dan Ohlson, COMPASS

Moderator: Tanya Heikkila, University of Colorado Denver; Delta Independent Science Board

In this session, panelists discussed needs for developing a long-term adaptive management framework for salinity management in the Delta. Panelists discussed the metrics and model outputs needed to understand the wide range of trade-offs associated with different management strategies, emphasizing the difficulty of selecting metrics. They also highlighted the importance of developing improved conceptual models that demonstrate how management actions are linked to metrics and values to help guide decisions. To be successful in the long term, panelists thought that an adaptive management approach should be highly collaborative, with diverse partners across jurisdictional boundaries throughout the state. Panelists felt that existing modeling tools, such as CalSim, could be enhanced to improve accessibility and transparency, thereby fostering greater trust in modeling-informed decisions.

Social Dimensions Focused Working Group

The DSP hosted two focused working groups to explore social dimensions of salinity management, which was identified as a gap. At these working group meetings, participants highlighted the types of salinity management actions they were most interested in exploring and the groups of people that future researchers should contact to understand the implications of salinity management actions on communities. Feedback from these working groups informed the specific salinity management actions to highlight and other questions to discuss in breakout groups during Workshop 2.

Workshop 2: March 2024

Day 1

Keynote presentation

Day 1 of the second workshop began with a keynote presentation by Dr. Deanna Sereno of the Contra Costa Water District. The presentation included a review of the primary physical drivers of salinity in the Delta, an examination of how they have changed, and an assessment of potential future change. She also discussed the laws, regulations, and actions designed to manage salinity, as well as some of the significant trade-offs that need to be considered. She emphasized that in-Delta salinity conditions are the result of decisions made outside the legal Delta, highlighting the scale and complexity of salinity management within the Delta.

Breakout groups: Building conceptual models of salinity management model development

Breakout groups built on previous efforts, specifically the DRERIP conceptual model of the major hydrodynamic drivers associated with water and constituent transport in the San Francisco Bay and the Delta, to think beyond the purely hydrodynamic aspect of salinity and salinity management actions. The DRERIP conceptual model served as a scaffold from which the breakout groups expanded to identify indirect effects of salinity management actions on people, ecosystems, and infrastructure. Discussion focused on three topics: (1) nature-based solutions (NBS), (2) policy solutions, or (3) infrastructure.

Once in breakout groups, facilitators led participants through a structured exercise to co-produce a conceptual model of salinity management actions within their group's theme. Groups used Mural, an online collaborative whiteboard, to build the model and respond to prompts from the facilitator. For each theme, participants brainstormed possible salinity management actions that fit within their group's theme, voted on specific actions for discussion, and then worked with the facilitator to build out a conceptual model for each selected action. Facilitators first asked how the proposed action would connect to components of the CALFED hydrodynamic model before asking participants to think more broadly about the impacts on people and ecosystems. Participants then populated new components and drew arrows from one component to another based on the perceived relationships and connections between different components. Groups repeated this process for each selected salinity management action. Then, participants were asked to explicitly identify the trade-offs – both positive and negative – associated with each selected action. Finally, time permitting, participants identified what relationships within their co-created conceptual model they were most uncertain about or generally wanted to know more about.

After the workshop, DSP staff worked to synthesize and combine the conceptual models from the different groups to create a more holistic model. First, staff combined the two NBS models and the two policy models to form one comprehensive NBS model and one comprehensive policy model. The infrastructure breakout group did not produce a model in the same way as the other groups, as described below. Finally, the combined NBS and policy models were combined into a single, comprehensive conceptual model.

Nature-based solutions conceptual models

The NBS breakout groups predominantly focused on different forms of wetland restoration for salinity management and the wide range of associated ecosystem services.

Policy conceptual models

The policy-themed breakout groups focused on concerns and details surrounding strategies rather than their potential impacts. This manifested in the combined policy conceptual model having fewer overall components than the combined NBS conceptual model, and the discussed components were almost exclusively situated within the social dimension of the Delta ecosystem. Despite having fewer components, the participants discussed more strategies than the NBS groups, including strategies that were not explicitly policy-related, such as wetland restoration. The groups also emphasized key factors influencing salinity management, including technical modeling, historical knowledge and influences, social values, and governance processes.

