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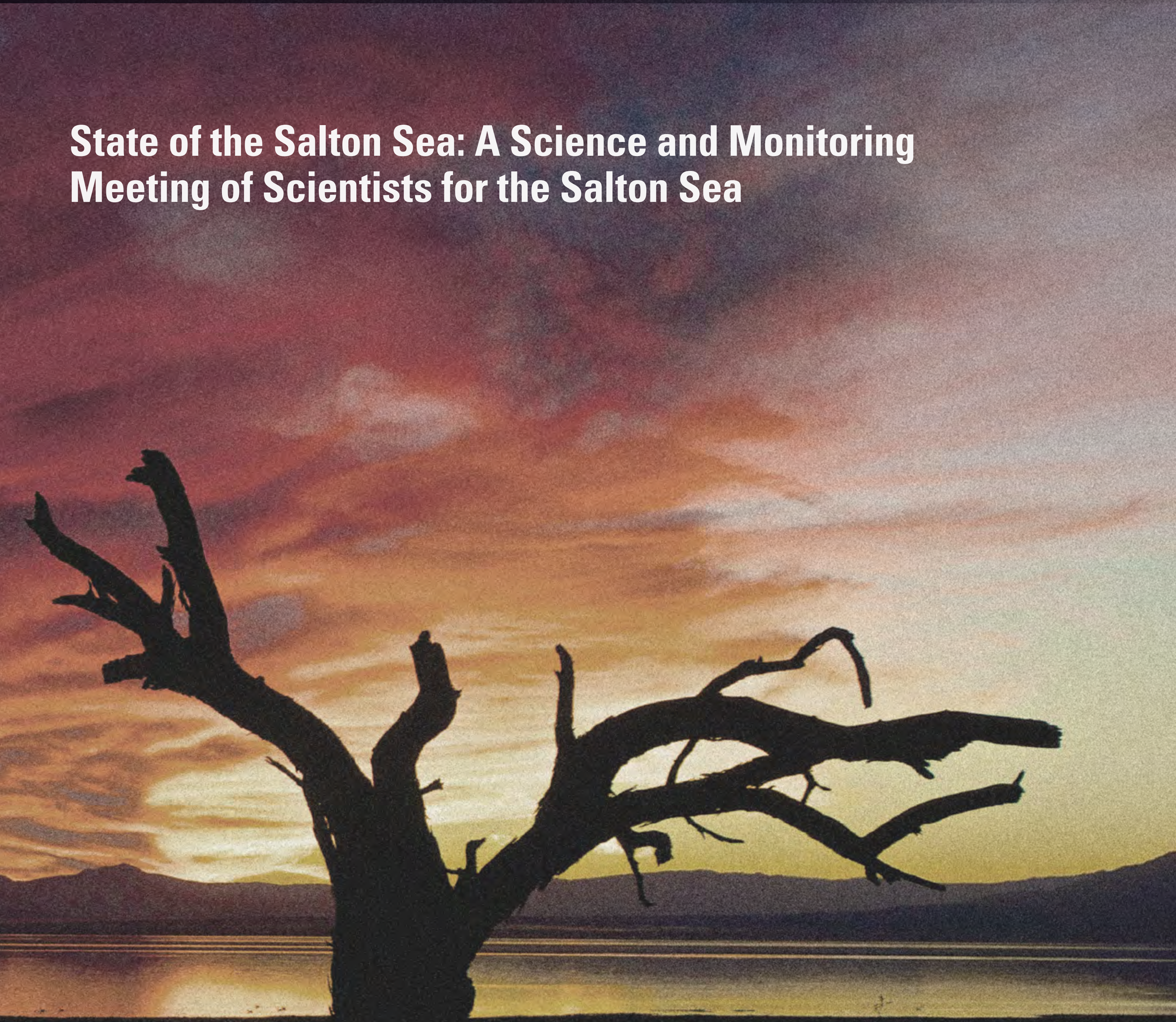
State of the Salton Sea: A Science and Monitoring Meeting of Scientists for the Salton Sea



Open-File Report 2017–1005

U.S. Department of the Interior
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Cover. Salton Sea. Photograph by Douglas A. Barnum, U.S. Geological Survey.

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All appendixes can be downloaded at https://doi.org/10.3133/ofr20171005

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Abbreviations

AM	adaptive management
C	carbon
CDFG	California Department of Fish and Game (now California Department of Fish and Wildlife)
CEP	Controlled Eutrophication Process
CEQA	California Environmental Quality Act
CIMIS	California Irrigation Management Information System
CVWD	Coachella Valley Water District
cyberinfrastructure	equipment, software, and policies for collecting, storing, and distributing digital information
DO	dissolved oxygen
DFW	California Department of Fish and Wildlife
DMS	dimethyl sulfide
drain water	surface and subsurface water from agricultural fields
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPS	extracellular polymeric substance, a natural biopolymer form of organic matter
ET	evapotranspiration
FTE	full-time equivalent
FTG	focused technical group
GIS	geographic information system
GPS	Global Positioning System
GUI	graphical user interface
HRT	hydraulic retention time
H_2S	hydrogen sulfide gas
IID	Imperial Irrigation District
Kd	a partitioning coefficient value used in selenium modeling
km	kilometer
LCRB	Lower Colorado River Basin
MAP	Monitoring and Assessment Plan
MODFLOW	a USGS three-dimensional finite-difference groundwater model
MWD	Metropolitan Water District of Southern California
N	nitrogen
NEPA	National Environmental Protection Act
NGO	non-government organization
NH_3	ammonia
NH_4	ammonium
NIWQP	National Irrigation Water-Quality Program
NOx	nitrogen oxides
P	phosphorus

Abbreviations—Continued

PEIR	Programmatic Environmental Impact Report
PGPR	plant growth promoting rhizobacteria
pH	a measurement of acidity or alkalinity from 0 to 14
playa	the exposed floor of a desert basin usually occupied by a shallow lake
$PM_{10}/PM_{2.5}$	particulate matter that will pass through a 10 or 2.5 micrometer filter
QA/QC	quality assurance/quality control
QSA	Colorado River Quantification Settlement Agreement of 2003
Reclamation	Bureau of Reclamation
Salton Basin	interchangeable phrase for the Salton Sink
Salton Sink	a terminal depression within the Salton Trough of southeastern California where water collects
Salton Trough	an active tectonic pull-apart basin within the Imperial, Riverside, and San Diego Counties of southeastern California
SALSA2	a computer program developed to facilitate evaluation of alternatives in an uncertainty framework. The model provides tools for the analysis of future hydrologic and salinity conditions at the Salton Sea
SCH	species conservation habitat project
SDCWA	San Diego County Water Authority
Se	selenium
seiche	a standing wave in an enclosed or partially enclosed body of water
SoSS	State of the Salton Sea Science meeting
SSA	Salton Sea Authority
SSC	Salton Sea Science Committee
SSM	Salton Sea Model Army Corps of Engineers simulation model
SSNWR	Sonny Bono Salton Sea National Wildlife Refuge
SSP	Salton Sea Strategic Science Plan
tail water	surface runoff water from agricultural fields
tile water	subsurface runoff water from agricultural fields
TDS	total dissolved solids
TFF	trophic transfer function, a value used in selenium modeling
TSS	total suspended solids
UC	University of California
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

State of the Salton Sea: A Science and Monitoring Meeting of Scientists for the Salton Sea

By Douglas A. Barnum[1], Timothy Bradley[2], Michael Cohen[3], Bruce Wilcox[4], and Gregor Yanega[2]

Introduction

The Salton Sea (Sea) is an ecosystem facing large systemic changes in the near future. Managers and stakeholders are seeking solutions to the decline of the Sea and have turned to the scientific community for answers. In response, scientists gathered in Irvine, California, to review existing science and propose scientific studies and monitoring needs required for understanding how to retain the Sea as a functional ecosystem. This document summarizes the proceedings of this gathering of approximately 50 scientists at a September 8–10, 2014, workshop on the State of the Salton Sea (SoSS).

In 1997, a similar gathering of nearly 100 scientists and others in Palm Springs, Calif., yielded a number of scientific proposals establishing a foundation for a program of integrated science investigations. The 1997 workshop results were combined with recommendations from a U.S. Geological Survey (USGS) Tiger Team (Shipley and others, 1999), resulting in the eventual creation of a Strategic Science Plan (SSP) for the Salton Sea (Salton Sea Science Subcommittee, 2000). The vision from the 1997 workshop of an integrated and coordinated program of scientific investigations, embraced by the SSP, was implemented through the SSC and the USGS Salton Sea Science Office (Science Office). The integrated science program, mandated by the Salton Sea Reclamation Act of 1998 (Public Law 105–372) and spelled out in the SSP, directly led to an increased scientific understanding of the Salton Sea ecosystem. The workshop concluded that "rehabilitation of the Sea is essential and requires that current ills be rectified in a manner that allows the Sea to sustain social values of importance to the human populations of the Imperial and Coachella Valleys, as well as society in general" (U.S. Fish and Wildlife Service, 1997). The 2014 SoSS workshop built upon the foundations of the 1997 workshop, with particular emphasis on changes in the condition of the Sea and its environment in the intervening years.

Over the past five decades, investigations of the Salton Sea have addressed water quality, biological, recreation, and (or) economic issues at the Salton Sea (California Resources Agency, 2006, chap. 8). Many stakeholders believe that the Salton Sea has been "studied to death" (Claiborne, 1996). Although it is true that a great deal of research has been completed at the Salton Sea, much of it has been short term and focused on specific topics with little or no integration across science disciplines, time, and space. Additionally, there have been numerous attempts at resource management of the Salton Sea (previously referred to as restoration planning).

Study objectives have differed, but the main focus has generally been on methods to control the salinity and elevation of the Salton Sea (California Resources Agency, 2006, chaps. 1 and 4). Most investigations resulted in proposed plans to preserve the Salton Sea as a thriving fishery and recreational destination, and most of these plans addressed methods to preserve the "whole Sea." More recently, however, studies have recognized that maintaining a smaller Salton Sea should be considered, owing to declining inflows to the Salton Sea (California Resources Agency, 2006).

Is this really "restoration"?

Ecological management involves an assumption that human intervention can reverse environmental degradation to a prior state of ecological health, integrity, and sustainability (Society for Ecological Restoration International, 2004). With implementation of the Quantification Settlement Agreement and other changes affecting inflows, it has become apparent to many managers and decision-makers that meeting public expectations for a "whole sea fix" of the Salton Sea (Sea) may not be possible, and thus "restoration" is no longer an appropriate description for planning intent. Similarly, conservation of the Sea, which would involve preserving existing biodiversity of species while maintaining the habitat according to historical standards, is something no Salton Sea planning yet accomplishes. The goals of current planning efforts are broad, and no single plan has been

(*continued on next page*)

[1]U.S. Geological Survey
[2]University of California, Irvine
[3]Pacific Institute
[4]Imperial Irrigation District

agreed to by all parties setting forth specific management targets (for example, number of bird species, fish productivity, acres of habitat, water quality, contaminant levels, or dust emission levels). Providing scientific guidance and developing conceptual proposals is difficult, and a true adaptive management program is not attainable without a plan for management of the Salton Sea with defined and measurable goals.

Current plans for managing the Salton Sea have focused on the reality of diminished inflows and therefore a smaller lake in the future. Any planning strategy will aim to protect as much of the historical, biological, and physical functioning of the lake as is practical with significantly less water. In this sense, management of the entire Salton Sea is no longer an objective. The objective is to provide rehabilitation and management of resources or their functions to the greatest practical extent possible. This strategy is called Salton Sea resource management. Scientists at the State of the Salton Sea meeting developed proposals directed towards providing science to support any Salton Sea management plan.

For the purpose of this document, “resource management” or simply “management” is used in place of the word “restoration,” except in original excerpted documents found in appendixes.

Prior investigations considered hundreds of alternatives for managing Salton Sea salinity, nutrients, and water elevation. Some alternatives generated revenue to help pay for rehabilitating the Sea. These alternatives have been addressed in multiple studies, as summarized in chapters 1 and 4 of the “Salton Sea Ecosystem Restoration Program Draft Programmatic Environmental Impact Report” (California Resources Agency, 2006).

Although there have been multiple efforts to characterize the Salton Sea ecosystem and develop management plans, it was not until 1996 that a comprehensive and integrated research needs assessment was developed (U.S. Fish and Wildlife Service, 1997). The 1997 report captured the combined thinking of scientists and managers and identified several areas of scientific research that would be required for a fuller, more complete understanding of the Salton Sea necessary to undertake any management project. The report defined these broad categories of science as physical environment, biological environment, cultural resources, pathogens and diseases, and contaminants. These categories form the basic framework for all scientific investigations at the Salton Sea. Some science categories continue to receive greater emphasis because limited funding has required the prioritization of projects.

A Salton Sea Science Subcommittee (SSC) authorized by Public Law 105–372, representing a broad range of Federal, State, local, and other stakeholder interests, endorsed a long-range Strategic Science Plan for the Salton Sea (Salton Sea Science Subcommittee, 2000). Whereas the U.S. Fish and Wildlife Service 1997 report established the types of science needed, the SSP further established the governing processes and expectations of how this science program should be conducted. The SSP provided the framework for scientific investigations and remains the source for identifying how scientific studies should be undertaken to better understand the Salton Sea ecosystem. Based substantially on the U.S. Fish and Wildlife Service (1997) analysis of science needs, and in consultation with many stakeholders, the SSC authorized and funded a number of initial reconnaissance-level projects.

The structure of this SoSS document follows the basic framework of the U.S. Fish and Wildlife Service 1997 report, placing emphasis on physical environment (air and water quality), biological environment (birds, fish, invertebrates, carbon, and algae), contaminants, and socioeconomics.

The SoSS meeting in 2014 was convened to build upon previous scientific efforts and to provide guidance to managers on what experts believe are the most critical science needs going forward. Experts were invited to participate in the SoSS meeting based on a review by the organizing committee of individuals with subject area expertise and experience working at the Salton Sea or in similar environments. The SoSS organizing committee presented a synopsis of known science to the gathered scientists, who were then tasked to evaluate the completeness of that science and make recommendations for science needs to fill information gaps. Participants were challenged to think and act independently of their organizational affiliation in order to generate conceptual proposals designed to address scientific and monitoring concerns identified by the managerial meeting participants.

Reconnaissance investigations identified and funded by the Salton Sea Science Subcommittee

- Survey of Algal Toxins in the Salton Sea
- Avifauna of the Salton Sea: Annual Phenology, Numbers, and Distribution
- Fisheries Biology and Fish Ecology of the Salton Sea
- Salton Sea Desert Pupfish Investigations
- Reconnaissance of the Biological Limnology of the Salton Sea
- Limnological Assessment of the Salton Sea, Riverside and Imperial Counties
- Survey of Selected Microbial Pathogens in the Salton Sea
- Environmental Reconnaissance of the Salton Sea: Sediment Contaminants
- Baseline Reconnaissance Vegetation Mapping of the Salton Sea

Goals and Objectives of Salton Sea Management

Federal, State, and local governing organizations with an interest in developing management plans have stipulated a number of goals and objectives (table 1). These goals are obviously broad, and there is no single plan agreed to by all parties setting forth specific management targets (for example, number of bird species, fish productivity, acres of habitat, and water quality). Thus, providing scientific guidance and developing conceptual proposals is difficult without identifiable resource management goals. Without a resource management plan, it is not possible to design methods for evaluating effectiveness of planned management actions or implement any type of adaptive management plan.

Scientists at the SoSS meeting were directed to develop conceptual proposals amenable to the broad goals and objectives outlined in table 1, as well as ones that could be applicable to any future Salton Sea resource management plan.

The USGS Science Office was established by the U.S. Department of the Interior in 2000 to function as an independent and unbiased advisor on Salton Sea science activities initiated as a result of PL 105–372, which was derived from the U.S. Fish and Wildlife Service 1997 workshop and actions of the SSC related to Salton Sea management (Salton Sea Science Subcommittee, 2000). Since its establishment, the Science Office has been integral to building a more complete understanding of the science of the Salton Sea through convening expert workshops (for example, Salt Deposition, Air Quality, Water Quality, Selenium, Eutrophication, Shallow Saline Habitat), coordinating expert reviews of management proposals, participating in California's 2003–7 Programmatic Environmental Impact Report (California Resources Agency, 2006), and providing staff to serve as chair of the State of California's Salton Sea Science Committee. The Science Office also led the development of a plan outlining science and monitoring needs for the Salton Sea (Case and others, 2013).

The scientific investigations that emerged from the 1997 Salton Sea workshop provided a wealth of new and interrelated scientific understandings of how the Sea functions (Barnum and others, 2002; Hurlbert, 2007; Hurlbert, 2008). Almost 20 years later, there is a clear need to build upon those concentrated scientific investigations. Unresolved issues include the need for monitoring efforts to fill the gaps in our knowledge, which suffer from a lack of funding. Furthermore, the Sea has changed dramatically since 1997, with increasing salinity, declining inflows, reductions in the quantity and quality of shoreline and island habitats, further declines in dissolved oxygen concentrations and invertebrate populations, and increased exposure of sediments as the Sea recedes (fig. 1). Additionally, the rate of change for all of these issues at the Salton Sea will increase significantly after 2017, due to the impacts of a major water transfer combined with the termination of supplemental mitigation water. Documenting current conditions will provide an invaluable baseline for understanding future changes. Addressing these gaps in knowledge is critical to the success of any Salton Sea management effort. Limited monitoring of the Sea and associated management efforts and lack of appropriate guidance for these management efforts hinder the ability of scientists and managers to adequately evaluate success or failure of projects.

This document reports the results of a meeting of scientists and managers convened over a 3-day period in Irvine, Calif., in 2014 to (1) review the science conducted to date, (2) assess gaps in our knowledge, and (3) make recommendations for immediate and near-future science and monitoring needs, including anticipated funding requirements.

Table 1. Salton Sea management goals and objectives as stated by governing organizations.

Organization and source	Goals and objectives
Federal Public Law 105–372 Salton Sea Reclamation Act of 1998	• Continued use of the Salton Sea as a reservoir for irrigation drainage. • Reduce and stabilize the overall salinity of the Salton Sea. • Stabilize the surface elevation of the Salton Sea. • Reclaim in the long term, healthy fish and wildlife resources and their habitats. • Enhance the potential for recreational uses and economic development of the Salton Sea.
State of California California Resources Agency, 2006 Executive Summary Salton Sea Ecosystem Restoration Draft Programmatic Environmental Impact Report	• Restoration of long-term stable aquatic and shoreline habitat for the historic levels and diversity of fish and wildlife that depend on the Salton Sea. • Elimination of air quality impacts from the restoration project. • Protection of water quality.
Salton Sea Authority (http://saltonsea.ca.gov/)	• Restore healthy habitat. • Revitalize economy. • Retain agricultural drain. • Stabilize salinity. • Preserve shoreline and sea elevation.

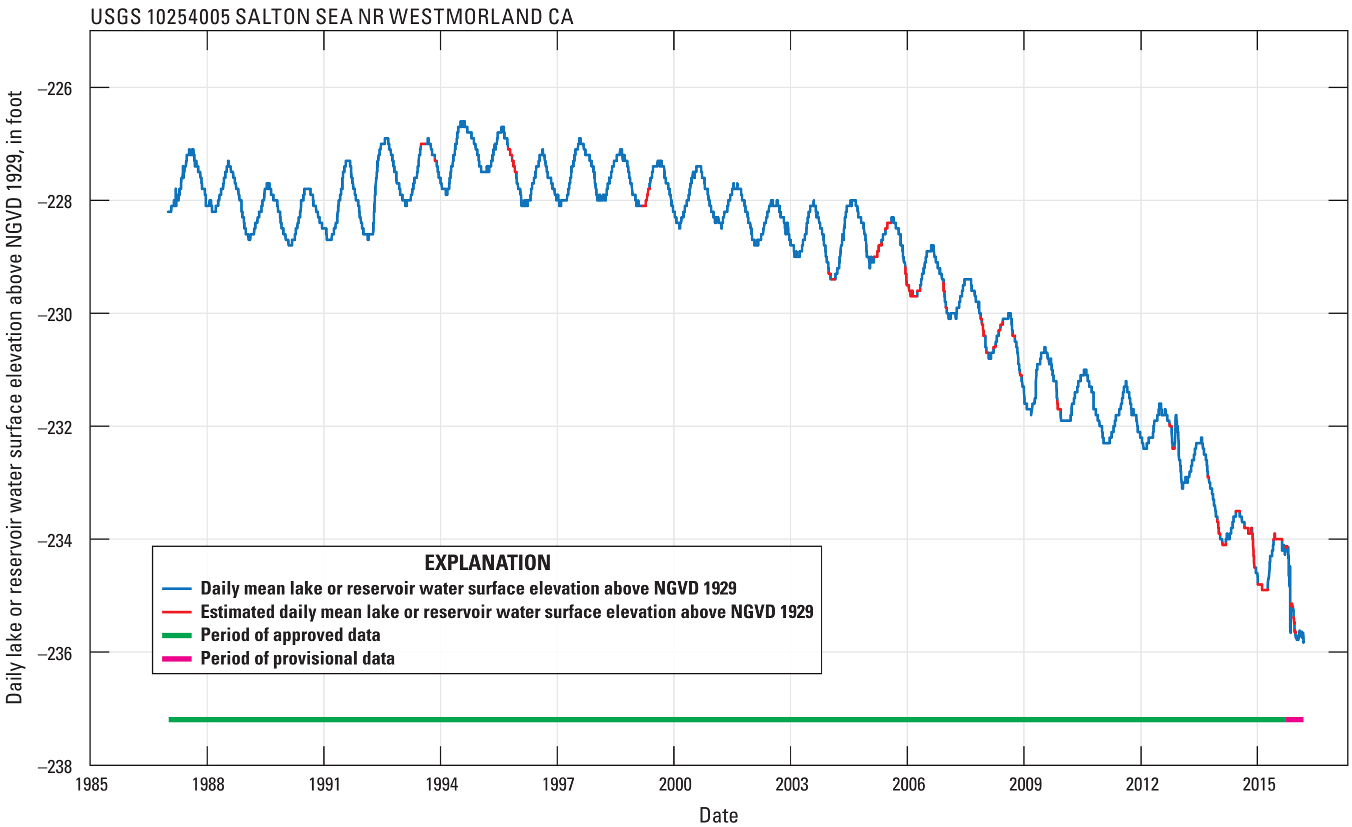

Figure 1. Chart of Salton Sea lake surface elevation from U.S. Geological Survey gage 10254005.

Background and Justification

The Salton Sea is California's largest lake (fig. 2). The Sea provides critical habitat for migratory birds and is an important cultural, economic, and recreational resource. The Salton Sea is a critical stop for migratory birds on the Pacific Flyway. Over 400 species of birds, including 80 percent of the western population of White Pelicans and 20 species of concern, have been observed at the Sea. The Salton Sea lies at a critical geographic juncture for migratory birds (fig. 3*A*, *B*). Actions that may affect migratory birds and the wetlands they use are of high interest because of the loss of more than 90 percent of California's historic wetlands. Regional, national, and international issues are associated with management of the Salton Sea because of its influence on air quality, potential selenium contamination, and habitat for migratory birds. Water transfers from agricultural uses in the Imperial Valley to municipal uses in coastal southern California authorized by the 2003 Quantification Settlement Agreement (QSA; Coachella Valley Water District and others, 2002) will decrease agricultural return flow to the Salton Sea and result in loss of aquatic and wetland habitat, increased salinity, a lower water elevation, and degraded air quality if no action is taken (fig. 4). By reducing the amount of water applied to agricultural fields in the Imperial Valley, the QSA effectively reduces the amount of water flowing into the Salton Sea. In return, the QSA stipulates that Imperial Irrigation District (IID) must make "mitigation water" available to the Salton Sea to reduce the impacts of the water transfer on the Salton Sea. This stipulation of the QSA, negotiated to allow time to develop a comprehensive plan for addressing Salton Sea management, ends on December 31, 2017, after which mitigation water will no longer be a requirement. In a scenario in which nothing is done to manage diminishing inflows, increasing salinity, and other issues (termed a No Action Alternative), then the Sea level is expected to decline rapidly after mitigation water termination (California Resources Agency, 2006). Other external factors will also affect the Sea level, such as declining inflows from Mexico, increasing urbanization, changing agricultural practices, more efficient irrigation methods, and climate change (California Resources Agency, 2006). Additionally, if a No Action Alternative is adopted, the volume of water flowing into the Sea will decrease substantially, the Salton Sea's surface elevation will drop by 20 feet or more, its volume will decrease, and salinity will triple. One hundred square miles of lakebed will be exposed to the region's blowing winds, and dust emissions will increase (fig. 5; Cohen and Hyun, 2006).

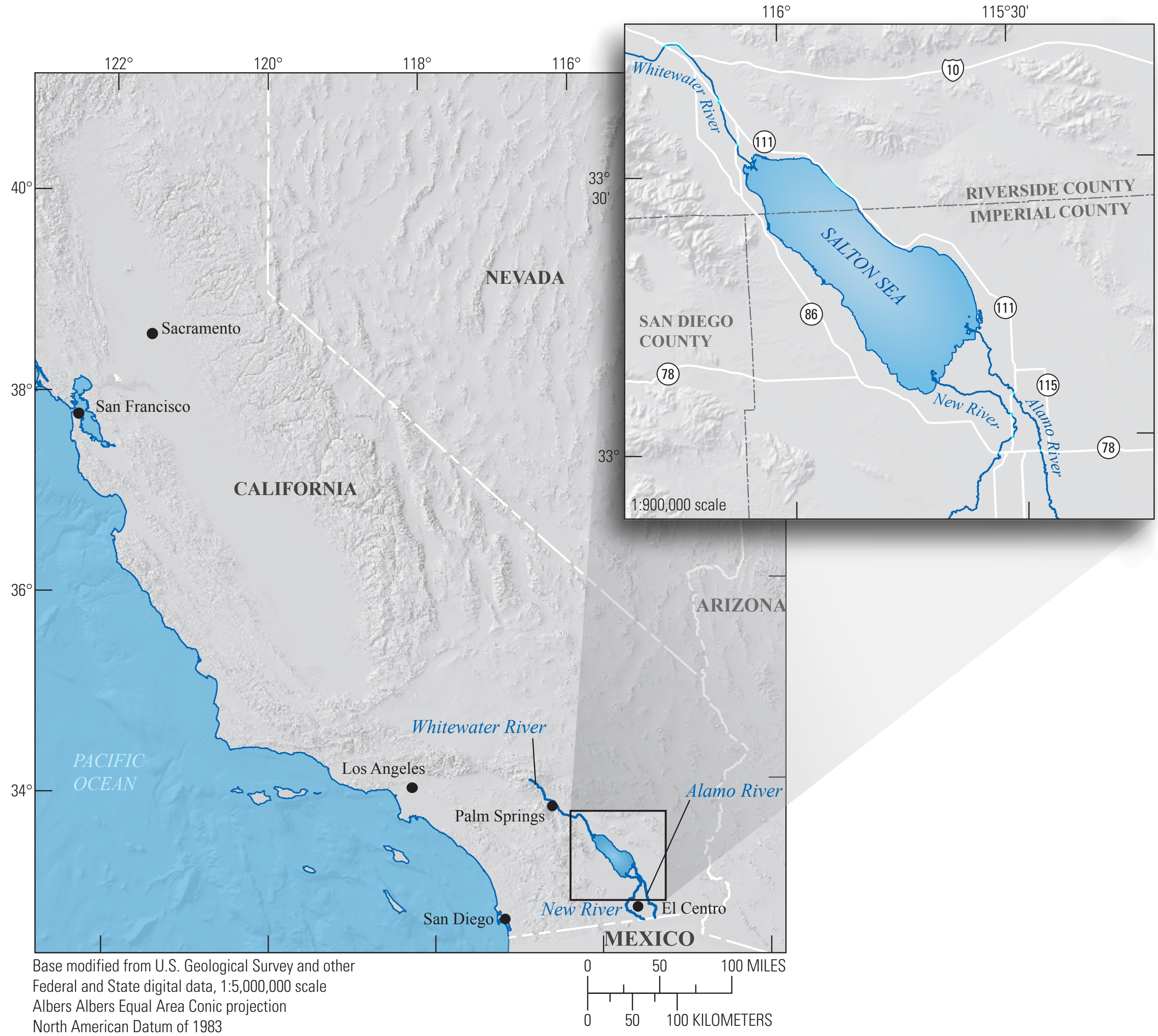

Figure 2. Map showing location of the Salton Sea.

A

B

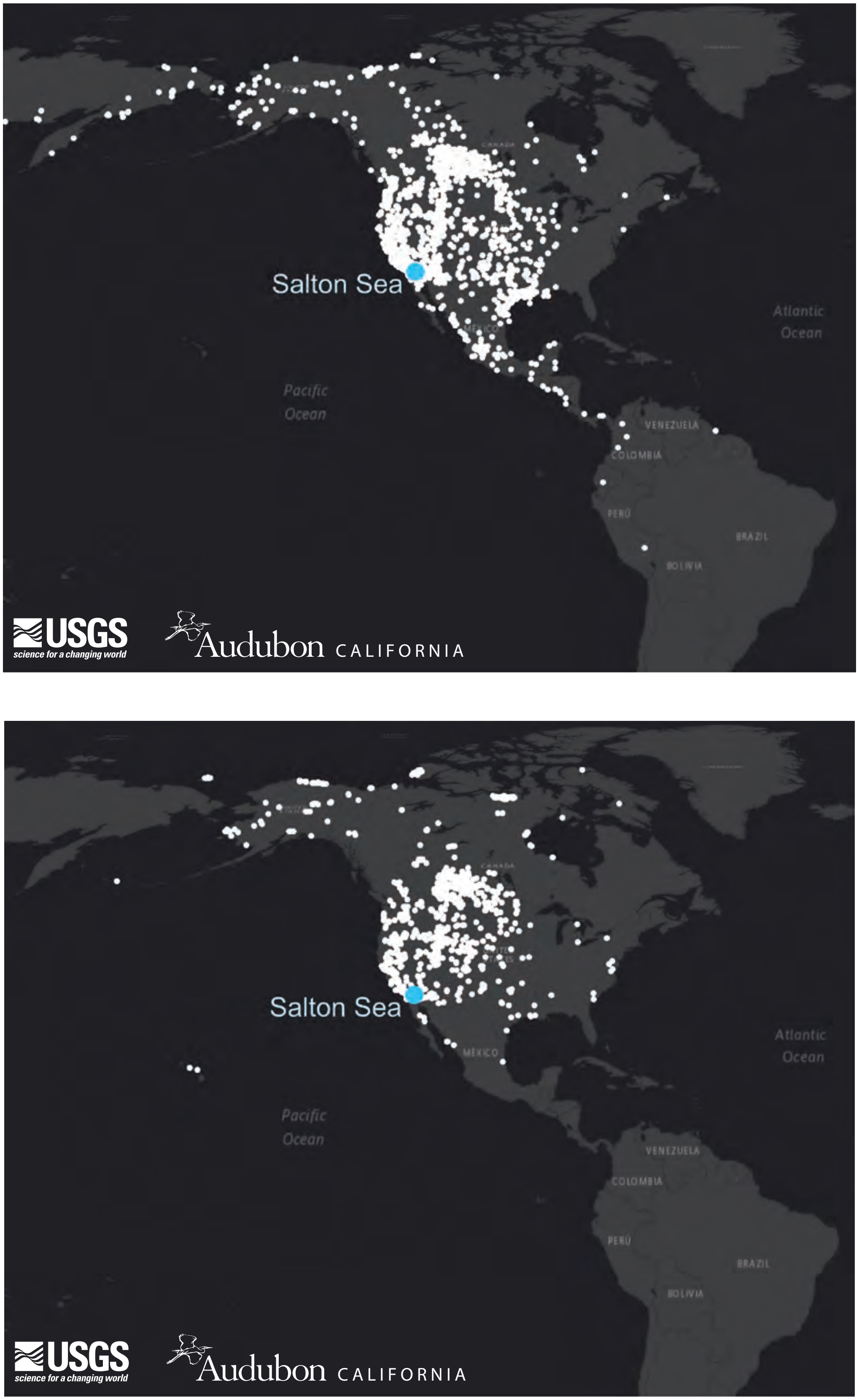

Figure 3. *A*, Map showing locations of bird-band recoveries for all birds banded at the Salton Sea and recovered anywhere. The data display depicts the Salton Sea as a point of origin for birds. *B*, Map showing locations of bird-band recoveries for birds banded elsewhere and recovered at the Salton Sea. This data display depicts the Salton Sea as a destination point for birds.

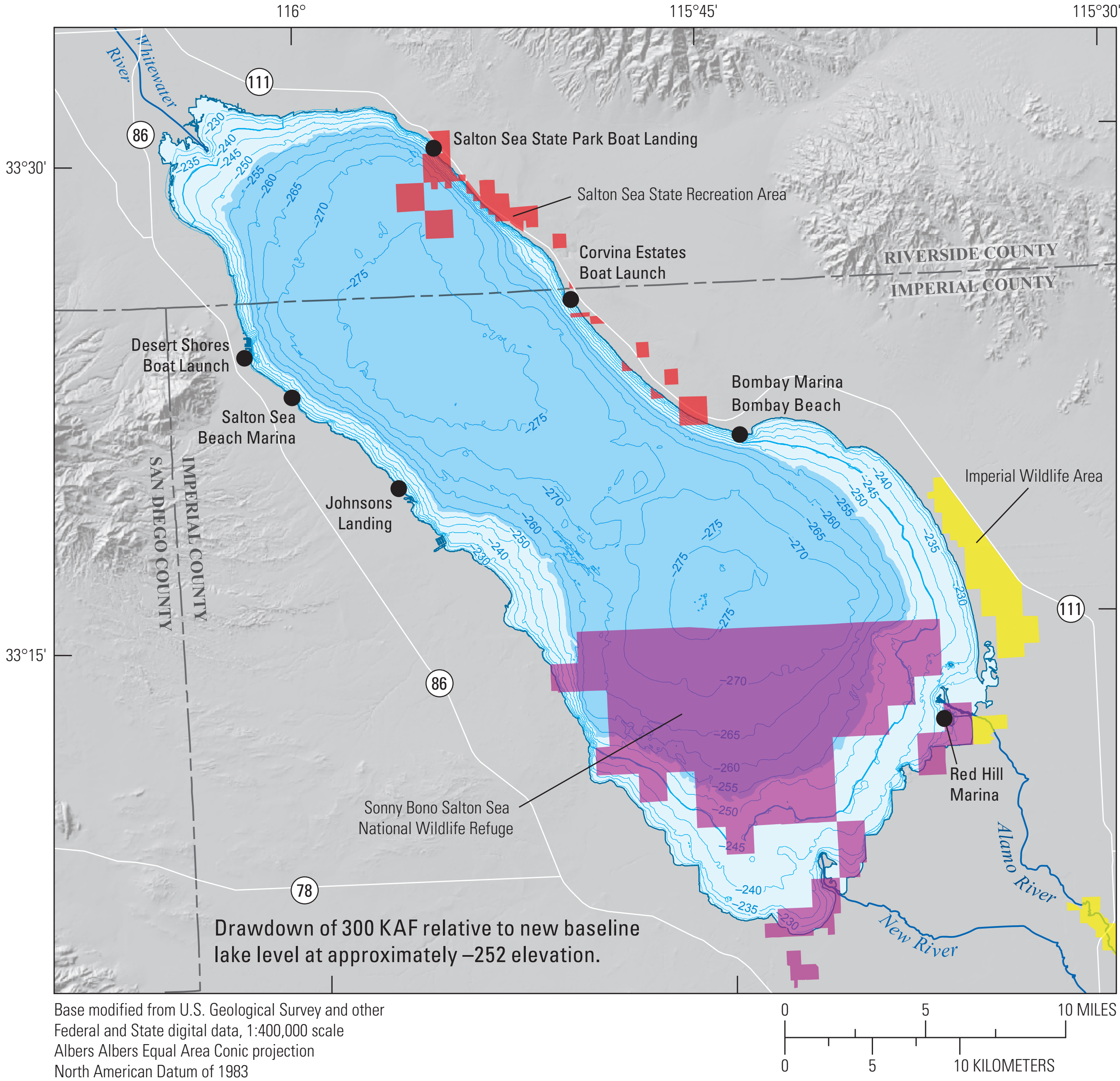

Figure 4. Map of the Salton Sea modeling projection of No Action Alternative, indicating future exposed playa and lake level. White region is indicative of playa exposed as water recedes from –232 feet (below sea level) to No Action Alternative projected level of –252 feet (below sea level). Magenta overlay indicates approximate footprint of the Sonny Bono Salton Sea National Wildlife Refuge. Data from University of Redlands Salton Sea Database Program. KAF, thousand acre-feet.

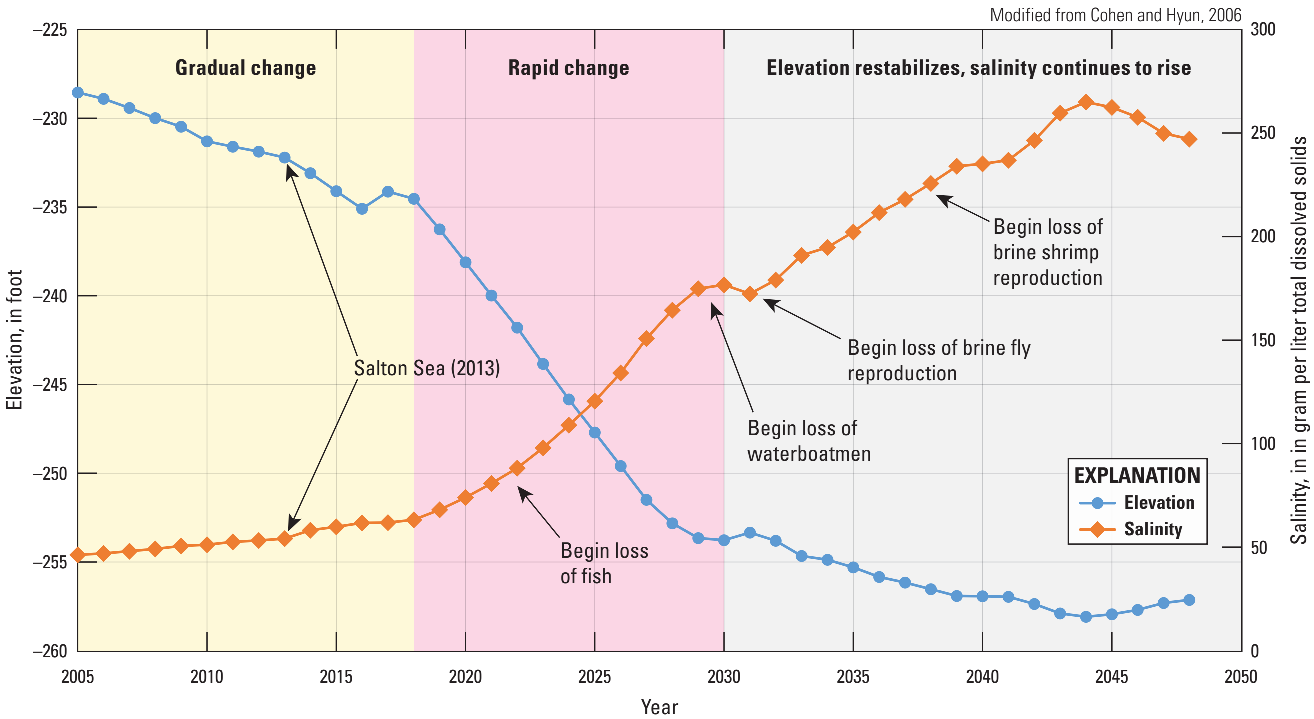

Figure 5. Projected changes to salinity and lake surface elevation and effects on major aquatic biota. Orange zone indicates current period of gradual change. Pink zone indicates period of rapid change owing to increasing water transfer amounts to urban southern California and elimination of mitigation water sanctioned by the Quantification Settlement Agreement (QSA).

