DELTA STEWARDSHIP COUNCIL
A California State Agency

BUILDING AN EFFECTIVE DELTA SCIENCE ENTERPRISE

Briefing Paper for October 5-6, 2020 Long-term Science Needs Assessment Workshop
Co-hosted by the Delta Plan Interagency Implementation Committee and the
Delta Independent Science Board

If you need assistance interpreting the content of the document or have comments, please e-mail disb@deltacouncil.ca.gov

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Purpose of the Science Needs Assessment Workshop

The purpose of the Science Needs Assessment Workshop is to explore rapid environmental change facing the Delta relative to climate and other change impacts and to develop a comprehensive science needs assessment that will contribute to a long-range science strategy. This workshop brings together state, federal, and non-governmental scientists and managers around a common goal of clearly defining what critical challenges need to be addressed first and where capacity is needed to keep pace with rapid change over the next 25 to 50 years.

The workshop will: 1) identify key science efforts that will provide answers and insights for likely management questions in the long-term; and 2) discuss how to organize the science enterprise to address these complex and changing problems. The workshop will focus on identifying major research needs and future efforts toward understanding changes in climate and other factors on key physical, chemical, biological, and human processes identified in the Delta Plan and the science infrastructure needed to support these efforts.

This document provides Science Needs Assessment Workshop participants with context and structure for workshop discussions. The statements in this pre-workshop briefing paper are meant to spur reaction, long-term thinking, and to stimulate ideas for discussions.

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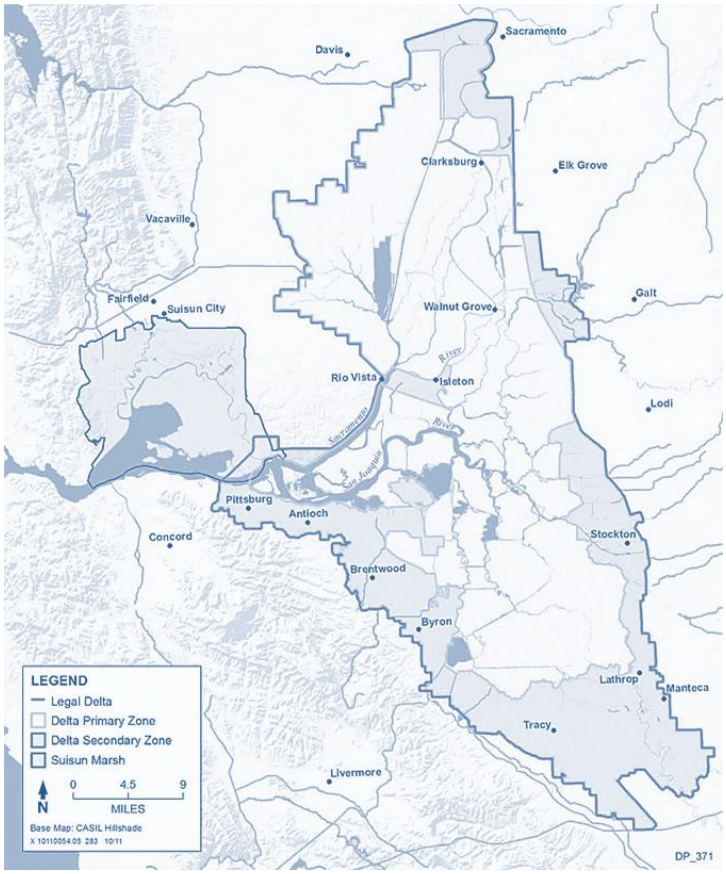
INTRODUCTION: RAPID CHANGE IN A DYNAMIC AND COMPLEX SYSTEM



California's Delta—including the Sacramento-San Joaquin Delta and Suisun Marsh—is a dynamic and complex system, which has changed substantially over the past two centuries. Fundamental environmental and socio-economic drivers in the Delta continue to change at a seemingly ever-increasing pace and we face a future that will likely be very different from the present. Climate change, sea level rise, a growing population, earthquakes and major flooding, new invasive species, increasing water supply diversion demands, shifts in land use, and declines in native species will further test our capacity to recover ecosystem health in the Delta environment, maintain adequate water for California's people and economy, and support local economic and other activities. Management decisions and policies made now could constrain options for the future in ways we cannot envision today. We must, therefore, ensure that the scientific community provides insights for managing with *change*, as a lot of change lies ahead.

To date, the Delta's overall *science enterprise* has developed science focused primarily on current management challenges. Three guiding documents attempt to coordinate these efforts in the current *Delta Science Strategy*:

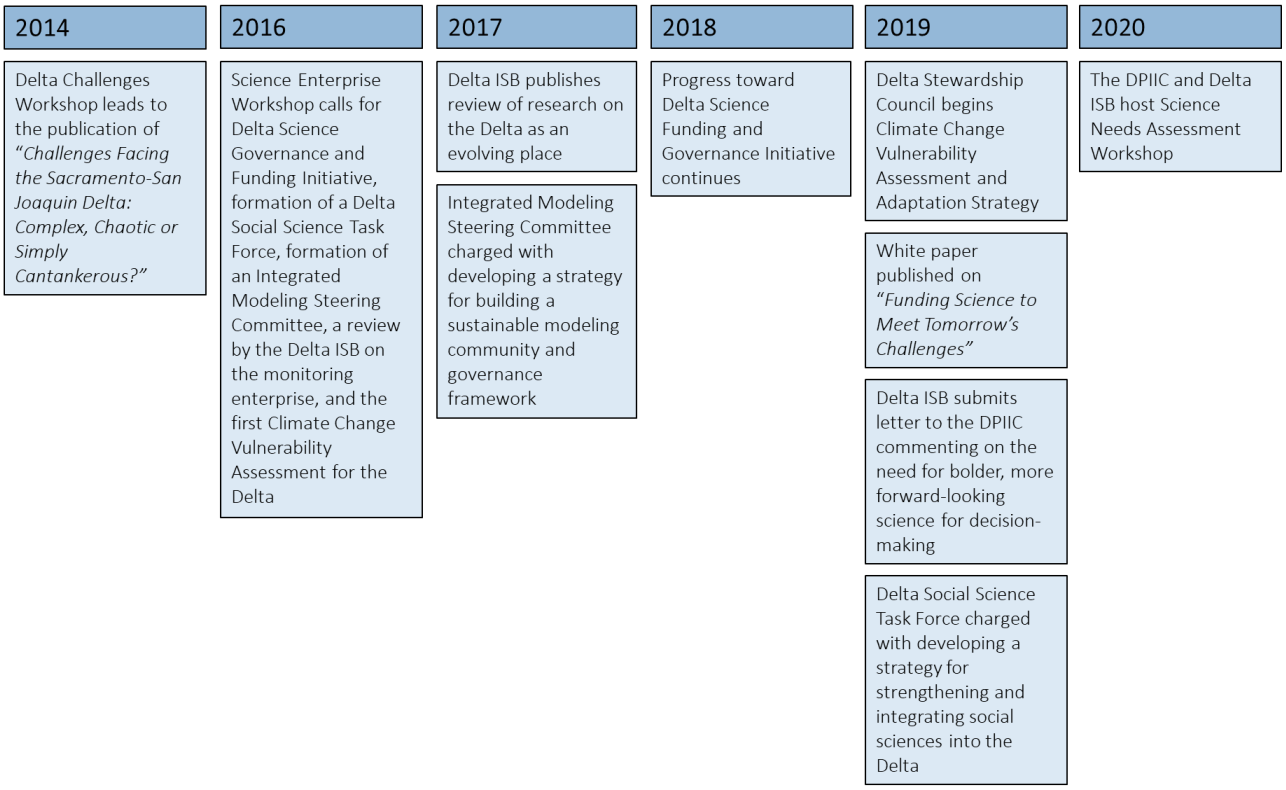
- A Delta Science Plan, updated in 2019, identifies mechanisms to foster interagency collaboration and communication;
- A Science Action Agenda (2017 to 2021) identifies a prioritized list of shared science activities to fill gaps in information and support management; and
- The State of Bay-Delta Science (2016) reviews and summarizes current scientific knowledge of the Delta.