Infrastructure conceptual model

The conversation in the breakout group focused on infrastructure solutions for salinity management, with an exclusive focus on the potential of a salinity barrier at the Carquinez Strait, which was proposed in 1929. However, the group primarily used Mural as a notetaking tool rather than as a conceptual figure, so a narrative discussion is provided below.

The proposal of a salinity barrier at the Carquinez Strait would have created a freshwater reservoir separated from the San Francisco Bay, available for water export. Numerous studies investigated the potential of the concrete saltwater barrier, but it was ultimately abandoned due to ecological, transportation, and water quality concerns. The group then explored several modifications to the original proposal, including fish ladders to accommodate anadromous fish, narrow channelized passages to allow for fish migration styled after lessons learned from Dutch engineering, and passages constructed with rocks. Other modifications would also need to account for flow regimes that can flexibly respond to tides and weather, while also meeting the temperature requirements of fish and invasive species. Ultimately, the group agreed that any proposed solutions would impact a wide range of parties, necessitating a structured decision-making process that incorporated those diverse perspectives.

Combined conceptual model

The combined conceptual model shows a complex web of relationships identified by workshop participants. Starting from background processes that lead to decisions, the model illustrates how salinity management actions generate various intermediate outcomes and processes tied to ecosystem services, ultimately determining final outcomes and processes. Models like this can help managers design projects more holistically and better balance trade-offs. A detailed version of this combined conceptual model is available upon request by emailing AdaptiveManagement@deltacouncil.ca.gov.

Breakout groups: Actor mapping

Following conceptual model development, the conversation shifted to identifying impacted groups in an exercise known as actor mapping. Actor maps are tools for visually identifying impacted groups and the degree to which they are directly impacted by an action or activity (in this case salinity management). This is an essential step in understanding which groups could help inform key metrics, values, and trade-offs in decision making processes. Participants worked together in small groups to co-produce actor maps identifying the wide range of groups affected by salinity management.

During this exercise, participants arranged groups based on how directly or indirectly they felt those groups were impacted by salinity management. Then, participants shared whether they felt each group had adequate representation at the salinity management decision-making table, helping identify which groups may need to be prioritized in future collaborative efforts.

Presentation: The state of salinity modeling in the Delta

Modeling the distribution of Delta salinity is a critical component of water operations that release flows into the Delta to meet salinity standards (like D1641 discussed above). However, the flexibility of Delta salinity modeling has historically been challenged by simulating three-dimensional flow dynamics over the large and complex environment of the Delta. These challenges have limited the number of scenarios that can be run to evaluate the effects of rising sea levels or changes to the Delta's structure (i.e., water levels, engineering features, wetland restoration, and levee breaches). In this presentation, Dr. Larsen gave an overview of how Delta salinity modeling is commonly done, as well as recent innovations that enable salinity modeling to be more flexible for a range of scenarios.

Day 2

Presentation: Delta salinity during drought: Modeling salinity management from regional response to statewide scales

Day 2 of the second workshop began with presentations from leaders of the DSP-funded pilot modeling project team, including John DeGeorge from Resource Management Associates, and Eli Ateljevich and Lily Tomkovich from DWR. This presentation introduced a new salinity modeling methodology that combines the use of high-resolution hydrodynamic and salinity transport models of the Delta with the CalSim statewide water operations model to estimate potential water savings associated with salinity management actions, such as large-scale ecosystem restoration. The presentation demonstrated the use of this methodology by sharing preliminary output from a scenario with landscape changes in Suisun Marsh.

Breakout groups: Discussion of modeling results

These breakout groups featured facilitated discussions where participants provided feedback to and interacted with the pilot modeling project team. Participants discussed their observations from the preceding presentation, including any potential trade-offs and areas of concern. They then provided targeted feedback on the hydrodynamic metrics that they were most interested in and preferred approaches to data visualization.