Now that the “big picture” science has mostly been accomplished, managers and scientists can focus on science designed to generate a better understanding of these broad findings and fill in identified gaps in our knowledge; this would allow better modeling of system dynamics and a better understanding of unknown effects of rehabilitation projects. Scientists in previous workshops have identified issues such as hydrogen sulfide, thermoclines, water mixing regimes, and potential fatal flaws of some rehabilitation strategies. The science of these early efforts has also led to a greater understanding of selenium, wildlife diseases and pathogens, critical resource needs for maintaining fish and bird populations, and the critical role of aquatic invertebrates and microbes in the ecosystem. Scientists have begun to understand how to rehabilitate this degraded system within the constraints of less water, no new water, and degraded water as the only sources available to sustain the viability of this ecosystem while providing for the maintenance of biological diversity, avoiding toxic emissions, and ameliorating air quality concerns using less water. For adaptive management to function, scientists now must work in concert with resource managers, decision-makers, and engineers to ensure projects are based on the best possible science.

Although initial scientific studies were done during 1998–2003, the Salton Sea ecosystem was not well understood when the QSA was implemented in 2003. Our understanding of the ecosystem is better today, but the changes scheduled for implementation at the end of 2017 could have far reaching effects on the ecology of this lake and beyond its boundaries. Since 2003, despite stakeholder meetings, expert workshops, and efforts by the State of California (California Resources Agency, 2007), little new science has been conducted and limited monitoring has occurred. During 2000–10, the Federal government submitted an Environmental Impact Statement/Environmental Impact Report (EIS/EIR; Bureau of Reclamation, 1998), several feasibility studies were completed (Tetra Tech, 2004; Bureau of Reclamation, 2007), and the State of California submitted a Programmatic EIR/EIS (California Resources Agency, 2007). All of these activities relied heavily on the initial round of scientific investigations (for more in-depth background, see California Resources Agency, 2006, chaps. 1, 4, and 8).

Many stakeholders have advocated for no new science, recommending instead for moving forward with building management project components; however, no agreed-upon plan has been created for managing a future Salton Sea nor a definition of what constitutes “restoration” (see text box p. 1). The USGS Salton Sea Science Office has suggested that whereas there is a need to initiate construction of management project components, it is also necessary to continue to conduct science and monitoring activities concurrent to and after construction using a process known as adaptive management. Adaptive management (AM) is a structured, iterative process of decision making, with an aim to reduce uncertainty over time by continuously monitoring the system and adjusting decision-making accordingly. The AM approach recognizes the uncertainty of future conditions and helps protect current and future investment in these activities. Moreover, an AM approach to management requires an active science and monitoring program to provide timely analysis and feedback to managers on management program effectiveness (Williams and others, 2009; Case and others, 2013).

The USGS has led and assisted in numerous efforts focused on science of the Salton Sea (U.S. Fish and Wildlife Service, 1997) and in developing framework guidance documentation (Shipley and others, 1999) leading to the issuance of the Salton Sea Strategic Science Plan (Salton Sea Science Subcommittee, 2000). The Science Office continued in facilitating the interaction and coordination of science and management in order to support and better understand management actions. The Science Office also organized management and science leadership meetings to secure diverse input into future science and monitoring needs based on an AM approach as suggested by State and Federal managers (Bureau of Reclamation, 2007; U.S. Army Corps of Engineers and California Natural Resources Agency, 2013).

Adaptive management is a process of structured decision-making. It acknowledges inherent uncertainty about natural resource responses to management actions and utilizes this structured decision-making to reduce uncertainty to improve management results (Williams and others, 2009).

> Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a ‘trial and error’ process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.
>
> (Williams and others, 2009)

Organizing Committee and State of the Salton Sea Meeting Development

The USGS Salton Sea Science Office initiated the SoSS meeting in coordination with the University of California at Irvine (UCI), the Pacific Institute, and IID. Funding to support the State of the Salton Sea meeting and subsequent report development was provided by the Bureau of Reclamation (Reclamation), USGS, UCI, and IID. Through the Science Office, USGS provides access to decades of national and international expertise in water quality, hydrology, dust emissions, geothermal and volcano science, contaminants, and biology. Through land and water rights in Imperial County, IID is an influential stakeholder in all Salton Sea issues. The Pacific Institute, based in Oakland, Calif., is a leading nonprofit research and policy organization with long-standing involvement in the Salton Sea through active stakeholder participation and publication of several reports analyzing the consequences and costs of inaction in Salton Sea management (Cohen and others, 1999; Cohen and Hyun, 2006; Cohen, 2014). The UCI has internationally recognized expertise in many sustainability-related domains and has engaged its research, teaching, and service resources to address sustainability challenges facing the Salton Sea region.

The original idea for a State of the Salton Sea meeting of scientists arose from discussion between Doug Barnum (USGS) and Michael Cohen (Pacific Institute) and was then endorsed by USGS and U.S. Department of the Interior leadership. Representatives from UCI and IID were invited to join, and this group of individuals became the organizing committee. The support of each organizing committee member’s agency was essential to the success of this venture. The combined capabilities of the organizing committee members were instrumental in working to coalesce the diverse interests of scientists, natural resource managers, and decision-makers, with a common objective of identifying science and monitoring needs for the Salton Sea.

Applied research is the type of research that is used to answer a specific question that has direct applications to solving problems. Alternately, basic research is driven purely by curiosity and a desire to expand our knowledge. Resource managers appreciate the role of basic science, but in the end they need answers to solve problems. The inherent conflict between basic and applied science is routinely expressed by resource managers and decision-makers in large-scale management projects by advising science managers to focus on “science to inform management rather than science for the sake of science.”

Managerial Meetings

A critical aspect of the renewed examination of the scientific issues at the Sea was that the organizing committee sought input from stakeholder groups, resource managers, and policy-level decision-makers prior to the SoSS meeting. These managerial meetings were held in Sacramento and El Centro, Calif., in July and August, 2014, respectively. Organizations and specific individuals were invited to solicit input from decision-makers and agency staff on key science questions that need to be addressed to ensure that habitat, air quality, and renewable energy projects at the Salton Sea are successful. Invitees were asked to help identify gaps in the current knowledge and to identify policy and project-level research needs that could be addressed by focused scientific efforts. Input from these meetings was used to develop guidance for the subsequent State of the Salton Sea meeting in which scientists were tasked with developing a research agenda and funding proposals to address the questions posed at the policy meetings. This approach was taken to specifically develop science and monitoring proposals to meet the needs identified by managers.

The organizing committee, working with stakeholders (table 2), held two 1-day managerial meetings of natural resource managers, policy-makers, and legislative aides to discuss and describe unresolved and uncertain scientific issues of Salton Sea management (table 3). These meetings were held so that stakeholders and policy-makers could talk directly with the organizing committee, express their concerns, and weigh in on science and monitoring needs. These early discussions enabled scientists to discriminate among issues for which scientific research is necessary to provide missing information and issues for which adequate scientific research is available but perhaps not adequately communicated.

The managerial meetings made use of a group agreement to put aside differences and focus on the task of identifying concerns and needs for management of the Salton Sea for the next 5 to 15 years. The aims and timeline of the meeting were agreed upon by all participants, and any objective or issues that fell beyond the scope of the current discussion were agreed to be discussed at a later time. The focus was on listening to each speaker with the belief that all participants wanted to achieve the meeting's goals. A trained facilitator was responsible for keeping participants on time and on task throughout the proceedings.

The general format of the managerial meetings included brief introductions of all participants and short presentations on the recent history of the Sea (with an emphasis on the last 15 years) to provide everyone with context and understanding of core scientific findings. Participants were then asked to briefly present their agency's concerns about the Sea and perceptions of the data needs for the Sea. Scribes captured concerns and data needs in each presentation and posted these notes on the wall, where small groups convened to discuss and digest the patterns that emerged from individual presentations. The meetings included group discussions that sought to elicit all managerial concerns but also consensus regarding the most critical knowledge gaps. A summary of information collected in these managerial meetings is included in table 3 and in greater detail in appendix 1.

Table 2. Organizational representation at the managerial meetings.

[Some organizations had multiple representatives]

Organizational representation
Bureau of Land Management
California Assembly for Water, Parks, and Wildlife
California Natural Resources Agency
California Department of Water Resources
California Department of Fish and Wildlife
Coachella Valley Water District
Defenders of Wildlife
Great Basin Air Pollution Control District
International Brotherhood Of Electrical Workers
Imperial County Air Pollution Control District
Imperial Irrigation District
Metropolitan Water District
Office of Senator Barbara Boxer
Office of Congressman Raul Ruiz
Office of Assemblyman V. Manuel Perez
Office of Congressman Juan Vargas
Riverside County
South Coast Air Quality Management District
San Diego County Water Authority
Salton Sea Authority
Sierra Club
University of California Cooperative Extension
Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Geological Survey

Table 3. Summary of management needs and concerns regarding science and monitoring of the Salton Sea (from appendix 2).

Topic	Concerns and data needs
Air quality	What is the predicted consequence of a smaller lake for air quality, dust, public health, plants, and agriculture? How emissive is the soil and how variable is the playa? Can we predict site emissivity; can we control emissivity? What can we do about hydrogen sulfide emissions?
Water quality	Water is limited, and there is concern about water quality (including selenium). Water conservation practices (for example, irrigation practices and crop selection) among farmers will have a profound influence on water levels. Does selenium in soil and water bioaccumulate and have biological effects? How does the changing hydrology affect water supply and management? How does hydrology affect hydrogen sulfide, selenium, and anoxic lake conditions? How do proposed changes in lake depth affect lake hydrologic functions?
Biological concerns	Need to evaluate availability, quality, and quantity of habitat. Can we model the resilience and mutability of the lake ecosystem? Do we expect a “tipping point” or nonlinear responses of biological systems to changing environmental features? Biological impacts that we have not been considering, and threatened populations (for example, desert tortoise, pile worms, desert plants, Clapper Rail, pupfish)? Disease vectors. Tilapia physiology and salinity tolerance thresholds. Mechanism of ecosystem transition from fish-driven food chain to something else? What happens to bird populations as fish decline? Changes in water chemistry and impact on vertebrate and invertebrate populations.
Data clearinghouse	There is broad support for a centralized system for ensuring that raw data, synthesized data, maps, reports, and literature are properly curated and made available for access by management, scientists, and the public.
Monitoring	Gap between monitoring capacity and monitoring need.

Goals and objectives of managerial meetings

It is a rare event to have a large meeting in which natural resource managers, policy-makers, and legislative aides can have a direct dialogue with scientists on concerns and science needs for any single issue. One group tends to request that scientists adhere to recommending only ideas whereby the product is used to inform management rather than what is perceived as science for the sake of science. The other group tends to view all science as productive and is accustomed to thinking along a continuum of ideas. The State of the Salton Sea organizing committee set out to acknowledge and foster an interactive relationship of managers with scientists, using the organizing committee as the intermediary. In doing so, both groups were effectively brought together to discuss and describe unresolved and uncertain scientific issues of Salton Sea resource management.

State of the Salton Sea Meeting

Following the managerial meetings, the organizing committee gathered scientists to discuss the current state of the scientific understanding of the Salton Sea, science and monitoring needs, and suggestions for the administration of a robust science program to provide input to an adaptive management program as management of the Sea is initiated. This SoSS meeting of scientists took place September 8–10, 2014, on the campus of University of California at Irvine at the Arnold and Mabel Beckman Center of the National Academies of Science and Engineering. The invitation only, closed session meeting format was motivated by the concern of the organizing committee for a rigorous and frank exchange of information. By having an invitation only meeting of scientists, it was the intent of the organizing committee that it should be a science-driven event as a means of advising managers on science and monitoring needs. Previous meetings of this nature (for example, the U.S. Fish and Wildlife Service workshop in 1997, Science Office sponsored workshops, and focused technical groups for the California Resources Agency in 2007) have met with great success using a format in which the first day focuses on reviews of science conducted to date, and then subsequent days involve expert topical-issue working groups meeting in breakout sessions to develop wide-ranging lists of critical science and monitoring needs, followed by prioritization within and among groups, estimated topical budgets, and summary writing assignments. Participants (appendix 2), a detailed description of the agenda (appendix 3), and meeting guidelines (appendix 4) are provided in appendixes to this document.

The workshop topics included biological and water resources, contaminants, air quality, carbon and algae, and socioeconomics. The selection of these broad categories was based on similar topic identification presented in earlier discussion efforts (for example, U.S. Fish and Wildlife Service, 1997; Salton Sea Science Subcommittee, 2000; Case and others, 2013). A focal point for initiating these discussions was the Salton Sea Ecosystem Monitoring and Assessment Plan (MAP; Case and others, 2013). To stimulate development of conceptual proposals, guidance was provided to scientists prior to the meeting of the types of focused investigations and monitoring needs:

- Reanalysis of inflow data and long-term modeling of lake elevation and salinity
- Endangered pupfish populations analysis and recovery strategies in a receding Sea
- Fugitive dust characterization, hot spots, treatment options, and modeling
- Integrated monitoring of invertebrates, fish, and bird populations among existing and soon-to-be-constructed wetlands
- Remote sensing technological applications supporting focused investigations and monitoring
- Groundwater modeling and assessment of availability to support management activities
- Microtargeting of selenium treatment technologies
- Investigations of algal-based solutions for carbon capture, sequestration and carbon credits
- Investigations of algal-based solutions for selenium remediation
- Investigations of bivalves as biofilters for nutrient, sediment, and selenium remediation
- Chemical composition of PM_{10} captured in air quality monitoring stations as related to human health and agricultural productivity
- Status of the fisheries
- Status of regional bird populations
- Water and sediment chemistries and quality
- Status of contaminants of concern, particularly selenium and current-use pesticides

After reviewing the current conditions of the Sea, the organizing committee shared with the participating scientists the concerns, needs, and data gaps identified by the managers in the two meetings in El Centro and Sacramento, Calif. It was emphasized that these needs should take priority during discussions and that conceptual proposals should be generated that address these critical needs in a timely and cost-efficient manner.

Workshop participants were placed on teams to develop conceptual proposals that addressed the needs of managers as identified in the managerial meetings. By compiling and publishing these conceptual proposals in this SoSS document, the intent is to provide managers, legislators, and other stakeholders with scientific input and direction in developing long-range plans. The document is not intended to develop funding for any specific topic, nor is it intended that any conceptual proposal is to be accepted "as is." If a comprehensive science program is developed, then these conceptual proposals may serve as the framework for implementing the science necessary to inform management decisions relative to any resource management plan devised. It is anticipated that the conceptual proposals and their estimated budgets contained herein will serve as a template for contracting of competitive awards (see appendix 4). These conceptual proposals are intended solely as brief introductions to recommended science and monitoring needs.

A future science program based on these conceptual proposals would provide geographic information system (GIS) data layers. The collection of those data layers would be coordinated to maximize collaboration, avoid unproductive duplication, and render the data available as quickly as possible to the many cooperators. The data would be spatially referenced so that all information could be incorporated into a model of the Salton Sea ecosystem in GIS. This Salton Sea GIS model would allow synthesis of the individual data layers into an interactive model that could evaluate complex interactive changes to the ecosystem under differently engineered projects and managed scenarios (see Case and others, 2013).

Synopsis of Conceptual Proposals

Under most future scenarios, changes to all aspects of the Salton Sea ecosystem will occur. Inflows are diminishing, nutrients and salts are increasing, selenium and pesticide contamination remain of concern and are likely to increase. Water depth, temperature, volume, and location will be altered dramatically. Salinity will induce changes to the community of aquatic invertebrates and fish, causing significant changes in population structure and abundance. Associated responses of the avian community are to be anticipated. Given the magnitude of anticipated changes to the Salton Sea ecosystem, scientists participating in the State of the Salton Sea meeting gathered and attempted to describe science and monitoring needs necessary to understand how the ecosystem will respond to these changes. By better understanding ecosystem functioning, scientists can provide support for the AM decision process.

Scientists were able to build upon previous investigations and develop a series of conceptual proposals, which will help fill voids in knowledge of the Salton Sea ecosystem (table 4, full narratives provided in appendix 5). Furthermore, a number of long-term monitoring and assessment needs supportive of an AM program were identified. Six teams covering diverse categories such as air quality, contaminants, biology, water quality and hydrology, carbon and algae, and socioeconomics produced 34 proposals with a total funding of $46,880,000 (2015 dollars).

The 1997 workshop (U.S. Fish and Wildlife Service, 1997) yielded 39 proposals with associated funding of $36,097,600 (~$53,443,000 in 2015 dollars). There are many similarities between the results of the 1997 workshop and results of the 2014 State of the Salton Sea meeting in terms of issues of investigation. Much of the effort for the 1997 workshop was expended on simply understanding the “big picture” of the various components of the Sea and how these components interact. Workshop participants in 1997 were asked to prioritize their proposals, whereas time constraints precluded any such effort in the 2014 SoSS workshop. Despite the acknowledged importance at the 1997 workshop, the topic of air quality was believed at the time to be an issue that was decades into the future, compared to the urgency of understanding large-scale fish and bird mortalities, foul odors, excessive nutrients, increasing salinity, and contaminants. There is a continued need to understand the influence of contaminants and pesticides on the ecosystem, particularly in newly constructed habitats, and the consequences of declining inflows and increasing salinity. However, the next generation of science will need to be designed to fill in identified gaps in our knowledge from previous work; this would allow better modeling of ecosystem dynamics and a better understanding of unknown effects of rehabilitation projects. Air quality—influenced by fugitive dust from exposed sediments and its effects on human health and the environment—is a topic the gathered scientists agreed should be a major focus of the next phase of research and monitoring. Air quality concerns are further supported by feedback from the managerial meetings, which indicated that priority should be given to initiating research on air quality investigations related to fugitive dust and associated human health issues. It should be noted that of all the options under consideration for addressing the myriad of air quality issues, water applied to maintain wet soil is a tested and proven technology, yet it may be one of the least available for implementation given the demands on limited water resources in the region. Constructed wetlands similar to the USGS/Reclamation Shallow Habitat project (Miles and others, 2009), Red Hill Bay (A.K. Miles and M.A. Ricca, unpub. data, 2011; U.S. Fish and Wildlife Service, 2014) and Species Conservation Habitat (U.S. Army Corps of Engineers and California Natural Resources Agency, 2013) may be the most efficient use of limited water supplies as they not only suppress dust but may also provide many other benefits. Despite promising research from the USGS/Reclamation Shallow Habitat project, there remain concerns as to the ability of larger constructed wetlands to avoid issues related to water quality, fish mortality, fish population sustainability, hydrogen sulfide, avian nesting and foraging, and algal blooms. Thus, while there is an urgent need for studies of air quality, there is also a need to not lose focus on the continued evaluation for total efficacy of constructed wetlands and other issues related to a reconfiguration of the Sea. Constructed wetlands within the lakebed are an important first step towards implementing Salton Sea resource management, and expectations of success run high not only for habitat value to be provided but also for air quality management to be sustained. Yet, if efficacy of constructed wetlands is not evaluated and they fail to meet expectations, then migratory bird resources remain at risk, air quality continues to degrade, and much more expensive and complex options may be required. Similarly, the ever changing water quality dynamics of this lake suggest continued monitoring and evaluation be implemented because of the important interactive and synergistic effects water quality has on many aspects of the Salton Sea ecosystem.

Time constraints of the SoSS meeting prevented the full development of several ideas. Nevertheless, the organizing committee included the title for these undeveloped ideas and a funding level suitable for addressing each conceptual proposal as part of table 4 and again in appendix 5.

Air Quality

The ramifications of the QSA decision of terminating mitigation water in 2017, thus accelerating exposure of Sea sediments, was a principal consideration of the meeting. A considerable amount of attention was given to proposals designed to evaluate playa exposed by receding water levels. Air quality concerns over $PM_{10}/PM_{2.5}$ levels, chemical composition of fugitive dust, impacts of fugitive dust on human health and agricultural productivity, and methods for suppressing fugitive dust were major topics of discussion. A new avenue of potential threat to human health lies in the propensity of water like the Salton Sea to develop assemblages of toxic cyanobacteria. Under high wind conditions, these toxins may be entrained in the mist generated by large waves and transported large distances. Perhaps a greater risk is that these toxic algae contain microcystins that remain toxic after the algae have died and been deposited on the sediments. Investigations into the potential human health risk of airborne particulate matter containing these microcystins from exposed playas could shed new emphasis on the already important issue of fugitive dust control.

Water Quality

The importance of the early limnological and water quality research simply cannot be overstated in terms of understanding not only the Sea's hydrodynamics but also the flow of nutrients, primary productivity, contaminants, and biology. With such large scale alterations of the Sea structure envisioned by most management alternatives under active consideration, it is imperative to continue with studies of water quality in order to understand how the Sea will be altered and the ramifications of those alterations on the functions of this dynamic ecosystem. With this in mind, the water-quality group developed proposals focused on modeling energy and material fluxes, water balance simulations for various sizes and configurations of a future Sea, and an adaptive management monitoring structure to facilitate and support management decisions.

Contaminants

The concerns related to contaminants, such as legacy and new generation pesticides, selenium, arsenic, and other anthropogenic pollutants remain high. The concerns remain high because many of the proposed management alternatives reviewed in the past 15 years have included components that, if implemented, could worsen the effects of these contaminants on the Salton Sea ecosystem. To avoid the unintended consequences of implementing a potentially flawed management strategy, the contaminant group recommended further research particularly on selenium and pesticides. Legacy pesticides such as DDT remain in the ecosystem, although at low levels, and have the potential to affect breeding bird populations. Likewise, little is known about other legacy pesticides and how they may affect birds, fish, or their prey items in constructed wetlands. Despite numerous expert technical workshops on selenium, managing this element to avoid adverse effects remains a significant technical and financial challenge. The contaminant group suggests additional research to quantify and evaluate biological risks to fish and bird populations.

Carbon and Algae

A group separate from the biology group was provided to consider issues related to carbon capture, carbon sequestration, and the role of algae in these ideas. Carbon uptake is an idea requiring evaluation not only for assigning monetary value to the Salton Sea for potential carbon banking but also for assessing agricultural-land carbon uptake and the potential sequestration of inorganic carbon in groundwater of saline desert systems. This in turn may provide some economic valuation in the control of greenhouse gasses and could then be measured against growth of greenhouse gasses attributed to water exports. The topic of algae farming related to biofuels production was not considered here because it is being addressed by multiple outside interests.

Biology

The biology group focused on the impacts of increasing salinity on biota in a remnant Sea and in constructed habitats. The biology group also emphasized the development of advanced models synthesizing information across multiple variables, allowing for interactive and predictive analysis of management actions. Much of the scientific effort in earlier biology investigations of the Salton Sea involved the attempt to understand existing resources, describe populations and numbers, and examine relationships to physical and chemical variables of the Sea. The biology group suggested that future investigations may be better focused on evaluating the biological functioning of constructed wetlands, biological tolerance limits to salinity, population modeling, and examining synergistic effects of critical habitat loss at the Salton Sea and elsewhere on migratory bird populations.

Socioeconomics

The emphasis of this effort lies in three integrated components: (1) equity oriented collaborative research aiming to better understand the social and cultural story of communities interacting with the Salton Sea, (2) a demographic and land-use survey aiming to identify and map land uses, and (3) an economic study to assess how management activities could impact land uses and to outline costs over time for both management and impacts on the changing economic characteristics of the communities surrounding the region. The socioeconomic group recognized that in many environmental management projects, the social sciences are largely unrecognized and thus usually receive only cursory treatment if at all. The proposal provided is an attempt to gather scientifically valid social science data on human dynamics associated with planned alterations for the Salton Sea ecosystem.

Administration

Data storage and management, data retrieval and service to stakeholders, and archiving data and documents (cyberinfrastructure) for future generations are critical science support activities. This support for science is integral to the proper functioning of a decision-support system for management. Cyberinfrastructure is a grouping of program elements for resources necessary to integrate, assess, and prioritize data and information, an element thoroughly addressed most recently by Case and others (2013).

Through integration, scientists and decision-makers will be better able to effectively and efficiently coordinate field activities for maximum savings of time and money. In addition, the integration of protocols, standards, and practices will help assure that data will be scientifically valid and usable for the widest possible variety of assessments and uses. Integration starts in the planning phases and extends throughout the collection, interpretation, reporting, assessment, and AM parts of the restoration process.

Data assessment focuses on the query and retrieval of data stored or accessible from a centralized data-retrieval system and applying statistical and other analytical techniques to the data. This step helps to simplify the collected data, test for change and differences, develop and test hypotheses, and evaluate uncertainty. It is through rigorous assessment that progress toward restoration goals can be measured, and it is through regularly scheduled assessments that AM can be effectively implemented. A key part of any resource management plan will be the objective consideration of priorities for data collection. These priorities include immediacy (human health and safety), scientific need, management need, cost, ease, and availability of an alternative (if any).

An advantage, however, of the rigorous technical integration and assessment process is the ability to provide incentive and justification for the prioritization of activities and the efficient application and focus of stakeholder support. Priorities for integration will be guided by the overall objectives and needs identified for ecosystem restoration in general. Priorities for short-term monitoring efforts also will be strongly influenced by needs to document and assess status and trends. The highest priority questions identified by each technical focus group will be used to establish priorities within the existing available funding.

Proposal ADMIN1 provides for estimates of initial funding for these activities. A variety of plans have been developed outlining the structure of a data-management system (see Case and others, 2013; appendixes 6, 7, and 8).

Recommendations for Support of an Effective Science and Monitoring Program

One of the outcomes of the combined managerial and SoSS meetings was the realization that the Salton Sea effort is lacking a comprehensive, integrated science and monitoring program. The 1997 science-needs workshop (U.S. Fish and Wildlife Service, 1997) recognized and incorporated a series of recommendations on how best to support a large science effort. These needs were largely unmet, yet they have been identified regularly in a variety of published documents (appendixes 7 and 8). These unmet needs were once again identified in the SoSS meetings.

Future management of the Salton Sea will rely extensively on a competent and integrated science program capable of analysis, integration, synthesis, and data storage to sustain management's need for decision-support services. To address this issue, the organizing committee has provided a tabular summary of identified science support needs (table 5). Case and others (2013) provided an extensive discussion and documentation of a comprehensive, integrated monitoring program for the Salton Sea applicable to any future project design. Furthermore, a narrative discussion of an integrated science program is described in more detail in appendix 6.

The Salton Sea project will involve a major restructuring of every component of the ecosystem over several decades. This will involve a series of complex engineering and environmental projects designed to ensure that a smaller lake with much less water can be ecologically sustainable. Development of a comprehensive cyberinfrastructure for this process can ensure that design criteria and data from these projects will be consistent among studies and available for scientists, engineers, and project managers to build upon for decades to come. The principal objectives of a cyberinfrastructure component to the Salton Sea project are to

- Establish and enforce standards for data documentation
- Establish data transfer and storage protocol
- Make data easily accessible and in a useable format
- Establish adequate program support

Table 4. Proposal title and estimated dollar value to conduct research/monitoring activities for the Salton Sea.

[Values rounded to nearst $10,000 and presented in 2015 dollars. —, not available]

Proposal title	Proposal total	Topic subtotal	Grand total
Air quality			
AQ1. Measurements in and around Salton Sea area to assess potential particulate matter emissions	$1,150,000	—	—
AQ2. Potential toxicity of suspendable sediment from Salton Sea playa	$1,100,000	—	—
AQ3. Dust /pollution emissions modeling for the Salton Sea playa and surrounding impacted areas	$760,000	—	—
AQ4. Reduction of fugitive dust emissions from dirt roads and a receding Salton Sea using a biogenerated soil enhancer	$1,300,000	—	—
AQ5. Toxic algae as a human health risk in a receding lake sediment environment (no proposal submitted but identified as an urgent need)	$1,250,000	—	—
Topic subtotal	—	$5,560,000	—
Water quality			
WQ1. Energy and material fluxes across the air-water and sediment-water interfaces of the Salton Sea	$2,050,000	—	—
WQ2. Integrated water balance simulations under changing management and climate scenarios	$2,440,000	—	—
WQ3. Monitoring for adaptive management	$2,250,000	—	—
WQ4. Modeling the plagues and pleasures of variable sized water bodies at the Salton Sea	$2,340,000	—	—
Topic subtotal	—	$9,080,000	—
Contaminants			
CONTAM1. Identifying variation in selenium risk to wildlife in the Salton Sea Basin related to wetland management and management strategies.	$1,280,000	—	—
CONTAM2. Synthesis of existing environmental contaminants data for the Salton Sea	$460,000	—	—
CONTAM3. Concentrations of pesticides and selenium in fugitive dust, Imperial Valley, California	$290,000	—	—
CONTAM4. Evaluating the effects of agricultural irrigation practices on pesticide and selenium concentrations in agricultural tail water and tile water, Salton Sea, California	$140,000	—	—
CONTAM5. Pesticide degradation in an experimental wetland, Imperial Valley, California	$210,000	—	—
CONTAM6. Evaluation of the risks and rewards associated with wetland management using reclaimed Salton Sea water versus recycled agriculture water	$1,410,000	—	—
CONTAM7. Assessing the potential for pesticide exposure in a newly constructed wetland: Red Hill Bay, Salton Sea, California	$200,000	—	—
CONTAM8. Assessing the potential for pesticide exposure in a newly constructed wetland: Species Conservation Habitat Project, Salton Sea, California	$230,000	—	—
CONTAM9. Selenium transport, fate, and risk with full implementation of water conservation	$250,000	—	—
CONTAM10. Selenium hot spots	$500,000	—	—
Topic subtotal	—	$4,970,000	—

Table 4. Proposal title and estimated dollar value to conduct research/monitoring activities for the Salton Sea.—Continued

[Values rounded to nearst $10,000 and presented in 2015 dollars. —, not available]

Proposal title	Proposal total	Topic subtotal	Grand total
Carbon, CO_2, and algae			
CARBON1. Carbon capture assessment of the Salton Sea, constructed wetlands, and agricultural lands of the Imperial and Coachella Valleys	$750,000	—	—
CARBON2. Nutrient and selenium control in drain water to the Salton Sea	$4,070,000	—	—
CARBON3. Carbon sequestration in deep-cycled groundwater	$500,000	—	—
Topic subtotal	—	$5,320,000	—
Biology			
BIO1. A dynamic ecosystem model for evaluating and managing changes in the Salton Sea	$2,630,000	—	—
BIO2. Ecosystem services and the role of agricultural land in supporting bird life	$500,000	—	—
BIO3. Generating a brine shrimp source population for a changing Salton Sea	$1,530,000	—	—
BIO4. Characterization of the base of the food chain at the Salton Sea	$900,000	—	—
BIO5. Salinity tolerance of key organisms in the Salton Sea ecosystem	$1,910,000	—	—
BIO6. Migratory connectivity for birds using the Salton Sea	$1,500,000	—	—
BIO7. Ecosystem-friendly biogenerated soil enhancer for berm stabilization of engineered marshes and wetlands in the Salton Sea watershed	$1,190,000	—	—
BIO8. A predictive, dynamic biodiversity model for monitoring, management, and science in the Salton Sea ecosystem	$3,240,000	—	—
BIO9. Comprehensive monitoring and data assessment of the complete Salton Sea ecosystem: Invertebrate survey	$3,950,000	—	—
BIO10. Inventory of extant biological, chemical, and physical resources	$2,000,000	—	—
Topic subtotal	—	$19,350,000	—
Socioeconomic			
SOCIAL1. Social and community research proposal	$1,100,000	—	—
Topic subtotal	—	$1,100,000	—
Administration			
ADMIN1. Development and implementation of an integrated database and library archive	$1,500,000	—	—
Topic subtotal	—	$1,500,000	—
Total	—	—	$46,880,000

Table 5. Recommendations for support of an effective science program for the Salton Sea.

[—, not available]

Suggested components required for a science program to support management decisions	Supporting document	Component identified and supported by managerial meeting
Secure on-site facility with sleeping quarters, wet and dry labs, a full complement of all equipment needed for data collection and analysis to be used in common by all researchers.	U.S. Fish and Wildlife Service, 1997	—
The knowledge imparted through these studies would be the minimum required for well-founded decision-making with respect to both a technical project and subsequent management.	U.S. Fish and Wildlife Service, 1997	Yes
The scientists strongly recommended that protocols be established and strictly followed governing data collection techniques, sites, frequency, geographic referencing, analysis, security, availability, and integration in a geographic information system ecosystem model.	U.S. Fish and Wildlife Service, 1997; Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Information would be presented to the public at periodic conferences and in published conference proceedings.	U.S. Fish and Wildlife Service, 1997; Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
An oversight team should be formed to help monitor, coordinate, and support the study efforts. Team composition should be representative of the researchers, involved agencies, and others with vested interests.	U.S. Fish and Wildlife Service, 1997	Yes
Implement a comprehensive, open scientific review process to refine the existing draft management goals and objectives from a scientific ecosystem perspective. Based on this review, agree upon performance measures as benchmarks against which to measure true success of management.	U.S. Fish and Wildlife Service, 1997; Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Develop and continue to refine reliable, flexible conceptual models encompassing ecosystem components and their functional relationships.	U.S. Fish and Wildlife Service, 1997; Shipley and others 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Develop a long-term ecosystem monitoring program to establish baselines, measure management outcomes, and help refine future actions.	Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Beyond monitoring of baseline conditions, include investigations of episodic, extreme, and unpredictable events such as fish and wildlife die-offs, algae blooms, and unusual climatic events that have the potential to significantly affect the ecosystem or influence individual valued resources.	Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Identify and prioritize investigations relevant to management, based on conceptual models and identified information gaps. Develop quantitative, integrative, predictive models based upon identified conceptual relationships.	Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Establish a data and information management program to make results of long-term monitoring and focused investigations available to resource managers, scientists, stakeholders, and the public. Funding should be adequate for sustaining long-term service at a public institution.	Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Yes
Establish an organizational structure and process to implement the long-term Strategic Science Plan.	U.S. Fish and Wildlife Service, 1997; Shipley and others, 1999; Salton Sea Science Subcommittee, 2000; Case and others, 2013; this document	Inferred support is due to support of Science Program elements (appendix 2 this document).

Conclusion

During late summer of 2014, State of the Salton Sea meetings were held to discuss future science and monitoring needs for the lake. Two meetings were held to gain input on managers' information needs, and a third meeting assembled science experts to develop proposals addressing those identified needs. Scientists were able to build upon previous investigations and develop a series of conceptual proposals that will help fill voids in our knowledge of the Salton Sea ecosystem. Furthermore, a number of long-term monitoring and assessment needs supportive of an adaptive management program were identified. Six teams covering diverse categories such as air quality, contaminants, biology, water quality and hydrology, carbon and algae, and socioeconomics produced 34 conceptual proposals with a total funding need of $46,880,000 (2015 dollars). A similar workshop in 1997 yielded 39 proposals with associated funding of $36,097,600, or about $53,443,000 in 2015 dollars.

Feedback from the managerial meetings, combined with the sense of urgency conveyed by the gathered scientists, indicates that priority should be given to initiating research on the air quality investigations identified in this document. The focus of immediate, urgent priority is related to air quality, fugitive dust, and related human-health issues. Science conducted between 1998 and 2006 focused on ecosystem functions, enabling a much better understanding of the Salton Sea, but little research has focused on air quality as a possible variable in declining inflows to the Salton Sea. Air quality, as affected by hydrogen sulfide emissions, fugitive dust emissions increasing owing to exposure of sediments (PM_{10}/$PM_{2.5}$, pesticides, and other contaminants), and related effects on human health are of increasing concern. However, the gathered scientists cautioned that there is also a need to not lose focus on the continued evaluation for total efficacy of constructed wetlands and other issues related to an anticipated large-scale reconfiguration of the Sea.

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USGS

Barnum and others—**State of the Salton Sea: A Science and Monitoring Meeting of Scientists for the Salton Sea**—Open-File Report 2017–1005

Appendix 1. Notes from Meetings with Managers and Policy-Makers Addressing Gaps in Salton Sea Science, Fall 2014

Over the summer of 2014, the organizing committee (see appendix 2) convened two meetings of natural resource managers, policy-makers, and legislative aides to help outline future science and monitoring needs for the Salton Sea region. The notes below summarize the essence of these meetings. These notes aim to capture the discussion that took place at the first two meetings and is not a comprehensive or complete list of the things discussed. Comments are presented without attribution. This document is not a statement of position or recommendation for any particular way forward.

Meeting Goal

The objective of the meetings was to identify gaps in knowledge in the science of the Salton Sea where they intersect with present need. The meetings with policy-makers and managers in Sacramento and El Centro, California, produced a set of guidelines and suggestions to be considered by scientists at the State of the Salton Sea meeting in Irvine. The scientists assembled in Irvine will produce a report with recommendations for future study and should promote research that will fill in the gaps identified.

Group Agreement and Meeting Mechanics

The meetings made use of a group agreement to put aside differences and focus on the task of identifying concerns and data needs for the Salton Sea. The aims and timeline of the meeting were agreed upon by all participants, and any objective or issues that fell beyond the scope of the current discussion were agreed to be “parked in the bike rack,” so that they may be addressed at a later time. There was a focus on listening to each speaker with the belief that all participants wanted to realize the meeting’s goals. The moderator was responsible (along with a timekeeper) for keeping participants on time and on task throughout the proceedings.

The general format of the meetings included brief introductions of all participants and short presentations on the recent history of the Sea (with an emphasis on the last 15 years) to provide all listeners with a context and understanding of core concepts. Participants were then asked to present their views of their concerns about the Sea and their perception of the data needs for the Sea on their agency’s behalf (verbally, in under 5 minutes). Scribes identified concerns and data needs in each presentation and posted these notes on the wall, where small groups convened to discuss and digest the patterns that emerged from individual presentations. The meetings closed after a brief group discussion.