Against the backdrop of changes in climate and other factors, the pace of change in the Delta has been great and will accelerate. We must look beyond the time horizons of challenges addressed in the current science strategy to address the challenges of the future that will substantially differ from the present, with different science needs and opportunities. We must build on existing efforts to develop a bold, forward-looking, long-term science strategy to map a path and structure for Bay-Delta science that complements near-term efforts.

Climate change is perhaps the biggest single driver of changes to environmental conditions in the future Delta. Climate has far reaching impacts; we can't control it regionally and it affects all major Delta management issues and goals. It is, however, predictable to some degree. Both the Delta Plan and the 2016 State of the Bay-Delta Science, identified climate change as a fundamental 'stressor' affecting most other major drivers in the ecosystem. As specified in the State of the Bay-Delta Science, "The Delta's climate is characterized by high variability, and climate change is expected to accentuate this variability, resulting in both more extreme flood risks and greater drought risks. Thus, the Delta of the future will be very different than the Delta we know today" (Dettinger et al. 2016). The Delta will face other major changes that management will have to address, including new invasive species, changes in land use patterns, aging infrastructure and demand for new projects, and cascading effects of environmental regulations (with broad impacts on water quality, restoration, and groundwater), shifting agricultural markets and new innovations and technologies. And while management will face these challenges and more, we also must accept that impacts will likely change based somewhat on the management decisions made and responses to future conditions.

The Delta Reform Act requires Delta management decisions to use best available science. The cornerstone of Delta management is *adaptive management*, which works on the premise that one can learn by studying the effects of management policies and then reassessing those policies if new information indicates that other approaches will better achieve desired outcomes. Even so, a recent review by the Delta Independent Science Board (Delta ISB) found that improvements to implementing adaptive management can be made in the region (Delta ISB 2016; Wiens et al. 2017). Adaptive management depends on an ability to forecast outcomes; management informed by careful forecasts of future conditions has a better chance of success. We must ask if our science efforts today are on the right track to predict future conditions so current and future management actions can be effective for a rapidly-changing Delta. If we are concerned that our science isn't doing all it can, where can we improve? What are emerging issues? *How do we build an effective forward-looking science enterprise for the Delta?*

How Did We Get Here?



As an organized science enterprise and community, we started to grapple with longer-term questions and concepts over five years ago via a series of workshops and initiatives.

The **2014 Delta Challenges Workshop** brought together the former lead scientists of the Delta Science Program to summarize the challenges for water supply and ecological resource managers for the Delta. The primary outcome was the publication, *Challenges Facing the Sacramento-San Joaquin Delta: Complex, Chaotic or Simply Cantankerous?* Major challenges identified by the panel included: over-allocation of water, decaying infrastructure, ecosystem and native species decline, contaminants, and complexity of the management structure. The publication continues to be cited frequently and helped to shape the conversation regarding what is needed and what is possible. The authors stated that "the challenges are so complex as to meet the definition of a 'wicked' problem. Such problems can't be ignored, defy straight-forward characterization, and have no simple solutions. Yet they must be actively managed to maximize beneficial and minimize adverse outcomes." The authors concluded, "As we enter an era of increasing uncertainty about climate and water supply, science conducted in collaboration among multiple institutions must be brought to bear and decisions must transcend individual agency directives or the needs of special interests" (Luoma et al 2015).

The 2016 Science Enterprise Workshop (SEW; patterned after the 2013 SEW sponsored by the Puget Sound Partnership and the University of Washington) brought together over 200 scientists, policy makers, and managers for three intensive days of discussion on management, communication, and funding of applied science in support of decision-making. The workshop was intended to provide responses to a persistent line of questioning from those working within the California Bay-Delta system and similarly-sized ecosystems: How can we make science more directly useable and on-point for management decisions? How can we better fund and support critical science investigations? How can we be better organized and efficient, and what governance structures work best to inform decision-making? And for Delta policymakers, how do we draw more attention to the California Bay-Delta and create better recognition of the Delta's importance?

The main message from the SEW was: coordinating disparate science activities on complex regional resource issues is inherently difficult, but careful attention to issues and practices can improve the ability of science enterprises to support and inform decision-making. The Executive Summary provided a set of core recommendations around leadership; efficient use of available funds; and science credibility, legitimacy, and value to decision-makers:

- Ensure clearly defined leadership and decision-making structures with active engagement at the highest level;
- Adopt real adaptive management;
- Integrate social sciences with natural science and engineering to understand the full scope of management issues;
- Use competitive funding mechanisms to attract the brightest and best;
- Increase the use of integrated modeling and forecasting to support decision-making;
- Improve communication and discussion of scientific findings;
- Do not neglect the implications of climate change, including sea-level rise; and
- Improve connection of science and management across San Francisco Bay, the Delta, and the upper watershed.

Many of these recommendations have been pursued and the term "science enterprise" is now commonly used to refer to the collection of science programs and activities that exist to serve managers and stakeholders in a regional system.

The SEW resulted in the Delta Science Funding and Governance Initiative, the formation of the Delta Social Science Task Force and the Integrated Modeling Steering Committee, and the Climate Change Vulnerability Assessment and Adaptation Strategy (known as Delta Adapts: Creating a

Climate Resilient Future initiative). It also stressed the need for a Monitoring Enterprise Review by the Delta ISB that was being planned at the same time as the SEW.