Presentation: Co-design and modeling

In this presentation, Brett Milligan from UC Davis explored public and stakeholder-driven modeling processes. He used the Franks Tract Futures Project to illustrate how iterative, participatory modeling may lead to more equitable, multi-benefit outcomes for those involved and for communities potentially impacted by planning and design efforts. He also described a newer initiative called Just Transitions in the Delta which uses a participatory scenario building process to collaboratively learn, build trust, and explore trade-offs across a variety of distinct salinity management scenarios.

Appendix B: Delta Stewardship Council Delta Science Program Salinity Management Modeling Pilot Project Details

Background

The Delta lead scientist at the time, Dr. Laurel Larsen, recommended a Directed Action research project funded by the Delta Stewardship Council's Delta Science Program to address knowledge gaps and interests identified in the first workshop. Participants at the first workshop voiced a preference for modeling scenarios with various restoration and sea level rise scenarios, which guided the modeling approach. This pilot modeling project was co-led by Resource Management Associates and DWR.

Project Objectives and Workflow

The goal of the project was to develop and test a methodology for creating fast surrogate models for use in CalSim that represent the relationship between Delta salinity, hydrology, and operations under management and sea level rise scenarios.

This pilot analysis technique explored a limited number of representative drought scenarios under changes to Delta geometry (specifically tidal wetland restoration) and sea level rise. The modeling workflow for the project is outlined in Figure B-1.