Meeting Dates, Locations, and Participants

Meetings were held on July 30, 2014, in Sacramento at the University of California Center in Sacramento, Calif., and on August 6, 2014, at the Imperial Valley College in El Centro, Calif. The meetings were attended by 54 participants from 25 organizations to discuss the science of the Salton Sea. The planning team of Doug Barnum (USGS), Michael Cohen (Pacific Institute), Bruce Wilcox (IID), Tim Bradley (UC Irvine), Abby Reyes (UC Irvine), and Gregor Yanega (UC Irvine) attended both meetings.

El Centro Attendees

Dan Farris (Coachella Valley Water District); Lee Case (USGS retired); Larry Purcell (San Diego County Water Authority); Elizabeth Iannone (Office of Congressman Raul Ruiz); Tom Anderson (U.S. Fish and Wildlife Service); Kent Nelson (California Department of Water Resources); Micah Metrosky (International Brotherhood of Electrical Workers local union 569); Sup. John Benoit (Riverside Co.); Pat Cooper (Riverside Co.); Brad Poiriez (Imperial County Air Pollution Control District); Reyes Romero (Imperial County Air Pollution Control District); Val Simon (Bureau of Reclamation); Felicia Sirchia (U.S. Fish and Wildlife Service); Bianka Velez (Assemblyman V. Manuel Perez); Rebbeca Terrazas-Baxter (Cong. Juan Vargas); John L. Scott (Metropolitan Water District); Karen Riesz (California Department of Fish and Wildlife); Oli Bachie (University of California Cooperative Extension); Carrie Simmons (U.S. Bureau of Land Management); Jessica Lovecchio (Imperial Irrigation District); Kelly Bishop (Imperial Irrigation District); Mariana Valdez (Imperial Irrigation District); Thomas Zale (U.S. Bureau of Land Management); Stephanie Dashiell (Defenders of Wildlife); Joaquin Esquivel (Sen. Barbara Boxer); Sarah Friedman (Sierra Club); and Juilan Carmona (Sierra Club).

Sacramento Attendees

Becky Blasius (Bureau of Reclamation); Kealii Bright (California Department of Natural Resources); Diane Colburn (California Assembly for Water, Parks, and Wildlife); Dan Denham (San Diego County Water Authority); Jason Low (South Coast Air Quality Management District); Vivien Maisonneuve (California Department of Water Resources ; Kara Mathews (San Diego County Water Authority); Kent Nelson (California Department of Water Resources); Ted Schade (Great Basin Unified Air Pollution Control District); Chris Schoneman (U.S. Fish and Wildlife Service); Roger Shintaku (Salton Sea Authority); Val Simon (Bureau of Reclamation); Phil Rosentrater (Riverside Co.); Rachel O'Brien (South Coast Air Quality Management District); and Michael Flores (California Department of Fish and Wildlife).

Summaries of Agency Concerns and Data Needs

Concerns

Participants were asked to identify (1) large issues (or "problems") for their agencies with respect to the Salton Sea region and (2) perceived gaps in knowledge (or data). During the meetings, a scribe summarized the comments of individual agencies. Small groups then analyzed emergent patterns, added ideas that seemed to be missing from the whole, and distilled the common themes. This is a notation of that summary, presented without attribution. Presentation order of this summary does not imply importance or hierarchy.

- Concerns about air
    - What is the predicted consequence of a smaller Sea for air quality, dust, and public health? ("How emissive is the soil and how variable is the playa?")
- Concerns about water

    - Water is limited, and there is concern about water quality (including selenium). Water conservation practices (for example, irrigation practices and crop selection) among farmers will have a profound influence on water levels.
- The need to keep farmers involved
    - Effectively all of the water entering the Sea is agricultural runoff.
- Communication and education
    - Topics that need communication include the following:
        - Identifying public health risks and the cost of doing nothing;
        - The science and public health narrative to politicians and the public, including messaging, education, and outreach;
        - Imparting a sense of urgency and awareness for the plight of the Sea;
        - Linking regional issues to statewide and national issues, including human health, hunting, drought, agricultural issues, dust impacts, and renewable energy.
- Development of a shared vision and strong governance
    - Identify near-term and long-term projects and make explicit the links between them. This includes integration, planning, and scalability of projects.
    - Facilitate prioritization of issues and formulation of policy to generate a legislative path.
    - Including all stakeholders in discussion of common values (that is, tribes, farmers, other forms of industry, local workers/people, politicians and governors, etc.)
- Environmental justice and social justice
    - There is a need to consider social justice in all of the projects involving management and mitigation of the Sea.
    - What are the socioeconomic implications of the projects and how can they be properly directed?
- Engineering practicability
    - What should we build (shared vision)?
    - Given the physical characteristics of the Sea (its location and substrate), what can we build and how do we do it?
    - Are there benchmarks or precedent for proposed engineering projects?
    - Can small-scale projects be scaled up? How accurately can we project the cost of these ventures?
- Institutional memory and comparative study
    - In order to learn from what's been done, avoid repeating past mistakes.
        - There needs to be greater availability of all documentation. This information needs to be available both in summary form (communication) and as a complete data archive (science inventory and database management).
        - Can we learn from the history of other inland saline water bodies including Mono Lake, Owens Valley/Lake, the Great Salt Lake, the Aral Sea, Lake Urmia, etc.?
- Renewable energy development and economic concerns
    - How will growth and development of renewable energy (solar and geothermal energy in particular) impact the economy of the region, population size, water availability, and efforts to support management?
- Biological concerns
    - Availability of habitat;

- Organismal responses to lowering Sea levels and climate change;
- Carbon capture and release;
- The resilience and mutability of the Sea ecosystem;
- How much time do we have before things change (temporal sensitivity)?
- Do we expect a "tipping point" or nonlinear responses of biological systems to changing environmental features?

Data Needs

- Air quality
- Dust
  - Where is it formed/coming from?
  - What are its components?
  - How variable are soil/dust profiles around the Sea?
  - What are the public health impacts of dust?
  - Is proposed mitigation appropriate?
  - Are current monitoring practices adaptive (iterative)?
  - What is the geographic extent of the problem?
- Hydrogen sulfide emissions
  - What are the limnological conditions associated with hydrogen sulfide emissions?
  - Are there public health concerns associated with hydrogen sulfide emissions?
  - What impacts might these emissions have on biological systems at the Sea?
  - How will hydrogen sulfide emissions be affected by proposed projects at the Sea
- Water quality
  - What are the levels of selenium in soil and water? Bioaccumulation
  - How will selenium deposition change with changing water levels and management project activity?
- Hydrology
- Water supply and management
    - How does hydrology affect hydrogen sulfide, selenium, anoxia, and additional water sources?
    - How do proposed changes in Sea depth affect hydrology?
    - What questions should we be asking of the proposed management projects (from a hydrological perspective)?
- Data clearinghouse
  - Availability, accessibility, and long-term curation of data
    - Where is data coming from?
    - Is there a data structure and strategy in place for creating public access to all relevant data?
    - What kinds of data should be made available?
    - Where is it housed and does it have a long-term strategy and funding source?
    - Who should be responsible for metadata, data formatting (for example, data norms)
    - Who is responsible (best suited) for interpretation of data and summarization of data?

- Mapping
    - There is a need for detailed mapping of lands around and under the Sea;
    - There is a need for mapping the shoreline of the Sea on a temporal scale.
- Economic impact of the Sea
    - What are the costs of various U.S. management plans?
    - Estimates of what it will cost if nothing is done?
    - Potential for economic growth
        - What are the impacts of renewable energy for biological systems?
        - How many new jobs/people will accompany development of renewable energy industry?
        - Will renewable energy bring money to the region?
- What are realistic funding sources now?
    - What can be done to generate interest in future funding?
        - Can we shape what gets funded?
        - What is the mechanism by which we prioritize and coordinate funding efforts?
        - Can we streamline how money flows from government agencies so that funds can be dedicated more quickly and effectively for time sensitive projects?
        - What is the current rate of visitation to the Salton Sea area and what is the current revenue associated with these visitors?
- What are the microclimate benefits and characteristics of the Sea?
    - International inputs and collaboration
    - International issues of air quality, water inputs, species conservation, etc.
- Engineering: Site-specific knowledge
    - Need for geotechnical data about different management proposals
- Scalability of engineering and management projects
    - Do we/can we know how proposed management efforts in marshes and wetlands (SCH) will behave across spatial scales?
    - We need to establish benchmarks for engineering aims at Sea.

Biological Issues

- Neglected players
    - Are there biological impacts that will affect nonobvious U.S. players (desert tortoise, pile worms, desert plants) that we have not been considering?
- Monitoring
    - Is there a gap between monitoring capacity and monitoring need at the Sea? If so, where are these gaps?
    - Is there a role for citizen science to play in filling gaps in monitoring needs? For example, birders contribute surveys to eBird, and these data are in use in scientific literature. Are there other ways that citizen science can contribute and at the same time foster greater communication and outreach about the Sea?
    - What becomes of threatened populations (Clapper rail, pupfish) as water levels drop?
- Disease vectors
    - What steps can we take in policy and management design that will minimize the risk of mosquito outbreak?

- Tilapia physiology and salinity-tolerance thresholds
- Ecological transitions
    - Mechanism of ecosystem transition from fish-driven food chain to something else;
    - "Tipping point" dynamics of ecosystem;
    - Ecological resilience of Sea ecosystem;
    - What happens to bird populations as fish decline?
- Carbon balance at the Sea
- Habitat
    - Where is the availability and distribution of aquatic habitat as management proceeds?
    - How do bird populations use farmland? For which populations is this critical?
    - Will flooded fields be maintained?
    - Can the integrity of the freshwater inlets be maintained and will they be sufficient to support pupfish populations as salinity rises?
- Water chemistry
    - What changes in water chemistry will occur and how will they impact vertebrate and invertebrate populations?

Agricultural Questions

- Dust
    - What is the impact of dust on crop growth?
    - Do all plants/crops respond similarly to dust?
    - If dust does impact crop growth or fitness, what are the mechanisms by which this occurs?
- Irrigation, water conservation, crop choice
    - What are the effects of changing farm practices on water availability (crop selection, irrigation method)?
    - What role can agriculture play in reduction of phosphorus inputs into the Sea?

Communication, Public Outreach, and Education

- Need data and summary of environmental and public health impacts at the Sea to enable politicians to advocate for a conservation position.
- Information about the Sea needs a broader (statewide, nationwide, global) context.
- Ramifications of public health crisis, etc.
- What are the shared narratives of the Sea?
- How do we convey these narratives?
- What does the future Sea look like?
    - Is the infrastructure and communication network in place to enable clear passage of information from source to the voting public? (a marketing question)
    - How should we undertake public education about the Sea?
- Do we have a strategy for engaging and including the various stakeholders around the Sea?
- How can we engage young people about issues germane to the Sea and make the Salton Sea region appealing to a broad audience?

Planning

- How do we prioritize which data gaps are addressed first?
- How do we integrate small and large projects across agencies?
- Can we build a model that predicts the [multivariate] cost and benefit of different action scenarios to give managers a more explicit and quantitative way of visualizing and justifying decisions?
- How do we streamline agency involvement in management so that we agencies can "plug into the system" to help?
- Governance structures
- What can or should be done to promote effective governance?

Management Projects

Species Conservation Habitat Plan (SCH)

- How will berms perform?
- How long will berms last?
- How will they perform in face of earthquake?

Red Hill Bay Project (IID)

- Are there interactions between renewable energy and wildlife?
- What is the best strategy/distribution of salt and freshwater ponds?
- What are the effects of managed marshes for maintaining biodiversity?
- Is dredging the mouth of Red Hill Bay possible?

Appendix 2. State of the Salton Sea Workshop Participants and Working Groups

[Rover designation participated among all groups. Contact information is current as of September 2014.]

Name	Agency	Email	Group
Orlando, Jim	USGS	jorlando@usgs.gov	Contaminants
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Roberts, Carol	USFWS	carol_a_roberts@fws.gov	Contaminants
Blasius, Becky*	Reclamation	bblasius@usbr.gov	Contaminants
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Shuford, Dave	PRBO	dshuford@pointblue.org	Biology
Marusenko, Yev	UC Irvine	ymarusen@uci.edu	Biology
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Shintaku, Roger®	Salton Sea Authority	rshintaku@saltonsea.ca.gov	Rover
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Windham-Myers, Lisa	USGS	lwindham-myers@usgs.gov	Carbon
Carlberg, Jim	Kent Bioenergy	jamesmcarlberg@gmail.com	Carbon
Goulden, Michael	UC Irvine	mgoulden@uci.edu	Carbon
Cohen, Michael*	Pacific Institute	mcohen@pacinst.org	Carbon
Baskin, Rob	USGS	rbaskin@usgs.gov	Water
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Anderson, Michael	UC Riverside	michael.anderson@ucr.edu	Water
Curry, Deb	USGS	dcurry@usgs.gov	Water
Holdren, Chris	Reclamation	gholdren@usbr.gov	Water
Kjelland, Michael	Army Corps of Engineers	Michael.E.Kjelland@usace.army.mil	Water
Case, Lee*	USGS, retired	hlcaseiii@yahoo.com	Water
Schladow, Geoff	UC Davis	gschladow@ucdavis.edu	Water
McCarthy, Graham	UC Irvine	gmccarth@uci.edu	Water
Nelson, Kent®	CDWR	Kent.Nelson@water.ca.gov	Rover
Burkhart, Nina	USGS Fort Collins	burkardtn@usgs.gov	Social
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Reyes, Abby*	UC Irvine	abigail.reyes@uci.edu	Social
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Feldman, David	UC Irvine	feldmand@uci.edu	Social
Witherspoon, Boykin	Cal State San Bernardino-Palm Desert	bwithers@csusb.edu	

*Designates Team Lead ®Designates Rover

Appendix 3. Agenda for State of the Salton Sea Workshop, September 8–10, 2014

Workshop was held at Beckman Center, University of California, Irvine.

Monday, September 8, 2014	
Optional field trip to the Salton Sea (Bus provide by IID)	
Tuesday, September 9, 2014	
7:30 – 8:00 AM	Registration
8:00 – 8:45 AM	Opening Welcome Tim Bradley, UCI Salton Sea Initiative Meeting Preliminaries Abby Reyes, UCI Sustainability Initiative *Housekeeping, Meeting Goal, Proposed Agenda, Group Agreements* Brief Introductions by Participants
8:45 – 8:55 AM	Welcoming Address Frank LaFerla, Dean of Biological Sciences, UC Irvine
8:55 – 9:00 AM	Welcoming Address Mark Sogge, Regional Director, USGS
9:00 – 9:30 AM	Keynote Address Anne Castle, Asst. Secretary for Water and Science, Dept. of the Interior
9:30 – 9:40 AM	Welcoming Address Kevin Kelley, General Manager, Imperial Irrigation District (IID)
9:40 – 10:00 AM	Break
10:00 – 11:15 AM	Background Presentations Doug Barnum, USGS, *Science of the Sea: Major Investigations and Findings* Michael Cohen, Pacific Institute, *Revisiting a No Action Scenario* Tim Bradley, UCI, *A Changing Lake* Bruce Wilcox, IID, *Recent Management Activities of IID & Salton Sea Authority* Kent Nelson, CA Dept. Water Res., *The Salton Sea: A Conservation Strategy* Armin Munevar, CH2MHill/IID, *Revised SALSA2 Model for Water and Salt Balances Long-Term Planning*
11:15 AM – noon	Guidance from the Managers' Meetings Abby Reyes, Managers' Meetings Goal and Objectives Doug Barnum, Today's Meeting Goal, Objectives, Format, Deliverables Gregor Yanega, UCI Salton Sea Insititute, Results from Managers' Meetings
Noon to 1 PM	Lunch

Tuesday, September 9, 2014, continued	
1 PM – 2:30 PM	Guidance from the Managers' Meetings, continued Discussion, continued Framework and instructions for breakout groups
2:30 – 3 PM	Break
3 PM – 5 PM	Breakout Groups: Session I *meet in assigned group with team lead*
5 – 6 PM	Reconvene Team Leads report back on highlights and next steps Instructions for going forward *Dinner provided by University of California, Irvine*

Wednesday, September 10, 2014 (subject to revision based on meeting needs)	
8:00 – 8:15 AM	Roadmap Recap
8:15 – 10 AM	Breakout Groups: Session II *Research proposal outline development*
10 – 10:20 AM	Break
10:20 – 11:20 AM	Breakout Groups: Session III *Research proposal outline development*
11:20 AM – 12:15 PM	Reconvene Team Leads report back on ideas under development Discussion: Areas of concurrence, common science & monitoring needs
12:15 – 1:00 PM	Lunch
1:00 – 3:00 PM	Breakout Groups: Session IV *Research proposal outline development; wrap up*
3:00 – 4 PM	Reconvene Team Leads report back on highlights; anticipated next steps for group Assignments Review, Essential Conversations, Last Words
By 4:00 PM	Adjourn

Appendix 4. Summary of Information Presented to Participants, Workshop Guidelines, and Proposal Instructions

This appendix contains a summary of how the workshop was conducted and basic operational guidelines for the participants. The material presented to the participants includes a justification for the workshop and why it is important, a description of how and why the workshop was structured, a brief retrospective examination of existing scientific knowledge and management history of the Salton Sea, workshop goals and objectives, workshop operating ground rules, and guidelines for the development of conceptual proposals and budgets.

The Salton Sea is a lake that has markedly declined. Failure to act soon will result in further degradation. The State of the Salton Sea workshop was a needs assessment workshop held in Irvine, California, September 8–10, 2014. USGS organized the workshop in close collaboration with University of California, Irvine (UCI); Pacific Institute; Imperial Irrigation District (IID); and the Bureau of Reclamation (Reclamation) to further refine a process to address the natural resource issues and research and investigate needs for ***any*** proposed solution to rehabilitate the Salton Sea ecosystem. This proceeding from the State of the Salton Sea workshop summarizes the deliberations of approximately 50 scientists regarding approaches that must be taken if the Sea is to remain serving as a functional ecosystem.

Scientists participating in this workshop all agreed that rehabilitation of the Sea is essential and requires that decisive intervention will be required to allow the Sea to sustain its important ecological and economic values. Science of the Salton Sea is complex and is reflected in the diversity of disciplines represented at this workshop. The multidisciplinary nature of the workshop consisted of expertise in air quality, water quality, physical environment, biological environment, contaminants, carbon and CO_2 uptake, algae, and socioeconomics. To effectively rehabilitate this degrading environment, resource managers will require a fully integrated and collaborative understanding of the complex science of the Salton Sea and engineers will rely on this integrated information to design and develop approaches to arrest the degradation.

Previous science workshops (U.S. Fish and Wildlife Service, 1997) identified science necessary to begin understanding the “big picture” dynamics of this large lake. Now that the “big picture” science has mostly been accomplished, it is important to keep moving science forward following those initial studies with equally important science designed to generate a better understanding of these dynamics, designed to fill in identified gaps in our knowledge, thus allowing better modeling of these dynamics, and pursue new science to elucidate unresolved or unknown effects of rehabilitation projects. Science identified in previous workshops has identified major interactive issues such as hydrogen sulfide, thermoclines, water mixing regimes, and potential catastrophic effects of some rehabilitation strategies. It was the science of these early efforts which has led to a greater understanding of selenium, wildlife diseases and pathogens, of critical resources needs for maintaining fish and bird populations, and of the critical role of aquatic invertebrates and microbes in this ecosystem. Scientists have begun to understand how to rehabilitate this degraded system and live within the constraints of less water, no new water, and degraded water as the only sources available to use. Scientists have begun to learn how to provide for the maintenance of biological diversity, avoid toxic emissions, and ameliorate air quality concerns while using less water. Scientists now must work in concert with resource managers, decision makers and engineers to implement our findings and make sure these projects are based on the best possible science knowledge.

For the State of the Salton Sea workshop, scientists were invited based on their prior scientific involvement and (or) expertise relevant to the myriad of issues of the Salton Sea. Many of the invited scientists participated in a bus tour of the Sea on Monday, September 8, in which discussions were held concerning major scientific findings and demonstrations of how the science produced by earlier efforts is being implemented in embryonic efforts of lake rehabilitation.

The main part of the meeting convened on campus at UCI's Beckman Center. Beginning on September 9, Assistant Secretary of the U.S. Department of Interior Anne Castle and other notables set the stage for the group with opening remarks addressing the importance of science in rehabilitation of the Salton Sea (see appendix 3). Included in these presentations was a summary discussion of the results from the two manager meetings (appendix 1). This discussion provided the scientists with a vision for the needs of resource managers and decision makers. The two-meeting format was devised as a means of including both science and management perspectives with respect to science and monitoring needs of the Salton Sea. Following this, organizing team members each provided short presentations designed to inform the group of major scientific findings in the previous 15 years as a means of bringing the entire group up to speed on the existing state of scientific knowledge for the Sea. Team Leads for each topical grouping were identified, and then participants were assigned to topical groupings (appendix 2). Team membership was assigned based on each scientist's expertise while recognizing that everyone may hold multiple areas of expertise. Cross discipline discussions were encouraged.

Prior to breaking into group work sessions, a set of proposal guidelines and templates were provided. These guidelines were established in order to provide a common set of values and document framework to avoid institutional differences in pay scales, overhead rates, and equipment procurement.

Key issues such as what defines science investigations versus monitoring programs were discussed among team leaders and presented to the scientists. For this workshop, science investigations are those studies with a clear set of testable hypotheses and generally tend to be short-duration studies for very specific reasons. Conversely, monitoring studies are to be longer term data collection as a means of testing compliance with stated objectives. For example, selenium studies can be conducted to ascertain ecological effects or to ascertain concentrations associated with certain irrigation practices. Both would be considered a science investigation. Monitoring of selenium could be routine sampling of constituents relative to a regulatory standard as a means of detecting problems as they arise, then prescribing more intensive studies to ascertain why the concentrations are observed. Science investigations can establish expected values for bird or fish diversity and abundance to provide management agencies goals as part of adaptive management programs. Monitoring programs then can inform management as to how effective any specific program is at providing the desired diversity or abundance and assist management in making adjustments. Each developed proposal was required to indicate precisely how the proposed science would help inform management decisions.

Although proposal concepts developed in this workshop may appear to be linked to specific organizations, agencies or scientists, participants were advised that there would be no institutional ownership of any contributions. All proposal concepts were captured and reported in appendix 5. A list of all participants, their affiliation, and current email address is captured in appendix 2, not to justify the document nor as an endorsement, but to provide notice of participation.

A proposal template was provided to all team leaders, and standard budget values were established for pay rates and overhead to be consistent across all proposals and disciplines. All contributions were strictly conceptual proposals with a minimum of detail and no requirement to provide supporting citations, although allowed. Proposals were developed with a 3- to 5-year implementation period. Teams differed on budget development. Some teams developed very detailed breakdowns of each budget category. Although this helped several teams organize the budget process, it was not a requirement for these conceptual proposals. Once published, these conceptual proposals may serve as the basis for further discussions by resource managers and decision makers. At that point, consideration may warrant the implementation of a science program to seek detailed proposals to support management agency information needs.

Budget standardized values provided to authors

- Senior-level research scientist $150,000/12 months
- Graduate students, technical support, post-docs $ 80,000/12 months
- Pay is pro-rated by months per year
- Overhead rate is set at 50%

Proposal Template

Title
Introduction/background (Not to exceed 1 page)
Justification
Objectives (bullets)
Products (bullets)
How does this inform management? (Not to exceed one-half page) Does it address any of the management concerns or data needs, which ones?

Budget	Year1	Year2	Year3
Labor			
Equipment			
Supplies			
Miscellaneous			
Total			

Proposal developed by

References Cited

U.S. Fish and Wildlife Service, 1997, Saving Salton Sea—A research needs assessment: U.S. Fish and Wildlife Service, 96 p.

Appendix 5. Suggested Scientific Studies

Introduction

This document is expected to serve as the basis for further discussions by resource managers and decision makers concerning whether to seek funding support for a robust science and monitoring program. Should funding be secured, then consideration will be developed for implementing a larger science oversight team with responsibility for securing detailed proposals suitable for response to a Request for Proposals (RFP) and peer review (see appendix 6). During proposal development, teams were asked to provide a Point of Contact for each concept. Contact names are provided, with contact information for all participants listed in appendix 2. Although a general proposal template was provided at the SoSS meeting, as long as scientists provided the key elements of the template, they were allowed to write in their own style. Thus, these conceptual proposals are included here as written by the persons listed as Point of Contact, with minor editing and modifications to format. These contributions authored by non-USGS authors do not represent the views of position of the USGS and are published solely as part of this volume.

A proposal template was provided to all team leaders, and standard values were established for pay rates and overhead in an attempt to be consistent across all proposals and disciplines. Standard values were established to avoid institutional differences in pay for principal investigators, technical support staff members, student assistants, and overhead assessments (appendix 4). However, differences among scientists and groups led to some differences in approaches to formulating a proposal and in budget development; these are reflected in the actual proposals. These are strictly conceptual proposals with a minimum of detail. Proposals were developed with a 3- to 5-year investigation period. Time constraints of the SoSS meeting prevented the development of several concepts into proposals. Nevertheless, the organizing committee included the title and some discussion for these undeveloped concepts with a suggested funding level suitable for addressing each concept.

Air Quality Proposals

AQ1. Measurements in and around Salton Sea area to assess potential particulate matter emissions

Introduction and Background

With the predicted decline Salton Sea water level, the amount of exposed playa will increase, thereby creating the potential to increase ambient particulate matter less than 10 µm (PM_{10}) in the surrounding areas, affecting communities in the Imperial and Coachella Valleys. Health effects of PM_{10} pollution include respiratory system hardship, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter.

The magnitude, timing, and type of emissions drive all aspects of PM air quality concerns. Understanding characteristics and quantities of emissions under varying conditions is a requirement for accurate emissions estimates in modeling the Salton Sea air quality system. Generic emission factors are nearly useless for the Salton Sea playa as they were estimated for very different landforms and generally homogeneous land uses (for example, agriculture).

Field measurements of emission factors provide scientific data to provide an improved understanding of temporal and spatial variability. These measurements can be simply aggregated (averaged or similar) for use in models or their range can be used for sensitivity analysis of model results. However, the current area of Salton Sea is vast thus adding to the complexity of predicting emissivity of exposed playa as the water levels decline. The power of the emissions measurement can be amplified substantially if specific parameters can be identified that would serve as explanatory factors for emissions in defined areas. Moreover, the development of a method for determining playa composition and emission properties before it's exposed would incorporate these explanatory factors into a predictive model. Empirical data collected in the field would provide input or at least improve the accuracy of a predictive physical model for emissions which can then be applied to prioritize and maximize PM mitigation strategies for the Salton Sea.

Justification

Understanding the geographical distribution of potential PM emissions from the current and predicted playa exposure from the decline of the Salton Sea water level would provide information that can be used to determine areas of highest potential health impacts from PM which will assist in prioritizing dust mitigation strategies.

Objectives

1. Collect measurements of PM_{10} and $PM_{2.5}$ emission factors or surrogates for such measurements with sufficient density to capture the spatial variability in emissions that is inherent to the exposed playa. Emission factors of saline lake deposits are highly dependent on meteorological conditions. Therefore, measurements should be designed to ensure that this temporal variability can be captured.
2. Relate emission factors to physical and chemical properties of the playa deposits. Doing so would extend the predictive power of the field measurements when trying to extend those data to locations where measurements of emission factors are not collected but where physical and chemical properties of the soil are easily obtained.
3. Determine the impact of disturbance on the emission factors. Identify the longevity and frequency of this impact (if any) and the magnitude of the impact in relation to soil physical and chemical properties.
4. Use measurements to determine if emissions of PM_{10} and $PM_{2.5}$ can be estimated for currently inundated sediments that are going to be exposed in the near future.
5. Use the existing/enhanced monitoring network to evaluate the fidelity of measured/estimated emission factors and empirical emission models developed in 1 and Products
6. The principal product from this effort is a spatially resolved dataset of measured/estimated PM_{10} and $PM_{2.5}$ emission factors for windblown dust under varying wind conditions from exposed Salton Sea playa. Documentation for this dataset would include assumptions, limitations, and quantified uncertainties of individual measurements (representativeness is a different story). This stand-alone dataset can be used to obtain basic aggregated information about emissions (magnitude range, average, seasonality).

7. Physical and chemical characterization of playa sediments at the same locations where emissions are measured or estimated as part of Objective 1 tasks may allow further refinement of location and time-specific estimates for emission inputs into a larger air quality model. The products from this could include relationships between emissions factors and soil texture, salt chemistry, moisture content, bulk density, mineral content and/or other properties.
8. As with the products of Objective 2, the product of this effort would include relationships (mathematical) between magnitude, frequency, and timing of surface disturbance (principally by Off Highway Vehicle activity). These would be used as modifiers to emissions estimates with the overall purpose of improving accuracy.
9. One component of this work would provide a comparison of physical and chemical properties of currently exposed playa sediments with those of currently inundated sediments. The proposed study would sample for inundated Salton Sea sediments and then dry them, assess chemical and physical properties as well as emissions testing. A second component would provide a comparison of measured emissions from exposed playa with emissions measured from inundated sediments that were acquired, dried, and tested for emissions. This would result in a transect map of emissions from exposed shoreline up to some distance (depth) of inundated sediment. The goal of this effort is to be able to predict the potential emissivity of sediments before they are exposed.
10. Comparison of time-resolved monitoring of PM_{10} and $PM_{2.5}$ is important to independently "confirm" the accuracy of the emissions estimates that have been informed by the accomplishment of objectives 1–4. While the existing monitoring network would be very valuable for this comparison, it may be desirable to perform such comparison with a denser short-term network.

How Does This Project Inform Management?

- Provides PM emissivity data which can be applied directly in the area measured to calculate potential PM health impacts if no mitigation were implemented;
- The emissivity measurements, chemical and physical properties evaluation, and inundated area measurements may provide more spatially resolved emission factor data into a predictive model for identifying areas of highest PM emissions and forecasting of control technology benefits;
- Provides better quantification on the range of PM impacts from current Salton Sea playa exposure and predicted future exposure. This would provide a scientific basis for identifying the need and location priority for mitigation planning efforts;
- Air monitoring provides a validation of the emissions model.

Budget

Objective	Senior Personnel	Technical Personnel	Travel	Equip-ment	Operating /lab	Overhead	Total
1	$60,000	$160,000	$25,000	$50,000	30000	$110,000	$435,000
2	$25,000	$80,000	$5,000	n/a	$50,000	$52,500	$212,500
3	$10,000	$15,000	$10,000	n/a	$15,000	$12,500	$62,500
4	$75,000	$80,000	$20,000	$40,000	$100,000	$77,500	$392,500
5	$30,000		n/a	n/a	n/a	$15,000	$45,000
TOTAL							$1,147,500.00

Point of Contact

Bruce Wilcox, Vic Etyemezian, Reyes Romero, Jason Low, Oli Bachie, Charles Zender, Philip Fine

AQ2. Potential toxicity of suspendable sediment from Salton Sea playa

Introduction and Background

With the predicted decline Salton Sea water level, the amount of exposed playa will increase, thereby creating the potential to increase ambient particulate matter less than 10 µm (PM_{10}) in the surrounding areas, affecting communities in the Imperial and Coachella Valleys. Known health effects of PM_{10} pollution include respiratory system hardship, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter. There may be additional health effects associated with PM_{10} and $PM_{2.5}$ that are specific to the Salton Sea sediments.

Salton Sea has been a terminal lake for about a century. Material that flows into the Sea either deposits or seeps into the sediments, evaporates or volatilizes out of the Sea, or is removed by physical (dredging/ precipitation) or biological (food chain) means, or is chemically altered or degraded into intermediate and final products. Over 50% of the inflows into the Salton Sea are one type of agricultural runoff or another. These inflows are likely to include salt minerals and other solutes that are leached from agricultural fields, organic material that is dissolved or suspended in the runoff water, and suspended soil and other particles. Additionally, agricultural chemicals such as pesticides, herbicides, and fertilizers may also be leached or suspended (depending on solubility and phase) into runoff water. These materials all end up in the Salton Sea. There they may be concentrated in solution, partitioned between sediment and water, chemically altered, or removed by any number of means.

Toxic materials can be grouped into two primary categories, inorganic and organic. The inorganic group contains principally metals such as selenium, chromium, and arsenic whereas the organic group (containing carbon based compounds other than carbon monoxide and carbon dioxide) contains principally biocides and soil amendments. Although not traditionally considered as environmental toxics, the high salinity of the Salton Sea sediments may have health impacts on humans and the ecosystem, chiefly by causing irritation in the lungs, eyes, and skin—it is presumed.

Whereas there are toxic chemicals everywhere in the environment, the health threat that a specific chemical poses in a specific setting is related to three factors. First, the inherent toxicity of the chemical determines what quantities of the chemical are a concern. For example, table salt is toxic in very large quantities, whereas nerve warfare agents are toxic in very small quantities. Second, the concentration of the chemical in the environment at the point of exposure determines the availability of the chemical to cause concern. For example, the lead in lead-acid batteries is certainly toxic. Yet, the concentration of lead that the driver is exposed to as a result of being in the proximity of a battery is very low. Thus, the large quantities of lead in the car battery pose no health threat to the nearby driver because the concentrations of lead are very low at the point of exposure (driver's nostrils or mouth). Third, the duration that someone spends being subjected to particular concentration determines the exposure. Generally, the longer the duration, the higher the exposure, the greater the likelihood of toxicity impacts. Diesel exhaust is classified by the State of California as a known toxin. Everyone in the state is exposed to some level of diesel exhaust daily. However, the individual who works at a shipyard where truck and ship exhaust are a mainstay of the work day is exposed to much higher levels of diesel exhaust than the average California resident. All other factors being equal, the shipyard worker has a higher likelihood of being impacted by the toxicity of diesel exhaust.

Justification

Identifying the potential toxic components and their concentrations within the suspendable fraction of the Salton Sea sediments can help determine if there are health risks to the community and if so, which chemicals are driving those health risks. Used in conjunction with emission and dispersion models this information can support an exposure assessment for the community.

Objectives

1. Collect and characterize samples of suspendable dust material from exposed sediments of the Salton Sea. Sample characterization is targeted on potentially toxic components.
2. Determine if toxicity of currently inundated sediments that will likely be exposed in the future can be reasonably predicted by bulk sampling methods.

Products

The product from this effort is characterization of the toxic chemical profile from exposed sediments of the Salton Sea. The samples for such analysis should be collected to reflect the likely suspendable and respirable fraction of dust in the sediment. Such characterization will include concentrations, chemical/physical states, and other chemical information (associations with minerals or partitioning between phases) of toxic chemicals. This will consist of a comparison between exposed sediments and currently inundated sediments—with respect to toxic chemicals content. This information will be analyzed to determine if it can be used to inform of potential toxicity of inundated sediments once they are exposed.

How Does This Project Inform Management?

- Provides data on toxicity of sediment material beyond what is known generically about PM_{10} and $PM_{2.5}$ from non-Salton Sea sources.
- Enables coupling with emission and dispersion models for exposure assessment of communities by location, time of year, occupation, etc.

Budget

Objective	Senior Personnel	Technical Personnel	travel	Operating /lab	Overhead	Total
1	$300,000	$80,000	$25,000	$250,000	$190,000	$845,000
2	$50,000	$80,000	$5,000	$50,000	$65,000	$250,000
TOTAL						$1,095,000.00

Point of Contact

Bruce Wilcox, Vic Etyemezian, Reyes Romero, Jason Low, Oli Bachie, Charles Zender, Philip Fine

AQ3. Dust/pollution emissions modeling for the Salton Sea playa and surrounding impacted areas

Introduction and Background

Develop dust emissions model that will assess potential effect of air quality on humans, agriculture and other biological life around the Salton Sea shore. The emissions model can be used as a tool to provide a plan for potential dust mitigation strategies. Existing data will be used in the development of the model and can be supplemented with data from the companion proposal (AQ1)

The model will also be used to evaluate the effectiveness of control measures and can be used to assess the potential effects of Salton Sea shore dust on humans, agricultural and other biological resources.

Justification

The development of a model that identifies emissivity potential of exposed playa to be used to further develop dust emissions control strategies.

Objective

Develop and implement an emission model to quantify dust emission from exposed playa. The model will also help to identify potential high emissive areas and predict the potential dispersal of those emissions. The model will use emissions inventory and dispersion modeling to predict the impact of playa emissions to the PM_{10} and $PM_{2.5}$ air quality standards.

Products

An emissions model to predict PM_{10} and $PM_{2.5}$ emissions from Salton Sea exposed playa. The benefit of the emissions model would also help to identify the similarities and differences of air quality around the Salton Sea to other identified air quality problems. It also helps to assess the potential problems of dust from Sea onto neighboring agricultural lands. It will also inform the development and implementation of control strategies.

How Does This Project Inform Management?

The results of the model will be used to inform the management team in defining the parameters and spatial extent of the emissive area and develop/implement of control measures for those areas of the playa.

Integration

The emissions predictions of the model can be used in the evaluation of potential impacts to human health, as well as the economic impacts to agricultural industry.

Budget

	FTE	Year 1	Year 2	Year 3
Senior PI	$150,000 per year	$150,000	$75,000	$75,000
Tech	$80,000 per year	$80,000	$40,000	$40,000
Overhead	50%	$115,000	$62,500	$62,500
Equipment	Direct Cost	$15,000	$10,000	$10,000
Travel	Direct Cost	$12,000	$6,000	$6,000
Total		$$372,000.00	$193,500.00	$193,500.00
Grand Total				$759,000

Point of Contact

Vic Etyemezian, Jason Low, Oli Bachie, Reyes Romero, Charles Zender, Philip Fine, Bruce Wilcox

AQ4. Reduction of fugitive dust emissions from dirt roads and a receding Salton Sea using a biogenerated soil enhancer

Introduction and Background

The Salton Sea, situated in the Lower Colorado River Basin (LCRB), is under duress due to several factors including increased water demands of large, rapidly growing urban centers like San Diego, California and Mexicali, Mexico. The Colorado River Quantification settlement agreement (QSA) of 2003 has drastically lowered the amount of fresh water inflows to Salton Sea, resulting not only in changes to the amount of water in the Sea, but also in changes the geochemistry and overall the water quality. These changes can dramatically affect the population dynamics of numerous species endemic to the region.

According to climate model projections (Seager and others, 2012), the Colorado River headwaters are expected to have an annual stream flow decline of 10 percent and as much as a 20 percent drop in spring runoff in California and Nevada. The Salton Sea water levels are projected to be reduced in the future leading to potentially significant effects to air quality due to fugitive dust from wind erosion of exposed sediments (Imperial Irrigation District and Bureau of Reclamation, 2002; California Resources Agency, 2006; Case and others, 2013). A major concern is that as the Salton Sea recedes exposed contaminated sediments might be dispersed in dust storms throughout the surrounding communities. Imperial County already struggles to contain health-degrading air pollution, with about 250 tons of smoke and dust released into the air daily (Polakovic, 2001).