In April 2020, the Delta Social Science Task Force, coordinated by the Delta Stewardship Council and UC Davis, released *A Social Science Strategy for the Sacramento-San Joaquin Delta*, which provides recommendations to strengthen and integrate social sciences into the landscape of the Delta. This integration was called for at the SEW and in the Delta ISB's review of research on the Delta as an evolving place (Delta ISB 2017).

The Integrated Modeling Steering Committee (IMSC) was charged in 2017 with developing a strategic plan for building a sustainable modeling community and a governance framework that links the short, intermediate, and long-term decision universe with key management questions and management priorities while optimizing the available resources. The goal of the project is to assess the current state of integrated modeling in the Delta; identify the opportunities for such modeling to address Delta problems; identify key challenges and technological solutions to facilitate integration; and develop a strategic plan for future implementation by the Delta Stewardship Council and the IMSC.

The Monitoring Enterprise Review is a broad review of the monitoring enterprise in the Delta. The objective is to develop recommendations that may improve how current and future monitoring programs meet the informational needs of management agencies; individual and larger-scale monitoring programs can be better coordinated; and monitoring data can support implementation of adaptive management and assessments of performance measures. The Monitoring Enterprise Review is expected to be completed in 2021.

The Delta Stewardship Council is preparing a Climate Change Vulnerability Assessment and Adaptation Strategy (known as the Delta Adapts: Creating a Climate Resilient Future initiative) to improve understanding of regionally specific climate change risks and address how Delta communities, infrastructure, and the ecosystem can adapt to future conditions. A technical advisory group and a stakeholder group are providing input and guidance to the Delta Stewardship Council on this effort.

The Delta Science Funding and Governance Initiative continued the discussion around the need for consistent and reliable science funding for best available science started at the 2016 SEW and discussed during a 2017 State of the San Francisco Estuary Conference panel. The panel of Delta science and policy leaders committed to address adequately funding science in the Delta to more fully support robust decision-making.

In response to the panel discussion, the Delta Science Funding and Governance Initiative was launched with the support of the Delta Plan Interagency Implementation Committee (DPIIC). The Initiative, coordinated by the Delta Stewardship Council, included federal and state agencies and environmental and water user stakeholders. Focusing on understanding how science is funded, how to improve the tracking of science funding, and how to increase funding for Delta science, the Initiative issued the white paper, *Funding Science to Meet Tomorrow's Challenges* in April 2019, making 7 findings and 10 recommendations.

In response to the early drafts of the Initiative white paper and the 2019 Delta Science Plan, the Delta ISB submitted a letter to DPIIC on February 11, 2019. The letter comments that the Delta science enterprise must become better organized and "accelerate efforts to address the rapidly growing and interlinked challenges for science-based policy and management decisions in the Delta…". The letter encourages DPIIC, working with local governments, non-governmental organizations, and university expertise to, "initiate and lead a bolder, forward-looking, and better integrated science and management program that provides policy-makers and managers with better scientific information and management options for the Delta." To move forward, the Delta ISB called for a comprehensive scientific needs assessment based on fundamental system-wide scientific and management challenges facing the Delta.

Over the spring and summer of 2019, the Initiative refined the recommendations in the white paper and included a science needs assessment as the priority action. The resulting implementation report identified three priority near-term actions as foundational to building long-term and sustainable science funding:

- Improve efficiency: Implement common accounting and reporting protocols, and coordinate critical review of science funding in the Delta;
- Prioritize: Identify and prioritize key management questions for water resilience and science investments as part of updating the multi-agency Science Action Agenda for 2022 to 2026 in the Delta; and
- Look forward: Conduct a workshop to assess the evolving science needs in the Delta in a rapidly changing environment and develop a science needs assessment based on workshop proceedings.

The Science Needs Assessment Workshop is a critical link and next step in our ongoing effort to grapple with longer-term questions and concepts collectively as a science enterprise.

What Do we Need To Do?

The Delta's overall science enterprise must be adroit enough to answer a wide variety of management and policy questions over time, many of which cannot now be anticipated, with a changing environment. Science efforts focused on the Delta's problems should address two broad missions: 1) answering immediate and near-term science questions to support current management and policy-making challenges; and 2) addressing and preparing to answer forward-looking policy and management questions as they arise and before they arise, for long-term problems. The latter is the focus of this workshop.

A science needs assessment can help us develop a long-term science strategy that identifies and prioritizes primary research needs to better anticipate major climate change related drivers and their impacts on key physical, chemical, biological, and human processes identified in the Delta Plan. This assessment must be driven by management and stakeholder needs in the context of projected changes and environmental drivers. With that said, there is debate about what comes first: the management need or the science need. This debate is yet to be resolved, but we need to start somewhere.

Moving forward will require scientific leadership and vision, identification of long-term scientific priorities, and organizational and funding structures (governance issues) to expand interagency science integration. As stated earlier, the workshop is to provide a basis to develop a comprehensive scientific needs assessment based on system-wide scientific and management challenges facing the Delta relative to climate and other change impacts over the next 25 to 50 years. From the science needs assessment, a science strategy can be developed that includes recommendations on what we need to know to support future decisions and how we can develop a structure to support, encourage, and accomplish our science needs.

The science needs assessment will also inform the 2022 to 2026 Science Action Agenda and implementation of specific actions in the Delta Science Funding and Governance Initiative. And all of these efforts will collectively help us to develop a robust, adaptive, and long-term Delta Science Strategy.

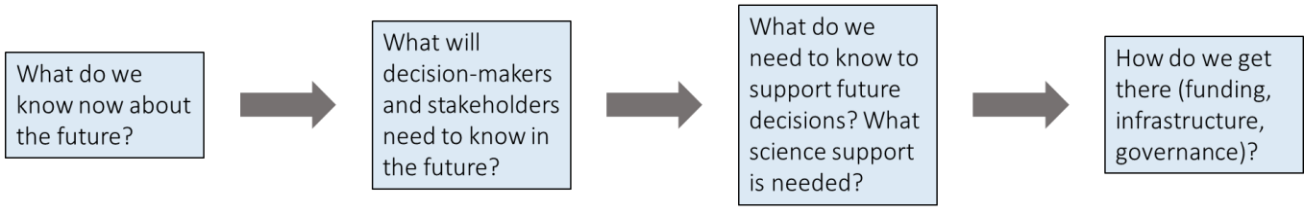
In parallel with the workshop, the Delta ISB is developing a discussion paper on how to conduct research to prepare and respond to rapid environmental changes. Both this workshop and the Delta ISB's discussion paper will help guide development of the science needs assessment.

Approach to Developing the Science Needs Assessment

For this briefing paper, a science needs assessment is defined as a systematic approach that identifies future scientific priorities, and the information and infrastructure needed to achieve these priorities. Scientific priorities should be based on science, management, stakeholder, and policy needs. There is no single standard approach to developing a science needs assessment, however, best practices show that mechanisms such as workshops, literature reviews and synthesis, surveys, focused interviews, and horizon scanning can be used to gather and organize ideas on science needs. *Appendix B* summarizes these and additional mechanisms and approaches that other regions have taken and cites various journal articles for more information.

