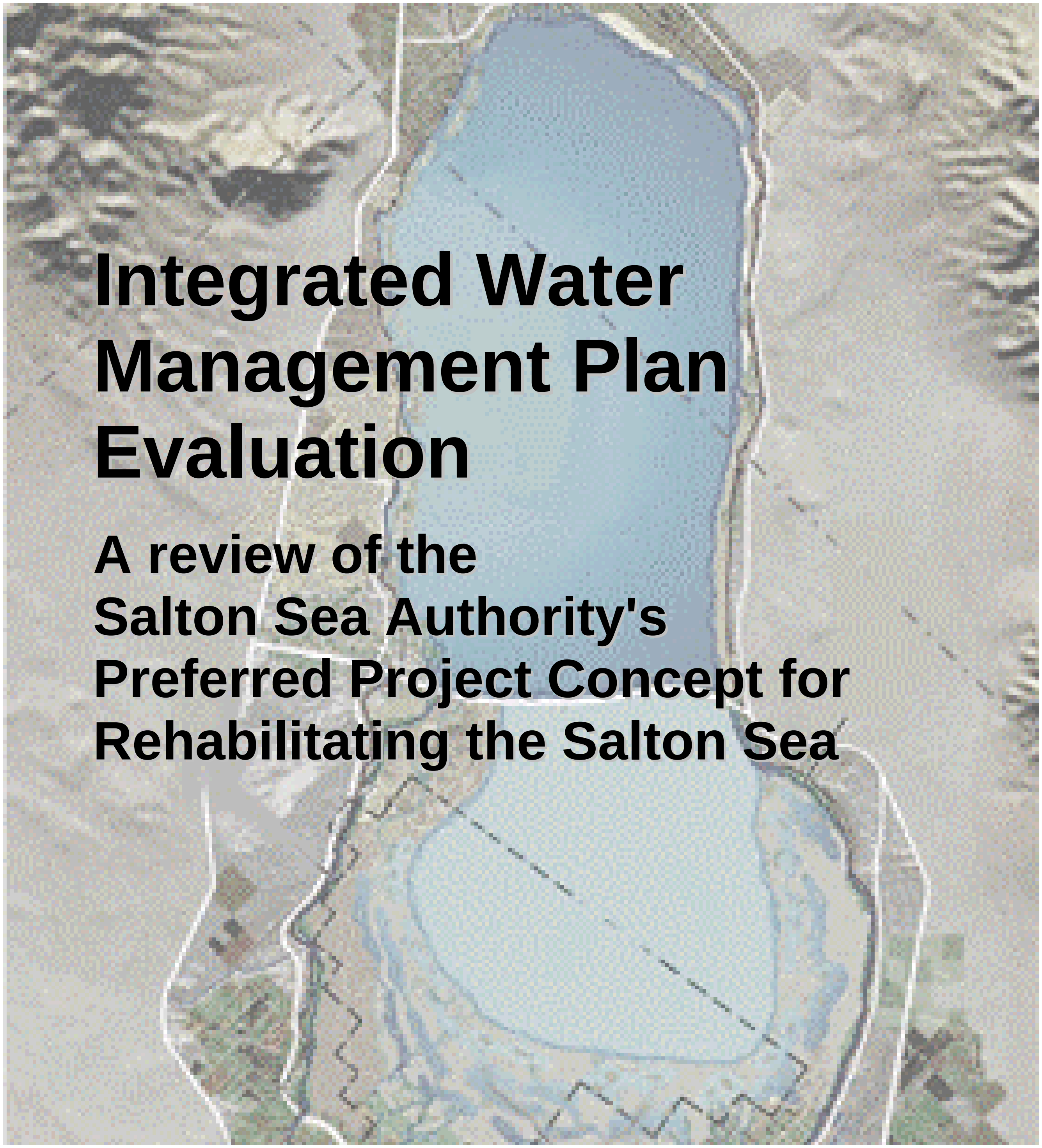
RECLAMATION

Managing Water in the West



Integrated Water Management Plan Evaluation

A review of the Salton Sea Authority's Preferred Project Concept for Rehabilitating the Salton Sea

U.S. Department of the Interior
Bureau of Reclamation

U.S. Geological Survey
Salton Sea Science Office

March 2005

The U.S. Geological Survey Salton Sea Science Office convened an experts workshop to evaluate a Salton Sea rehabilitation proposal known as the *Integrated Water Management Plan* (IWMP). The objective of the evaluation process was to develop a credible description of the future physical and biological conditions created by implementation of the IWMP. The compilation of the Integrated Water Management Plan (IWMP) Workshop proceedings was funded by the Bureau of Reclamation. The views and opinions contained within the report are those of the experts convened for the workshop and are not necessarily the views or opinions of their respective agencies or the U.S. Department of Interior.