Air quality in the Salton Sea Air Basin does not currently achieve California or National Ambient Air Quality Standards for PM_{10} and ozone (Case and others, 2013). The pollutants of greatest concern in the Salton Sea area are PM_{10} and $PM_{2.5}$ from wind erosion (fugitive dust), soil disturbance, and fuel combustion (Case and others, 2013). The Salton Sea Ecosystem Monitoring and Assessment Plan (Case and others, 2013) states that monitoring of existing conditions for ambient air quality at and near the Salton Sea is needed as a baseline for use with future evaluations of air-quality management and mitigation efforts.

In addition, salinity increases from reduced freshwater inflows will affect the viability of avian and fish habitats in the Salton Sea (Kjelland, 2008). Areas adjacent to the Salton Sea support tamarisk and halophytic shrubs (for example, arrowweed) and it is expected that as the

Sea recedes, this vegetation could encroach onto the exposed playa (Case and others, 2013). Not only would this vegetation reduce air-borne particulates via soil stabilization, but it also serves as habitat for roosting and nesting shorebirds as well as cover for passerine birds during migration (Case and others, 2013). Therefore, it seems plausible that enhancing the rate of vegetation expansion into the receding Salton Sea area would be a good approach for soil stabilization and dust abatement. Any effort to reduce air-borne particulates must not jeopardize the biota in and around the Salton Sea.

An alternative to traditional soil stabilization measures (which tend to increase salinity), such as the application of magnesium chloride- or petroleum-based products, is desired so that salinities do not increase from reduced inflows and management actions. One alternative to magnesium chloride- or petroleum-based products for soil stabilization and dust reduction is to use an extracellular polymeric substance (EPS), a naturally occurring biopolymer that is a form of soil organic matter. For example, a recently developed and commercially available *Rhizobium tropici* biopolyme*r* works as a soil amendment to reduce dust emissions and protect surface water quality. Because the *R. tropici* evolved as a symbiotic partner of a legume, a non-halophytic plant species, other EPS that plant-microbe systems use to re-engineer soil will also be evaluated for soil stabilization in a saline environment.

Plant growth-promoting rhizobacteria (PGPR) are a diverse group of soil bacteria that, in the presence of a host plant, encourage significant plant growth (Milošević and others, 2012). The PGPR effects are believed to be the result of the production of an EPS. The EPS are high-molecular-weight compounds composed of sugar residues. They are secreted by a microorganism associated with plant roots. Using the EPS, plant microbes act symbiotically to re-engineer the surrounding soil in order to maximize the potential for survival of both organisms. There are many modes of action through which this organic polymer can be expressed including fixing nitrogen, increasing the availability of nutrients in the rhizosphere, mitigating abiotic stressors such as salinity and pH, enhancing root growth and morphology, and promoting other beneficial plant-microbe interactions (Laspidou and Rittmann, 2002). The secretion of EPS by bacteria is also recognized as a cohesive force in promoting surface erosion resistance in soils and sediment (Droppo, 2009; Gerbersdorf and others, 2008a, b). The biopolymer produced by *R. tropici,* and potentially other forms of EPS associated with high salinity soil-plant-microbe systems, provides similar soil enhancements in a long-lived, but ultimately biodegradable, material without the environmental concerns associated with petroleum-based polymer. In addition, the biopolymer acts as a carbon storehouse for readily biodegradable sugars that would otherwise be oxidized to CO_2 and contribute to elevated greenhouse gasses in the atmosphere.

A technique has been patented by the U.S. Army Corps of Engineers (USPTO No. US 7,824.569 B2; Newman and others, 2010) through which *R. tropici*-derived biopolymer can be produced in an aerobic bioreactor. The biopolymer is then separated from the bacteria and growth media and can be applied to the soil as either a slurry or powder. Previous research has identified EPS that can be produced on an industrial scale from two *Rhizobium* species, *R. tropici* and *R. fredii*. The *R. tropici* production is under ERDC patent and has had some commercial success in the agricultural marketplace. The *R. fredii,* grows well in alkaline soils and is significantly different in its chemical activity from the *R. tropici* material.

The biopolymer acts in several ways to increase soil stabilization and enhance revegetation of disturbed soil and reduce fugitive dust emissions (Larson and others, 2012, 2013):

- Biopolymer soil amendment increases germination rate and the drought resistance of plants so they require less water (fig 5-1).
- Biopolymer soil amendment results in increased root mass and root fine structure which holds soil effectively, reducing wind and water erosion and stream sedimentation (fig 5-2).
- Biopolymer binding of soil particles contributes to increased resistance to wind erosion which reduces production of fugitive dust in the PM_{10} range, maintaining air quality standards (fig 5-3).

These compounds are just two of many extracellular materials produced by symbiotic soil bacteria. Along with the evaluation of *R. tropici* and *R. fredii* generated EPS as soil amendments for dust control at the Salon Sea, bench- and mesoscale-scale evaluation will be performed to identify and characterize new EPS-producing soil microorganisms, concentrating on those that thrive under saline conditions. We will evaluate the potential of these new EPS compounds for enhanced vegetative growth and soil stabilization. The most promising of these pairings will be selected for pilot- and field-scale testing. The goal will be to develop the technical maturity evidence so that these advanced remediation techniques can be demonstrated and validated under field conditions.

For example, osmo-adaptation and increased plant salt tolerance have been studied using EPS-producing bacteria (Ashraf and others, 2004; Qurashi and Sabri, 2011). Bacteria known to produce EPS under saline conditions include *Oceanobacillus*, *Staphylococcus*, *Aeromonas*, and several strains of *Bacillus*. A number of these producers of extracellular material will be evaluated for the potential to be used in a production process similar to that used for *R. tropici* and *R. fredii.* The resulting EPS will be removed from the cell culture via ethanol precipitation followed by dialysis and subjected to testing and evaluation of its potential for enhanced remediation in saline soil. A halophyte-friendly EPS would have the capacity to initially reduce dust generation due to the physical bonding of fine soil particles by the polymer and secondly producing a vegetative cover that lasts over time by making the high salinity soil more capable of supporting vegetation.

Understanding the long-term impacts of biopolymer application is complex, and spatially-explicit modeling can provide a relatively inexpensive tool that can explore how biopolymer application perpetuates through the ecosystem, with the potential for being a solution that does not require repetitive applications. Modeling of these alternative scenarios to fully understand the benefits of such efforts in terms of predicted dust reduction effectiveness over the entire Salton Sea area and under projected future conditions can be conducted by modifying an existing Salton Sea Simulation Model (Kjelland, 2008; Kjelland and others, 2014). The model could be upgraded with the development of an air quality sub-model to examine the effects of a non-treatment, that is, do nothing, scenario (control) versus data generated from the proposed treatment scenarios.

Justification

The Salton Sea area has been designated by the EPA as a PM_{10} non-attainment area. The reduced air quality and projected future conditions necessitate an environmentally sound, cost-effective treatment option to stabilize soil from dirt roads and exposed areas as the Salton Sea recedes. The treatment option should not exacerbate water quality issues that could negatively impact biota in and around the Salton Sea. Notably, as the Salton Sea recedes the exposed areas could be treated with magnesium chloride, but there is always the possibility that the rain events

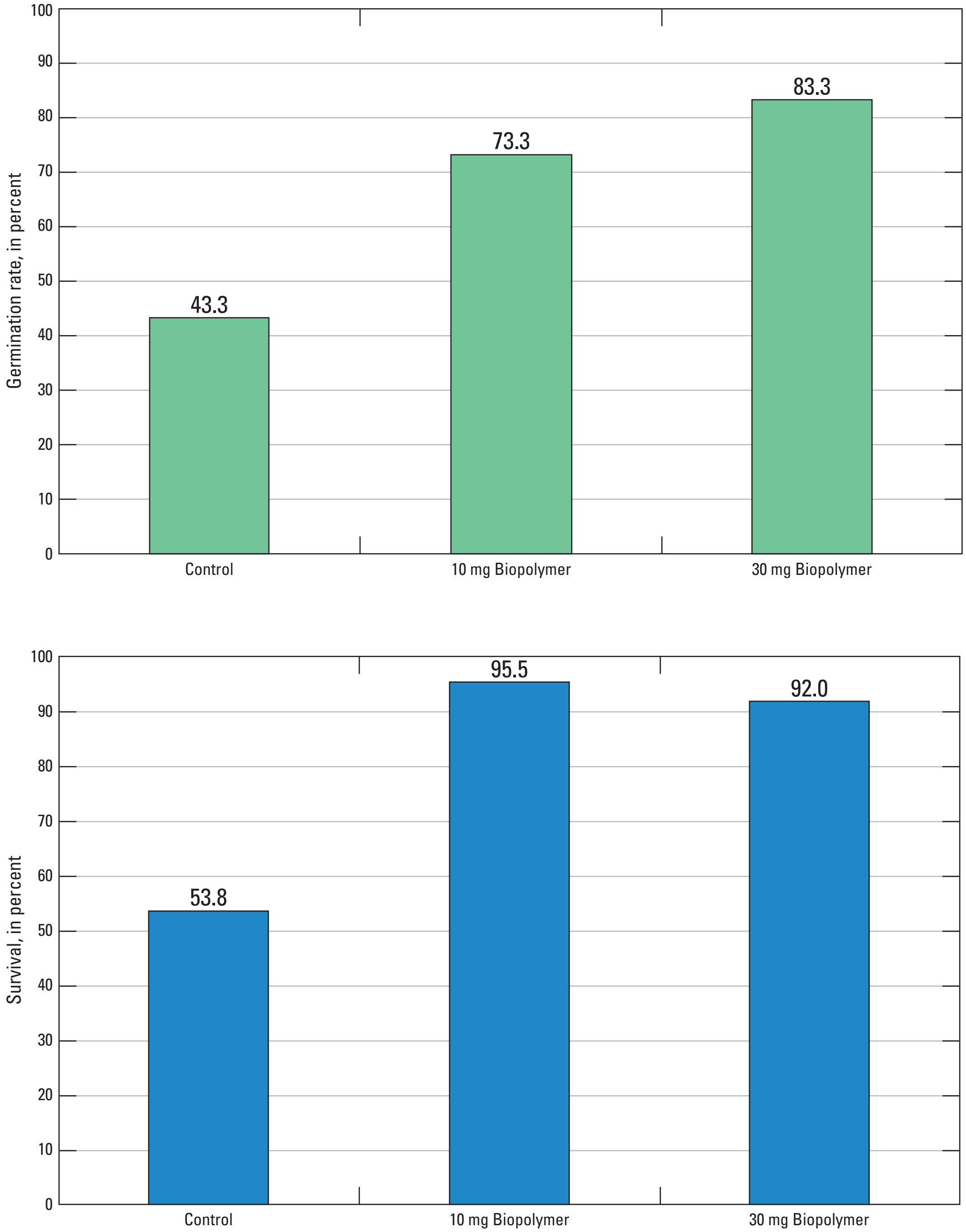

Figure 5-1. Biopolymer application increases germination rate (top) and the plant survival (%) during drought.

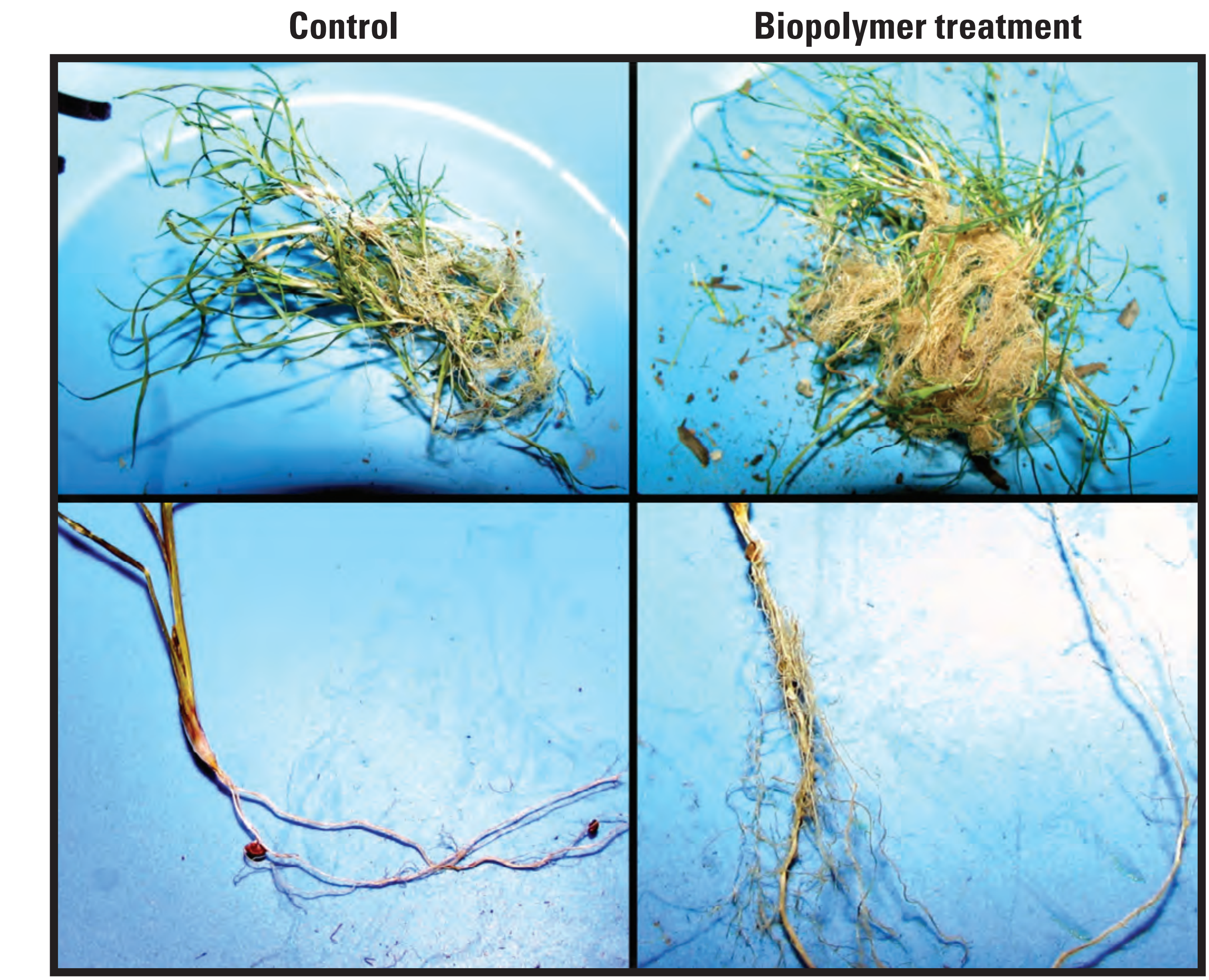

Figure 5-2. Biopolymer application demonstrates increased resistance to water erosion as a result of an increased root mass as well as root fine structure.

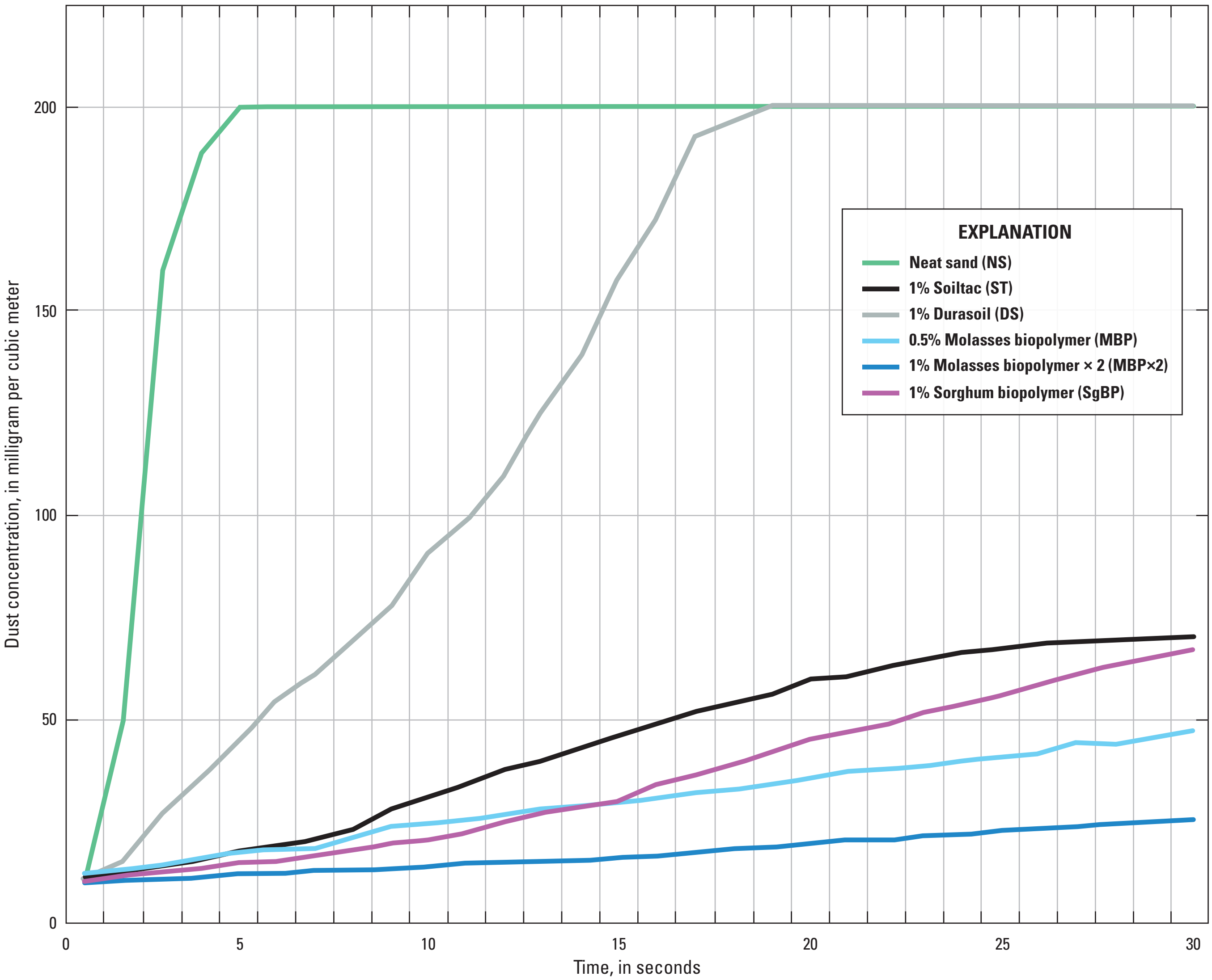

Figure 5-3. Biopolymer application demonstrates increased resistance to wind erosion compared to traditional petroleum-based soil amendment.

could cause erosion of the material into the Sea or the Sea could rise (for example, hurricane induced precipitation event) thereby inundating the treated area. The aforementioned possibilities exclude the use of petroleum based soil stabilization treatment options.

The Salton Sea project will benefit from the use of the *R. tropici* biopolymer soil amendment in several ways:

- The use of a biopolymer soil amendment will reduce the use of petroleum-based soil modifiers for soil strengthening and erosion control. This will eliminate the generation and leaching of hazardous petroleum-based products and by-products;
- Decreased maintenance/ irrigation requirements;
- Revegetation using the biopolymer requires less watering for seedling establishment and maintenance, which conserves water resources;
- Reduction of soil loss through wind and water erosion will protect surface water quality;
- Reduced road maintenance will decrease financial and labor requirements of the project

Objectives

Bench Scale

- Evaluate EPS production of several bacterial strains known to be salt tolerant and determine if the EPS can be produced and concentrated in a commercial manner;
- Evaluate the characteristics of the EPS for plant growth promotion and soil stabilization.

Field Scale

- Determine how well several dust abatement treatments including the following: a) the *R. tropici* biopolymer, b) Magnesium chloride, c) Salton Sea water, and d) no treatment (control) might affect vegetation growth on exposed areas near the Salton Sea as a means of soil stabilization;
- Determine how well several dust abatement treatments including the following: a) the *R. tropici* biopolymer, b) Magnesium chloride, c) Salton Sea water, and d) no treatment (control) compare in terms of effectiveness at reducing fugitive dust emissions from dirt roads near the Salton Sea, in order to compare the costs versus benefits of each treatment (or none, that is, control);
- Determine how well several air-borne particulate abatement treatments including the following: a) the *R. tropici* biopolymer, b) magnesium chloride, c) Salton Sea water, and d) no treatment (control) compare in terms of effectiveness at reducing air-borne particulates from different soil types at and within the Salton Sea, in order to compare the costs versus benefits of each treatment (or none, that is, control);
- Development of an air quality module to be incorporated into Salton Sea Simulation Model. Comparison of model scenarios that explore ecosystem level impacts of treatment versus control (no treatment) of *R. tropici* biopolymer application.

Products

Peer-Reviewed Journal Articles

Air quality model addressing Salton Sea projected elevations and selected treatment versus no treatment (control) scenarios and associated impact on air-borne particulate production at the Salton Sea.

Technical Reports

A report summarizing the results which will include recommendations for implementation of biopolymer soil amendment as it pertains to the Salton Sea Watershed. The report will be published in the scientific peer reviewed literature.

The Process for Integration

The findings from this study will be vital for determining the costs and benefits of alternative dust abatement measures that may be incorporated in scaled-up versions of the project for dust control within the Salton Sea Watershed.

How Does This Project Inform Management?

The findings from this project will elucidate best management practices which can then be directly applied to long-term solutions and coordinated with project and program decisions for possible full-scale implementation.

Budget

$1,295,500

The proposed project will require $1,295,500 for the three-year effort. This will include Federal labor and biopolymer production.

Point of Contact

Michael E. Kjelland

AQ5. Toxic algae as a human health risk in a receding Sea environment.

A significant component of the algal blooms at the Salton Sea are Cyanobacteria (Carmichael and Li, 2006; Reifel and others, 2001; Reifel and others, 2002). Certain groups of cyanobacteria produce various toxins. The Salton Sea produces an unknown amount of cyanobacteria, and as the salinity increases a greater biomass of cyanobacteria will be produced as they are capable of surviving elevated salinities. More than 40 species of cyanobacteria produce a range of cyanotoxins, some with well documented toxic effects, but many others are less well known (Stewart and others, 2009). Cheng and others (2007) report that cyanobacteria present several routes of exposure for human health concerns, including ingestion of water, dermal contact with water, and inhalation of aerosols from wind-generated wave action. Perhaps a more prominent mechanism for cyanotoxin exposure at the Salton Sea could be inhalation of aerosolized microcystins entrained in fugitive dust on exposed playa as the Sea recedes.

One of the most common cyanotoxins documented worldwide are microcystins. Microcystins may adsorb onto naturally suspended solids and dried crusts of cyanobacteria and can precipitate out of the water column and reside in sediments for months (D'Anglada and others, 2015). Some studies suggest that aerosolized cyanotoxins may constitute a significant risk factor for the development of Amyotrophic Lateral Sclerosis and other neurodegenerative diseases in desert ecosystems (Cox and others, 2009; Craighead and others, 2009). Metcalf and others (2012) further suggest that the concentration of microcystins detected in desert crust has important implications for human health.

Richer and others (2015) stated in part, "low molecular weight cyanotoxins produced by biological soil crusts are persistent in the environment, and can survive even the removal of the crusts themselves. Thus, over many years a potentially large reservoir of cyanobacterial toxins can accumulate in desert soils, with possible health consequences for human exposure to particulate matter in dust storms, and from disturbance of desert soils from construction activities and military activities that result in loss of soil structure. Mechanical disturbance of either surface or below surface on dry or wet soils may equally contribute to human exposure to cyanotoxins through inhalation."

Beyond the potential for adverse effects on human health, there are other considerations for the effects of cyanotoxins. Corbel and others (2014) observed that terrestrial plants including agricultural crops, are capable of cyanotoxin bioaccumulation, thus presenting additional potential human health risk through consumption of affected food crops. Investigations into the potential human health risk of airborne particulate matter containing these microcystins from exposed playas could shed new emphasis on the already important issue of fugitive dust control.

No proposal submitted but identified as an urgent need.

Budget

$1,250,000

Point of Contact

Jason Low, Bruce Wilcox, Vic Etyemezian

Water Quality Proposals

WQ1. Energy and material fluxes across the air-water and sediment-water interfaces of the Salton Sea

Introduction

Interfacial processes regulate physical, chemical and biological conditions of lakes and reservoirs. Processes at the air-water and sediment-water interfaces are especially important at the Salton Sea due to its tremendous surface area and relatively shallow depth that can strongly link sediment biogeochemical reactions to the water column and to air quality. The vast size of the Sea results in a tremendous evaporative flux of water to the atmosphere, on the order of 1 M acre-feet of water evaporated each year. This evaporative flux is thus an important part of the water budget as well as the heat budget of the Sea. The exchange of heat across the air-water interface, combined with wind-forcing, regulates the temperature, stratification, and mixing of the water column, as well as dissolved oxygen (DO) concentrations, rates of sulfate reduction and accumulation hydrogen sulfide (H_2S), ventilation of H_2S, dimethyl sulfide (DMS) and NH_3 to the atmosphere, fish kills, and a host of other conditions.

Justification

Understanding the water quality, air quality, habitat value and functioning of the Salton, both in its present configuration and in the future, as well as Species Conservation Habitat, requires improved understanding of the energy and material fluxes across the air-water and sediment-water interfaces, and the processes regulating these fluxes. While previous research has gone some of the way to understanding these processes in the current Sea, the magnitude of changes likely in the future Sea and species conservation habitat ponds are so large that the underlying physics and chemistry will be very different, and outside the range of experience globally.

Objectives

The objectives of this study are to quantify the fluxes of energy (both heat and energy) and material across the air-water and sediment-water interfaces of the Salton Sea, including Species Conservation Habitat.

Approach

Energy and material fluxes, and the processes regulating these fluxes, on the Salton Sea and Species Conservation Habitat will be quantified through direct measurement, remote-sensing and numerical modeling. Measurements will include *in situ* water column profiles of temperature, DO, pH, redox, turbidity, and chlorophyll-*a* concentrations, as well as H_2S and NH_3 levels in the water column, sediment porewater and air phases. Eddy covariance measurements will be conducted to quantify fluxes of H_2S, NH_3, CO_2 and heat to the atmosphere. In addition to measurements at discrete locations at the Sea, the surface temperature field and upwelling events will be determined from remote sensing. Numerical models will be calibrated against available historical data and new *in situ* and remote sensing measurements. Meteorological data from California Irrigation Management Information System stations around the Sea will be used with the watershed-agricultural water budget model to drive the 3-D hydrodynamic-water quality model. Following calibration and validation, the numerical model will be used to forecast future water quality, pelagic and benthic habitat quality and air-quality under reduced inflows, assess management alternatives, and guide adaptive management of the Salton Sea and Species Conservation Habitat. A 3-D hydrodynamic model will simulate physical conditions at the Sea, including stratification-mixing, internal seiche development, shoreline migration, and wave-mixing/sediment resuspension. The hydrodynamic model will be coupled to a water quality model that will simulate DO, pH, chlorophyll *a*, H_2S, NH_3, sediment diagenesis, including C burial, and potentially also zooplankton and fish. The coupled hydrodynamics-water quality model will also be used to predict emissions of H_2S and NH_3 to the atmosphere and include daily volatilization fluxes as well as episodic destratification/upwelling events.

Products

The key products of this project include rigorous assessments and assessment tools for the management of air, water and ecological resources at the Sea. A numerical model and a series of reports, dissertations, theses, and peer-reviewed publications will be developed from this comprehensive study.

Budget

	Year 1	Year 2	Year 3	Total
Personnel				
Faculty (3 @0.25 FTE)	112,500	112,500	112,500	337,500
Postdocs (1)	80,000	80,000	80,000	240,000
Graduate Students (3)	120,000	120,000	120,000	360,000
Undergraduate Students (2)	20,000	20,000	20,000	60,000
Equipment	100,000	25,000	0,000	125,000
Supplies	40,000	40,000	25,000	105,000
Travel	60,000	60,000	60,000	180,000
Total Direct Costs	532,500	457,500	417,500	1,407,500
Indirect costs (50%)	216,250	216,250	208,750	641,250
Total	748,750	673,750	626,250	2,048,750

Point of Contact

Michael Anderson, Geoff Schladow, Michael Goulden

WQ2. Integrated water-balance simulations under changing management and climate scenarios

Introduction and Background

The QSA of 2003 has drastically lowered the amount of inflows to Salton Sea, resulting not only in changes to the amount of water in the Sea, but also in changes the geochemistry and the overall water quality. These changes will have unknown and potentially significant effects on the population dynamics of numerous species.

The ability to estimate and forecast these changes, and then understand how management actions further change the system, begins with comprehensive understanding and ability to manage the water resources, which requires extending the capabilities to analyze the movement and use of water throughout the hydrologic cycle in a process-based context. A straightforward way to do this is the development of a model that provides a connection to both natural and anthropogenic uses of the water throughout the simulated hydrosphere in the context of a supply-and-demand framework of movement and use.

Substantial data and several models have been developed for this area. The Army Corp of Engineers has a model of the Lower Colorado River Basin (LCRB), which includes the Salton Sea Model (SSM, fig. 5-4). The model is a spatially explicit, stochastic, simulation model representing water flow, water volume and quantity of Total Dissolved Salts (TDS) and Phosphorus (P), in the LCRB as it enters the Salton Sea. This model is an integrated hydrodynamic-ecological model that simulates hydrodynamics, nutrient cycling, and population dynamics of several species of birds and fish. The model was developed, evaluated, and applied to simulate the potential effects on the population dynamics of selected fish and avian species at the Salton Sea under six different management scenarios (Kjelland, 2008; Kjelland and others, 2014).

MODFLOW is a USGS three-dimensional finite-difference groundwater model which can be used to delineate structures such as sand and clay materials and give high resolution

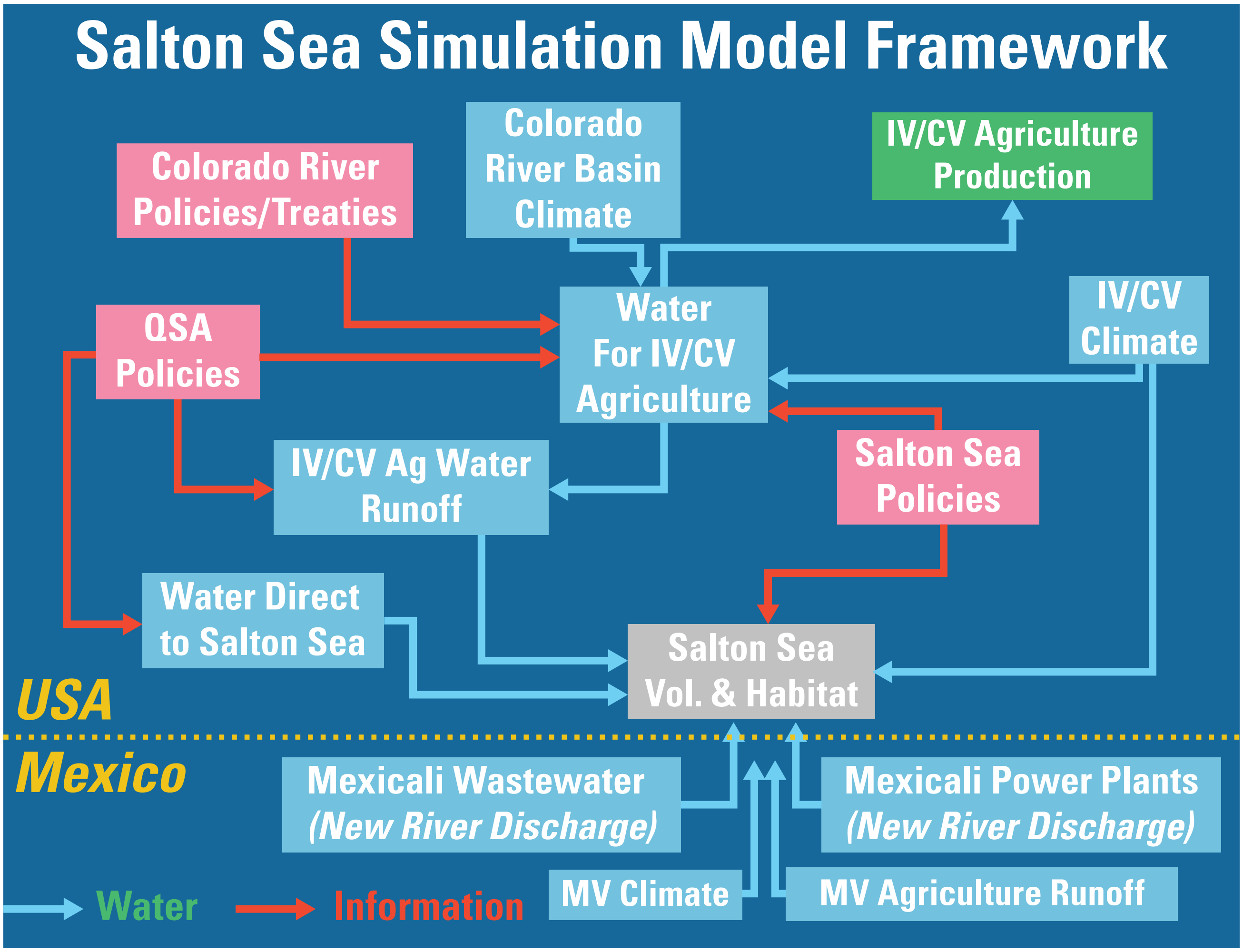

Figure 5-4. Salton Sea Conceptual Model—generalized components. CV, Coachella Valley; IV, Imperial Valley; MV, Mexicali Valley.

assessment of groundwater movement. Lawrence Livermore Laboratory developed a version of MODFLOW for the Bureau of Reclamation in order to evaluate groundwater resources in the Imperial Valley. The model focused on the impacts of lining the All American Canal, production scenarios in West Mesa, and potential aquifer storage and recovery in East Mesa (Tompson and others, 2008).

A new version of MODFLOW is now available. This version includes a deformable mesh that can simulate deformation from geothermal activities and land subsidence. The model incorporates this deformation into surface-water flow and other landscape processes. Another new feature is the Farm Process that adds ability to dynamically simulate the integrated supply-and-demand components of irrigated agricultural, and fully integrating the groundwater model and the surface water simulation capabilities.

Justification

All of the proposed actions for restoring the ecosystem of the Salton Sea are constrained by water and funds. Ultimately, the plans under consideration now for incremental habitat development, use of water for dust control, and possible water quality improvement via algal scrubbing must be based on realistic estimates the availability and quality of water delivered to the Sea. A spatially distributed integrated hydrologic model would allow the managers to more accurately quantify the amount and movement of water and to test possible scenarios such as climate changes and management strategies.

Objectives

We propose to update and modify the SSM by creating a spatially distributed model that will give the land managers a more explicit and quantitative way to determine the effects of possible management scenarios, including alternative cropping and irrigation practices that are currently not included in the SSM. As part of this model creation, we will compile historical data as well as develop new data sets, generating model input regarding wells, canals, service areas, habitat regions, Salton Sea attributes and geohydrologic framework attributes. We will also extend the current analysis of landscape energy balances with additional remote sensing and meteorological data analysis to develop detailed land-use data and consistent time-series estimates of actual evapotranspiration (ET) rates.

This will allow quantification of the physical, chemical and biological responses of the Salton Sea to the amount and type of water that is released to it. Specifically, this model will integrate surface-water flow with groundwater use to evaluate the quantity and quality of water delivered to the Salton Sea, and ultimately will allow us to identify the suite of scenarios that will maximize the wise use of water resources. The model can specifically address

- The rate at which the elevation of the Salton Sea will decline
- Effect of local groundwater inputs on the Sea elevation
- The effects of various cropping and irrigation management strategies
- Determination of evaporation rates
- Effects of changing agricultural practices on quantity and quality of water reaching the Sea (surface water, tile water, and groundwater)
- Integrate water use for dust control
- Integrate water use for incremental wetlands development
- Integrate water use for algae scrubbing

Products

A modeling tool that integrates the spatially-explicit, stochastic-simulation Salton Sea model with the spatially-distributed hydrologic model. This will be overlain with a graphical user interface (GUI) to allow scientists and mangers to evaluate various management scenarios. Peer-reviewed journal articles will be developed that describe new model components and how those components affect model dynamics.

The Process for Integration

The findings from this project can be applied to long-term solutions and coordinated with project and program decision-making processes for potential full-scale implementation of those scenarios resulting in preferred outcomes.

How Does This Project Inform Management?

Adding a more detailed hydrodynamic code to the SSM would provide a more explicit and quantitative way of testing management scenarios while gaining a better understanding of how a management action would affect the greater Salton Sea ecosystem. This would lead toward better-informed decision-making via an integrated and coupled-systems dynamics modeling approach for determining the long-term costs and benefits of different action scenarios.

Budget

		Year 1	Year 2	Year 3
Senior Scientist	2.12 years			
	Build/Calibrate Model	428,000	200,000	
	Build/Refine GUI		173,600	
	Automate GUI data uploads/downloads		75,600	
	Model transfer and instruction			48,000
	Write report/model archive		190,000	208,800
Scientist/Tech	2.83 years			
	Data Assembly and Analysis, including GIS	578,500		
	Build/Calibrate Model	93,600		
	Model transfer and instruction			31,200
	Write report/model archive		189,000	55,800
Supplies		30,000	30,000	30,000
Travel		25,000	30,000	25,000
Yearly Total		1,155,100	888,200	398,800
TOTAL				2,442,100

Point of Contact

Michael E. Kjelland, Ph.D., and Debra S. Curry

WQ3. Monitoring for adaptive management

Introduction and Background

Monitoring is a critical component of any Sea management project. It is required to define baseline conditions, to determine the effectiveness of any control measures that are implemented, to calibrate/validate modeling efforts, and to evaluate the applicability of models that are being used to guide future actions.

Justification

Continued monitoring of the remnant Salton Sea is needed to evaluate changes that are occurring as a result of decreasing water inputs, to evaluate Sea modeling efforts, and to evaluate the effectiveness of watershed management measures. Monitoring will be required to assess the conditions in the habitat ponds to ensure that they are functioning as predicted and meeting adaptive management targets. Results can be used to make any necessary changes in operations to ensure that project goals are being met.

A basic monitoring program for the Sea would build on the current Bureau of Reclamation and USGS programs that include quarterly monitoring at three locations within the Salton Sea and the three river inlets, inflows, and Sea elevation. Data collected by the program includes profiles for temperature, dissolved oxygen, pH, and conductivity; nutrients; major ions; total and dissolved solids; selenium; and total and organic carbon. Chlorophyll *a* is also included as a measure of primary production.