The science needs assessment will be developed by considering four different issues, each building on the previous:

1. **What do we know now about the future?** What can we forecast about future changes in environmental drivers?
2. **What will decision-makers need to know in the future?** What are the implications of these future changes on management and stakeholder needs?
3. **What do we need to know to support the future decisions?** What do we need to know to answer these management needs and questions and what science needs to be done to provide that information?
4. **How do we develop a structure to support, encourage, and accomplish our science needs?** What scientific capabilities and expertise are needed to answer likely management and policy-focused questions as they arise? What governance and funding structure would support us looking farther into the future to better anticipate and prepare for long-term challenges for the Delta? *(See appendices C, D, E, F, and G.)*



For this effort, we will develop the science needs assessment utilizing a workshop and additional discussions, based on the management areas identified in the Delta Plan as our framework to organize discussions.

Science Needs Assessment Workshop

Workshop Goals

The workshop will: 1) identify key science efforts needed to provide answers and insights for likely management questions in the long-term; and 2) discuss how to organize the science enterprise to address these complex and changing problems. The workshop will focus on identifying major research needs and future efforts toward understanding changes in climate and other factors on key physical, chemical, biological, and human processes identified in the Delta Plan and the science infrastructure needed to support these efforts. The questions noted above and during the next few pages will form the basis of our dialogue.

Leading up to the workshop, DPIIC and the Delta ISB will be hosting a four-part discussion seminar series on April 28, June 3, July 8, and September 9 to generate dialogue around each of the four key questions listed above. Each seminar will have a panel to define and describe the issue, and provide the opportunity for those in attendance to discuss various topics.

Audience

The primary audience for this workshop are those conducting, prioritizing, coordinating, synthesizing, funding, and using science in the Delta. We encourage participants who do and synthesize science in the system, as well as those who use the science to make decisions. These could be scientists from the natural and social science fields, engineers, managers, decision-makers, and policy-makers.

STRUCTURE

The workshop will take place virtually and will consist of two major breakout sessions to help inform the science needs assessment. The discussion seminars leading up to the workshop, along with the Science Action Agenda (SAA) Management Questions Workshop on September 29, will set the stage for the conversations during the breakout sessions.

The first breakout session will focus on "What do we need to know to support the future decisions?" (Question 3 listed above). Participants will be broken out into the following groups, based on management themes developed from a review of the Delta Plan and Science Action Agenda. These themes were first used for the Delta ISB's Review on the Monitoring Enterprise (Nelitz et al. 2019) and are also being used for the Science Action Agenda Workshop on September 29 (with slight modifications to meet project needs).

- Water Supply Management - Decisions that influence how water resources affect the Delta and its users. Such actions include water operations, water storage, water demand, water conveyance / infrastructure, and groundwater protection and management (See Delta Plan Chapters 3 and 6).
- Flood Management - Decisions that influence how flood waters are managed affecting people and property in the Delta, as well as ecosystems. Such actions include construction and operation of flood control structures, protection and expansion of floodways, floodplains, and bypasses, and subsidence reversal (See Delta Plan Chapters 4, 5, and 7).
- Habitat Management - Decisions that influence how terrestrial, riparian, and aquatic habitats are managed within the Delta. Such actions include restoration, protection, and the use of flows and habitat to improve ecosystem conditions (See Delta Plan Chapter 4, Science Action Agenda: Action Area 3).
- Native Species Management – Decisions affecting the abundance of native aquatic or terrestrial-animal species relevant to the Delta. Such actions influence incidental take or mortality (e.g., at fish screens and water intakes), harvest (e.g., recreational harvesting of fish and wildlife), and population enhancement (e.g., through hatcheries) (See Delta Plan Chapter 4).
- Invasive Species/Non-native Species Management - Decisions affecting the population abundance and habitats of invasive / non-native species in the Delta. Such management actions include managing introductions, avoiding creation of favorable habitat conditions, and control populations (e.g., harvest, culling, biocontrol) (See Delta Plan Chapter 4).
- Water Quality Management - Decisions affecting surface and groundwater quality within the Delta. Such actions include wastewater management (e.g., effluent recapture,

recycling, and treatment of wastewater), pollution discharge controls (e.g., pyrethroids, methylmercury, CECs, pesticides, nutrients), and their adverse events on aspects of water quality in the Delta such as dissolved oxygen, turbidity, salinity, HABs) (See Delta Plan Chapter 6; Science Action Agenda: Action Area 4).

- Land Use Management - Decisions affecting terrestrial land designation, use, and cover within the Delta (e.g., of urban, agricultural, and natural / protected areas). Such management actions include land zoning, designation, conversion, and ownership, as well as land use (See Delta Plan Chapter 5; Science Action Agenda: Action Area 1).
- Delta as an Evolving Place – Decisions affecting the local human dimensions of the Delta including cultural, recreational, natural resource, and agricultural values. Such management actions include protecting the Delta's lands and communities and sustaining a Delta economy with a mix of agriculture, tourism, recreation, commercial and other industries, and components of state and regional infrastructure (See Delta Plan Chapter 5).

The second breakout session will focus on "How do we develop a structure to support, encourage, and accomplish our science needs?" (Question 4 listed above). The session will be broken out by science governance topics:

- Coordination opportunities
- Funding
- Institutional change
- Leadership
- Data management

As described in the Delta Science Plan, science governance is "a form of collaborative governance that involves collectively prioritizing research questions, setting goals for science efforts, determine best practices for how science is conducted and results of these efforts."

Prior to the workshop, participants will have an opportunity to select which breakout session they want to attend. Each breakout session will conclude with a brief report out from the breakout session facilitators. The agenda and workshop materials, including the breakout discussion questions, will be transmitted before the workshop to all registrants.

POST-WORKSHOP NEXT STEPS

Our intent is to use the Science Needs Assessment Workshop and Discussion Seminars to further the development of more useful and coherent scientific activities to provide insights for the

many Delta problems and solutions which span multiple agencies over long time scales, and which are expected to change significantly and rapidly in the coming decades.

Following the workshop, the workshop planning team will take the information gathered and draft the science needs assessment and related recommendations for next steps, including further discussions and implementation. We anticipate presenting these to DPIIC and the Delta ISB in early 2021 for discussion and endorsement. The science needs assessment and recommendations also will inform the 2022 to 2026 Science Action Agenda and implementation of specific actions in the Delta Science Funding and Governance Initiative.

Appendices

Appendix A: Glossary and Links to Documents

The following common terms and documents are referenced above. Cited references appear on page 32.