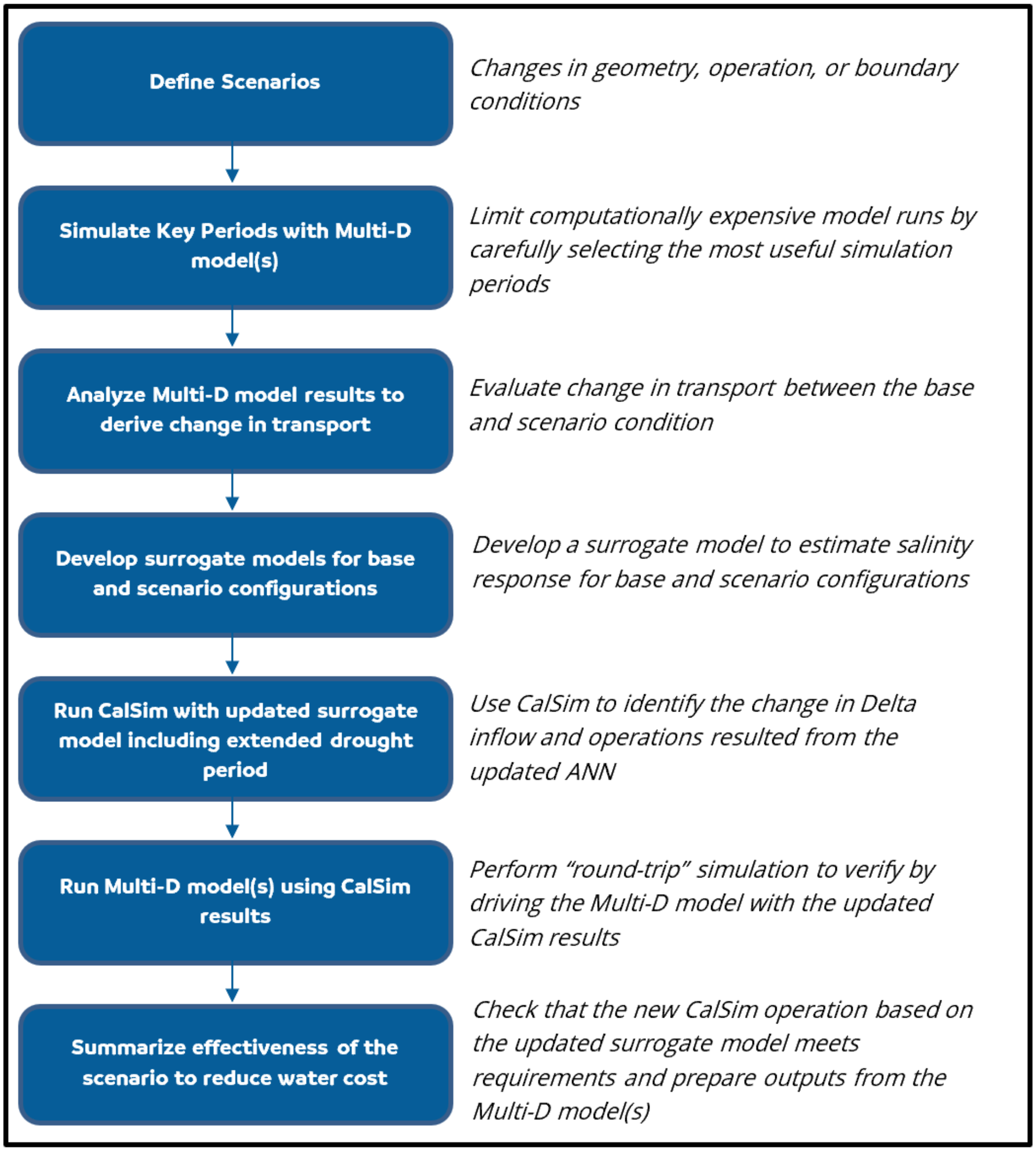

Figure B-1: The modeling approach for the pilot project.

Modeling Scenarios

The scenarios, which through previous modeling studies have been shown to impact salinity transport in the Delta, constitute a diverse set of tests for the surrogate concept. The challenge for this pilot project was to determine if the scenarios would produce salinity impacts that would carry through the surrogate training process successfully and result in significant change in water operations relative to the baseline surrogate.

A. *Baseline*. The **baseline scenarios** include restoration sites to represent the Delta at its current state: Yolo Flyway Farms, Lower Yolo Ranch, Lindsey Slough, Decker Island, Dutch Slough, Winter Island, Bradmoor and Arnold Islands, Tule Red, Hill Slough, Wings Island

B. *Restoration Scenarios.* Three hypothetical restoration scenarios were included:

(1) **Suisun Marsh Region Restoration Scenarios** adds two projects to the baseline grid: Grizzly Island and Chipps Island. Opening Grizzly Island to tidal inundation is a bookend scenario that has been considered in other modeling studies, including the Delta Adapts project. This scenario was not intended as a detailed restoration proposal, but rather as a test of opening a significant area to tidal flow through connections in Montezuma Slough. Grizzly Island has three connections to the existing grid. They are wide, lowered breaches connecting to the surrounding channels.

(2) **Cache Slough Region Restoration Scenarios** adds three projects to the baseline grid: Lookout Slough, Prospect Island, and Little Egbert.

(3) **Franks Tract Futures Scenarios** adds one major project to the baseline grid: Franks Tract Restoration, which is a re-envisioning of the landscape around Franks Tract State Recreation Area. This multi-benefit plan includes wetland restoration, recreational enhancements, and benefits to salinity control, based on some of the same premises as the West False River Drought Barrier. It aims to minimize dispersion of saltwater from the Western Delta into Franks Tract towards compliance areas in the Central Delta. The project geometry tested for this project was the preferred alternative selected through a multi-year planning process involving state agencies, local recreational users, and residents.

Sea Level Rise Considerations

The scenarios will include a scenario with 3 feet of sea level rise, which corresponds to the 2070 High scenario according to the Ocean Protection Council's 2024 guidelines. The Delta response will be analyzed for surrogate training using a fixed sea level increment. One risk is that salinity levels will exceed Delta standards too often, and additional flow will need to be applied to ensure that training of CalSim surrogates occurs within the desired range of compliance.

Future Potential

The pilot project was successful in producing updated surrogate models for use within CalSim that represented changes in Delta salinity response derived from multi-dimensional modeling of the test scenarios. The CalSim output using these surrogates was able to quantify changes in water operations, particularly in drought conditions. While there are many questions that this demonstration modeling exercise does not address, it introduces a more efficient modeling approach that allows for the exploration of a wider range of topics and concerns.

To read the full final report from this modeling project, contact AdaptiveManagement@deltacouncil.ca.gov.