Habitat ponds will require monitoring on a monthly basis, at a minimum, for the same variables measured in the Sea to evaluate mixing and water quality and to provide data for hydrodynamic and water quality modeling in the ponds. Thermistor chains and other unattended sampling devices should be deployed to adequately describe mixing.

The habitat ponds are likely to require extensive additional biological monitoring and monitoring for toxins and other compounds of interest. Monitoring for those projects would be covered under separate proposals.

Objectives

- Develop monitoring plans for both habitat ponds and the remnant Salton Sea;
- Ensure that sufficient boat access is available at the Salton Sea and habitat ponds to enable data collection;
- Include sufficient sites/variables to support modeling efforts and address other research questions;
- Obtain detailed profile data in the habitat ponds to define their thermal structure and dissolved oxygen conditions;
- Create a data repository to ensure that all data collected are accessible and available for use on future projects. If possible, this would be compatible existing State of California databases.

Products

- Current data on chemical and biological conditions in habitat ponds and the remnant Sea to support chemical and hydrological modeling efforts
- Infrastructure to provide required information on Sea level and river inflows
    - Maintain gaging stations on the Alamo, New, and Whitewater Rivers (currently provided by USGS. May require additional funding in the future.)
    - Maintain the existing water level gage near Westmoreland (provided by USGS) and add two additional stage level gaging stations on the north and west sides of the Sea to provide information on seiches and water circulation
    - Maintain boat access to the Sea and provide boat access at each habitat pond (provided by IID)
- Quality assurance plans for each project involving monitoring
- Data repository for all Salton Sea monitoring data

How Does This Project Inform Management?

Data collected by the monitoring efforts will provide a sound, scientific basis for evaluating the success of proposed management efforts. It will also be used to guide adaptive management as management efforts continue.

Budget

	Year 1	Year 2	Year 3	Year 4	Year 5
Senior Scientist to oversee the monitoring program	$37,500	$37,500	$37,500	$37,500	$37,500
Senior Scientist to develop and maintain a data	$15,000	$15,000	$15,000	$15,000	$15,000
Technical support (2) to collect and process samples	$40,000	$40,000	$40,000	$40,000	$40,000
Laboratory costs = (will depend on the number of sites selected and variables included)	$120,000	$120,000	$120,000	$120,000	$120,000

	Year 1	Year 2	Year 3	Year 4	Year 5
Operation of water level stations (3 at $25,000 each)	$75,000	$75,000	$75,000	$75,000	$75,000
Supplies and boat maintenance	$20,000	$20,000	$20,000	$20,000	$20,000
Equipment	$270,000	$80,000			
Travel	$10,000	$10,000	$10,000	$10,000	$10,000
Overhead (50% of salaries)	$46,250	$46,250	$46,250	$46,250	$46,250
	$713,750	$443,750	$363,750	$363,750	$363,750
Grand total					$2,248,750

Point of Contact

Chris Holdren, Michael Anderson, Geoff Schladow, Deborah Curry

WQ4. Modeling the plagues and pleasures of variable-sized water bodies at the Salton Sea

Introduction

The thermal structure (or stratification) of lakes is determined by both external factors, such as inflows, outflows, and meteorological conditions through their effects on heat fluxes and mixing processes, and intrinsic factors such as basin morphometry (geometry). The geometric properties of a waterbody (length, area, depth) play a large role in controlling the mixing regime. Vertical mixing and the associated transfer of oxygen into the Sea and dissolved gases (for example, H_2S) out of the Sea are already known to be controlled by the size of the Sea.

Under the present range of alternatives being considered, the present Salton Sea will inevitably change in size, form and composition. The spectrum of possibilities will include a shrinking Salton Sea, Species Conservation Habitat ponds (SCH) of variable shape and depth, and channels. The shrinking Sea (or the alternative of a separate brine sink) is inevitable. Its hypersaline nature (and the associated changes in physical properties) will make it unique in many respects and represent a major challenge in accurately modeling. Stratification will increasingly be influenced by the growing density difference between the Sea and the principal inflows from the New and Alamo Rivers. It will still be large, possibly the largest water body in California, meaning that its complexity and its influence locally and regionally will be profound.

Within this context of changing physical processes, biological and chemical processes will be taking place. Some of these processes are reasonably well understood, but as conditions change our understanding of the processes diminishes significantly. Some of the key information gaps are addressed in a separate proposal (see WQ1).

Some of the key issues that a modeling approach need to address include predictions of the distribution of nutrients that will occur, based on the evolving set of physical processes. They will dictate primary productivity, which in turn will alter oxygen distribution. The oxygen distribution is one of the controlling factors for Sea chemistry, impacting H2S and NH4 release, fish survivability, carbon sequestration potential and heavy metal release.

Justification

- In order to understand the suitability (and ultimate habitat success) of particular aquatic habitats for their intended purpose, it is critical to understand (through modeling and associated monitoring) the thermal, biological and chemical conditions of the waterbody and how these conditions vary at timescales ranging from daily, through seasonal, annual and decadal. This includes temperature, salinity, DO, algal concentration, and if necessary toxins/contaminants;

- The future episodic releases of H_2S and NH_4 may increase in intensity, as venting to the atmosphere is likely to occur less frequently in smaller water bodies. Understanding the mechanisms and likelihood of massive gas releases, and devising operating strategies to reduce the human health effects, is critical;
- Soil carbon preservation and sequestration potential can only be undertaken when accurate projections of primary productivity and respiration are possible;
- Modeling is the only available tool to assess the impacts of climate change on all future Salton Sea strategies. Using regionally downscaled (5 km) projections of climate for the next 100 years under a range of carbon emission scenarios, the models can be run to see whether the strategies and practices that seem appropriate under today's conditions are in fact sustainable in the face of expected climate change.

Objectives

1. To modify the existing numerical models (3D and 1D) developed for the Salton Sea under earlier funding, to represent the broad range of possible water bodies (remnant Sea, SCH, channels) that may emerge at the Salton Sea.
2. To model the physical (thermal regime, salinity regime, light regime, circulation, upwelling, mixing); biological (primary productivity, respiration, zooplankton, macro-invertebrate and fish grazing); and chemical (H_2S, NH_4, DO regimes) processes in a remnant Sea, habitat ponds of various configurations and channels.
3. Devise geometries and operating strategies to maximize habitat potential, carbon sequestration, and water quality, while at the same time minimizing adverse conditions that lead to emissions of H_2S and NH_4.

Products

- A set of process-based, numerical models (3D and 1D) incorporating the relevant physics, biology, and chemistry (including the proposed air-water and sediment-water research). These models will serve as assessment and management tools available in the public domain.
- Model results for a range of water-body configurations developed in consultation with resource-agency management.
- Recommendations for best practices in the design and operation of habitat ponds to maximize project objectives and minimize adverse outcomes.
- New understanding on the expected behavior of hyper-saline lakes, and the unique biogeochemistry of the Salton Sea.

How Does This Project Inform Management?

The products will directly inform management on the feasibility, likely success potential, pitfalls and sustainability of the full spectrum of Salton Sea alternatives. In addition, by engaging management directly in the formulation of the scenarios to be modeled, it will help formulate a reduced set of alternatives for consideration.

Budget Proposal

This is recommended to be a three-year proposal. It is critical that information to be developed in WQ1 be incorporated into the models.

Budget

	Year 1	Year 2	Year 3
Senior Personnel	300,000	300,000	300,000
Staff/Students	192,000	192,000	192,000
Equipment	50,000	30,000	20,000
Travel	10,000	10,000	10,000
Overhead (50% of salary)	246,000	246,000	246,000
	798,000	778,000	768,000
Grand total			2,344,000

Point of Contact

Geoff Schladow, Michael Anderson, Fabian Bombardelli, Lisa Windham-Meyers

Contaminants Proposals

CONTAM1. Identifying variation in selenium risk to wildlife in the Salton Sea basin related to wetland management and management strategies.

Introduction and Justification

Management of ecosystem services originally provided by the Salton Sea involves construction of wetlands that also require mitigating ecological risks due to tradeoffs between limited availability of clean water and elevated environmental contaminants in agricultural drain water. In particular, selenium (Se), an essential element that rapidly becomes toxic at low doses (Hamilton, 2004), occurs at concentrations approaching and often exceeding toxicity thresholds in agricultural drain water flowing into the Sea. The risks to wildlife from using selenium-laden drain water for wetland creation that can ultimately lead to ecological disasters have been well documented (Skorupa, 1998; Ohlendorf, 2002). However, use of Colorado River water for Salton Sea management is not permitted by the QSA. Thus, the only water sources allowable for wetland management are agricultural drain water in drains and rivers and the Salton Sea. Habitats developed with these sources of water will incur varying levels of risks to wildlife.

Hence, monitoring variation in selenium exposure to wildlife (especially foraging and breeding waterbirds) and accumulation in representative sample matrices across time and space is a critical component of any Salton Sea management effort. In addition, different wetland types with varying salinity regimes and inflows of agricultural drain water will result in different community structure/food-web dynamics and associated routes of trophic transfer of selenium and rates of bioaccumulation. Importantly, these wetlands provide a natural experimental study design with replicated treatments to explicitly evaluate Se risk related to specific management practices in a rigorous fashion. Source water and salinity from these wetlands include 1) a blend of water from agricultural drains and the Salton Sea (for example, Species Conservation Habitat-New River Delta, Redhill Bay), pure agricultural drainwater (for example, Morton Bay, Imperial/Brawley wetlands [New River], and Shank wetland [Alamo River]), and direct deliveries of Colorado River water (for example, waterfowl ponds, IID Managed Marsh). The blended-water approach aims to dilute high selenium agricultural water with low selenium Salton Sea water, which is predicted to reduce Se risk. Wetlands flooded with agricultural-drainage water, especially those with emergent vegetation, are predicted to have the highest Se risk. A statistically rigorous sampling strategy of biota inhabiting these marshes with adequate sample size and seasonal controls will allow the following objectives to be achieved.

Objectives

- Quantify selenium risk to insectivorous waterbirds in invertebrate taxa in each wetland management treatment representing benthic (for example, Chironomidae—midge larvae), epipelagic (for example, Corixidae—waterboatmen) or epibenthic (Ephydridae—brine flies) based food-webs;
- Quantify selenium risk to piscivorous waterbirds in fish taxa occurring semi-naturally (for example, CarbonMosquito fish, sail-fin molly) and intentionally stocked (for example, tilapia) taxa in each wetland management treatment; and
- Measure rates of selenium bioaccumulation taxa in each wetland management treatment via caged fish experiments;
- Leverage collected data against existing baseline pre-management at blended water sites and existing Colorado River (for example, Miles and others, 2009; Sickman and others, 2011; A.K. Miles and M.A. Ricca, unpub. data, 2011).

Products and Integration

- Synthesized Se risk assessment for wetlands that will mitigate for the decline and inevitable ecosystem state transition of the Salton Sea;
- Establishment of standardized Se monitoring protocol in for managed wetlands, which will provide the framework for a comparable and repeatable data over time, with appropriate matrices, and facilitate hypothesis testing;
- Selenium in water and sediment alone do not strongly predict bioaccumulation of Se in upper trophic levels (Hamilton, 2004). However, additional development of Kd and trophic-transfer coefficients can be accomplished by working in collaboration with researchers quantifying water and sediment sampling for selenium, including studies of sediment and water biogeochemistry and selenium speciation;
- Collaborative work with associated pesticide monitoring in ag source waters;
- Samples can be archived or collected simultaneously for analysis of current use or legacy pesticides.

Management Implications

Previous sampling efforts aimed at measuring risk, while highly informative, have generally been disjointed and piecemeal. It is predicted that blended water marshes will have diminished risk relative to those with maintained entirely with agricultural drainwater. This risk assessment may be flexible for selenium waterborne concentrations near the EPA threshold of 5 μg/L particularly in high sulfate-rich saline waters.

Budget

	Year 1	Year 2	Year 3
Salary: PI	75,000	75,000	75,000
Salary: Staff	120,000	120,000	40,000
Analytical (Se @ 125 Sample)	150,000	150,000	
Supplies	5,000	5,000	
Travel	15,000	15,000	10,000
Total Direct	365,000	365,000	125,000
Indirect (50%)	182,500	182,500	62,500
Total	547,500	547,500	187,500
Grand total			1,282,500

Point of Contact

Mark A. Ricca, Ph.D.

CONTAM2. Synthesis of existing environmental contaminants data for the Salton Sea

Introduction and Background

A common refrain among stakeholders is that the Salton Sea has been "studied to death." While a great deal of research has been completed at the Salton Sea, much of it has been short-term and focused on specific topics without good integration across time and space. There is a need to assimilate these disparate efforts into a more cohesive whole in order to make sense of the vast volumes of data that are available across the 50-plus years and full areal extent of the data collection efforts. This is true for the study of environmental contaminants as much as any other subject of study that has been undertaken at the Salton Sea and its environs.

As a result of the 1999–2000 studies and the creation of the Salton Sea Database by the University of Redlands, a great deal of collection has already been achieved. Work still remains to improve on those data and more collected since that time. A primary effort remains to organize and evaluate the information in a way meaningful to the development of a comprehensive model of contaminant transport and fate in the agro-ecosystem of the Salton Sink.

Justification

Because there is much information awaiting discovery in existing environmental contaminants data sets, we are proposing to pursue an effort to assimilate the available information into an organized data set that can then be analyzed for patterns that were not clear from any one investigation alone. Selenium is a systemic concern; this element is brought in with the water used for irrigation and is then distributed throughout the irrigated portions of the Imperial and lower Coachella valleys. Pesticides are also of concern, and the use and risk varies over time as crops change and new pesticides become available. As a result of a variety of initiatives (Salton Sea Science Subcommittee, Imperial Irrigation District water conservation and transfer projects, Coachella Valley Water District water management planning, Regional Water Quality Board impaired waters evaluations, etc.), a great deal of information has been gathered over time using a variety of methods and presented in a variety of formats. A more coherent picture of contaminant transport, fate and impacts is available if adequate time could be dedicated to a focused effort to organize the data, integrate them in temporally and spatially meaningful ways, and assess potential risks to human health and the environment associated with existing patterns of water movement throughout the system. This will establish a baseline and context for all other studies of contaminants relative to planned habitat projects and management scenarios associated with Salton Sea management.

Objectives

- Establish a complete of data set for contaminants in the Salton Sea as possible using existing bibliographies, public documents and expert interviews;
- Organize those data based on spatial and temporal configurations of data collection;
- Examine the data set using a variety of investigative and statistical techniques to elucidate patterns that assist in identifying sources, transport mechanisms, and fate associated with contaminants in the Salton Sink;
- Using the patterns developed, identify gaps on our information that need to be filled; and
- Assess risks to human health and wildlife, acknowledging the uncertainties associated with existing information gaps.

Products

A comprehensive database of information collected to date would be provided as a result of this effort. A written report would be developed that would provide a thorough description of the various data collection efforts that have been incorporated into the new database, spatial and temporal scales used in the collection efforts, patterns identified in contaminant fate and transport, information gaps, a risk assessment based on this information, and any management recommendations coming out of this effort.

Process for Integration

The purpose of the effort is to integrate all of the available information for contaminants. This will need to be considered in the context of current trophic structures in the Salton Sea and in constructed habitats in the Salton Sink. This will also need to link to the practices and processes that provide the inputs of contaminants to the Salton Sea habitats.

Project Information for Management

As a final product of this effort, it is hoped that recommendations will be developed to optimize the form and function of existing and constructed habitats to maximize the net environmental benefit that can be achieved with those efforts. Include discussion here or separately the need for a database management and document archiving system.

Budget

	Year 1	Year 2	Year 3
Senior Researcher	25,000	25,000	25,000
Graduate students	80,000	80,000	40,000
Travel	5,000	5,000	5,000
Equipment / computer time	5,000	5,000	5,000
Overhead 50(% of salary)	52,500	52,500	31,500
	177500	177500	106500

	Year 1	Year 2	Year 3
Grand total			461,500

Point of Contact

Boykin Witherspoon

CONTAM3. Concentrations of pesticides and selenium in fugitive dust, Imperial Valley, CA

Introduction

It is estimated that up to 95% of California's wetland habitat has been lost to development and agriculture in the last century (Dahl, 1990). With this loss of habitat, the Salton Sea has become a critical area of refuge for birds along the Pacific Flyway. Over 420 species of birds have been documented at the Sea with more than 270 species using it on a regular basis. - These include 19 species that are listed by either the Federal government or the State of California as endangered, threatened, or of concern. The Salton Sea resides in a closed basin at the northern end of the Imperial Valley and water levels are sustained almost entirely by agricultural runoff.

Water transfer agreements negotiated between the Imperial Irrigation District and Metropolitan Water District and with the San Diego County Water Authority have begun to reduce the amount of water entering the Salton Sea. This reduction in inflows has caused the level of the Sea to drop nearly 2.5 feet over the last 5 years, reducing available habitat and exposing large areas of sediments. Under current conditions, areas of the Imperial Valley frequently exceed PM_{10} non-attainment thresholds. Additionally, the Imperial Valley has one of the highest childhood asthma rates in California. Newly exposed lakebed sediments are likely to become airborne during wind events in the Imperial Valley. Sediments at the Sea are known to contain elevated concentrations of both pesticides and selenium (LeBlanc and others, 2004a, b).

Justification

Many areas within the Imperial Valley frequently exceed PM_{10} threshold values. There is a lack of information on concentrations of pesticides and selenium in airborne dust in the Imperial Valley and this project would provide critical information on this subject to resource managers in the region.

Objectives

- Document concentrations of over 125 current-use and legacy pesticides and selenium monthly in atmospheric dust from six monitoring sites in the Imperial Valley for a period of two years;
- Document pesticide and selenium concentrations associated with up to five dust-storm events;
- Provide results and interpretation of data to stakeholders and the public.

Products

- Quarterly reports;
- A peer-reviewed final report;

- All laboratory results from this project will be entered into the USGS National Water Information System database.

Information to Management

Results from this study will help inform State agencies and resource managers of the potential for human exposure to pesticides and selenium via airborne dust in the Imperial Valley.

Budget

Tasks	Subtasks	Year 1	Year 2	Year 3	Total
Task 1: Project Oversight and Reporting		$11,000	$7,000	$3,000	$21,000
Task 2: Routine Sampling and Analysis	USGS Sampling Labor	$5,000	$5,000		$10,000
	Supplies and Travel	$5,000	$5,000	$3,000	$13,000
	GC/MS Analyses	$100,000	$100,000		$200,000
	Selenium Analyses	$15,000	$15,000		$30,000
Task 3: Reporting	Interpretive Report	$2,000	$8,000	$10,000	$20,000
Cooperator Funding		$110,000	$111,000	$13,000	$234,000
USGS matching funds		$28,000	$29,000	$3,000	$60,000
Total Study Funding		$138,000	$140,000	$16,000	$294,000

Personnel

Hydrologist	(.2FTE/yr)
Research Chemist	(.1FTE/yr)
Chemist	(.2FTE/yr)

Point of Contact

James Orlando, Mark Ricca

CONTAM4. Evaluating the effects of agricultural irrigation practices on pesticide and selenium concentrations in agricultural tail water and tile water, Salton Sea, CA

Introduction

It is estimated that up to 95% of California's wetland habitat has been lost to development and agriculture in the last century (Dahl, 1990). With this loss of habitat, the Salton Sea has become a critical area of refuge for birds along the Pacific Flyway. Over 420 species of birds have been documented at the Sea with more than 270 species using it on a regular basis. These include 19 species that are listed by either the federal government or the State of California as endangered, threatened, or of concern. The Salton Sea resides in a closed basin at the northern end of the Imperial Valley and water levels are sustained almost entirely by agricultural runoff.

Previous studies by federal, state, and local agencies have documented elevated levels of both current-use and legacy (organochlorine) pesticides in water and associated with suspended and bed sediments in the Alamo and New Rivers and the Salton Sea (Crepeau and others, 2002; LeBlanc and others, 2004, b; Sapozhnikova and others, 2004). Studies have also shown that selenium concentrations are near levels of concern in surface-waters of the Imperial Valley (Miles and others, 2009). A more recent study that sampled both the Alamo and New River inputs to the Salton Sea demonstrated that the highest pesticide concentrations and the greatest loads occur in the Alamo River (Orlando and others, 2008). Additional research has sought to link these elevated levels of contaminants to effects on birds, fish, and invertebrates in the Salton Sea ecosystem (deVlaming and others, 2004; Henny and others, 2008; Miles and others, 2009).

Traditional agricultural irrigation practices in the Imperial Valley are primarily flood and sprinkler. In an effort to reduce agricultural water use in the Imperial Valley, new irrigation practices are starting to be employed and these include subsurface drip and overhead sprinkler systems. Data on the influence of these various irrigation practices on pesticide and selenium concentrations leaving fields in tail water and tile water would be value to both farmers and resource managers in the region.

Justification

Reductions is agricultural water use, coupled with water use efficiency, are goals embraced by multiple stakeholders within the Imperial Valley. Implementing changes in agricultural-irrigation practices are one means of addressing these goals. Irrigation practices are likely to influence the concentrations of contaminants (pesticides and selenium) in tail water and tile water. An evaluation of the effects of different types of irrigation on contaminant concentrations would be of great benefit to stakeholders in the region.

Objectives

- Document the occurrence of over 125 current-use and legacy pesticides and selenium in tail water and tile water from multiple agricultural fields (alfalfa) employing different types of irrigation practices;
- Provide results and interpretation of data to stakeholders and the public.

Products

- Quarterly reports;
- A peer reviewed final report;
- All laboratory results from this project will be entered into the USGS National Water Information System database.

Information to Management

Results from this study will help inform farmers, agricultural extension specialists and regional resource managers of the influence of traditional and emerging irrigation practices on pesticides and selenium concentrations in tail water and tile water.

Budget

Tasks	Subtasks	Year 1	Year 2	Total
Task 1: Project Oversight and Reporting		$11,000	$7,000	$21,000

Tasks	Subtasks	Year 1	Year 2	Total
Task 2: Routine Sampling and Analysis	USGS Sampling Labor	$5,000	$5,000	$10,000
	Supplies and Travel	$5,000	$5,000	$13,000
	GC/MS Analyses	$35,000	$20,000	$55,000
	LC/MS/MS Analyses	$18,000	$7,000	$25,000
	Selenium Analyses	$8,000	$5,000	$30,000
Task 3: Reporting	Interpretive Report	$2,000	$8,000	$19,000
Cooperator Funding		$69,000	$47,000	$116,000
USGS matching funds		$15,000	$10,000	$25,000
Total Study Funding		$84,000	$57,000	$141,000

Personnel

Hydrologist (.2FTE/yr)
Research Chemist (.1FTE/yr)
Chemist (.2FTE/yr)

Point of Contact

James Orlando, Mark Ricca

CONTAM5. Pesticide degradation in an experimental wetland, Imperial Valley, CA

Introduction

It is estimated that up to 95% of California's wetland habitat has been lost to development and agriculture in the last century (Dahl, 1990). With this loss of habitat, the Salton Sea has become a critical area of refuge for birds along the Pacific Flyway. Over 420 species of birds have been documented at the Sea with more than 270 species using it on a regular basis. These include 19 species that are listed by either the Federal government or the State of California as endangered, threatened, or of concern. The Salton Sea resides in a closed basin at the northern end of the Imperial Valley and water levels are sustained almost entirely by agricultural runoff.

Previous studies by federal, state, and local agencies have documented elevated levels of both current-use and legacy (organochlorine) pesticides in water and associated with suspended and bed sediments in the Alamo and New Rivers and the Salton Sea (Crepeau and others, 2002; LeBlanc and others, 2004a, b; Sapozhnikova and others, 2004). Studies have also shown that selenium concentrations are near levels of concern in surface-waters of the Imperial Valley (Miles and others, 2009). A more recent study which sampled both the Alamo and New River inputs to the Salton Sea demonstrated that the highest pesticide concentrations and the greatest loads occur in the Alamo River (Orlando and others, 2008). Additional research has sought to link these elevated levels of contaminants to effects on birds, fish, and invertebrates in the Salton Sea ecosystem (deVlaming and others, 2004; Henny and others, 2008; Miles and others, 2009).

Water-transfer agreements negotiated between the Imperial Irrigation District and Metropolitan Water District and with the San Diego County Water Authority have begun to reduce the amount of water entering the Salton Sea. This reduction in inflows has caused the level of the Sea to drop nearly 2.5 feet over the last five years, reducing available habitat and exposing large areas of sediments. Inflows from the Imperial Valley are projected to decrease dramatically beginning in 2018 with full implementation of the transfer agreements. Efforts are currently underway by state and federal agencies to protect portions of the ecosystem through construction of species conservation habitat ponds and other mitigation measures designed to provide a range of aquatic habitats supporting migratory birds, fish and other wildlife dependent on the Salton Sea. It is likely that these ponds could be designed and built in such a manner as to enhance pesticide degradation and limit the subsequent exposure of biota to these contaminants.

Justification

Conservation of threatened and endangered species, migratory birds, and other species of concern is vitally important to multiple stakeholders in the Salton Sea region. This project addresses these priorities by providing robust data on pesticide degradation in managed wetlands that could be used to inform the design, construction and operation of future wetland habitats.

Objectives

- Document daily changes in concentrations of environmental mixtures of current-use pesticides due to degradation, in a functional experimental wetland;
- Provide results and interpretation of data to stakeholders and the public.

Products

- Quarterly reports;
- A peer reviewed final report;
- All laboratory results from this project will be entered into the USGS National Water Information System database.

Information for Management

Results from this study will provide data to resource managers on the subject of pesticide degradation in managed wetlands and help inform the design of future managed wetland habitats in the Salton Sea area.

Budget

Tasks	Subtasks	Year 1	Year 2	Total
Task 1: Project Oversight and Reporting		$11,000	$7,000	$18,000
Task 2: Routine Sampling and Analysis	USGS Sampling Labor	$15,000		$15,000
	Supplies and Travel	$8,000	$2,000	$10,000
	GC/MS Analyses	$50,000	$20,000	$70,000
	LC/MS/MS Analyses	$60,000	$20,000	$80,000
Task 3: Reporting	Interpretive Report	$2,000	$18,000	$20,000
Cooperator Funding		$120,000	$55,000	$175,000
USGS matching funds		$26,000	$12,000	$38,000
Total Study Funding		$146,000	$67,000	$213,000

Personnel

Hydrologist	(.2FTE/yr)
Research Chemist	(.1FTE/yr)
Chemist	(.3FTE/yr)

Point of Contact

James Orlando

CONTAM6. Evaluation of the risks and rewards associated with wetland management using reclaimed Salton Sea water versus recycled agriculture water

Introduction

In the arid Southwest, conflict over diminishing water supplies from the Colorado River is expected to intensify as a consequence of intensifying climate change and human-population growth. Ecosystem services provided by wetland habitats in the Southwest are most vulnerable to degradation as sources of clean water are taxed heavily by multiple anthropogenic stressors, and perhaps no place better exemplifies the risks and challenges to wetland management in the region than the Salton Sea.

The Salton Sea is a 900 km^2 terminal basin created in its present form during 1905 when a levee failure diverted much of the Colorado River into the basin. Since then, the Sea has been sustained by runoff from extensive agricultural development in the Imperial Valley made possible by water from the Colorado River. Recent transfer agreements defined in the Quantification Settlement Agreement (QSA) and related water conservation measures will reduce agricultural runoff to the Sea by an estimated 30% in 2018. Long-term, the surface area of the Sea is expected to shrink by 364 km^2 (~60%) by 2078 (California Resources Agency, 2007). Numerous human-health and ecological hazards will ensue, compounding the loss or impairment of thousands of hectares of wetlands necessary for waterbirds and endangered pupfish as the Sea contracts. Moreover, large expanses of managed wetlands have contracted steadily, and dry playas have become common as water-inflows to the Sea are reduced.

Justification

Agricultural drain-water will remain available, provided that extensive farming in the region continues, yet the sole use of this water-source for management has ecological risks from high levels of selenium that have been well documented in other wetland ecosystems (Skorupa, 1998). Hence, most previous (for example, Miles and others, 2009) and planned management efforts (for example, U.S. Army Corps of Engineers and California Natural Resources Agency, 2013) utilize a blended water approach that seeks to minimize selenium (SE) risk by mixing high-selenium agricultural runoff (> 5.0 ppb) with low-selenium (< 2.0 ppb) and high-salinity water from the Salton Sea. The combination of increased salinity and diluted source input is predicted to reduce Se risk, in part, by preventing development of wetland vegetation that can promote and accelerate bio-availability and bio-accumulation of selenium. However, costs associated with the blended-water approach are high because active pumping is required to move Salton Sea water upslope to blend with river water. The alternative of using a low-cost gravity delivery system for river water without blending has a risk of exposing wildlife to higher concentrations of selenium. For the blending option, as the Sea recedes, pumping distances and costs will likely increase along with necessary pump maintenance, so high costs of pumping might hamper larger-scale management efforts. Conversely, a gravity fed water source without the costs of blending has the potential to create many more acres of habitat at the Salton Sea than currently exists, given the amount of agricultural water available, albeit with a higher risk of selenium toxicity. These management decisions must be made using adequate scientific information quantifying the risk of both options.

Objectives

Miles and others, (2009) demonstrated a blended water approach in a complex of evaporative ponds. They found that blended water did not appear to affect selenium risk compared to wetlands fed by either Colorado River water or agricultural drain-water. However, comparative and replicate experimental treatments involving evaporative pond complexes sustained primarily by agricultural drain-water were not possible. Further evaluations of ecological benefits vs. costs of blended vs. agricultural water sources in wetlands using an evaporative pond-complex or other designs would aid determination of whether less expensive management options could be implemented. Hence, a novel research and monitoring design that takes advantage of existing or planned Salton Sea management, and suggest possible experimental treatments could help better answer the blended water vs. non-blended water selenium-risk question. Take advantage of planned management efforts for SCH at New River Delta (U.S. Army Corps of Engineers and California Natural Resources Agency, 2013) and/or Redhill Bay (U.S. Fish and Wildlife Service, 2014) that will use the blended-water approach;

- Determine selenium concentration in source water, sediments, and wetland biota (benthic and pelagic invertebrates, fish) on a seasonal basis for one-year;
- Switch source water to agricultural drain-water, and determine changes in Se risk as measured by sampling the same matrices;
- Repeat or adapt source-water management, pending results from the first two years;
- Ideally, source water type (blend vs. agricultural) would differ between the complexes at the beginning of the study to enable a better cross-over design;
- Approach can be downscaled for implementation within a single pond complex with multiple cells, or timing and frequency of source-water changes can be modified in consultation with resource managers. For example, change-overs could occur seasonally with variable duration (for example, one-month blend–three-month agricultural water versus three-month agricultural–one-month blended water). Sampling of Se risk would then correspond to changes in source water management.

Products and Information

- Results provide the foundation for future adaptive management for Salton Sea management and increased cost-effectiveness balanced against ecological benefits and risks;
- Estimates of selenium mass balance;
- Leverage data collection and costs with existing selenium-monitoring proposals;
- Results and interpretation of data provide to stakeholders and the public;
- A peer-reviewed final report.

Information to Management

Results from this study will help inform managers, scientists, and regulators of the potential for selenium exposure to migratory birds, fish and invertebrates within shallow, saline water habitat created with blending water from the Salton Sea and agricultural runoff. This study will aid in developing water use/reuse and species protection management strategies.

Budget

	Year 1	Year 2	Year 3
Salary: PI (.5 FTE)	$ 90,000	$ 90,000	$ 90,000
Salary: Staff	$ 120,000	$ 120,000	$ 48,000
Analytical (Se)	$ 150,000	$ 150,000	
Supplies	$ 10,000	$ 10,000	
Travel	$ 20,000	$ 20,000	$ 20,000
Total Direct	$ 390,000	$ 390,000	$ 158,000
Indirect (50%)	$ 195,000	$ 195,000	$ 79,000
Subtotals	$ 585,000	$ 585,000	$ 237,000
Grand Total			$ 1,407,000

Point of Contact

Mark A. Ricca, Becky Blasius

CONTAM7. Assessing the potential for pesticide exposure in a newly constructed Wetland: Red Hill Bay, Salton Sea, CA

Introduction

It is estimated that up to 95% of California's wetland habitat has been lost to development and agriculture in the last century (Dahl, 1990). With this loss of habitat, the Salton Sea has become a critical area of refuge for birds along the Pacific flyway. Over 420 species of birds have been documented at the Sea with more than 270 species using it on a regular basis. These include 19 species that are listed by either the federal government or the State of California as endangered, threatened, or of concern. The Salton Sea resides in a closed basin at the northern end of the Imperial Valley and water levels are sustained almost entirely by agricultural runoff.

The 2003 QSA included provisions for water transfer agreements between Imperial Irrigation District and other water districts which now have begun to reduce the amount of water entering the Salton Sea. This reduction in inflows has caused the level of the Sea to drop nearly 2.5 feet over the last 5 years, reducing available habitat and exposing large areas of sediments. Inflows to the Sea are projected to decrease dramatically beginning in 2018 with full implementation of the transfer agreements and the termination of mitigation water. Efforts are currently underway by state and federal agencies to protect portions of the ecosystem through construction of ponds and other mitigation measures to provide a range of habitats supporting migratory birds, fish, and other wildlife dependent on the Salton Sea.

The Sonny Bono Salton Sea National Wildlife Refuge (Refuge) is embarking on a project to reclaim a 420 acre portion of dry playa in Red Hill Bay of the Salton Sea by constructing shallow, saline-water ponds. This effort will restore wetland ecological functions for an area which once provided habitat for migratory birds. The QSA and other legislation (for example, Public Law 105–372) precludes the use of Colorado River water for Salton Sea restoration which complicates habitat development in a region where all sources of water are degraded. Thus, the Red Hill Bay project will utilize a mix of agricultural wastewater (Alamo River) and Salton Sea water to create wildlife habitat in an effort to make the best possible use of these degraded water supplies (least ecological risk). This water-reuse practice has previously been discouraged for managed Refuge habitats due to contaminant (pesticides and selenium) concerns.

Previous studies by federal, state, and local agencies have documented elevated levels of both current-use and legacy (organochlorine) pesticides in water and associated with suspended and bed sediments in the Alamo and New Rivers and the Salton Sea (Crepeau and others, 2002; LeBlanc and others, 2004a, b, Sapozhnikova and others, 2004). Studies have also shown that selenium concentrations are near levels of concern in surface-waters of the Imperial Valley (Miles and others, 2009). A more recent study which sampled both the Alamo and New River inputs to the Salton Sea demonstrated that the highest pesticide concentrations and the greatest loads occur in the Alamo River (Orlando and others, 2008). Additional research has sought to link these elevated levels of contaminants to effects on birds, fish, and invertebrates in the Salton Sea ecosystem (deVlaming and others, 2004; Henny and others, 2008; Miles and others, 2009).

This proposal is in an effort to fund research designed to provide data on the occurrence of current-use and legacy pesticides present in water and suspended sediments in input waters to Red Hill Bay and in sediments within the bay itself. These data will provide critical knowledge of baseline conditions prior to and during saline-pond habitat construction and will aid resource managers in developing adaptive management strategies for future operation of the site. With proper scientific support, it is believed that the Red Hill Bay project will demonstrate how water reuse can be successfully implemented to support habitat conservation projects throughout the Salton Sea region.

Justification

Conservation of threatened and endangered species, migratory birds, and other species of concern is vitally important to the U.S. Fish and Wildlife Service, and the National Wildlife Refuge System is focused on collaboratively addressing landscape-scale conservation through scientifically based adaptive management. This project addresses these priorities. The current Salton Sea was accidentally flooded in 1905 and has been sustained with agricultural runoff ever since. This flooding occurred during a period of widespread draining of wetlands in California, and while unintentional, the habitats created at the Salton Sea provided mitigation habitat for migratory birds of the Pacific Flyway. Because of the number of birds and diversity of birds at the Salton Sea and surrounding habitats, it is important to maintain habitat for migratory birds and to do so using scientifically based approaches. Salton Sea management efforts are focused on doing this. Successfully creating healthy replacement habitat is important to the many species of migratory birds that pass through the region, and this importance could potentially be extended beyond the region as additional habitat losses occur due to climate change. With the amount of agricultural water available, the potential exists to create many more acres of productive habitat at the Salton Sea than currently exists, but these management decisions should be made with the proper scientific support and context.

Objectives

- Document the occurrence of current-use and legacy pesticides present in Alamo River and Salton Sea water and suspended sediment entering the Red Hill Bay wetlands;
- Document the occurrence of current-use and legacy pesticides in bed sediments present in Red Hill Bay prior to pond construction;
- Document the occurrence of selenium in Alamo River and Salton Sea water entering the Red Hill Bay wetlands;
- Provide results and interpretation of data to stakeholders and the public.

Products

- Quarterly reports;
- A peer reviewed final report;
- All laboratory results from this project will be entered into the USGS National Water Information System database.

Information to Management

Results from this study will help inform Refuge managers of the potential for pesticide exposure to migratory birds, fish and invertebrates within shallow, saline water, habitat to be created in Red Hill Bay. Additionally, this study will aid U.S. Fish and Wildlife Service personnel in developing water use/reuse and species protection management strategies for future operation of the site.

Budget

	FY 1	FY 2
Operating Expenses		
Dissolved organic carbon	$1,000	$ 800
Particulate organic carbon analyses	$2,000	$ 800
Selenium analyses	$8,000	$8,000
Travel and per diem	$4,450	$4,450
Shipping	$ 740	$ 740
Supplies and Equipment		
Field supplies (Bottles, filters, etc)	$ 800	$ 800
Laboratory supplies (Gasses and consumables)	$11,450	$16,580
Salaries		
Hydrologist (.2 FTE/yr)		
Project Oversight and Reporting	$ 5,250	$5,000
Sample Collection	$8,500	$5,700
Pesticide Analyses	$3,000	$1,500
Database Management	$1,000	$2,200
Final Report Preparation	$5,200	$18,400
Research Chemist (.1 FTE/yr)		
Pesticide Analyses	$19,250	$18,750

	FY 1	FY 2
Chemist (.2 FTE/yr)		
Pesticide Analyses	$17,160	$6,000
Final Report Preparation		$2,140
Chemist (.1 FTE/yr)		
Sample Collection	$3,500	$2,100
Pesticide Analyses	$8,000	$5,640
Total for FY	$99,300	$ 99,600
Project Total Budget		**$ 198,900**

Point of Contact

James Orlando, Mark Ricca

CONTAM8. Assessing the potential for pesticide and selenium exposure in a newly constructed wetland: Species Conservation Habitat Project, Salton Sea, CA

Introduction

It is estimated that up to 95% of California's wetland habitat has been lost to development and agriculture in the last century (Dahl, 1990). With this loss of habitat, the Salton Sea has become a critical area of refuge for birds along the Pacific flyway. Over 420 species of birds have been documented at the Sea with more than 270 species using it on a regular basis. These include 19 species that are listed by either the Federal government or the State of California as endangered, threatened, or of concern. The Salton Sea resides in a closed basin at the northern end of the Imperial Valley and water levels are sustained almost entirely by agricultural runoff.