2014 Delta Challenges Report: https://resources.ca.gov/CNRALegacyFiles/docs/DeltaChallenges-v13.pdf.

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 specific objectives.

*Climate Change Vulnerability Assessment and Adaptation Strategy (*known as Delta Adapts: Creating a Climate Resilient Future initiative): http://deltacouncil.ca.gov/delta-plan/climate-change-vulnerability-assessment-and-adaptation-strategy.

Coequal goals: The two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resources, and agricultural values of the Delta as an evolving place *(CA Water Code 85054)*

Core monitoring: Monitoring that provides information on a seasonal and daily basis to inform specific decisions on operations for water supply and fish species status. Core monitoring is conducted almost entirely to fulfill requirements for regulatory compliance.

Delta ISB Letter to DPIIC: http://deltacouncil.ca.gov/pdf/isb/products/2019-02-11-isb-letter-to-dpiic.pdf.

Delta ISB Review on Delta as an Evolving Place Review: https://mavensnotebook.com/wp-content/uploads/2017/08/DISB-Delta-as-a-Place-Finalv3.pdf-Adobe-Acrobat-Pro-1.pdf.

Delta ISB Discussion on Preparing for Rapid Environmental Change: https://www.deltacouncil.ca.gov/pdf/isb/products/2020-04-13-isb-rapid-change-discussion-memo.pdf

Delta Plan: http://deltacouncil.ca.gov/delta-plan/.

Delta Plan Interagency Implementation Committee: http://deltacouncil.ca.gov/dpiic/.

Delta Science Enterprise: The collection of science programs and activities that exist to serve managers and stakeholders in a regional system.

Delta Science Plan: A shared guidance document intended to strengthen, organize, and communicate science to provide relevant, credible, and legitimate decision-support for policy and management actions. http://deltacouncil.ca.gov/pdf/2019-delta-science-plan.pdf.

Delta Science Strategy: a set of three guiding documents to be used by the Delta science and management community to achieve the vision of One-Delta, One Science. http://deltacouncil.ca.gov/delta-science-program/delta-science-strategy

Long-term: occurring beyond the next 25 years.

Science Action Agenda: A four-year science agenda for the Delta that prioritizes and aligns science actions to inform management decisions, fills gaps in knowledge, promotes collaborative science, builds the science infrastructure, and achieves the objectives of the Delta Science Plan. https://scienceactionagenda.deltacouncil.ca.gov/

Science activities: A broad range of efforts including compliance monitoring, modeling, exercises to identify science issues that may be of management concern in the near future, research focused on supporting decision-making, as well as more basic research that can support future management issues.

Science Enterprise Workshop Documents: https://mavensnotebook.com/science-enterprise-workshop/.

Science Funding and Governance Initiative Implementation Report: http://deltacouncil.ca.gov/pdf/dpiic/meeting-materials/2020-03-03-final-dsfgi.pdf

Science Needs Assessment Discussion Seminar Recordings: https://www.youtube.com/playlist?list=PLqTHCliW1HhoajhlAhxoL2OfUmgiaZUXv

Short-term: occurring within the next 5 to 25 years.

Social Science Task Report: https://deltacouncil.ca.gov/delta-science-program/delta-social-science-task-force.

State of Bay-Delta Science: http://deltacouncil.ca.gov/delta-science-program/delta-science-strategy.

Targeted foundational research: Science efforts that provide the knowledge and context to inform long-term management and policymaking, while also identifying and understanding emerging issues so that natural resource managers can be better prepared for future challenges.

This is not typically supported by funds allocated for science efforts linked to regulatory requirements.

Targeted immediate research: Science efforts that answer current management questions by providing evidence to support or refute hypotheses. This is not typically supported by funds allocated for science efforts linked to regulatory requirements.

APPENDIX B: SELECT EXAMPLES OF SCIENCE NEEDS ASSESSMENT MECHANISMS AND APPROACHES

Several science enterprises have undertaken similar efforts using a variety of mechanisms to develop their science needs assessments. Mechanisms employed often include:

Briefing papers

Workshops

Literature reviews and synthesis

Surveys and focused interviews, and

Discussions with policy-makers and experts

The following provides examples of mechanisms and efforts undertaken by specific science enterprises.

Name	Purpose, process, product, time frame
NRC: Grand Challenges in Environmental Sciences	Identify grand challenges and priorities for environmental research, based on informational letters solicited from experts Final 2001 Report to National Research Council No explicit timeframe
2009 Great Lakes Science Needs Assessment	Develop a strategy to address climate change impacts on the Great Lakes coastal systems Workshop, Summary report of workshop recommendations 1. Scientists present on current state of scientific understanding 2. Stakeholders voice concerns and needs related to climate change impacts 3. Identify presently available science to address concerns 4. Identify new scientific infrastructure that would enhance capability to meet stakeholder needs 5. Identify information gaps and needed infrastructure Immediate (2 to 4 years) and long term (5 to 7 years) time frames
2012 Gulf of Mexico Needs Assessment	Based on a set of previously identified management goals, scientists and managers brought together to describe current conditions related to each management goal, identify science gaps to fill, and the necessary science activities/infrastructure needed to achieve the goals "Long term" time frame but not very explicit

Name	Purpose, process, product, time frame
2015 to 2025 Chesapeake Science Strategy	Guide science activities to address the Chesapeake Bay Watershed Agreement (2014 to 2025), to support the Department of the Interior (DOI) involvement in the Bay restoration efforts, and align with the USGS Mission Area (MA) Science strategies USGS staff developed science questions based on management needs
NOAA Office of National Marine Sanctuaries (OMNS) Science Needs Assessment	Evaluation of the science and information requirements (capability, information, and products) of the ONMS as defined by the management issues facing each sanctuary in the National Marine Sanctuary System (NMSS) Synthesis of management plans, condition reports, science plans, regional and local reports, 2-page summaries with management issue, questions and informational needs, scientific approach and actions, etc. Unclear timeframe; ongoing
Ocean Science Trust Science Needs Assessment	Goals to explore science questions/information gaps playing a key role in holding back appropriately informed decision making; understand decision making processes; identify science products including the appropriate format and timing that would be most useful in impacting management and policy making Workshop and interviews of scientists and decision makers Unclear timeframe; prepared in 2015
Delta Science Action Agenda 2017 to 2021	Currently implementing

For additional information:

- National Research Council's outcomes of "Grand Challenges in Environmental Science:" https://www.nap.edu/read/9975/chapter/1
- NOAA's Science Needs Assessment on National Marine Sanctuaries: https://sanctuaries.noaa.gov/science/assessment/
- Ocean Science Trust's Science Needs Assessment on Sea-level Rise on Floodplain Management https://www.oceansciencetrust.org/wp-content/uploads/2016/11/NeedsAssesment_SLRFPM_Mar2015_Public_FINAL.pdf
- Urban forestry Science Needs Assessment: https://www.fs.usda.gov/treesearch/pubs/36322

APPENDIX C: AREAS OF SCIENCE EXPERTISE AND THEIR CURRENT ORGANIZATION

Areas of Expertise

Scientific specialization can be organized in many ways. The organization of specializations below focuses on different processes within the Delta, rather than traditional academic disciplines. This more applied problem-process view of scientific specialization seems more conducive to the integration of academic disciplines for problem-solving.

Almost all Delta problems involve a mix of scientific fields. Significant and high-level scientific and technical expertise is needed in the areas described below. No single discipline suffices for almost any Delta problem. This section summarizes many specialized fields commonly important for Delta problems and some general science capabilities needed to both support the specialized fields and assimilate these specialties for strategic and problem-focused understandings and solutions. These topical and general scientific capabilities should become available as a community resource to every agency.

- Organization
  Examining how people and institutions are organized to manage, understand, and make decisions. This area draws from fields of law, political science, sociology, anthropology, and related disciplines.
- Hydrodynamics
  Examines how water flow in the Delta, which is the fundamental physical basis for water availability, quality, and aquatic ecosystems. This area draws from water resources engineering and fluid mechanics, field methods, computational fluid mechanics, and related fields.
- Water quality
  Examines chemical concentrations and interactions in the Delta, usually strongly affected by Delta hydrodynamics. This draws from fields of chemistry, field methods, environmental engineering, and computational methods.
- Water demands
  Examines understanding agricultural, urban, environmental, recreational, and navigation demands for water and land in the Delta, and their quantitative representation. This work relies on expertise, ideas, and methods from economics, engineering, and sociology, with a major challenge for better representing environmental and ecosystem water demands, likely to draw more from ecological specialties.

- Water operations
  Examines how water management decisions (pump, gate, reservoir, diversion, and other operational decisions) can be technically orchestrated for management purposes. This work draws from water resource systems engineering, operations research, modeling, and data management, and often must interface closely with other specialties.
- Delta levees
  On the maintenance, vulnerabilities, and engineered changes in the Delta's physical structure. This draws mostly from geotechnical engineering and geologic expertise.
- Wetlands
  Examines these physically distinct ecosystems, integrated specialized hydrology, hydraulics, and geochemical processes, ecology, biology, environmental engineering, recreation, economics, and management.
- Aquatic ecology
  Examines ecological processes and performance for these special conditions, drawing from ecology, biology, environmental engineering, and management.
- Avian ecology
  Examines ecological processes and performance for these special conditions, drawing from ecology, biology, environmental engineering, and management.
- Invasive species
  Examines processes and management of invasive species, drawing from specialized ecology, biology, law, behavioral psychology, economics, and management.

These areas of scientific and technical activities encompass a wide range of scientific expertise, from social sciences and law to a variety of specialties within engineering and the physical and biological sciences, and the humanities. The Delta has big wide-ranging problems that require substantial effort and diverse forms of expertise. These problems are bigger than the expertise available to even the largest government agency or research entity, and their solutions require the confidence of and collaboration with many outside of the institutions conducting the scientific work.

Some major science problem areas receive little formal attention, such as organization, levees, recreation, and water demands. Other areas benefit from moderate levels of resources. (No area will likely admit to having too much scientific activity.)

Importantly, rather little integration of scientific and technical activities occurs for Delta problems commonly held among more than one agency. The whole of insights from scientific efforts for the Delta is typically much less than the sum of its fragmented parts. Naturally, the technical development of data and tools, development of understanding, and the application of

understanding tends to focus on the missions and concerns of specific sponsoring agencies. This hinders the development of common understandings of Delta problems and solutions across agencies and interests.

Many agencies with broad regulatory responsibilities (e.g., SWRCB, CDFW, etc.) have little internal modeling and model development capabilities, and must rely on models and modeling developed by others. Their access to modeling expertise is sometimes limited by the professional relationships of major consultants with regulated parties. The development, documentation, and application of these models are decentralized, with results rarely becoming commonly available for non-sponsoring agencies and interests.

Current Organization of Scientific Expertise

The Delta's overall science enterprise needs to better integrate many scientific efforts by a wide range of state, federal, and local agencies, stakeholders, and academic researchers.

The problems of the Delta often interact and span multiple state, federal, and local agencies. However, the expertise and focus of most science and technical activities tend to be specialized within agencies or individual agency programs, often neglecting broader state and local relevance. Table 1 (from the 2019 Delta Science Plan, Appendix C: Science Governance and the Collaborative Delta Science-scape) lists major areas of scientific and technical activities regarding the Delta, and major state, federal, and local agencies participating in these activities. Major focus areas include agriculture, the 2008 and 2009 biological opinions on the long-term operations of the State Water Project and Central Valley Project (BiOps), flood control, land use, monitoring, recreation, restoration, science coordination, water quality, water rights, water supply and wildlife.

Table 1. State and Federal Government Organizations

Name	Acronym	Focus topics	Regulatory (Y/N)?
Federal	N/A	N/A	N/A
National Aeronautics and Space Administration	NASA	land use, monitoring, water quality, water supply	N
National Marine Fisheries Service – Southwest Fisheries Science Center	NMFS – SWFSC	BiOps, wildlife (see Notes below)	Y
US Army Corps of Engineers	USACE	flood control	Y
US Department of Agriculture	USDA	agriculture	Y
US Department of Interior	USDOI	N/A	N/A
US Bureau of Reclamation	Reclamation	agriculture, BiOps, flood control, land use, monitoring, recreation, restoration, science coordination, water quality, water supply, wildlife	N
US Environmental Protection Agency	USEPA	water quality	Y
US Fish and Wildlife	USFWS	restoration, wildlife	Y
US Geological Survey	USGS	monitoring, water quality	N
State	N/A	N/A	N/A
California Department of Food and Agriculture	CDFA	agriculture	Y
California Environmental Protection Agency	CalEPA	N/A	N/A
Central Valley Regional Water Qual. Control Board	CVRWQCB	agriculture, monitoring, restoration, water quality	Y
Office of Environmental Health Hazard Assessment	OEHHA	water quality	Y
State Water Resources Control Board	SWRCB	flood control, water quality, water rights	Y
California Natural Resources Agency	Resources	N/A	N/A
California State Parks and Recreation	State Parks	land use, recreation	Y
Central Valley Flood Protection Board	Flood Board	flood control	Y
Department of Fish and Wildlife	DFW	BiOps, wildlife	Y
Department of Water Resources	DWR	flood control, restoration, water supply	N
Delta Protection Commission	DPC	agriculture, land use, recreation	Y
Delta Science Program	DSP	science coordination, water quality, water rights, water supply, wildlife	N
Delta Stewardship Council	DSC	water supply, restoration	Y
Sacramento-San Joaquin Delta Conservancy	Delta Conservancy	restoration	N
Southern California Coastal Water Research Project	SCCWRP	water quality	Y

Table 1 Notes

- Focus Topics: These columns represent agency activities specific to the Bay-Delta region.
- US Department of Agriculture and Department of Interior are in the table due to Department-level representation in DPIIC.
- National Marine Fisheries Service – Southwest Fisheries Science Center (NMFS-SFWSC): Since the release of the Delta Science Plan in June 2019, we now more fully understand the role that the NMFS-SWFSC plays in the science enterprise. NMFS-SWFSC is emphatically not a regulatory entity, and BiOps are not a focus for the center. However, we did not change the data from the original table.