Water transfer agreements authorized under the 2003 QSA have begun to reduce the amount of water entering the Salton Sea. This reduction in inflows has caused the level of the Sea to drop nearly 2.5 feet over the last five years, reducing available habitat and exposing large areas of sediments. Inflows from the Imperial Valley are projected to decrease dramatically beginning in 2018 with full implementation of the transfer agreements and termination of mitigation water. Efforts are currently underway by state and federal agencies to protect portions of the ecosystem through construction of Species Conservation Habitat (SCH) ponds and other mitigation measures designed to provide a range of aquatic habitats supporting migratory birds, fish and other wildlife dependent on the Salton Sea.

The State of California Natural Resources Agency is embarking on a project to reclaim 640 acres of dry playa near the outlet of the New River within the Salton Sea by constructing shallow, saline-water ponds in an effort to restore the habitat functions this area once provided to migratory birds and other wildlife when wet (U.S. Army Corps of Engineers and California Natural Resources Agency, 2013). Because the terms of the QSA precluded the use of Colorado River water, the SCH project will utilize a mix of agricultural wastewater (New River) and Salton Sea water to create wildlife habitat. This water reuse practice has previously been discouraged for managed habitats due to contaminant (pesticides and selenium) concerns.

Previous studies by federal, state, and local agencies have documented elevated levels of both current-use and legacy (organochlorine) pesticides in water and associated with suspended and bed sediments in the Alamo and New Rivers and the Salton Sea (Crepeau and others, 2002; LeBlanc and others, 2004a, b; Sapozhnikova and others, 2004). Studies have also shown that selenium concentrations are near levels of concern in surface-waters of the Imperial Valley (Miles and others, 2009). A more recent study which sampled both the Alamo and New River inputs to the Salton Sea demonstrated that the highest pesticide concentrations and the greatest loads occur in the Alamo River (Orlando and others, 2008). Additional research has sought to link these elevated levels of contaminants to effects on birds, fish, and invertebrates in the Salton Sea ecosystem (deVlaming and others, 2004; Henny and others, 2008; Miles and others, 2009).

Justification

Conservation of threatened and endangered species, migratory birds, and other species of concern is vitally important to state and federal land managers. This project addresses these priorities. The current Salton Sea was accidentally flooded in 1905 and has been sustained with agricultural runoff ever since. This flooding occurred during a period of widespread draining of wetlands in California, and while unintentional, the habitats created at the Salton Sea provided mitigation habitat for migratory birds of the Pacific flyway. Because of the number of birds and diversity of birds at the Salton Sea and surrounding habitats it is important to maintain habitat for migratory birds and to do so using scientifically-based approaches. Salton Sea Resource Management efforts are focused on doing this. Successfully creating healthy replacement habitat is important to the many species of migratory birds that pass through the region, and this importance could potentially be extended beyond the region as additional habitat losses occur due to climate change. With the amount of agricultural water available, the potential exists to create many more acres of productive shallow wetland habitat at the Salton Sea than currently exists, but these management decisions must be made in the proper scientific context.

Objectives

- Document the occurrence of over 125 current-use and legacy pesticides and selenium in New River and Salton Sea water and suspended sediment entering the SCH wetlands for the period of two calendar years;
- Provide results and interpretation of data to stakeholders and the public.

Products

- Quarterly reports;
- A peer reviewed final report;
- All laboratory results from this project will be entered into the USGS National Water Information System database.

Information to Management

Results from this study will help inform State managers of the potential for pesticide and selenium exposure to migratory birds, fish and invertebrates within shallow, saline water, habitat to be created in SCH. Additionally, this study will aid State personnel in developing water use/reuse and species protection management strategies for future operation of the site.

Budget

Tasks	Subtasks	Year 1	Year 2	Year 3
Task 1: Project Oversight and Reporting		$11,000	$7,000	$3,000
Task 2: Routine Sampling and Analysis	USGS Sampling Labor	$5,000	$5,000	
	Supplies and Travel	$5,000	$5,000	$3,000
	GC/MS Analyses	$42,000	$35,000	$7,000
	LC/MS/MS Analyses	$28,000	$23,000	$5,000
	Selenium Analyses	$15,000	$12,000	$3,000
Task 3: Reporting	Interpretive Report	$2,000	$8,000	$9,000
Subtotals		$108,000	$95,000	$30,000
Grand Total				$233,000

Point of Contact

James Orlando, Mark Ricca

CONTAM9. Selenium transport, fate, and risk with full implementation of water conservation

Introduction and Background

Results of a detailed study by the National Irrigation Water-Quality Program (NIWQP), U.S. Department of the Interior, indicate that factors controlling contaminant concentrations in subsurface irrigation drain-water in the Imperial Valley are soil characteristics, hydrology, and agricultural practices (Setmire and others, 1993). Higher contaminant concentrations commonly were associated with clayey soils, which retard the movement of irrigation water and thus increase the degree of evaporative concentration. Regression of hydrogen- and oxygen-isotope ratios in samples collected from sumps yields a linear drain-water evaporation line that extrapolates through the isotopic composition of Colorado River water, thus demonstrating that Colorado River water is the sole source of subsurface drain-water in the Imperial Valley. Ratios of selenium (Se) to chloride indicate that selenium present in subsurface drain-water throughout the Imperial Valley originates from the Colorado River. Biological sampling and analysis showed that drain-water contaminants, including selenium, are accumulating in tissues of migratory and resident birds that use food sources in the Imperial Valley and the Salton Sea. Selenium concentration in fish-eating birds, shorebirds, and the endangered Yuma clapper rail were at levels that could affect reproduction. More recent studies provide additional evidence of selenium-induced reproductive effects in nesting birds at the Salton Sea. Management implications are that the biological effects of selenium in the Salton Sea area warrant further consideration in the construction of waterbird habitats. The effects to be addressed include reproductive impairment in nesting shorebirds and selenium accumulation in fish which may make them hazardous food items for fish-eating birds.

Justification

Previous studies indicated that reproductive effects may be occurring at low levels in the Salton Sea environment among nesting birds. The Salton Sea is not a static environment, and various factors have changed over time that may alter the nature and extent of impacts from selenium contamination in the Salton Sea watershed. Setmire and others, (1993) reported some sumps (which pump tile water surface drains) with mean monthly Se concentrations of 267 µg/L, with maximum values as high as high as 360 µg/L, while direct discharges of tile water had values as low as 2 µg/L. The high values were associated with high-clay soils. The dramatic variability suggests that agricultural lands (and potentially practices) may similarly vary across the Imperial Valley. Identifying specific agricultural field characteristics that contribute disproportionately high Se loadings could lead to more cost-effective Se management strategies, including treatment.

Objectives

- Develop a GIS database of selenium data from the Setmire and others, 1993, Schroeder and others, 1993) and more recent (California Resources Agency, 2006);
- Evaluate soil characteristics and agricultural practices spatially relative to data from those efforts;
- Identify a subset of sampling points to re-sample using a stratified-random design to capture the range of soil types and previous selenium concentrations measured in subsurface drain-water;
- Conduct sampling of these points once full implementation of the water conservation program is in place using the same temporal sampling regime as was conducted during the Detailed Study;
- Concurrently collect data on crops and irrigation practices as context for interpretation of the new selenium data;
- Enter data onto the GIS system to allow comparison of selenium concentrations across the Imperial Valley among studies;
- Assess any patterns in changes of selenium concentrations relative to changes in agricultural practices;
- Identify locations with consistently high selenium concentrations as targets for treatment to reduce overall concentrations of selenium entering the Salton Sea or associated constructed habitats.

Products

- GIS database of selenium concentrations and agricultural practices and soil information (to the extent available);
- Report providing any associations between selenium concentrations and soil types and (or) agricultural practices;
- Recommendations for locations amenable to treatment and appropriate treatment options to consider.

Process for Integration

The information that is developed should be incorporated into models for selenium fate and transport in the Imperial Valley and used to assess risk associated with using specific drainwater inputs into constructed habitats.

Project Informing Management

- Identify specific water sources that should be avoided for use in wildlife habitats;
- Identify specific inputs that are amenable to treatment;

Budget

Item	Cost
Salary—Principal Investigator (@ $150,000/year)	
Oversight of study activities (0.2 FTE)	$ 30,000
Data analysis and report writing (0.4 FTE)	$ 60,000
Salary—Technical Support ($80,000/year)	
Field sample collection—2 technicians (0.25 FTE X 2)	$ 40,000
Sample management—1 technician (0.1 FTE)	$ 8,000
Report preparation tasks—1 technician (0.4 FTE)	$ 32,000
Travel and per diem	$ 36,000
Supplies and shipping costs	$ 5,000
Selenium analysis (includes grain size and total organic carbon in soils)	$ 35,000
Total	$246,000

Point of Contact

Carol Roberts, Mark Ricca

CONTAM10. Selenium hot-spots

Justification

Setmire and others, (1993) and Saiki and others (2010) report selenium concentrations in agricultural drains of the Imperial Valley. Some of these selenium concentrations were elevated (monthly mean selenium of 267 µg/L, with maximum values as high as high as 360 µg/L), while other drains had values as low as 2 µg/L. The high values reported by Setmire and others (1993) were associated with high-clay soils. The variability suggests that agricultural lands (and practices?) may similarly vary across the Imperial Valley with regard to selenium concentrations in soils. Identifying specific agricultural fields that contribute disproportionately high-Se loadings could lead to more cost-effective Se management strategies, either by avoiding use of water from specific drains or by incentivizing farmers to selectively fallow high-Se fields.

Objectives

- Review existing selenium data and input into GIS;
- New monitoring on potentially high-Se drains;
- GIS analysis of old & new Se data, toward identifying:
  - location & seasonality of high-Se drains and
  - location of high-Se agricultural lands; and

- Rank land parcels by likely Se-loading potential.

Products

- Map showing Se loadings by land parcels; and
- Map/table listing Se concentrations in drains.

How Does This Inform Management?

Managing Se concentrations in constructed shallow ponds currently requires blending input drain water with Sea water. This requires significant upfront capital costs, for pumps and new transmission lines, and long term energy and maintenance costs. Limited budgets mean that funds that otherwise could be directed toward additional habitat construction must now be allocated for blending and Se management.

The deliverables from the proposed research would specifically and directly address the challenge of Se risk, by allowing for the preferential avoidance of high-Se drain-water, or avoidance of initial Se loadings, or both. This could enable managers to avoid blending, in turn allowing for additional habitat construction.

Budget

$500,000

Point of Contact

Mark Ricca

Carbon, CO_2, and Algae Proposals

CARBON1. Carbon capture assessment of the Salton Sea, constructed wetlands, and agricultural lands of the Imperial and Coachella Valleys.

(No proposal developed but identified as a science need.)

The following items are notes from the team discussion relative to issues to be addressed concerning carbon sequestration at the Salton Sea.

The limited amount of time at the meeting did not allow for a full proposal development. However, the organizing committee decided to include these notes in the proposal section to indicate the type of discussion necessary to address this topic.

Carbon sequestration at the Salton Sea has generated interest in a number of categories. Although the existing Sea has a shallow photic zone, as indicated by relatively small secchi depth measurements (0.4 to 1.4 m [Holdren and Montaño, 2002), its large areal extent (≈350 mi^2) yields a potentially large capacity for carbon uptake through algae production. Chris Amrhein (UC Riverside, written commun., 2005) estimates primary productivity (algal biomass) at the Salton Sea to be equivalent to 55,000 metric tons of carbon yearly. This action requires the uptake of CO_2 from the atmosphere. Reducing inflows and the size of the Salton Sea will reduce this carbon assimilative capacity.

Based on the potential for carbon removal using algal based remediation systems, there has been considerable interest in developing algae farms expressly for the purpose of harvesting algae for biofuels production. One interesting approach to Salton Sea remediation has been offered as the CEP process, in which a high algal growth rate system is employed to uptake CO_2, nutrients, and possibly selenium. This process has potential for reducing eutrophication and for producing algae biomass for biofuels or as a means of recycling fertilizers to farm fields. What is not known about this topic is enormous. With an estimated 40 kg of carbon/acre/day removal at the Salton Sea, there is a need to better quantify the carbon balance and develop a means of monetizing this removal. Further, the group recommends an analysis of the carbon emissions balance of production at the Sea (current) versus Sea in a smaller size, as compared to increased carbon emissions brought about through transferring water away from the Sea to urban Southern California. There is also the question of how much carbon might be emitted from sediments exposed as the water level recedes. The scientists observed that several proposals submitted previously concerning algal growth and carbon production for Se mitigation but were never funded. The recommendation was that these types of proposals should be updated and reconsidered, especially since some initial studies showed 40% reduction in Se concentrations. There is considerable interest worldwide in the concept of carbon sequestration in natural and managed algae systems (Murray and others, 2011; Sankur and others, 2011; Carlberg and others, 2003; Chmura and others, 2003).

The SoSS group listed additional unknowns and concerns:

- Is this a long-term sink or temporary removal?
- Are other greenhouse gas capture/production scenarios involved?
- What is the mechanism/chemistry of C cycle in the Sea?
- Better understanding of large-scale Sea geochemistry & bio-geochemistry needed
- What's prospect for storing additional C as Sea stabilizes at smaller size?
- How well are elemental pools/fluxes/reservoirs known? C, N, pH, Se?
- Are constructed marshes a viable option to capture Carbon and other elements such as Se? How to measure risk of such projects?
- What is C uptake potential of shallow habitats? Likely to be much higher than Sea, on unit basis. Is this temporary or long-term?
- Are there other biological systems, for example, bivalves, capable of carbon uptake and sequestration? Is there the possibility of using non-native bivalves, currently in the ecosystem, despite their controversial existence?
- What are existing C reservoirs? Organic or inorganic? In anoxic sediments or more stable mineral form?

Budget

To address high priority concerns listed above: $750,000

Point of Contact

Michael Anderson, Lisa Windham-Meyers, Tim Bradley

CARBON2. Nutrient and selenium control in drain water to the Salton Sea: Evaluation of the Controlled Eutrophication Process (CEP)

Introduction

One of the major issues concerning the management of the Salton Sea is the control of agricultural and municipal drains that cause high nutrient loading rates and potential selenium toxicity in the tributaries and in the Sea. The eutrophic conditions often promote extensive algae blooms that eventually “crash” (die), settle, and undergo anaerobic decomposition. This can lead to the release of hydrogen sulfide and produce anoxic zones, particularly during wind events. These conditions often result in high fish mortality, loss of forage for resident and migratory bird populations, contribute to the occurrence of avian diseases, and produce foul odors.

Selenium toxicity is of concern in constructed shallow-habitat ponds around the margins of the receding Salton Sea, leading to expensive and potentially unsustainable management actions to reduce potential toxicity. Selenium is of concern due to the potential bioaccumulation in the aquatic food chain, which supports abundant and diverse bird populations. In addition, anaerobic bacteria and (or) microalgae can transform the selenium into a redox-state that is up to eight times more toxic than the form in the drain waters. Currently, pumping of low (<2 ppb) selenium Salton Sea water, to blend with higher selenium drain water, has been selected as the management approach to reduce the risk of selenium toxicity. Blending drain water and Sea water also increases salinity to more than 20 ppt to discourage the establishment of emergent aquatic vegetation that can bioaccumulate selenium.

Kent SeaTech Corporation and Clemson University developed the Controlled Eutrophication Process (CEP) (Carlberg and others, 2003) to assimilate and remove nutrients and potentially toxic selenium. At the pilot-scale, CEP has shown promising results when treating a small portion of the Whitewater River. In previous selenium-tracking studies, the CEP method removed over 40% by algae and in spiking studies more than 98% of selenium in sludge in anaerobic digestion of algae. By the addition of an anaerobic bacterial pre-treatment step and a microcosm benthic invertebrate post-treatment step, the level of removal could be far greater. What remains is to evaluate this process on a much larger demonstration-scale to show proof-of-concept on the New and (or) Alamo Rivers.

Justification

Proof-of-concept level evaluation of CEP could offer a cost-effective means of managing selenium in constructed habitat ponds at the Salton Sea, reducing or potentially eliminating the need to pump water from the Salton Sea for blending. Avoiding these high capital and operations costs for blending could enable limited funding to be directed toward the construction of additional habitat, with ecological and air quality benefits.

Objectives

- To determine the need for and the effectiveness of a pre-treatment solids settling step to reduce the turbidity caused by clay and silt in the water from the tributaries that can interfere with photosynthesis by microalgae in the CEP;
- To assess the need for plastic pond liners in the CEP algal production raceway ponds to prevent the formation of dead zones, resulting in *in-situ* algal settlement and re-mineralization of algae biomass and lost productivity;

- To determine optimal conditions of: water in-flow rates, water velocity, pond depth, and hydraulic retention time (HRT), to maximize nutrient assimilation by algae and to promote effective harvesting on a year-round basis;
- To develop methods to minimize the effects from the cold-water winter conditions on algal growth and to evaluate co-precipitation as a method for storing phosphorus during the cold-water winter months;
- To refine the algal-harvesting process to maximize removal efficiency and cost effectiveness of the various alternative harvest methods, including Tilapia Enhanced Sedimentation (TES) and Serial Selection for Bioflocculation (SSB);
- To improve methods for drying the algal biomass, to minimize contamination from high TSS (silt and debris), and to enhance the value of co-products;
- To evaluate the production and maximize the use of the algal biomass to produce valuable co-products that can be a source of revenue to reduce operating expenses;
- To assess the addition of an anaerobic bacterial pre-treatment step to reduce toxic selenium to a redox state more easily assimilated by algae;
- To evaluate a final post-treatment step using benthic invertebrates to assimilate residual selenium, and to develop harvesting and disposal methods; and
- To assess the technical and economic viability of the CEP water treatment process as the preferred nutrient and selenium control method for use in the management of the Sea.

Products (Bullets)

- Evaluation of the capacity of CEP units to remove selenium from the water column;
- Revised sizing guidance for CEP units relative to the size of constructed habitats; and
- Techno-economic model that helps determine the projected overall capital and operating costs of CEP for pre-treatment of New or Alamo River water.

How Does This Inform Management?

This proposal directly addresses the management need to identify a cost-effective method of managing nutrient and selenium concentrations in constructed habitat ponds. CEP has demonstrated promising results at the pilot scale; this proposal would serve as proof of concept.

Budget

	Year 1	Year 2	Year 3
Labor	$287,000	$295,000	$582,000
Equipment (construction)	210,,000	26,000	236,000
Maintenance & utilities	32,000	36,000	68,000
Supplies	40,000	60,000	100,000
Lab analyses	48,000	95,000	143,000
Miscellaneous-travel	16,000	16,000	31,000
Indirect	149,000	124,000	273,000
Subcontracts (academic)	110,000	110,000	220,000
Total	$892,000	$762,000	$1,653,000
Grand total			$4,069,000

Point of Contact

Jim Carlberg, Michael Anderson, Michael Cohen

CARBON3. Carbon sequestration in deep cycled groundwater

(No proposal developed but identified as a science need.)

The question of CO_2 sequestration in desert soils and groundwater has been a source of debate for some time (Grossman and others, 1995; Schlesinger, 1999; Ma and others, 2014). Soils have been recognized as the single largest sink for CO_2 (Post and others, 1982; Houghton and others, 1990). But the debate on how effective soil carbon storage is as a mechanism for sequestration as a means of reducing atmospheric concentrations centers on the issue of carbon flux from the atmosphere. A slow rate typical of soils is unlikely to alter the atmospheric balance (Schlesinger and Bernhardt, 2013).

Grossman and others (1995) observed that soils containing calcium silicates serve as a sink for atmospheric CO_2 and it is further reported that calcium in irrigation water can facilitate the formation of calcium carbonate, which may sequester CO_2 (Monger and Martinez-Rios, 2001)

Recent studies have furthered this controversy by suggesting that Deep groundwater may be a potentially overlooked mechanism for CO_2 storage in desert ecosystems (Evans and others, 2014; Li and others, 2015). These observations were criticized in conventional analyses of CO_2 uptake in which an unlikely amount of vegetation biomass in desert ecosystems would be required to attain the reported sequestration rates (Schlesinger and others, 2009). However, this problem may have been overcome recently with reports suggesting massive CO_2 storage as dissolved inorganic carbon (DIC) in shallow and deep groundwater (Li and others, 2015; Ma and others, 2014; Evans and others, 2014; Stone, 2008). Large carbon sequestration into groundwater has been reported in Russia (Lapenis and others, 2008) and irrigated agricultural lands of central California (Eshel and others, 2007), important because of the long residence time of groundwater. Li and others (2015) suggest that there is a “hidden” storage mechanism for carbon beneath Chinese deserts in the form of DIC.

Although the connection to Salton Sea resource management is not directly obvious, this topic along with other carbon related issues has the potential for monetization in some form, either as carbon capture credits, or carbon offsets involved with emerging climate change programs. It is recommended that a preliminary evaluation be made in order to quantify this potential

Budget

$500,000

Point of Contact

Lisa Windham-Meyers James Orlando

Biology Proposals

BIO1. A dynamic ecosystem model for evaluating and managing changes in the Salton Sea

Introduction and Background

Dynamic models, set in an ecosystem framework, provide an understanding of the relationships among organisms. This information serves as a decision-support platform for assisting with the adaptive management of natural systems. Development of such a model for the Salton Sea will maximize 30 years of accumulated natural history knowledge, providing the data needed to guide science, management, and policy at the Sea.

The Salton Sea is predicted to face rapid physical change as a result of reduced water inputs. These changes (in water level, salinity, oxygen availability) are expected to impact a number of key species in the system. Understanding whole system responses to population-level variability of key organisms and their responses to key abiotic inputs will provide a more complete understanding of the stability of the ecosystem as a whole, and act as a bellwether for management in anticipating (and responding to) ecological transition or collapse.

Justification

A dynamic ecosystem model can quantify and organize the biological and physical information that has already been collected at Sea, and make it available to stakeholders via an intuitive, visual interface. Given the basic need to understand the interplay among biotic populations and abiotic processes over time (at multiple scales and across hierarchical levels of organization, a predictive tool of this kind is of vital importance. This model provides the quantitative (or probabilistic) support stakeholders need to predict (or, anticipate) state transitions at the Sea, justify the mustering of resources, and manage these changes.

Objectives

The objectives of this project are two-fold. The models and their representations serve to synthesize existing data, predict important state changes, and interpret these realities for stakeholders (scientists, land managers, policy makers, and the public). Thus the models will be designed to:

1. Provide a synthesis of the data that captures extensive history of science on biological systems of the Salton Sea and identifies critical gaps in knowledge;
2. Develop a relational framework needed to understand processes that are important to the contemporary dynamics of the biological diversity of the Salton Sea and associate marshes (engineered/remediation marsh habitat);
3. Develop a predictive, numerical model to assess the risk of undesirable threshold change in the ecosystem state for the Sea and engineered mitigation/management projects;
4. Provide a conceptualization of biological systems at the Sea that can be aligned and integrated with physical and socio-economic studies and assessments;
5. Understand the nature of biological linkages (using current data) and linkage interaction strength (through data-model assimilation associated with specific experimentation); and
6. Develop a robust decision support system that guides monitoring and hypothesis generation important to adaptive management frameworks (by iterating the model with data from

monitoring and forecasting biodiversity behavior in the context of specific scenarios assessed by monitoring and experimentation).

Products

This project would consist of several phases, each with decision-making impact on management decisions. We divide our products into strategic and specific products.

Strategic Products

- Development of a synthesis product, where simply the biodiversity relationships will assist in expert opinion guidance on management actions;
- The development of a null-statistical model (likely neural-network model based approaches) that at minimum can be iterated with monitoring efforts to begin to describe year-to-year changes in the components of biological diversity in time and inform adaptive management efforts;
- Third, with targeted experimentation, develop an improved understanding of the strengths of species interactions within this ecosystem to better develop scenarios associated with perturbation of the system through loss of key species / functional groups (developed in collaboration with key stakeholders); and
- Finally, a mechanistic approach will advance multiple model formats to reliable forecasting tools that can be used to carry out adaptive management and to guide an evolution of monitoring.

Specific Products

- A graphic-based conceptual model of species interaction webs;
- A statistical model that is refined through data-model-experiment assimilation across the three-year project period;
- The initial development of a mechanistically based numerical model that is integrative with the hydrologic and biogeochemical tools being developed in other settings;
- Web-based visualization tools that highlight scenarios and model runs providing translation to important stakeholders, such as state and federal land managers;
- A process of stakeholder engagement to refine biological questions and enhance the dissemination of results across diverse research groups; and
- An addressable database with a general user interface available for use by many researchers in many settings.

How Does This Project Inform Management?

The dynamic ecosystem model would complement physical modeling by directly assessing the trends in biological systems. The model would inform best practices in monitoring by helping to assign value to different data sets in the context of how they inform model behavior and best predict real behavior in the system. The model would assist in forecasting changes that may mobilize emergency intervention, helping to prepare for worst-case scenarios of system collapse.

How will this project integrate?

Our goal would be to initially construct the model to be consistent with the Monitoring and Assessment Plan developed by Case and others (2013), so as to be informed by data likely to be collected by the diverse stakeholders. The long-term goal is to develop the model approach sufficient that coupling with physical models is possible (through either coupling approaches, such as Kepler, or through the development of sub-models to be run on the existing large-scale integrated systems models being produced by other groups, such as the hydrology group).

Budget

Category	Year 1	Year 2	Year 3
Postdoc Researcher I (1.0 FTE)	$80,000	$80,000	$80,000
Postdoc Researcher II (1.0 FTE)	$80,000	$80,000	$80,000
Grad Student (2.5 FTE		$200,000	$200,000
Senior Researchers (PI – 1.50 FTE)	$225,000	$225,000	$225,000
Stakeholder workshops	$45,000	$45,000	$45,000
Travel	$12,000	$12,000	$12,000
Misc. Supplies	$10,000	$10,000	$10,000
Directed Activities($5K/grad asst)		$20,000	$20,000
Subtotal	$452,000	$672,000	$672,000
Overhead	$203,500	$313,500	$313,500
Total Budget	$655,500	$985,500	$985,500
Grand Total			$2,626,500

Point of Contact

Travis Huxman, Yev Marusenko, Gregor Yanega, Tim Bradley, Tom Dietsch, Kathy Molina, Tom Anderson

BIO2. Ecosystem services and the role of agricultural land in supporting bird life

Introduction

Flood-irrigated crops in the Salton Sea region serve a variety of functions including sustained inflow to a shrinking Sea; removal of accumulated soil salts; nutrient cycling; microclimate enhancement; toxin sequestration; and support of avian communities (for example, long-billed curlew, white-faced ibis, mountain plover, cattle egret, numerous species of gulls). Various climatic and economic drivers have led to changes in agricultural practice resulting in the use of water-efficient crops and a shift toward water delivery systems that require less water.

Agricultural lands in the Imperial Valley represent an important greenway and stopover site for many birds that use the Pacific Flyway. We do not know the consequences of increased fragmentation or temporal fragmentation of habitat for birds in the area. How lands are managed will have a large impact on these populations.

The agricultural community is under pressure to use less water and farm more efficiently. The use of water on agricultural lands has implications, not ever, not only for farm production but also for environmental impacts. Some uses of water on farm lands have positive impacts. For example, flooding of rice fields in the winter in the Central Valley has marked positive effects on water fowl abundance and survival. In the Imperial Valley, factors directly affected by watering methods include soil salinization and selenium mobilization. As water use evolves in the

Imperial Valley, it will be important both for managers of wildlife and for farmers to have accurate data on the effects of water use in the fields on ecosystem function.

Justification

We propose a comprehensive study to understand the impacts of water use in the Imperial Valley on avian diversity and abundance. Changes to the salinity and water volume of the Sea can lead to changes in diversity and (or) abundance of avian species using the agricultural matrix. Synergies between farm practices that include flooding of fields and delivery of water to the Sea are of particular interest in a larger hydrological perspective. In sum, the Salton Sink south of the Sea remains an important habitat for many bird species distinct from those found at the Sea, and our understanding of their distribution and population trends require more comprehensive quantitative survey of the relative importance of crop choice, time of harvest, and water management practices for the cohort of species that rely on upland farm habitat. There are preliminary data for avian use of farmland conducted in 1998-2000 (Shuford and others, 2000). Survey efforts have been very uneven since this time, and the proposed work would build on that foundation.

Objectives

- Survey the farm practices of agricultural lands on the south side of the Salton Sea including acreage occupied by different crops and water budgets for each one of these;
- Sample bird use across a suite of flood-irrigated crops. Gather habitat data about the crop type, crop height, irrigation type;
- Coordinate sampling with farmers to obtain information concerning type of irrigation and timing of irrigation;
- Compare typical flood irrigation practices with water saving practices to assess how it affects bird use; and
- How do landscape features around fields affect their use? Is fragmentation of desirable landscape features correlated with bird abundance and diversity?

Products

- Provide data on bird use on crops with varying irrigation practices;
- Provide recommendations for different irrigation practices (timing of irrigation, type of irrigation) for bird use of agricultural landscape;
- A spatial analysis of bird use relative to various landscape features;
- An economic analysis of crop and irrigation practices at the Sea relative to bird use; and
- A secondary economic analysis assessing the "natural capital" and "service shed" concepts associated with carbon sequestration, dust mitigation, and biodiversity function that are provided by the Sea and the associated farmlands. Propose legislated water subsidy based on these values. (See an expansion of this concept at http://www.naturalcapitalproject.org/decisions/servicesheds.html).

This Work Will Inform Management

- By enabling managers to determine which irrigation practices are most beneficial to birds and evaluate economic viability;

- By tracking changes in avian diversity or abundance resulting from management projects and/or changes to water levels (and salinity levels) at the Sea; and
- By providing managers a set of recommendations for temporal strategies for incentivizing flooded fields to give the greatest benefit to bird life.

Budget

	Year 1	Year 2	Year 3
Personnel	89,000	89,000	89,000
Supplies	10,000	10,000	10,000
Travel	10,000	10,000	10,000
Miscellaneous	2,000	3,000	4,000
Subtotal	109,000	112,000	113,000
Overhead			167,000
Grand Total			501,000

Point of Contact

Gregor Yanega, Dave Shuford,

BIO3. Generating a brine shrimp source population for a changing Salton Sea

Introduction

The Salton Sea is heading towards a more saline future. The current salinity of approximately 60‰ (which is 1.7 times greater than seawater) will only increase as freshwater flows into the Sea diminish, and water is lost via evaporation. The Sea currently supports large populations of one fish species (a hybrid tilapia) and numerous invertebrate species (pile worms, barnacles, copepods, etc.), all of which support a vibrant bird population. It is the large bird populations for which the Salton Sea is known throughout the region. However, the salinity of the Sea will reach a "tipping point", above which salinities will become too high to allow most aquatic organisms to survive. The absolute value of the tipping point remains unknown for individual species, but there is consensus that the Sea will likely have a future devoid of fish. The loss of fish species will undoubtedly change the functioning of the Sea ecosystem. (Note: most of the Salton Sea would become fishless, but small fish populations could take refuge at the river mouths and in agricultural drains, which would have lower salinities.)

Once the Sea generally becomes devoid of fish, this will create an "ecological release" for aquatic invertebrate populations to exploit in the absence of predation by fish. Certain aquatic invertebrates (for example, waterboatmen and brine flies) will likely proliferate once predation by fish ceases and provide food for birds capable of exploiting them as food resource. Another organism that might be able to invade and thrive in such a saline, fishless environment would be brine shrimp (*Artemia* sp.). Brine shrimp are abundant in hypersaline lakes throughout the western United States, including the Great Salt Lake in Utah, and Mono Lake in California. Brine shrimp generally thrive in hypersaline systems where the salinity prevents predaceous invertebrates (for example, waterboatmen). In the Great Salt Lake and Mono Lake, brine shrimp and brine flies provide ample food resources for healthy bird populations. Therefore, with a goal of maintaining the Salton Sea as a critical avian habitat, the anticipation of the invasion of brine shrimp into the Salton Sea is important on many levels, but perhaps most importantly, because these organisms can help support some bird populations.

It remains unknown, however, how long a "phase shift" from a fish-dominated to a brine shrimp-dominated Lake would take. It could happen relatively quickly (for example, within a few months), or it could take several years to occur. However, the intervening period of time between fish and brine shrimp will be filled with other aquatic invertebrates, just no large populations of fish to support fish eating birds. The longer this phase shift takes to happen, the longer the Sea will go without adequate food resources to sustain its large bird populations. Thus, the potential exists for the Sea's bird population to become decimated. Migration elsewhere is becoming more and more problematic since the Western U.S. has lost a vast amount of its historic wetlands and those that remain do not have the carrying capacity capable of supporting migratory bird numbers typically recorded at the Salton Sea. The goal of this project is to stave off a "foodless" Sea by discerning which brine shrimp species would be best suited for the Salton Sea, and to create a brine shrimp breeding pond, in which to generate a brine shrimp population that can be released into the Salton Sea once the several tipping points arrive.

Justification

With more than 400-plus bird species using the Salton Sea as feeding and breeding grounds, the Salton Sea is one of the most important bird habitats in the western United States. Many bird taxa are local to the Sea, and others, use it as a stopover on migrations. In terms of human use of the Sea, the birds are the largest tourism draw to the area, bringing visitors and income to local communities. Therefore, in addition to losing valuable bird habitat, a fishless Sea we anticipate a loss of most fish-eating species of birds. The Sea would not attract the abundance of birds documented historically using the Sea and this could be detrimental to local economies. By having a viable population of brine shrimp ready to release into the Sea, this project has the potential to minimize such biological and economic losses.

Objectives

- Using Salton Sea water, determine which of the eight species of *Artemia* are most viable in Salton Sea water. Because each saline lake has unique chemistry, this is an important first step in establishing a population of *Artemia* that is appropriate for the Salton Sea;
- Build a 1-acre (approximately 2-feet deep) *Artemia* pond in which to establish a relatively large, robust population of *Artemia* that can eventually be released into the Salton Sea. The pond would need to be adjacent to the Sea to facilitate introduction of the *Artemia* to the Sea when the fish population has collapsed;
- Once the tipping point is reached, open the dam and allow the *Artemia* to invade the Sea and establish a Sea-wide population that is tolerant of the unique characteristics of Salton Sea water;
- After releasing the first batch of *Artemia*, the pond can be used to establish a second batch to be released to bolster the first introduction. This can be used to evaluate the relative success of releasing immature stage, adults, and/or fecund females. Multiple releases may be necessary to establish a viable population, or to supplement and amplify the rate of establishment of brine shrimp in the Sea;
- Provide a viable resource for the bird populations reliant on the Salton Sea for food;
- The *Artemia* would also likely serve as a food resource for the few fishes remaining at river mouths in the Sea, and in agricultural drainage canals. Thus, the brine shrimp would help support the remaining fish-eating birds by being food for the remaining fish; and

- After the *Artemia* are established and sustainable within the Sea, the cultured *Artemia* can be sold to the aquarium and/or aquaculture food industries to produce a source of revenue for the Salton Sea economy. *Artemia* populations are a valuable commercial enterprise in salt lakes around the world.

Products

- Produce a large population of *Artemia* that can be released into the Sea to facilitate and accelerate the rate at which brine shrimp colonize the Sea once the fish population collapses;
- Scientific papers on the selection of *Artemia* for the Salton Sea and on the rearing process; and
- Professional training on the management and rearing of *Artemia* populations.

How Does This Project Inform Management?

With a scientific consensus that the Salton Sea will reach a "tipping point" of salinity, above which fish will no longer be able to inhabit most of the Sea, mitigating the loss of food for the bird populations is a priority for management. Recognizing that the tipping point will be reached in the near future, this project provides a direct intervention to the loss of food resources for birds by generating a population of brine shrimp that is adapted to thrive in the Salton Sea.

Budget

	Year 1	Year 2	Year 3
Personnel	155,000	155,000	155,000
Equipment/Supplies	25,000	500,000	10,000
Travel	17,400	17,400	17,400
Subtotal	197,400	672,400	182,400
Total			$1,052,200
Overhead			$526,100
Grand Total			$1,578,300

Point of Contact

Dr. Timothy Bradley, Dr. Donovan P. German

BIO4. Characterization of the base of the food chain at the Salton Sea

Introduction

An adequate understanding of the current ecology of the Sea, as well as the direction and effects of future changes, depends on a thorough understanding of food webs in the Sea. Food webs describe the inter-relationships of producers (plants) that capture energy and nutrients, and consumers (animals and microbes) that feed upon the plants and are themselves fed upon by higher trophic levels. While the final consumers in the Salton Sea ecosystem (fish and birds) have been the subject of a great deal of scientific investigation, the food web upon which these animals depend is less well understood.

The goal of this project is not scientific study for its own sake, but rather the examination and quantification of the base of the ecosystem for the purpose of improved management of the resources at the Sea.

For example, as the Sea increases in salinity, we expect tilapia, the only remaining fish species of importance as a food for birds, to be excluded from the open waters. Several agencies associated with resource and habitat management at the Sea are in the process of building marshes adjacent to the Sea for the purpose of providing refuges for the fish. The goal of these projects is to provide habitat and food for birds. In order to predict how well these marshes will perform and what level of food production they can support, we need to have a better understanding of the organisms and processes that transfer energy and nutrients up the food chain. One approach is to build these marshes and see how well they work. That is a risky and very expensive approach. A parallel approach is to gather the scientific data regarding the organisms and interactions in the food chain in order to make testable predications about productivity, the effects of salinity, water management, and organism responses. These approaches are faster and cheaper than massive engineering projects, and they can serve to guide and inform decision-making during project design, implementation, and analysis. For example, if we find that a certain marsh is built to specification, but fails to be productive of bird food items, a knowledge of the underlying ecological factors will allow us to determine the reasons for this failure and correct the conditions. In the absence of such knowledge, we must fall back on trial and error with no underlying scientific framework.

Justification

Currently, data gaps exist due to lack of monitoring capacity and an incomplete understanding of food webs in the Sea. Studies incorporating both quantitative and qualitative approaches to the study of food webs in the Sea will allow us to understand the current flow of nutrients and energy up the food chain, as well as allowing predictions to be made regarding future changes and the effectiveness of mitigation procedures. Managers are already engaged in mitigative actions, and these will only increase as the negative effects of environmental changes become more apparent. A better understanding of ecological function in the Sea will lead to better and cheaper mitigation procedures.