Appendix D: Current Science Collaboration Efforts for the Delta

This appendix was taken from Appendix C of the 2019 Delta Science Plan.

Science Governance and the Collaborative Delta Science-scape

This appendix provides a more extended discussion and analysis of the network diagram displayed in Chapter 1 of the Delta Science Plan. The analysis focuses on the existing structure of the collaborative Delta science-scape and serves as a starting point for visualizing and understanding the complexity inherent in the endeavor of collaboratively governing the science of a complex social-ecological system. Future analyses will investigate the nature of these relationships and the processes contributing to decisions across collaborative organizations. These include identifying levels of engagement and commitment, scope of responsibility of each venue, and need for resources. The goal for these analyses is to serve as a tool to improve collaborative science governance in the Delta.

Collaborative Science Governance

Governance refers to the interactions among structures, processes, rules, and traditions that determine how people in societies make decisions and share power, exercise responsibility, ensure accountability, and give stakeholders a say in the management process (Sutherland & Woodroof, 2009). The interactions among structures, rules, and traditions provides the social context that allows collective action, rule-making, and institutions for social coordination (Dietz et al. 2003). In a complex social-ecological system like the Delta, governance is not about one individual or organization making a decision but rather multiple individuals within organizations and systems of linked organizations making decisions to advance the collective good.

Collaborative science governance is a form of governance that involves engaging people constructively across the boundaries of public agencies, levels of government and/or the public, private and civic spheres in order to collectively prioritize research questions, determine how science is conducted, and review and distribute the results. Collaborative science governance covers a range of science activities including how funding is directed to research programs aimed at achieving high priority science goals, best practices for carrying out research are established and communicated, and the results of science undergo review and are distributed to decision-makers and other users. The network analysis described here focus on the organizations involved in collaborative science governance as a first step.

Collaborative Delta Science Venues

The collaborative Delta science-scape is comprised of the formal, collaborative elements of the Delta science enterprise. This Appendix maps out the network of connections between the main collaborative Delta science venues that contribute to science governance via the wide range of organizations participating in those venues. Taken together, the venues coordinate across a diverse range of actors working on the full set of science activities and study topics in the Delta. It is important to note that this network does not capture the full range of collaborative science efforts in the Delta; only those which are organized as formal, ongoing, multi-party venues are represented. Table 2 provides the list of 11 collaborative venues including a description of their roles and the primary participants within each venue.

Who Participates?

The set of organizations participating in collaborative Delta science venues include actors from multiple levels of government as well as non-governmental organizations, public research institutions, and private consultants. The primary actors are state and federal agencies with responsibilities related to water supply, water quality, wildlife management and habitat restoration.

The six main federal agencies that participate in collaborative science governance in the Delta include the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. There are multiple state agencies responsible for managing water resources and/or wildlife and habitat restoration. These include, but are not limited to, the Department of Fish and Wildlife, the Department of Water Resources, and the State Water Resources Control Board.

A number of city and county general government actors appear in the Delta collaborative science-scape, while the private sector is involved peripherally. Water special districts are governmental entities usually associated with a local government jurisdiction and perform at least one of four specific duties: water delivery (e.g. public water agencies), waste disposal/sanitation (e.g. publicly owned treatment works), flood management, and water conservation. Water districts participate in the network individually or through larger member associations such as the Metropolitan Water District of Southern California (Metropolitan) or the State and Federal Contractors Water Agency (SFCWA[1]).

[1] Although SFCWA no longer exists, the organization has been a major player in the Delta science-scape and was included in the Delta Science Program's analysis of science governance and collaborative venues included in the 2019 Delta Science Plan.

Table 2. Collaborative science and policy venues in the Delta

Acronym	Full name	Role/Purpose	Primary participants
CSAMP/ CAMT	Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team Legislative Mandate: None (2008/2009 BiOps Judicial Mandate)	Collaboratively produce information and evaluate science and management actions associated with protection of species of concern and actions related to the State Water Project and Central Valley Project to improve performance of ecological systems and water supply	State and federal entities and stakeholders involved in the court ordered remand schedule for completing revisions to Delta Smelt and salmonid Biological Opinions (2008 and 2009 BiOps)
CWEMF	California Water and Environmental Modeling Forum Legislative Mandate: None	Increase usefulness of models for analyzing California's water related problems, facilitate exchange of information, resolve technical disagreements, ensure technical work takes into account stakeholder and management needs. Also non-partisan clearing house for models and peer review	State and federal entities, entities with interests in water, universities, environmental org, private consultants, and general public (over 100 individual member entities)
CWQMC	California Water Quality Monitoring Council Legislative Mandate: SB 1070 (2006)	Develop specific recommendations to improve the coordination and cost-effectiveness of water quality and ecosystem monitoring and assessment, enhance the integration of monitoring data across departments and agencies, and increase public accessibility to monitoring data and assessment information	State and federal entities, citizen monitoring groups, the public, scientific community, agriculture, regulated water community and water supply community
DPIIC/DASW	Delta Plan Interagency Implementation Committee/Delta Agency Science Workgroup Legislative Mandate: Delta Reform Act (2009)	Bring together directors and technical staff of agencies associated with the Delta Plan to coordinate their agency efforts to support goals of the Delta Plan	17 State and federal entities involved in Delta Plan implementation
DIISC	Delta Inter-agency Invasive Species Coordination Team Legislative Mandate: None	Foster communication and collaboration among California state agencies that detect, prevent, and manage invasive species and restore invaded habitats in the Sacramento-San Joaquin Delta	Federal, state, local , academic and other stakeholders