Objectives

- Gather baseline data on current food web structure and function;
- Identify components in the food web in the Sea that are critical for energy and nutrient transfer to higher organisms;
- Determine existing gaps/needs and potential unknown/understudied variables;
- Determine whether a greater and more detailed knowledge of algae, bacteria, and microzooplankton is required;
- Develop a strategy for effective sampling/monitoring;
- Understand and predict potential tipping point and other thresholds for major ecosystem/community changes; and
- Gather data that will allow mechanistic predictions of the effects of salinity change.

Products

- Database that can be utilized by all organizations and stakeholders;
- Models of ecological interactions and dependencies that can be utilized by all organizations and stakeholders;

- Reports to provide recommendations for action in current/ongoing projects and future efforts;
- Models of the effects of environmental projects to predict environmental outcomes and directions; and
- Scientific publications (can be used for policy guidance, science research hypothesis-testing, reports/synthesis for science committee).

How Does This Project Inform Management?

The data and models deriving from this work will be used to interpret and analyze to patterns in community changes and interactions as well as predicting future scenarios. These evaluation tools will be used by managers to supplement their current methods in determining action and proposed work.

Budget

	Year 1	Year 2	Year 3
Personnel	112,500	112,500	112,500
Supplies	85,000	85,000	55,000
Travel	10,000	10,000	10,000
Miscellaneous	2,000	3,000	4,000
Subtotal	209,500	210,500	181,500
Overhead			$300,750
Grand Total			$902,250.

Point of Contact

Timothy Bradley, Yev Marusenko

BIO5. Salinity tolerance of key organisms in the Salton Sea ecosystem

Introduction and Background

As the Sea recedes and salinity increases, a critical issue will be the survival and abundance of several organisms that are of great ecological significance. Despite previous work, substantial data gaps remain regarding organismal salinity tolerance. For some key organisms (such as barnacles and pile worms) inadequate data exist. For others (such as tilapia), the data do exist but they were determined using salt mixtures different from those in the Salton Sea. The data on tilapia include the effects of temperature. However, the data were collected on fish reared in marine waters, not Salton Sea water. The difference in ionic makeup can be critical in such studies.

Management decisions for the Sea as a whole and for the managed wetlands currently being constructed will depend on a solid understanding of the salinity tolerance of key organisms and of the “tipping points”, that is the salinity tolerance point at which major ecological shifts will occur. Two tipping points are envisioned for the Salton Sea going into the future. The first will occur when the fish die off due to salinity or salinity combined with other physiological stressors. This will change the ecology of the Sea in many ways, including elimination loss of algae removal by fish, and the loss of food for fish-eating birds. It is anticipated that brine shrimp and brine flies will then colonize the Sea and serve as consumers of algae and as food for some birds, although fish eating birds will no longer be supported at the Sea. Brine shrimp and brine flies do not currently inhabit the Salton Sea in significant numbers. These species are included due to the widely-held belief that they will become abundant after fish and other invertebrate predators (waterboatmen) have been eliminated from the Sea. A second tipping point is anticipated when the salinity exceeds the salinity tolerance of these two invertebrate species., after which the Salton Sea will be incapable of providing food resources for the vast majority of birds currently observed at the Sea. This second tipping point will also have a profound effect on the ecology of the Sea.

Objectives

The current proposal will examine the salinity tolerance of key species in the Sea using water with appropriate ionic makeup. The goal is not to examine the salinity tolerance of every organism in the Sea. Instead, the emphasis is on organisms we are characterizing as key organisms in the sense that they have profound and central effects on ecosystem functions at the Sea. These include pile worms, barnacles, *Tilapia*, brine flies and brine shrimp. These species have been chosen because of their importance for ecosystem function, particularly for their role in transporting nutrients and energy up the food chain to the birds. For some organisms, such as brine shrimp and brine flies, data on salinity tolerance exist in the literature. However, these data are for animals in other environmental conditions and other lake environments and the chemical composition of the Salton Sea water is different from other hypersaline lakes. Because the specific ionic makeup of individual salt lakes differs and is a critical determinant of the survival of biota, it is important to evaluate salinity tolerance to survival and reproduction using Salton Sea water and relevant temperatures.

Products

Data on the salinity tolerance of each of the key organisms will be provided. The data will be collected using two experimental designs. The first design involves rearing the organisms in Salton Sea water in the laboratory to precisely control water temperature. The second design involves mesocosms placed adjacent to or in the Salton Sea (using limnocorrals) in order to include local environmental factors (temperature, sunlight) appropriate to the environment.

Salinity tolerance data will be provided both in the form of raw data from the survival experiments, and in refined form indicating tolerance at three different temperatures: 15, 25 and 35 degrees centigrade. The salinities to be tested are 60, 75, 90, 105 and 120 ppt. These salinities have been chosen because they are thought to extend across the lower “tipping point” and possibly across the upper “tipping point” for some species. Each combination and permutation of the three temperatures and five salinities will be tested since each is ecologically relevant for conditions at the Lake.

How Does the Project Inform Management?

Managers and scientists have identified the issue of “tipping points” as critical to the management of the Sea and the adjacent managed habitats. The “tipping points” are times at which key species are eliminated from the ecosystem due to environmental change, principally increasing salinity. It is recognized that these tipping points are associated with great ecological shifts. It is important for us to anticipate those shifts and deal with them rapidly when they occur. We cannot predict and respond to those shifts without further information and insights.

Elimination of tilapia from the ecosystem will lead to great changes. These changes may be muted if pile worms remain in the system as a food resource for many birds. We need data, therefore, that will allow us to predict the time and order of species elimination as increases in salinity progress. Data on barnacles are needed not because they serve as a food for birds, but because they play a major role in the Sea as filter feeders on algae, bacteria and detritus suspended in the water. Their larvae are also an important food item for fish.

Predictions of ecosystem change at the Sea suggest that salinities will eventually proceed to a level too saline even for brine shrimp and brine flies. This "second tipping point" is equally important in driving our understanding of 1) future changes and 2) management strategies. We have therefore included organisms which are not currently in the Sea, but which are widely assumed to be colonizers at the Sea following the elimination of fish. For all of the above reasons, data on salinity tolerance represents a data gap which when filled will be of great use to managers at the Sea.

Budget

	Year 1	Year 2	Year 3
Personnel	395,000	395,000	395,000
Equipment	20,000	0	0
Supplies	14,000	10,000	10,000
Travel	10,000	12,000	12,000
Miscellaneous	0	3,000	4,000
Subtotal	439,000	420,000	421,000
Overhead			$630,000
Grand Total			$1,910,000

Point of Contact

Dr. Tim Bradley, Dr. Donovan German

BIO6. Migratory connectivity for birds using the Salton Sea

Introduction and Background

Bird populations are influenced by factors at multiple scales. Pilot pond efforts have included nesting islands for ground-nesting waterbirds, including individuals from one of only two breeding populations for Gull-billed Terns in the Western US. Nesting attempts at these islands have frequently been disrupted by influxes of common species that either displace nesting attempts or prey upon eggs and young birds. Similarly, fluctuations of populations observed in the Salton Sea may result from poor resources during another phase of a bird's annual life cycle. This may complicate efforts to adaptively manage ponds and achieve project goals.

Justification

The Salton Sea avifauna is known for irruptive population patterns with frequent invasions from the Gulf of California during poor resource years. Superabundant flocks have the potential to overwhelm local bird and fish populations during some years. This may undermine conservation efforts for sensitive bird species and attempts to manage fish populations within managed ponds. Similarly, adverse conditions outside the Salton Sea could also result in population declines of sensitive species. A better understanding of these larger-scale regional processes is needed. Regular bird monitoring is important for tracking local populations through time. However, additional research is needed on migratory connectivity and broader landscapes that affect bird populations at the Salton Sea.

Objectives

Determine Migratory Connectivity for key bird species:

- Identify regional water bodies in the region where environmental conditions may affect bird populations in the Salton Sea;
- Model bird movement patterns and analyze key factors that may affect conservation success within managed Salton Sea habitats;
- Determine relative importance of Salton Sea for transitory species during migration; and
- Analyze population fluctuations in the Salton Sea using available data from identified migratory localities.

From historical and census survey data, species will be selected for key groups:

- Species of Conservation Concern, that is, Gull-billed Tern, Black Skimmers, Yuma's Ridgeway Rail;
- Super-abundant/irruptive Species: Caspian Tern, Brown Pelicans, Eared Grebes; and
- Transitory Species using Salton Sea as a stopover location.

Approach

Identified species will be captured or opportunistically sampled (mortalities) with feather and blood samples. Those species identified for tracking will have satellite GPS units or geolocators attached.

Migratory Connectivity Techniques

- Telemetry/Geolocators: Satellite tracking devices mounted on larger birds can provide more complete geospatial data of bird movements at larger/regional scales. Similarly, geolocators can be mounted on smaller birds. However, birds with geolocators need to be recaptured to retrieve data.
- Stable Isotopes: Molt locations can be identified. With blood, diet and foraging habitats can be identified.
- Genotyping: DNA samples can be collected to identify breeding populations/locations for some species.

Products

- Geospatial models of short and long distance movements for key bird species to identify migratory connectivity with regional water bodies; and
- Hierarchical population models for key bird species that may affect biological resources in managed and unmanaged Salton Sea basin habitats.

How Does This Project Inform Management?

Geospatial models derived from transmitter data will identify key life-cycle localities to inform modeling efforts. Hierarchical models that incorporate data on environmental conditions at key life-cycle localities (breeding, overwintering, and migratory stopover sites) will provide a context for evaluating population changes and planning adaptive management actions.

Budget

$1,500,000

Point of Contact

Thomas Dietsch

BIO7. Ecosystem-friendly biogenerated soil enhancer for berm stabilization of engineered marshes and wetlands in the Salton Sea watershed

Introduction and Background

According to climate model projections by Seager and others, (2012), the Colorado River headwaters are expected to have an annual stream flow decline of 10 percent and as much as a 20 percent drop in spring runoff in California and Nevada, as warmer temperatures of 1–2 °C also boost evaporation in 2021–2040. Studies have projected that given a combination of circumstances, the Salton Sea water levels are likely to be reduced in the future leading to potentially significant effects to air quality due to fugitive dust from wind erosion of exposed lakebed playa (Imperial Irrigation District and Bureau of Reclamation, 2002; California Resources Agency, 2006; Case and others, 2013). The Colorado River Quantification Settlement Agreement (QSA) of 2003 has drastically lowered the amount of fresh water inflows to Salton Sea, resulting not only in changes to the amount of water in the Sea, but also in changes the geochemistry and overall the water quality, and also long-term impacts to the population dynamics of numerous species are expected.

In anticipation of these deleterious changes to the Salton Sea water levels and water chemistry, plans are underway to conserve viable habitat for species of concern, such as the Desert Pupfish and California Clapper Rail, and other Salton Sea biota by the construction of wetlands and marshes around the Sea. From an engineering standpoint, wetland and marsh impoundments must be engineered to counter seepage and withstand earthquakes.

The Salton Sea is subject to frequent seismic events and lateral spreading can take place and generally loose sediments, for example, areas with steep slopes, can collapse from lack of lateral support. The potential effects that seismic activity and potential subsidence (also due to ground water pumping and geothermal activity) can have on the wetland berms lead to the increased importance of enhanced stabilization of the engineered marshes and wetlands in the vicinity of the Salton Sea, for example, the Species Conservation Habitat Plan and Red Hill Bay Project, and within the Salton Sea watershed in general.

Justification

One of the concerns and areas identified as requiring more data with regards to habitat conversation includes the need for geotechnical data about different management proposals, for example, engineered wetlands to preserve biological habitat and diversity. Some of the issues revolving around the need for these data included determining how berms will perform given seismic activity, wind erosion, and rain event erosion; the cost-effectiveness of berm performance; mechanisms to enhance vegetative growth thereby stabilizing berms; and the need to determine how berms will interact with the endemic flora and fauna

Rhizobium tropici ATCC® 49672, a catalogued symbiotic nodulator of leguminous plants (Martinez-Romero and others, 1991), is also known for its production of a gel-like extracellular polymeric substance (EPS) (Gil-Serrano and others, 1990). The natural functions of the EPS in the rhizosphere include surface adhesion, self-adhesion of cells into biofilms, formation of protective barriers, water retention around roots, and nutrient accumulation (Laspidou and Rittmann, 2002). The secretion of EPS by bacteria is also recognized as a cohesive force in promoting surface erosion resistance in soils and sediment (Droppo 2009; Gerbersdorf and others, 2008a, b). The biopolymer produced by *R. tropici* provides similar soil enhancements to a petroleum-based polymer in a long-lived, but ultimately biodegradable, material without the environmental concerns. In addition, the biopolymer acts as a carbon storehouse for readily biodegradable sugars that would otherwise be oxidized to CO2 and contribute to elevated greenhouse gasses in the atmosphere. A technique has been patented by the U.S. Army Corps of Engineers (USPTO No. US 7,824.569 B2, 2010) through which *R. tropici*-derived biopolymer can be produced in an aerobic bioreactor. The biopolymer is then separated from the bacteria and growth media, concentrated, and can be applied to the soil as either a slurry or powder.

The use of a biopolymer as a soil modifier for erosion control and reduction of sediment transport was evaluated through slope stability and surface soil durability studies at bench- and meso-scale using soil types with a high potential for erosion (Larson and others, 2012). Application of the biopolymer at economically feasible loading rates maintained the slope elevation (fig. 5-5), and was able to reduce the transport of soil particulates in runoff water from the berm (fig. 5-6). The biopolymer performed effectively when used with soils at high risk for erosion. The biopolymer has been shown to enhance soil stabilization of berms and reduce the cost of levee maintenance and repair (Larson and others, 2013). It also has the potential to contribute to the formation of "blue carbon" sequestration in the wetland areas.

Objectives

11. Determine how well the biopolymer versus no biopolymer (control) can stabilize the wetland/marsh berms under given simulated seismic conditions near the Salton Sea using a shake table simulator;
12. Determine how well the biopolymer versus no biopolymer (control) can stabilize the wetland/marsh berms under given simulated wind conditions at the Salton Sea. Measurements include bulk density, soil texture, water holding capacity, and shear stress;
13. Determine how well the biopolymer versus no biopolymer (control) can stabilize the wetland/marsh berms under given simulated rain event conditions at the Salton Sea.using runoff water samplers for analysis of total suspended solids;
14. Determine how well the biopolymer versus no biopolymer (control) might enhance vegetation growth on the wetland/marsh berms near the Salton Sea as a means of soil stabilization? Measurements include soil organic and total carbon; plant abundance, above ground biomass, and density; as well as plant root analysis including density, below ground biomass, and diameter measurements;
15. Determine changes in the rhizosphere microbial communities (microbial vs fungal affects carbon sequestration). This will include measures of Microbial Biomass Carbon and

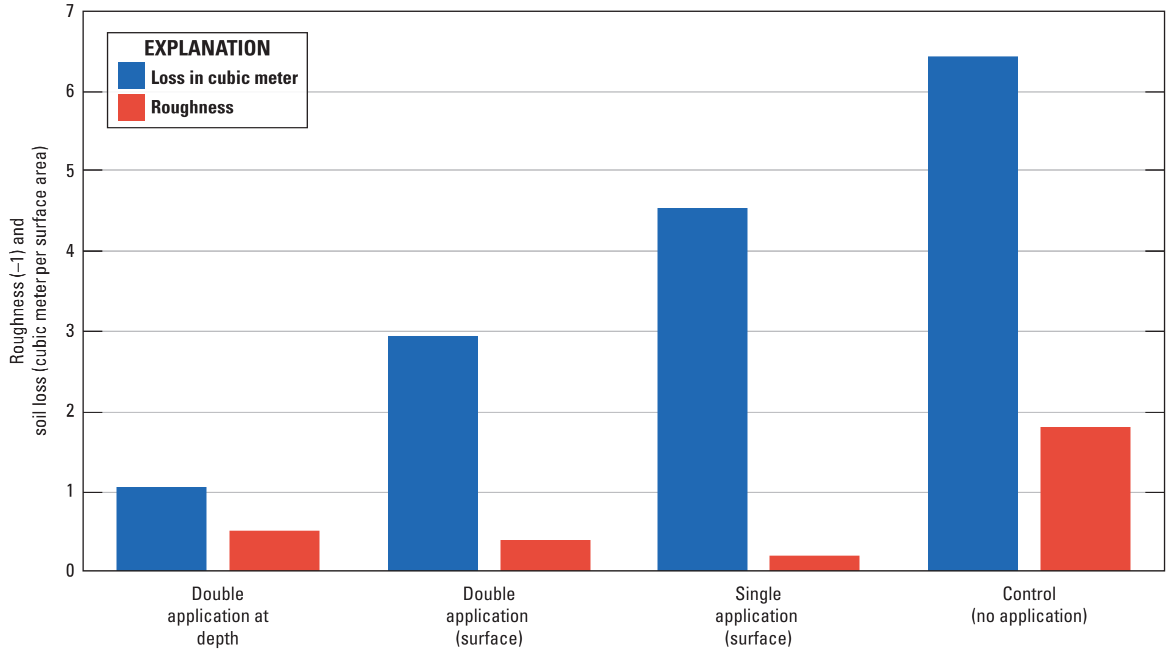

Figure 5-5. Soil loss from the berm surface and surface roughness for four experimental biopolymer application methods after six months of weathering.

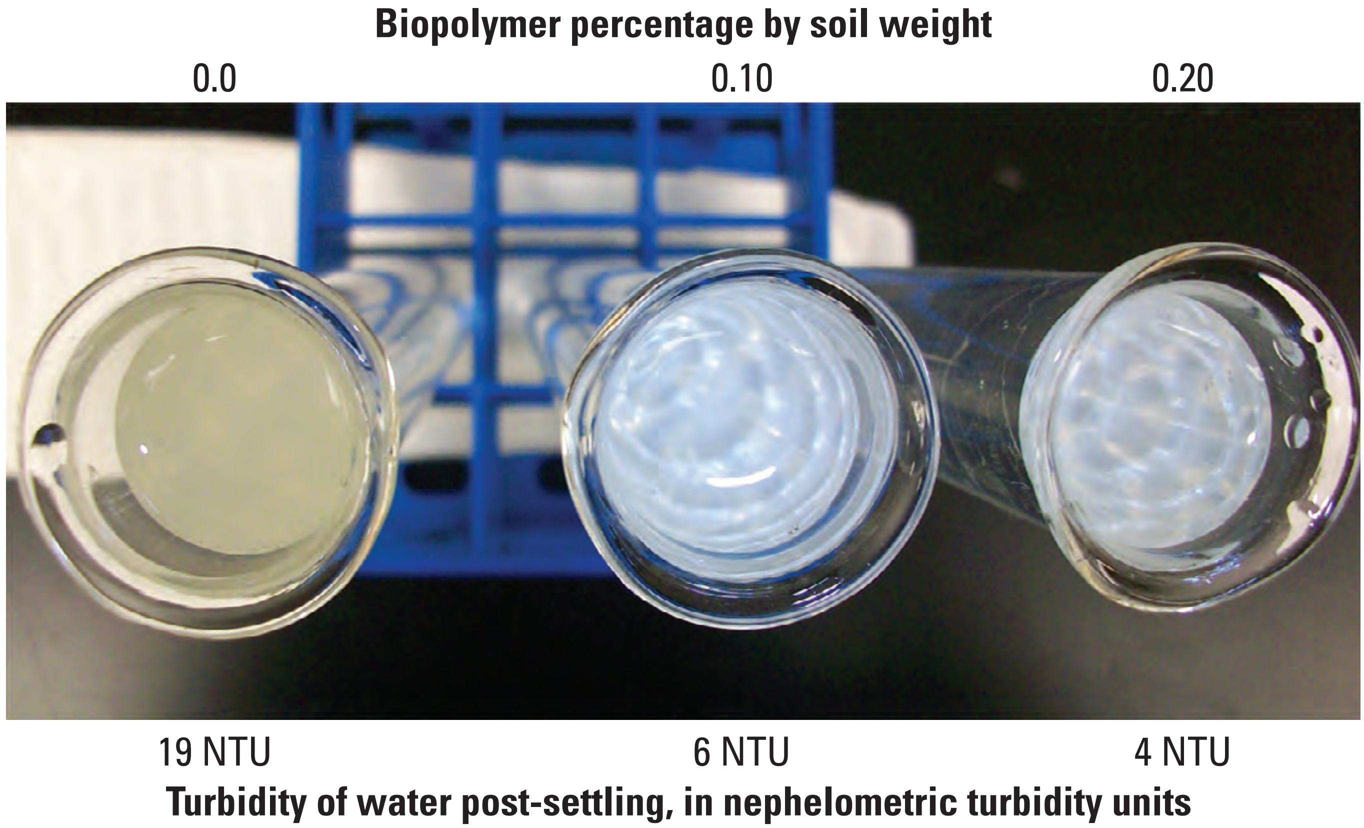

Figure 5-6. Reduction of total suspended solids in surface runoff water from soil treated with R. tropici biopolymer.

Potentially Mineralizable Nitrogen which represent the activity within nutrient pools and the potential nutrient processing capacity in the study area; and

16. If selected for field study, changes in the berm slope shape and elevation will be measured for all treatments using LIDAR to detect changes due to seismic or weather activity.

Products

- Peer-reviewed journal articles exploring the science of berm-biopolmer soil amendments; and
- A report summary of the results which will include recommendations for implementation of biopolymer soil amendment as it pertains to the Salton Sea Watershed.

How Does This Project Inform Management?

The findings from this project will elucidate best management practices which can then be directly applied to long-term solutions and coordinated with project and program decisions for possible full-scale implementation within the Salton Sea Watershed.

Budget

$1,185,900

The proposed project will require $1,185,900 for the three-year effort. This will include Federal labor and biopolymer production.

Point of Contact

Michael E. Kjelland, Ph.D.

BIO8. A predictive, dynamic biodiversity model for monitoring, management, and science in the Salton Sea hydroclimatic complex (alternative – The predictive ecosystem model)

Introduction and Background

The conservation of important biological diversity is more and more considered in the context of the habitat characteristics and key interactions with other organisms that influence the long term growth, survival and reproduction of any given taxa of importance. Such ecosystems frameworks are robust in terms of identifying potential anthropogenic hazards threatening conservation and developing the potential management actions that are key to long-term sustainability of a biological asset. For example, we know that plant-pollinator interactions constrain our management opportunities that favorably maintain the functioning populations of rare plants when pollinators are strict mutualists with extremely limited in distribution. We cannot expect these plants to have distributions that exceed the geographical extent of their pollinator. Additionally, we know that preserving the presence of organisms in the higher trophic levels of a particular ecosystem is a function of the presence of organisms lower in a given food web, and that certain expectations of the relationship between net ecosystem production and species abundance govern the upper limits of a managed system. As such, a key conservation / management tool is a robust understanding of how species are related to each other in an ecosystem, which can then be used as a decision support platform assisting with the adaptive management of natural systems.

For more than 30 years we have been sampling aspects of the biology present in the greater Salton Sea complex, accumulating a significant knowledge base on the natural history and autecology of important species to a number of key ecosystem services. This information is invaluable to decision and policy makers in aiding in the application of science to management decisions and complying with legislative goals. However, a significant challenge remains in creating such a synthetic product that can bring together the organismal dynamics, their interactions with each other and the environment, all in such a way to address specific management actions to be applied on the ground.

The Salton Sea is predicted to face rapid physical change in the very near future (~2017), upon the disruption of the current allocation of Colorado River Water to the water body, resulting in rapid changes in shoreline elevation and increases in salinity. These physical characteristics are expected to impact the growth and reproduction of key species in adverse ways, yet we do not now have a means of understanding how changes in individual organismal biology will cascade through the species complex. The resulting additional undesirable change impacting the overall status of the system as a result of the removal or reduction in abundance of key species is mostly unknown. Additionally, the ability to understand differences in the consequences of acceptable levels of population variability from threshold change would be important to develop to more rapidly respond to the evolution of system states that are indicative of whole-system collapse.

This approach requires a dynamical ecosystem model that would act as a vehicle to synthesize the biological knowledge base of key organisms in the Sea, that would provide a framework for linking physical modification of the system to changes in biological process, that would communicate important biological principles and patterns to the related, collaborative disciplines also engaged in conservation (hydrology, atmospheric sciences, socioeconomics, etc.), and that would act as a predictive tool for determining the risk of certain changes in ecosystem structure and function to allow for cost-benefit analysis and potential management actions associated with undesirable situations.

Justification

- The development of a dynamic ecosystem model would quantify and organize the tremendous biological information and create an accessible format for stakeholders;
- A dynamic ecosystem model would act to provide prioritization for studies on key ecosystem aspects that would most improve our understanding of the system so as to support management;
- A dynamic ecosystem model could provide the prediction and hypothesis testing processes that underlie effective adaptive management approaches to conservation;
- A dynamic ecosystem model would help to quantify, calculate, and insure equivalence in the ecosystem services being transferred from the natural system to the engineering alternatives in place that may be initiated to support a diverse number of management / mitigation priorities. This model would help optimize allocation of resources to different engineering attempts at approaching diverse management goals (maintaining fishery production, maximizing water flow from agricultural run-off);

- A dynamic ecosystem model would interact with and inform ecosystem valuation attempts and other economic, political and regulatory studies / assessments / decision-making schemes; and
- Allows us to understand how much habitat diversity is needed to support what kinds of aviary systems (what diversity of bird species).

Objectives

The objective of this project is to (1) provide a synthetic product of biological knowledge inclusive of the extensive history of science on biological systems of the Salton Sea, (2) develop a relational framework to understand processes that are important to the contemporary dynamics of the biological diversity of the Salton Sea and engineered systems, (3) provide an integrated conceptualization of biological systems to be aligned with physical and socio-economic studies and assessments, and (4) develop a predictive, numerical model to assess the risk of undesirable threshold change in the ecosystem state for the Sea and engineered mitigation / management projects.

Accomplishing such objectives would allow scientists, land managers, decision / policy makers and the public to robustly understand biodiversity linkages (using current data) and linkage interaction strength (through data-model assimilation associated with specific experimentation), and to develop a robust decision support system that guides monitoring and hypothesis generation important to adaptive management frameworks (by iterating the model with data from monitoring and forecasting biodiversity behavior in the context of specific scenarios assessed by monitoring and experimentation).

Products

This project would consist of several phases, each with decision-making impact on management decisions. First, we are focused on a synthesis product, where simply the biodiversity relationships will assist in expert opinion guidance on management actions. Second, we are committed to the development of a null-statistical model (likely nueral-network model based approaches) that at minimum can be iterated with monitoring efforts to begin to describe year-to-year changes in the components of biological diversity in time and inform adaptive management efforts. Third, with targeted experimentation, we can improve our understanding of the strengths of species interactions within this comprehensive ecosystem to better develop scenarios associated with perturbation of the system through loss of key species / functional groups (developed in collaboration with key stakeholders). Finally, with appropriate collaboration, a mechanistic approach will advance multiple model formats to reliable forecasting tools that can be used to carry out adaptive management and to guide an evolution of monitoring.

Specifically, we anticipate the production of (1) a graphic based conceptual model of species interaction webs, (2) a statistical model that is refined through data-model-experiment assimilation across the three year project period, (3) the initial development of a mechanistically based numerical model that is integrative with the hydrologic and biogeochemical tools being developed in other settings, (4) web-based visualization tools that highlight scenarios and model runs providing translation to important stakeholders, such as state and federal land managers, (5) a process of stakeholder engagement to refine biological questions and enhance the dissemination of results across diverse research groups, and (6) an addressable data base, available for use by many researchers in many settings.

How Does This Project Inform Management?

The dynamic ecosystem model would complement physical modeling by directly assessing the trends in biological systems. The model would inform best practices in monitoring by helping to assign value to different data sets in the context of how they inform model behavior and best predict real behavior in the system. The model would assist in forecasting changes that may mobilize emergency intervention, helping to prepare for worst-case scenarios of system collapse.

The goal would be to initially construct the model to be consistent with the Ecosystem Monitoring and Assessment Plan, so as to be informed by data likely to be collected by the diverse stakeholders. The long-term goal is to develop the model approach sufficient that coupling with physical models is possible (through either coupling approaches, such as Kepler, or through the development of sub-models to be run on the existing large-scale integrated systems models being produced by other groups, such as the hydrology group).

Budget

Category	Year 1	Year 2	Year 3	Year 4
Postdoc Researcher I	$80,000	$80,000	$80,000	$80,000
Postdoc Researcher II	$80,000	$80,000	$80,000	$80,000
Grad Student-2.5 FTE	0	$200,000	$200,000	0
Senior Researchers	$225,000	$225,000	$225,000	$225,000
Stakeholder workshops	$45,000	$45,000	$45,000	0
Travel	$12,000	$12,000	$12,000	$12,000
Misc. Supplies	$10,000	$10,000	$10,000	$10,000
Directed Activities($5K per GA)	0	$20,000	$20,000	0
Subtotal	$452,000	$672,000	$672,000	$407,000
Overhead (50% of direct costs)	$203,500	$313,500	$313,500	$203,500
Total Budget	$655,500	$985,500	$985,500	$610,500
Grand total				$3,237,000

Point of Contact

Dave Shuford, Travis Huxman, Lev Marusenko, Gregor Yanega, Tim Bradley, Tom Dietsch,

BIO9. Comprehensive monitoring and data assessment of the complete Salton Sea ecosystem: Invertebrate Survey

Note: The words “comprehensive” and “complete” are used because the monitoring will be inclusive of multiple aspects and scales of biota, not just birds.

Introduction and Background

Currently, data gaps exist due to either lack of monitoring capacity or incomplete understanding due to lack of awareness/knowledge of biological info (for example, # of organisms, species composition, nutrient cycling rates, interactions/feedbacks).

Perspective from Microbial Ecology Discipline

Microbes may undeniably have strong bottom-up effects that control abundance of all organisms in higher trophic levels (even if direct or indirect relationship with animals). The microbial contribution to nutrient cycling and metabolic toxic byproducts becomes important to study.

Tipping thresholds may be more noticeable in microbial communities than in larger organisms. Microbes instantly respond to chemical/environmental changes while larger organisms may reveal a sudden effect (that is, massive die-off). This gradual potential microbial community replacement can be used as an indicator/marker.

The footprint of microbial community changes during noticeable environmental fluctuations can be used for predictive power. For example, discovery of a particular microbial population (during survey monitoring) that is shifting in community dominance may suggest an upcoming environmental fluctuation event if we know that the microbe group has a history of being previously detected during environmental change.

The need to study and understand microbiology is difficult to market to the public—especially compared to nice fluffy birds—but can be done through various teaching/outreach modes about the importance of beneficial microbes and relevance for ecosystem/human health.

Justification

To gather baseline data on current levels and for long-term ecological monitoring (changes over time). The data can be used to guide decision-making for current and future goals.

Objectives

- Identify components in 'interaction model' that will require monitoring;
- Determine existing gaps/needs and potential unknown/understudied variables;
- Will enable prioritization of data needs;
- Develop strategy for effective sampling/monitoring;
- Involve citizens to help with gathering data (including public communication);
- Understand and predict potential tipping point and other thresholds for major ecosystem/community changes;
- Gather data at multiple temporal and spatial scales (short-term and long-term, different geographic strata);
- Identify novel microorganisms that can advance fundamental ecological theory as well as instigate economically-thriving biotechnology applications.

Products

- Intensive database that can be utilized by anyone/any organization;
- Data incorporated in reports for the Salton Sea Science Committee to help provide recommendations of action in current/ongoing projects and future efforts;

- Citizen science- broader impacts of community engagement, products from citizen action. For example, active citizens may feel more passionate about facilitating political influence;
- This data can be used in the 'interaction model' to advance subsequent iterations of the model and/or create various model versions depending on scenarios (for example, before/after tipping point); and
- Scientific publications (can be used for policy guidance, science research hypothesis-testing, reports/synthesis for science committee).

How Does This Project Inform Management?

Data will need to be interpreted/analyzed to assess patterns in community changes and interactions as well as predicting future scenarios. This simplified evaluation can be used by managers to supplement their goals in determining action and proposed work.

Budget

Salary – PI's plus techs	$320,000	$320,000	$320,000
Committee for determining monitoring efforts	$337,500	$337,500	$337,500
Data analysis	$80,000	$80,000	$80,000
Data management (storage/archiving, quality control, access)	Included in overhead	Included in overhead	Included in overhead
Overhead	$ 368,750	$ 368,750	$ 368,750
microbial supplies/analyses	$61,250 – costs for samples all years,		
Macroinvertebrates - Plankton	$10,000	$10,000	$10,000
Chemical and nutrient cycling analysis	$122,500 costs for samples all years,		
Travel and other support	$16,600	$16,800	$16,600
Totals	$1,316,600	$1,316,800	$1,316,600
Grand total			$3,950,000

Point of Contact

Yev Marusenko, Gregor Yanega

BIO10. Biological inventory—Inventory of extant biological, chemical and physical resources (include birds, fish, aquatic invertebrates, basic water quality, contaminants, water elevation, mapping of playa)

(No proposal developed but identified as urgent need.) Could be combined with another effort, for example, BIO9, to achieve significant savings.

Budget

$2,000,000

Point of Contact

Tim Bradley, James Orlando, Mark Ricca, Michael Anderson

BIO11. Bivalves as biofilters: Investigations of bivalves as biofilters for nutrient, sediment, and selenium remediation

(No proposal developed but identified as a science need.)

Budget

$500,000

Point of Contact

Tim Bradley, Lisa Windham-Meyers, Mark Ricca

Socioeconomic Proposals

SOCIAL1: Social & Community Research Proposal. Equity oriented collaborative research at the Salton Sea

Case and others (2013) outlines the need to integrate both social and economic considerations into its ongoing monitoring and assessment plan (see pages 119–135 in Case and others, 2013). In addition, a synthesis of needs outlined by regulatory agencies and managers in the Managerial meetings (see appendix 1) highlighted the importance the inclusion of local communities, laying a foundation for a shared vision and governance framework, understanding the environmental and social justice issues and better outlining the economic costs of management. Scientists have also expressed the need to better understand the “social” and “cultural” stories of the communities that interact with the Salton Sea, as well as build the capacity to integrate these stories into the scientific sharing of data and knowledge emerging from the ecological and biological studies.

In order to meet the concerns and needs expressed above, the conveners of the SSI are proposing a three-pronged strategy to integrate the social and community concerns into the overall research, monitoring and assessment plan. The three integrated components are **(1) equity oriented collaborative research aiming to better understand the social and cultural story of communities interacting with the Salton Sea; (2) a demographic and land-use survey aiming to identify and map land-uses; and (3) an economic study** to assess how management activities could impact land uses, outline costs over time for both management and impacts on the changing economic characteristics of the communities surrounding the region.

Introduction and Background

In a report by the Pacific Institute entitled “Hazard’s Toll” (Cohen, 2014), the costs of inaction in the Salton Sea would impose massive public health and environmental costs on the 650,000 community members and Californians more generally. The consequences of inaction also extend to the social and historic relationships in the communities surrounding the Salton Sea. Thus, an important component of resource management is to understand the needs and interests of the communities in proximity to the Salton Sea and a desire to listen and improve communication with those communities. While communication *from* managers and decision makers *to* community members is one aspect of this process, we are also cognizant of the importance of the ways in which local community knowledge can inform the science and planning processes; and how communities can be meaningfully engaged in these processes for policy advocacy and leadership.

Justification

Managers have communicated a need to better understand the communities that are connected to the Salton Sea. This proposal responds to that stated need. Specifically, managers indicated a need to develop a shared vision and shared governance, together with community members and scientists. They also stated a need to address environmental and social justice issues in the region in the context of Salton Sea planning. This project will provide this information while developing long-term community capacity for leadership, monitoring and evaluating the project.

Research Questions

Given the increased health risk and community vulnerabilities in the Salton Sea region and the desire for a shared vision and governance process between public institutions, researchers and communities, equity-based collaborative models of research at the local level are needed to facilitate this process. As such, the research needs a transformative approach. To this end, Proposal #1 aims to catalyze local communities in the Salton Sea region through interdisciplinary equity based collaborative scholarship that aims to generate sustainable solutions to the problems identified by the partnerships cultivated in the region. Specifically, the research questions aim to

- Identify the stakeholders in the region who interact with the Salton Sea;
- Seek understanding of the diverse communities in the region perceive the interact with the Salton Sea; and
- Cultivate the capacity of local communities to form sustainable partnerships with researchers, public sector agencies and each other to inform the decision-making processes around the Salton Sea.

Objectives

In order to help the Salton Sea communities build capacity to address the myriad sustainability challenges facing the region, we have formed a working group to develop an agenda for equity-oriented collaborative research. The Center for Collaborative Research for an Equitable California, a University of California led institution, is based at UC Santa Cruz. They define “collaborative research” as an umbrella term that actively engage communities and policy makers in the research process from start to finish. Other terms used to identify this approach to research include: community based participatory research and participatory based action research, among others.

This means that researchers, community-based organizations, and policy makers will work together to

- Frame the problems to be tackled and the questions that need to be answered around the Salton Sea;
- Undertake the research and interpret the results in terms of their significance for community and policy change; and
- Disseminate the research findings and advocate for change.

Collaborative research is engaged scholarship in action, in which researchers, community members, and policy makers respect the knowledge that each partner brings to the discussion so that together they might know better how to understand the complex problems facing our communities and how to design and implement research-based responses to those problems.

Our proposal seeks to use research includes methodologies that actively engage communities and policymakers in all phases of the research process. Elements include

- Providing a platform for knowledge sharing on current and incremental projects in and around the Salton Sea;
- Building the capacity of academic, agency and community research teams in equity oriented community engaged research practices;
- Building the capacity of relevant stakeholders in community visioning, action planning, community research;
- Fostering youth empowerment and sustainability leadership;
- Identifying community assets that can provide a foundation for a stronger capacity for sustainable management of the Salton Sea and its benefits for the community;
- Identifying the full range of affected groups, including underrepresented populations, affected by and concerned with the future of the region;
- Providing space for community discussions;
- Eliciting the current stories of how people identify their connection to the bioregion (ecologically, culturally, historically, and economically);
- Advising and coordinating messaging with Salton Sea Authority's public relations efforts;
- Connecting and integrating local and expert knowledge and fostering reciprocal co-creation of research questions; and
- Engaging disenfranchised groups (gender, race, class, status).

Elements of Methodology

A collaborative approach to the research methodology is qualitative in nature and will include an iterative and multi-pronged process of data collection, analysis and reporting. Various methods will be used to collect data such as in-depth one-on-one interviews, focus groups, or photo-voice. Such an approach to research is guided by principles such as:

- Co-creation of research questions; and
- Focus on capacity building in the community. Thus, the working group will determine the appropriate methods such as
  - Strategic Questioning (and training of);
  - Listening Sessions;
  - Linkage Building;
  - Community Organizing; and
  - Community Asset Mapping.

After generation of initial co-creation of knowledge, traditional social science surveys, ethnography, focus groups, in depth interviews, case studies and citizen science through high school science classrooms can be pursued.