Acronym	Full name	Role/Purpose	Primary participants
DRMP	Delta Regional Monitoring Program Legislative Mandate: None	Produce objective, cost-effective scientific information gathered in a streamlined way that provides a comprehensive understanding of water quality conditions and trends in the Delta	Central Valley Regional Water Quality Control Board, publicly owned treatment works, storm water programs, irrigated agriculture, water suppliers, natural resource and science managers, agency scientists
IAMIT	Interagency Adaptive Management Implementation Team Legislative Mandate: None	Work in support of integrated Adaptive Management for habitat restoration in the Yolo Bypass, Delta, and Suisun Marsh	Federal, state and local agencies, and stakeholders involved in planning, funding, implementation or regulatory oversight of Delta habitat restoration projects
IEP	Interagency Ecological Program Legislative Mandate: None	Collaboratively monitor, research, model, and synthesize information for adaptive management, water project operations, planning, and regulatory purposes relative to endangered fish and the aquatic ecosystem in the Bay-Delta	Nine State and federal agencies and departments
IICG	Interagency Implementation and Coordination Group Legislative Mandate: None	Coordinate and implement the Adaptive Management Program for the California WaterFix and current Biological Opinions on the coordinated operations of the Central Valley and State Water Projects	Representative from the five State and federal water operations and fisheries agencies, a State Water Project contractor and Central Valley Project contractor
Nutrient STAG	Nutrient Stakeholder and Technical Advisory Group Legislative Mandate: None	Responsible for providing productive input representing the range of different interests involved in, and who may be affected by, the development and implementation of a Delta nutrient management strategy	State, federal and local agencies involved in water resources management (supply, quality, stormwater, irrigation etc.), NGOs and industry stakeholders
WOMT	Water Operations Management Team Legislative Mandate: None	Considers recommendations of technical teams, water supply costs, and other factors to provide water operations guidance to DWR and USBR	State and federal agencies associated with the Central Valley and State Water Projects

Note: This table includes only the formal, ongoing Delta collaborative science venues and is not an exhaustive list of all collaborative Delta science activities.

APPENDIX E: SCIENCE INFRASTRUCTURE NEEDS FOR THE DELTA

Several support areas need to be strong for Delta science programs to be effective, and of high quality:

- Planning and budgeting
  There is a need to more formally and flexibly support scientific activities that involve and serve multiple agencies, particularly in supporting long-term development of common efforts. This function would coordinate science plans (and perhaps expenditures) among individual agencies and programs, and develop common assessments and forecasts of long-term problems and contingencies to be prepared for.
- Business functions
  Contracting among entities to support inter-institutional collaborations. Successful science requires a successful contracting mechanism, or set of mechanisms. Reducing contracting costs and delays is vital to effective scientific focus and effort. State and federal agencies are substantially debilitated by difficulties, delays, and restrictions in contracting.
- Scientific staff development and support
  All governmental agencies are facing profound challenges to their knowledge and effectiveness from the retirement of experienced staff and technical leaders. This requires continued attention to scientific staff development and support. Agencies (separately and together) need to support staff development (formal degrees and classes, short courses, mentoring), meetings, workshops, journal access, internship programs, etc. (extending beyond action 5.4 of the Delta Science Plan).
- Communications
  Within the science community, policy-making and stakeholder communities, and general public (generalizing beyond actions 2.4 and 2.5 and 2.6 in the Delta Science Plan.)
- Data management and computer science
  The Delta is probably the world's most monitored estuary. Despite efforts of the California Water Quality Monitoring Council since 2007 and the California Natural Resources Agency to implement the 2016 Assembly Bill 1755 (The Open and Transparent Water Data Act), the availability and documentation of data and the existence of cross-agency expectations, standards, and coordination for data and software management remain a major gap.
- Scientific standards
  For documentation, accessibility, data, models, etc. (extending beyond actions 3.3 to 3.7 in the Delta Science Plan).
- External Review
  External review is needed to keep research programs effective and well-adapted over time. External reviews should be done every five to seven years for most major programs. Review panels involving expertise from outside the program and agency also provide better exchange of perspectives, information, and opportunities across the Delta science enterprise.

Appendix F: Major Challenges Of Providing Science To Management

The California Bay-Delta science enterprise is both vigorous and fragmented. Scientific work is funded in multiple, independently or quasi-independently governed programs or venues, each with its own strategic aims, priorities, and practices. These programs for the most part serve specific management domains, with the boundaries and funding defined by resource managers. The absence of an overall governance mechanism to draw together the various programs and fill gaps has brought various challenges, which hinder the Bay-Delta science enterprise and make it less efficient and less able to decisively address the system's hardest problems.

Some major challenges for providing science to management include:

- Dispersion or duplication of effort, problems with resource allocation
- Transparency
- Multi-agency and stakeholder credibility
- Communication between science and management
- Availability of information, data, modeling, and documentation to other programs, agencies, and the public
- Anticipation and preparation for future needs
- Needs for experimental management and integrative research
- Science for advocacy versus collaborative settings
- Knowledge lags behind science
- Separations of expertise from program responsibilities
- Needs for professional development, given widespread agency retirements
- Trust
- Coordination

Appendix G: Science Funding to Support Science Needs

Even with clear science needs identified, determining appropriate funding support levels and mechanisms is challenging. Many variables are involved in this evaluation: intensity and durations for scientific activities, the mix of approaches to be used (field research, lab research, monitoring, synthesis, modeling, integrated assessment, etc.), and costs for achieving different levels of uncertainty. Also, many scientific questions are not simply and definitively answered, so completed research projects often identify new uncertainties and hypotheses to be addressed, sometimes before more actionable information and advice is available. The appropriate funding level varies from science to provide minimal input to policy makers (often with higher uncertainty around this advice) to more refined, time-consuming, and expensive input with sometimes less uncertainty.

Effective and trusted science requires consistent funding over time, for data collection, research, synthesis, and communications. For the Delta, most science funding currently is for monitoring. Consistent funding has been an on-going challenge for research, synthesis, and communications. Over the last decade, the vast majority of research support has come from bond funding via state propositions (e.g., Prop. 1 and 68). While these have been a valuable, they displace more assured long-term science funding for long-term assessments and research. The complexity of Delta issues requires sustained efforts to define and reduce key uncertainties. For both current and future issues, significant effort is needed for new field activities, laboratory instrumentation, consolidating information for modeling efforts, etc. Without consistent long-term funding, researchers tend to move to short-term issues or other regions, and we lose in building an integrated Delta-focused science enterprise. Consistent funding also is needed to maintain access to data and resources and support development and mentorship of young researchers as many current researchers near retirement.

Science funding within the Delta should support a mix of activities, including ongoing core monitoring, targeted long-term research and model development, funds for synthesis/analysis, and improved communication outreach to decision makers. The specific mix of these science components should be considered strategically. Ensuring the effective use of science funding, requires regular evaluation of science program effectiveness. This should be considered in advance, including who will evaluate, how frequently they assess funding effectiveness and priorities, and what issues/questions to address. In evaluating science funding effectiveness, science is not a simple input/output process: many funds spent this year are unlikely to immediately answer challenging management issues. Time is required to accumulate data and capabilities to provide actionable insight. This issue will be more important for the longer-term, forward-looking science considered for the workshop.

For more information, please review the Delta Science Funding and Governance Initiative links found in Appendix A.

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