Products

- At least three community listening sessions to facilitate collaborative conversations and co-creation of knowledge;
- Co-created work group of governance that can sustain a self- supporting framework to provide critical feedback and listen to Salton Sea managers and scientists;
- Capacity building workshops for "stakeholders" (using community asset mapping, strategic questioning);
- Workshops—training of trainers workshop for best practices in conducting citizen science (using community mobilizing);
- Youth-focused training on issues relevant to communities in the Salton Sea;
- Communication/outreach training for those who might engage with communities in discussing scientific findings and for communities who engage with scientists (the Extension model);
- One or more peer reviewed publications; and
- Policy notes or briefs for decision makers.

How Does This Project Inform Management?

The approach to collaborative research will

- Meet the stated management need to understand the social and cultural context in which policy decisions are made;
- Meet the stated needs of agency management to ensure that the Salton Sea management program is carried out in an inclusive manner that incorporates a wide range of issues and interests;
- Provide managers opportunities for capacity building so that they can better engage with diverse community groups;
- Provides communities with the capacity to engage with managers; and
- Formalize lines of communication between management process and community groups.

Budget

Item	Description	Year 1	Year 2	Year 3	Total
1 FTE	Post-Doc (PI)	$80,000	80,000	80,000	240,000
2 Grad Student		80,000	80,000	80,000	240,000
Community Facilitator	6 meetings/yr	12,000	12,000	12,000	36,000
Capacity Building Trainer	1 session/yr	5,000	5,000	5,000	15,000
Community Organizer		50,000	50,000	50,000	150,000
Supplies		5,000	5,000	5,000	15,000
Space rental community meetings		5,000	5,000	5,000	15,000
Travel & accommodation		10,000	10,000	10,000	30,000
Research supplies		5,000	5,000	$,000	15,000
Total					756,000
Overhead					340,500
Grand Total					$1,096,500

Point of Contact

Nina Burkardt, Abby Reyes, Mojgan Sami

Administration Proposals

Admin1. Development and implementation of an integrated database and library archive

This overarching need was identified in a number of individual proposals. It was also identified as an urgent need by the managers group meeting associated with the SoSS and has been identified as an urgent need by other science reports: U.S. Fish and Wildlife Service 1997; Shipley and others 1999; Science Subcommittee 2000; Case and others 2013).

The Salton Sea Ecosystem Monitoring and Assessment Plan (MAP) (Case and others 2013) provides a detail description for a data collection, analysis, and management system. This guide will provide for a systematic and standardized methods for data management that will help inform and guide potential management actions for the restoration of the Salton Sea ecosystem. One critical data-management element for a data management system is in determining which entity is responsible for system administration and how this relates to public access. Because many of the environmental and socioeconomic assessment and monitoring activities anticipated at the Salton Sea involve the collection of geospatial data, it is anticipated that a geographic information system (GIS) will be a primary platform used to manage, organize, analyze, and express these data. The long-term utility of geospatial data requires significant attention to the development of high-quality metadata, data lineage tracking, and quality assurance/quality control (QA/QC) of datasets.

Data collected by scientists working in the Salton Sea area will conform to the guidelines and standards discussed in the discipline-specific sections of the MAP. Ultimately, a distributed database is envisioned where the physical locations of the data are transparent to the user.

Effective data management will be integral to the success of a Science Program and, ultimately, to the success of the decision making and restoration activities that the monitoring data will inform. Data management complexity increases for long-term and broad-scale comparative studies and assessments in which scientists from numerous disciplines can be involved for long periods to address a complex series of questions or hypotheses. This necessitates increased attention to adequate metadata, QA/QC, archiving, and methods standardization (Michener, 1997).

Objectives

The principal objectives of the data management element are the following:

- Establishing and enforcing standards for data documentation.
- Establishing data transfer and storage protocol.
- Making data easily accessible and in a useable format.

Data collected under the various projects will be housed and made accessible either through the appropriate controlling agency. Data collection will follow the protocols laid out under the individual monitoring plans as identified in Case and others (2013). All deliverable products will contain metadata that meet the metadata standards as defined in Case and others (2013). The intent of this proposal is to initiate the development of an integrated database and document library in a searchable format accessible to scientists, managers, and the general public.

Budget

$3,000,000

Point of Contact

Boykin Witherspoon

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Appendix 6. Roles and Responsibilities of a Science Program in Management of the Salton Sea

Complex and interactive effects between chemical, biological, physical and other factors have caused a decline of overall environmental quality of the Salton Sea. In order to understand these complex interactions, it has long been recognized that a robust integrated science program was necessary to provide information to develop a management plan. In the late 1990s, the Secretary of the Interior and the Congressional Salton Sea Task Force requested a science plan to support the Salton Sea management effort under the Salton Sea Reclamation Act of 1998 (Public Law 105–372). Despite decades of planning efforts (California Resources Agency, 2006, chaps. 1 and 4) and a multitude of scientific studies, resolution of how to provide for the sustainability and economic viability of the Salton Sea region has not yet been accomplished. The State of California recently entered into a new phase of planning and is currently working on a plan for addressing the myriad of issues of the Salton Sea. With this new planning phase comes a potential for a massive reconfiguration of the Sea, encompassing a smaller lake, declining inflows, continued degradation of water quality, increase in salinity, loss of wildlife and fisheries habitat, fugitive dust generated from exposed sediments, and a need for economic development. A new plan with such vast anticipated changes will require a strong science effort to assist management agencies to achieve effective management of a future ecosystem—one that could be very different from the past. These integrated efforts include assuring that the Sea continues to provide desired levels and diversity of natural resources while accommodating changes in the environment that may result from human population growth within the area.

Origins of Integrated Salton Sea Science

The earliest attempt at organizing a comprehensive and integrated science program was in December 1997 with the incorporation of an interim Salton Sea Science Subcommittee (SSC) within the Salton Sea Management Project. The SSC, a coalition of Federal agencies, State agencies, and non-governmental organizations (NGOs), was tasked with developing guidance for a science effort needed to support management as mandated by PL 105–372. The primary purpose of the SSC was to provide a sound scientific foundation on which management judgments can be based in considering alternatives for achieving project goals. The SSC recognized that achieving this objective would involve data evaluation, identifying knowledge and data gaps, additional scientific investigations, information synthesis, and robust scientific integrity of the process. The SSC further identified two key components of a successful science program. First, there needs to be a Strategic Science Plan (SSP) which lays out the overall framework of goals and objectives of a science program. Second, there needs to be an organizational unit whose function is to enable and execute the SSP. This organizational unit, a

Science Office, was to be the permanent operational replacement for the SSC (Salton Sea Science Subcommittee, 2000).

An SSP was developed with assistance of a U.S. Geological Survey "Tiger Team," which was charged with evaluating the underlying science needs for understanding the Salton Sea ecosystem. Based in large part on this report (Shipley and others, 1999), the SSP was developed to provide a structure for scientific support for the project to replace the SSC (Salton Sea Science Subcommittee, 2000). The SSP provided recommendations for the development, function, and oversight of a pragmatic science effort to support long-term management actions for restoring the Salton Sea and calls for the following goals (Salton Sea Science Subcommittee, 2000):

- *"Establish a dedicated science office to serve as an interface with management efforts;*
- *Provide timely, objective scientific evaluation and technical assistance to management;*
- *Establish a long-term database program for supporting investigations and management actions;*
- *Establish a steady and reliable funding base for supporting SSRP (Salton Sea Restoration Plan) science needs;*
- *Implement a comprehensive, open scientific review process to refine the existing draft management goals and objectives from a scientific ecosystem perspective. Based on this review, agree upon performance measures as benchmarks against which to measure true success of management;*
- *Develop and continue to refine reliable, flexible conceptual models encompassing ecosystem components and their functional relationships;*
- *Develop a long-term ecosystem monitoring program to establish baselines, measure management outcomes, and help refine future actions;*
- *Beyond monitoring of baseline conditions, include investigations of episodic, extreme, and unpredictable events such as fish and wildlife die-offs, algal blooms, and unusual climatic events that have the potential to significantly affect the ecosystem or influence individual valued resources;*
- *Identify and prioritize investigations relevant to management, based on conceptual models and identified information gaps;*
- *Develop quantitative, integrative, predictive models based upon identified conceptual relationships; and*
- *Establish a data and information management program to make results of long-term monitoring and focused investigations available to resource managers, scientists, stakeholders, and the public."*

To this end, a Science Office was established under the auspices of the U.S. Geological Survey to plan, coordinate, evaluate, and synthesize information for support of the management decision process.

Rationale and Functions of a Science Program

There is a general perception that the Salton Sea has been "studied to death" (Claiborne, 1996), a catch phrase still popularized by the public, managers, and stakeholders. The perpetuation of this thought condones the dismissal of requisite scientific understanding of ecosystem complexity as nothing more than a roadblock to management action. A comprehensive understanding of the ecosystem and its changes is required to enact management plans that will achieve desired outcomes and ensure wise investment of public funds into viable solutions. This is the core of an adaptive management program.

A retrospective analysis of scientific information about the Salton Sea conducted by the SSC (1998 to 2000) disclosed that much of the information was dated and of limited use because of changes taking place within the Salton Sea ecosystem. This analysis revealed that there had been no studies of the Sea as a whole, and existing investigations were fragmented and did not provide a sufficient interface to meet NEPA/CEQA information needs. It was concluded from these evaluations that the immediate priority for science was to describe the current state of the Sea ecosystem (Salton Sea Science Subcommittee, 2000). In response, from 1998 to 2002 a series of integrated reconnaissance studies were identified, funded, and conducted (table 6-1) in a manner that provided "real time" information for use in the NEPA/CEQA evaluations (Salton Sea Authority and Bureau of Reclamation, 2000). The prioritization of information needed was determined to be an evaluation of the ecological factors resulting in major bird die-offs, followed by evaluations of important system processes within the Sea specifically related to nutrient cycling in order to better understand eutrophication. An effective integrated science program has been instrumental in securing this vast array of information and making it available to managers and the public (Barnum and others, 2002; Hurlbert, 2007; Hurlbert, 2008).

Table 6-1. Reconnaissance-level investigations administered by the Salton Sea Science Subcommittee (SSC) and USGS Salton Sea Science Office from 1998 to 2002 (Salton Sea Science Subcommittee, 2000).

Investigation	Organization/Author
Survey of algal toxins in the Salton Sea	University of California at San Diego, Scripps Institute of Oceanography
Avifauna of the Salton Sea: Annual phenology, numbers, and distribution	Point Reyes Bird Observatory
Fisheries biology and fish ecology of the Salton Sea	San Diego State University—Center for Inland Waters
Salton Sea desert pupfish investigations	Bureau of Reclamation
Reconnaissance of the biological limnology of the Salton Sea	San Diego State University—Department of Biology
Limnological assessment of the Salton Sea, Riverside and Imperial Counties	Bureau of Reclamation
Survey of selected microbial pathogens in the Salton Sea	U.S. Geological Survey—National Wildlife Health Center
Environmental reconnaissance of the Salton Sea: Sediment contaminants	Levine-Fricke Recon
Baseline reconnaissance vegetation mapping of the Salton Sea	University of Redlands
Ecology and management of avian botulism at the Salton Sea	U.S. Geological Survey—National Wildlife Health Center
Tilapia food habits	University of Southern Mississippi

Investigation	Organization/Author
Identification and ecology of disease-causing agents for eared grebes at the Salton Sea	U.S. Geological Survey—National Wildlife Health Center
Investigations of the cause of eared grebe mortality at the Salton Sea—Algal blooms and biotoxins	Wright State University

Without sufficient understanding of how the ecosystem works, some alternatives may have unintended consequences, exacerbating existing issues. For example, three recent independent and seemingly unrelated studies investigated the relationship of thermoclines, hydrogen sulfide, nutrients, and Sea mixing events[1] (Chung and others, 2008; Marti-Cardona and others 2008: Reese and others, 2008; Tiffany and others, 2007) (see footnote). These studies revealed that water deeper than 10–12 m may exacerbate the hydrogen sulfide problem, with potential for widespread ecosystem damage and risk of adverse human health effects. This caused planners to reject any alternative promoting a strategy of less surface area while concurrently maintaining a water depth of 12 m or more (California Resources Agency, 2006).

Historical Perspective of the Roles and Functions of a Science Program

A permanent Science Office was established within the U.S. Geological Survey as a continuation of the efforts of the SSC in summer of 2000. The office sustains the focus on peer review and production of high quality science evident in the SSC activities and is charged to adhere to a basic operational set of guidelines (table 6-2) as established by the SSP.

Table 6-2. The functions of a Salton Sea Science Office (Salton Sea Science Subcommittee, 2000).

Operational guidelines
Science leadership and coordination
Science information and data synthesis
Science oversight and responsibility for science activities
Assist resource management agencies with administration of science funding
Assist resource management agencies with science contract awards and negotiations
Science-outreach activities
Oversight of development and delivery of scientific products
Collaboration and coordination with resource management agencies
Networking with external agencies and organizations for data sharing and other science needs
Accountability and reporting for science program activities

The results from these scientific studies have provided the vast bulk of information used to evaluate proposed management actions and provides the most comprehensive scientific evaluations of the Salton Sea to date. Robust scientific findings often reveal relationships and facts that may differ from popular perceptions and “conventional wisdom” about the Sea, based on earlier investigations or more fragmented scientific efforts, and news accounts.

The SSC and USGS Science Office have provided numerous evaluations of proposed management actions. Multiple workshops have evaluated various science issues and assessed specific management concepts being considered as project alternatives. Examples of these efforts include (Salton Sea Science Subcommittee, 2000; U.S. Geological Survey, 2014)

- Expert workshop on eutrophication;
- Expert workshop on salt precipitation;
- Expert workshops on selenium;
- Expert workshop on air quality;
- Expert review of proposed alternatives from the Pacific Institute, U.S. Filter Corporation, Salton Sea Authority;
- Expert workshop on shallow saline wetlands; and
- Stakeholder and expert workshops on science and monitoring needs for the Salton Sea.

Adaptive Management as Foundation for Science Programs

The SSP asserts that, *"The complexity and magnitude of the management effort are such that no single action will result in achieving the management project goals. It is now acknowledged that a sustained, long-term management effort will be required, some of which will involve significant uncertainties. Therefore, a basic assumption is that the management effort will be an iterative process involving multiple actions and a phased approach. This type of need lends itself to a process commonly referred to as adaptive management. Among the many definitions and discussions of adaptive management is the common theme of providing a formal, systematic, scientifically defensible, and rigorous approach to learning from the outcomes of management actions, accommodating change, and improving management (Holling, 1978)"* (Salton Sea Science Subcommittee, 2000). In other words, a sustained long-term management program requires an investment in a sustained, long-term science program to synthesize and evaluate information through focused investigations, modeling, and monitoring. Moreover, appropriate iterative feedback mechanisms should be employed (for example, peer review, adaptive management) to insure integration of information within a management decision support framework.

As recommended by the SSP, *"A Science Office should not be involved in the direct conduct or supervision of individual scientific investigations. This office is the foundation for the science program and is accountable for the quality and productivity of science efforts funded as part of the management project. A Science Office should include standing committees to help set priorities and to address various issues. An External Advisory Committee of stakeholders in the Salton Sea would help identify priority scientific investigations at the Sea. A Science Advisory Committee, whose members are selected because of their technical expertise would meet to address specific technical issues, to assist in establishing science priorities, to serve as peer reviewers, and to provide requested scientific evaluations"* (Salton Sea Science Subcommittee, 2000).

A Science Program for the Future

Numerous documents compiled in the past two decades provide information on science and monitoring needs for management of the Salton Sea. Progress has been made on addressing a basic understanding of ecosystem functioning. Progress has also been made on identifying additional science and monitoring needs in order to continue our understanding of this dynamic and changing ecosystem as it undergoes a transformation due to full implementation of the QSA. For an exhaustive evaluation of future science and monitoring needs, we refer the reader to several recent documents, including appendix 5 of this document, environmental and program components of the Salton Sea Programmatic EIR (California Resources Agency, 2007), Species Conservation Habitat EIS/EIR (U.S. Army Corps of Engineers and California Natural Resources Agency, 2013), the Salton Sea Ecosystem Monitoring and Assessment Plan (Case and others, 2013), and Salton Sea Species Conservation Habitat Monitoring and Adaptive Management Plan (California Natural Resources Agency, 2015).

Management of the Salton Sea has always been anticipated to be a lengthy process that will require scientific support and investigations. A fact-based approach for resource management in and around the Salton Sea requires a synthesis of information that includes retrospective analyses, results from expert issue-focused workshops, and scientifically robust research integrated into a cohesive and adaptable plan. Connection of the science effort to ongoing rehabilitation efforts, to the continued effectiveness of the science being conducted, and the ability to support a management decision process is best accomplished through a science program to support resource managers' data and information needs. The organizing committee and participants in the 2014 State of the Salton Sea Meeting support the continuation of an independent science program for the Salton Sea based on the principle of unbiased science to support the management decision process.

FOOTNOTE

[1]These studies demonstrated that the Sea experiences periodic thermoclines causing thermal stratification of the water column. Thermoclines trap hydrogen sulfide gas originating from the rich organic deep sediments and cause anoxic conditions in the bottom waters of the Sea. Lake mixing events, usually brought about by high velocity winds (Schladow, 2005), destratify the water column, dissipate the thermocline and allow hydrogen sulfide gas to be released to the water column and vented to the atmosphere. Hydrogen sulfide mixing with the oxygenated upper water column in the presence of abundant calcium causes a chemical reaction creating calcium sulfate, commonly known as gypsum. The resulting gypsum can be seen as a green swirl on the Sea surface and has been observed by satellite imagery for decades, but was misinterpreted as algal blooms (figure 6-1). This reaction also consumes oxygen and creates anoxic regions of the Sea leading to large scale fish die-offs. These findings were significant by themselves, but Schladow (2005) investigated how some alternatives for Salton Sea restoration would affect this hydrogen sulfide scenario. Schladow's modeling suggests that alternatives proposing to reduce Sea surface area while maintaining a water depth greater than 10 m would produce a more persistent thermocline due to the lack of sufficient wind shear energy from a reduced fetch

(distance wind travels over water). The implications are that a more persistent thermocline would capture a greater amount of hydrogen sulfide gas. However, when the prolonged thermocline was dissipated, it would be rapid and the hydrogen sulfide would be released in a short period of time. This would create anoxic conditions throughout the Sea, kill all oxygen dependent life forms in the Sea, and potentially affect onshore wildlife and human health (Schladow, 2005). This integration of science provided a greater understanding of how these system dynamics work in concert with each other and provided information vital to the management decision process.

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Figure 6-1. Gypsum bloom (locally known as a green-tide event) at the Salton Sea, May through June 2003. Image courtesy of NASA-MODIS.

Appendix 7. Strategic Science Plan, 2000—Executive Summary

The Executive Summary contained in this appendix is a direct quotation (taken verbatim) from the following publication:

Salton Sea Science Subcommittee, 2000, Strategic science plan, Salton Sea restoration project: Salton Sea Science Subcommittee, 103 p., accessed at https://www2.usgs.gov/saltonsea/docs/history/strategic%20sci%20plan.pdf.

Executive Summary

Section I. Introduction

The Salton Sea is an ecosystem in peril. Its prehistory consists of a series of intermittent lakes dependent on infrequent flooding of the Colorado River, while the modern Salton Sea originated from the desire to harness the flow of the Colorado River for irrigation. What began as an accident of this attempt is now a permanent inland sea supported by wastewater and agricultural drainage rather than Colorado River flood flows. However, environmental degradation is challenging the ability of the Sea to sustain the biological components that society has learned to value as characteristics of this waterbody. Increasing salinity and increasing frequency and magnitude of wildlife losses indicate the Sea is under severe environmental stress. The Salton Sea Restoration Project originated to reverse this degradation, to stabilize fluctuating water levels, and to provide a permanent waterbody that sustains values of the human society that uses it. The project foundation is provided by Public Law (PL) 102–575, passed by Congress in 1992. PL 102–575 directs the Secretary of the Interior to “conduct a research project for the development of a method or combination of methods to reduce and control salinity, provide endangered species habitat, enhance fisheries, and protect human recreational values… in the area of the Salton Sea.” That PL was followed by the Salton Sea Reclamation Act of 1998 (PL 105–372), which directs the Secretary of the Interior to “complete all studies, including, but not limited to environmental and other reviews, of the feasibility and benefit-cost of various options that permit the continued use of the Salton Sea.”

Section I of this document provides background and historical information relevant to the Salton Sea Restoration Project (SSRP). Section II highlights the activities and accomplishments of the Science Subcommittee. Section III is the conceptual framework for a continuing Salton Sea Science effort that is pragmatically focused on and linked to the SSRP. Section IV contains supplemental information referred to within the other sections (reader is urged to read the original full report for access to all sections).

Section II. Science Subcommittee

The Salton Sea Science Subcommittee (SSC) was incorporated within the Salton Sea Restoration Project in December 1997 to guide the science effort needed to support restoration. The primary purpose of the SSC is to provide a sound scientific foundation on which management judgments can be based in considering alternatives for achieving project goals. Achieving this endpoint has been accomplished by evaluating data, identifying data gaps, and awarding contracts for focused scientific investigations. Using the principles of competition and peer review, eight reconnaissance projects, four studies of fish and avian mortality, and a nutrient cycling investigation were funded in 1998 and 1999 through the Salton Sea Authority (SSA) by a research grant provided the SSA by the U.S. Environmental Protection Agency. By September 1999, two projects had been completed, and eight synthesis documents had been written to provide input to the planning documents. These investigations are providing the most comprehensive scientific evaluations of the Salton Sea ever available. An additional eight issue-specific documents were prepared by SSC members to meet urgent needs of the planning process. Findings often differ from popular perceptions and conventional wisdom about the Sea, based on earlier investigations and more fragmented scientific efforts. As a result, speculation and unknowns are being replaced by practical knowledge. The SSC also provided presentations at scientific, agency, and environmental community forums and developed a strategic science plan (SSP) to guide the long-term integration of science within the SSRP.

Section III. Future Science Activities

The SSP provides recommendations for the development, function, and oversight of a pragmatic science effort to support long-term management actions for restoring the Salton Sea. Development of this segment of the SSP was assisted by input resulting from an SSC request for a U.S. Geological Survey "Tiger Team" to carry out an intense evaluation of needs. A strong scientific program specifically oriented at guiding management actions will provide a sound basis for management decisions, evaluation of progress toward achieving SSRP goals, and conceptual models for effective selection among alternatives to address specific SSRP actions.

The basic objective for the SSP is to provide a framework for a continued scientific effort in support of the restoration project that replaces the interim activities of the Science Subcommittee. This objective will be met by accomplishing the following goals:

- Establish a dedicated science office to serve as an interface with restoration efforts;
- Provide timely, objective scientific evaluation and technical assistance to management;
- Establish a long-term database program for supporting investigations and management actions; and
- Establish a steady and reliable funding base for supporting SSRP science needs.

Components of the Science Program

Environmental baselines need to be established to evaluate change from restoration efforts. Monitoring is performed to evaluate the success of restoration actions and to collect long-term data from which quantitative models can be validated. Conceptual models are used to guide the development of quantitative models by identifying processes and ecosystem functions thought to be important. Quantitative modeling then generates hypotheses about these processes and ecosystem functions that focused investigations can explore. Focused investigations fill in key information gaps, support monitoring by identifying important measures that were not initially recognized, and also help in validating quantitative models. These components interact to provide management with a solid base to assess functional system changes being achieved and the outcome of management actions relative to the SSRP goals.

Technical assistance provides the glue linking the science program to restoration management. A dedicated technical assistance component is included within this SSP to provide a focal point for management requests and to develop processes to support those requests in a timely manner.

The SSRP has need for data and information management. The projected long-term efforts of the project will be best served by formal agreement between the project and external programs for managing scientific data and information that clearly define the roles, responsibilities, and contributions of each entity. Key considerations regarding SSRP scientific data and information management are that these components are part of the integrated scientific effort rather than a separate scientific program. This is important because formatted input and availability of scientific data can be required only for investigations funded by the project. It would require a substantial investment in equipment, personnel, and facility costs to establish an internal database function within the science program.

The Science Office

Restoration of the Salton Sea is a lengthy process that will require scientific support and investigations for many years. Continuity of the science effort, effectiveness of the science undertaken in support of the SSRP, and efficiency of operations in serving management needs will be best served by a funded and staffed Science Office. This office should be established as an independent organization along with the management offices for the SSRP.
The functions of the Science Office are as follows:

- Science leadership and coordination;
- Science oversight and responsibility for SSRP science activities;
- Administration of science funding;
- Science contract awards and negotiations;
- Science outreach activities;
- Development and delivery of scientific products;
- Collaboration and coordination with the SSRP management agencies;
- Networking with external agencies and organizations for data sharing and other SSRP science needs; and
- Accountability and reporting for the science program.

The basic roles for the Science Office are that of science planning, coordination, evaluation, and contract awards and administration. The Science Office should not be involved in the internal conduct or supervision of individual scientific investigations. It is the foundation for the science program and is accountable for the quality and productivity of science efforts funded as part of the restoration project. The Science Office has two standing committees to help set priorities and to address various issues. The External Advisory Committee of stakeholders in the Salton Sea helps coordinate scientific investigations at the Sea, setting priorities and resolving science issues. The Science Advisory Committee, whose members are selected because of their technical expertise, meets as small focus groups to address specific technical issues, to assist in establishing science priorities, to serve as peer reviewers, and to provide requested scientific evaluations.

Field Station

The Salton Sea Restoration Project science activities would be greatly enhanced by a common use on-site field station. The primary purposes of this facility would be to increase cost efficiency by sharing equipment and to facilitate coordination and dialogue among scientific studies. This would be a working facility for investigators who should be isolated from external disturbances, such as tour groups and unscheduled visits by the public, media, and others. The site should provide stability for the life of the project and should not be subject to transient occupancy owing to other needs for the site by the landowner. The field station could be administered by one of four entities: the private sector, as an interagency cooperative agreement for shared government facilities, as sole responsibility of a government agency, or by the Salton Sea Science Office.

Funding the Science Program

The science program has no directed purpose without the SSRP; therefore, funding for the science effort should be part of total federal appropriations for the SSRP. Base funds provided the Science Office as an annual appropriation should be augmented by contributions from the state of California, grants for specific activities, and cooperative agency science activities that are funded through agency budget processes. Base funding should be tied to Congressional authorization for the Salton Sea Restoration Project because the purpose for the science program is to provide a sound scientific foundation for management decisions and actions associated with the restoration effort. Science requires time to gather information needed by management; therefore, funding for science should not be delayed if there is a delay between SSRP authorization and appropriations for construction. Federal funding for the Science Office will need to be provided through some federal agency as base resources to assure annual operating funds to sustain the science effort.

Funding the major components of the science effort should be approached in a manner consistent with the objectives of the following components:

- Modeling and Focused Investigations—base funds, contributed funds from outside sources, and grants obtained for specific areas of inquiry.
- Monitoring—routine activities should be provided by cooperative state/federal agency programs, using their internal budget processes and existing program expertise. Nongovernment agencies also may contribute to a coordinated monitoring effort. Specialized monitoring associated with pilot and demonstration projects will require SSRP or base funding.
- Technical Assistance—funding to be provided by the Science Office and charged against SSRP and other management offices requesting assistance. The nature of the assistance should dictate what costs would not be borne by the Science Office.
- Data and Information Management—combined funding by the Science Office, external grants, fees for services provided, and cost-sharing arrangements with stakeholder agencies and organizations.

The Role of Review Processes in Restoration Science

External peer review is a fundamental component of quality science programs and should be an uncompromised standard for Salton Sea science. Peer review processes should be incorporated within all science activities: competitive science awards, database evaluations, data and documents released for use of the public, and collaborative science, such as monitoring.

Transition from Science Subcommittee to a Workable Science Program

Several actions are needed to assure continuity of science support for the SSRP. These include, but are not limited to, maintaining the current executive director of the SSC to oversee the transition, appointing a permanent Science Office executive director, establishing the External Advisory and Technical Advisory Committees, holding a modeling workshop to develop a conceptual model of the Sea, and producing a publication on the "State of the Salton Sea," which summarizes current knowledge from studies directed by the SSC. Most critical to continuing the science support for restoration are obtaining temporary funding for science operations until the SSRP is authorized and obtaining commitments from stakeholder agencies for continuing oversight on current Salton Sea science investigations.

Appendix 8. Salton Sea Ecosystem Monitoring and Assessment Plan—Executive Summary

The Executive Summary contained in this appendix is a direct quotation (taken verbatim) from the following publication:

Case, H.L., III; Boles, Jerry; Delgado, Arturo; Nguyen, Thang; Osugi, Doug; Barnum, D.A.; Decker, Drew; Steinberg, Steven; Steinberg, Sheila; Keene, Charles; White, Kristina; Lupo, Tom; Gen, Sheldon; and Baerenklau, K.A., 2013, Salton Sea ecosystem monitoring and assessment plan: U.S. Geological Survey Open-File Report 2013-1133, 220 p., accessed at https://pubs.usgs.gov/of/2013/1133/.

Executive Summary

The Salton Sea, California's largest lake, provides essential habitat for several fish and wildlife species and is an important cultural and recreational resource. It has no outlet, and dissolved salts contained in the inflows concentrate in the Salton Sea through evaporation. The salinity of the Salton Sea, which is currently nearly one and a half times the salinity of ocean water, has been increasing as a result of evaporative processes and low freshwater inputs. Further reductions in inflows from water conservation, recycling, and transfers will lower the level of the Salton Sea and accelerate the rate of salinity increases, reduce the suitability of fish and wildlife habitat, and affect air quality by exposing lakebed playa that could generate dust.

Legislation enacted in 2003 to implement the Quantification Settlement Agreement (QSA) stated the Legislature's intent for the State of California to undertake the restoration of the Salton Sea ecosystem. As required by the legislation, the California Resources Agency (now California Natural Resources Agency) produced the Salton Sea Ecosystem Restoration Study and final Programmatic Environmental Impact Report (PEIR; California Resources Agency, 2007) with the stated purpose to "develop a preferred alternative by exploring alternative ways to restore important ecological functions of the Salton Sea that have existed for about 100 years." A decision regarding a preferred alternative currently resides with the California State Legislature (Legislature), which has yet to take action.

As part of efforts to identify an ecosystem restoration program for the Salton Sea, and in anticipation of direction from the Legislature, the California Department of Water Resources (DWR), California Department of Fish and Wildlife (CDFW), U.S. Bureau of Reclamation (Reclamation), and U.S. Geological Survey (USGS) established a team to develop a monitoring and assessment plan (MAP). This plan is the product of that effort.

The goal of the MAP is to provide a guide for data collection, analysis, management, and reporting to inform management actions for the Salton Sea ecosystem. Monitoring activities are directed at species and habitats that could be affected by or drive future restoration activities. The MAP is not intended to be a prescriptive document. Rather, it is envisioned to be a flexible, program-level guide that articulates high-level goals and objectives, and establishes broad sideboards within which future project-level investigations and studies will be evaluated and authorized. As such, the MAP, by design, does not, for example, include detailed protocols describing how investigations will be implemented. It is anticipated that detailed study proposals will be prepared as part of an implementation plan that will include such things as specific sampling objectives, sampling schemes, and statistical and spatial limits.

Monitoring of the Salton Sea ecosystem is critical for informed decision making and the success of restoration efforts. Information derived from monitoring activities will be used to guide the initial designs and management of restoration actions. Monitoring will also help ensure the success of management actions by identifying actions that are not having the desired effect so that they can be adjusted. The MAP is intended to foster the following specific objectives:

- Establish baseline conditions for the Salton Sea ecosystem.
- Establish metrics against which data gathered during long-term monitoring can be compared.
- Identify and prioritize filling of existing data gaps.
- Store, manage, and make monitoring data publicly available in a timely manner.

The scope of the MAP is intentionally broad to capture the potential range of processes and conditions influencing the Salton Sea ecosystem and its associated resources. By adopting a broad scope for the MAP, investigators will be able to identify linkages and interactions among resources and integrate monitoring actions needed to make full use of the collected data. The comprehensive nature of the plan also reflects the current uncertainty regarding the ultimate intent of restoration and the desire to collect an array of information that will not preclude informing specific restoration actions or alternatives.

The MAP will be subject to regularly scheduled reviews, and revised as needed as monitoring needs, technologies, and assessment methods evolve. Further, the initial monitoring protocols identified in the MAP could change over time as new and improved techniques and assessment methods are identified. Because many of the previously mentioned objectives have data as a component of the objective, data management through the entire life cycle of monitoring and assessment program is included within the scope of the MAP. Data management will be the responsibility of individual investigators and coordinated through the CDFW, as described in this plan.

The MAP is envisioned to be one of several components of an integrated science program that would coordinate and oversee (including peer review) data collection, data analysis (including a retrospective analysis), and an adaptive management strategy to support future restoration actions at the Salton Sea. This framework envisions a science integration and coordination entity that would answer questions relevant to policy and decision making by using the best available science and an adaptive management approach based on integrated assessment of data developed through the MAP, results of focused investigations, and a retrospective analysis of prior data and existing literature.

Identifying and prioritizing monitoring activities that would be implemented under this MAP will be the subject of a detailed implementation plan. The implementation plan will establish the elements of the MAP that should be performed and the scope of those activities. Monitoring activities to be performed will be identified on the basis of information needed for future environmental documentation, information needed to help resolve uncertainty, and information needed to provide a basis for comparison. Funding and logistics for the actual field work will be considered in development of the implementation plan.

This MAP is organized by separate, potentially stand-alone modules, describing monitoring of biological, hydrologic, geographic and geologic, air quality and climate, and socioeconomic resources, as well as data management activities. Each module includes a general overview, the monitoring objectives, key questions and information needs, the geographic scope, conceptual models, and recommended monitoring activities. Each section describing recommended monitoring activities includes a description of the purpose and justification for the monitoring activity, location, period and frequency of monitoring, protocol for data collection, a description of the data to be collected and the anticipated use of the data, recommended quality-assurance measures, data reporting guidelines, and an overview of similar current monitoring activities. Opportunities for coordination of activities are generally identified in the section on period and frequency of monitoring. References cited are part of each module, and additional supporting documentation is included at the end of the report in the appendices.

This MAP was developed with input from a wide variety of subject matter experts including scientists, managers, regulators, and staff representing a range of state, federal, academic, tribal, local, industry, and nongovernmental organizations. The overall intent was to be inclusive of the scientific community to assure that monitoring needs could be reasonably anticipated. A slightly modified version of the data-quality objective (DQO) process (U.S. Environmental Protection Agency, 2006) was used to help guide development of the MAP. This process included stating the problem, identifying the goal of the study, identifying the information inputs, defining the boundaries, developing the analytical approach, and developing the plan for obtaining the data. Focused technical groups (FTGs) of technical experts for each resource (biology, hydrology, geography and geology, air quality and climate, and socioeconomics) were tasked with identifying the purpose and objectives for monitoring of their specific resources and developing key questions (see appendices) that could be answered through monitoring, developing conceptual models, identifying specific monitoring activities, and identifying needed coordination and integration with other resource areas.

This monitoring plan was developed within the context of the final PEIR prepared by the California Resources Agency (California Resources Agency, 2007) and the future direction of ecosystem restoration defined by that process. Several assumptions related to decisions made through the development of the PEIR were used to further focus the initial monitoring plan. These relate primarily to the expected direction and configuration of ecosystem restoration, given what is currently known about the system, and factors that likely will influence the design and management of restoration features. These assumptions could change when the California Legislature provides direction on the restoration and identifies an implementing agency. These constraints and assumptions were grouped under one of the following categories: programmatic, environmental, engineering and physical, hydrological, and legal.

All monitoring activities recommended in this MAP are intended to help answer key questions anticipated to be asked by managers responsible for restoration of the Salton Sea ecosystem. These key questions were identified through brainstorming and a subsequent grouping process by FTG members. Not all questions identified by the FTGs could reasonably be expected to be answered by monitoring alone. Answers to some questions will need to be addressed by focused investigations or by specific studies and research. Focused investigations are not part of this MAP; however, some potential investigations and studies were identified by the FTGs and are included in a listing of key questions for each resource in the appendices.

Simplified conceptual models were developed for each major resource area. These models serve as initial starting points upon which to build more robust models and a clearer understanding of the overall functioning of the Salton Sea ecosystem. The conceptual models guide both long-term monitoring and focused investigations toward goals and objectives identified for restoration.

The development of this document was born out of a desire to establish common sets of processes and procedures to which all scientists can adhere as well as a framework for future science activities. This document further aspires to promote the integration of ideas, activities, and sampling strategies and locations to the greatest practical extent whenever possible. Success or failure in restoration of the Salton Sea ecosystem rests heavily on the degree to which science, through monitoring and focused investigations, can provide resource managers with skillful guidance for adaptive management. This guidance rests squarely on implementation of a rigorous framework for science, integration of all program activities, and incisive analysis.

Considerable attention was given to monitoring, design, and strategy as implementation of the MAP was contemplated, including retrospective analysis, quality assurance (QA), data assessment, peer review, and adaptive management. Retrospective data are data collected in the past that provide a foundation for the identification of data gaps, questions, and unknowns, which, in turn, will be used to identify specific data that will be collected under this MAP. Quality assurance is a critical element of all monitoring programs. Inclusion of a QA element helps ensure that the type, amount, and quality of data collected are adequate to meet study objectives. It is anticipated that focused investigations will be used in conjunction with data collected through the monitoring program to answer key questions and to assist with efforts to adaptively manage restoration activities. Data, analyses, and publications developed from this plan will be organized, stored, and made publicly accessible through a common distributed data management system (that is, the CDFW's Biogeographic Information and Observation System, or BIOS). Data collected and stored within the data management system will be publicly available for the application of statistical and other analytical techniques. This step helps to simplify the collected data, test for change and differences, develop and test hypotheses, and evaluate uncertainty. Data assessment is used to foster the integration, consolidation, and review of data, updating of the conceptual models, answering of key questions, reporting, and providing management recommendations within an adaptive management framework. Peer review is a critical step to help ensure that data collection and analyses are conducted in a manner that provides defensible scientific conclusions or findings. Adaptive management entails feedback between management practices and monitoring of responses in the ecosystem in order to measure the success of management actions and to fine-tune future actions accordingly. In practice, this means that science is used to design the actions, and then monitoring results are provided to managers overseeing management so that adjustments can be made, if needed. This feedback works best if scientists are engaged in the design of restoration actions as experiments whose outcomes can be predicted and then measured.

In cooperation with technical and management staff, and with input from stakeholder groups, the assessment and analysis of data are anticipated to lead to periodic updates of this entire MAP. Updates could be focused on specific resource areas or be applied to the entire plan. The plan is envisioned to be a living document and will need to remain flexible in order to respond effectively to unanticipated events.