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EXECUTIVE SUMMARY

The USGS Salton Sea Science Office convened an experts workshop, from November 15-17 in Riverside, California, to evaluate a Salton Sea rehabilitation proposal known as the *Integrated Water Management Plan* (IWMP) (also known as the 'North Lake Plan'). *Salton Sea Restoration: Preferred Project Report* (Salton Sea Authority 2004) describes the IWMP and provided the basis for this evaluation. As described further in the following, the IWMP would build a causeway across the middle of the current Salton Sea, creating a smaller north lake that discharges into a proposed 20,000 acres of shallow-water wetlands in the southern portion of the Sea, and a terminal brine pool, as well as various treatment wetlands.

A recently implemented water conservation and transfer agreement, along with several unrelated actions, will significantly decrease the volume of water flowing into southeastern California's Salton Sea in the next 20 years, shrinking the Sea and increasing salinity beyond the tolerances of most of the species currently present. Future conditions at the Sea will be very different from current conditions, whether or not the IWMP is implemented.

The surface elevation of the Salton Sea fluctuates by more than 0.3 meter (one foot) annually, primarily in response to agricultural irrigation patterns in the Imperial Valley. On January 1, 2005, the surface elevation of the Salton Sea was ~69.8 meters (228.86 feet) below mean sea level. The Sea is a terminal lake; the only outlet for its waters is via evaporation. The Sea is an officially-designated sump for the water draining from fields in the adjacent Coachella and Imperial Valleys; the Sea also receives agricultural and municipal drainage from the Mexicali Valley, in Baja California. The Sea is currently 33% saltier than the ocean and getting saltier each year. The Sea is also eutrophic, with extremely high levels of biological productivity, fed by fertilizers draining off of the fields in the basin. This productivity has attracted more than 400 species of birds to the area, including large numbers of breeding birds and special status species.

The objective of the experts workshop evaluation process was to develop a credible description of the future physical and biological conditions created by implementation of the IWMP. The objective of the evaluation process was not to support or reject the proposal. This was a scientific review process. Economic and recreational impacts generated by implementation of the proposal, although important, were beyond the scope of this evaluation process and were not addressed. The evaluation did not concern itself with regulatory, policy, political or agency positions. Based on the scientific expertise of the participants, the evaluation sought to identify any critical flaws in the proposal, as well as major beneficial outcomes, major questions to be resolved, and considerations of importance in judging the effectiveness of the proposal. The views and opinions reflected in this report are those of the participants and do not necessarily represent the views or opinions of their agencies or affiliations, nor do they necessarily represent the views of the U.S. Bureau of Reclamation or U.S. Geological Survey.

Evaluators found insufficient detail in the IWMP on several key issues, especially dust and selenium monitoring and management. Greater engineering-level details, as to sediment control and elevation control for the north lake, are also needed. The evaluators found that the IWMP's hydrologic features were based on a projected average annual inflow, when, in reality, seasonal fluctuations and annual variations in inflows are significant and may at times decrease the volume of inflows below that needed to support the IWMP's hydrologic features. The IWMP is critically incomplete in ways that make it impossible to judge whether it would be a desirable alternative. The workshop identified a number of potential problems with the IMWP, especially with regards to selenium and air quality.

Selenium

In general, the presence of selenium is a concern because of:

1) its ability to bioaccumulate in the food web;
2) the narrow range between the concentration that is nutritionally beneficial and that which is toxic;
3) its effect on fish and bird reproduction and embryonic development;
4) its role in causing immune deficiency; and
5) its effect on human health from consumption of contaminated fish and birds.

The majority of participants stated that the threats of selenium toxicity posed by the IWMP, especially in the constructed wetlands and by the use of river and drainage water in the shallow habitat in the southern basin, approached the level of a fatal flaw. A minority of participants stated that potential losses due to selenium toxicity should be weighed in relation to alternatives, such as losing all marine wetland habitats if no action is taken. Specific concerns and recommendations included:

- Selenium chemical load concentrations in rivers are expected to be greater than 10 μg/L and may exceed 15 μg/L (EPA limit is currently 5 μg/L);
- Selenium concentrations in the constructed wetlands will likely exceed recommended maximums, posing a threat to wildlife;
- Selenium concentration in the sediments of the north lake are expected to double, though there will be smaller increases in biota, and even less in the water column;
- River water will not be suitable for any wetlands or ponds even if it is mixed with lake water;
- Selenium's ability to suppress the immune system may affect the susceptibility of birds to avian diseases that have been identified and associated with large die-offs of wildlife at the Salton Sea in the past; and
- The IWMP should include an active selenium monitoring and management plan.

Air Quality

The workshop participants concluded that the exposure of Salton Sea lakebed, due to reductions in inflows, will likely lead to a dramatic increase in emissions of dust, in a region where air quality already fails to meet state and federal standards. These increased emissions of dust pose a grave risk to human and wildlife health. The IWMP does not offer an air quality management plan for addressing this risk. Specific concerns about the plan include:

- An absence of dust controls below the existing shoreline and above -235';
- The need for active dust management conflicts with the need to manage selenium exposure;
- Water used for dust management is not accounted for in the IWMP, and could further reduce the supply available for filling the various IWMP project elements.

Water Supply

Because of irrigation practices, inflows to the Salton Sea vary seasonally. These variations could cause significant reductions in the size of the IWMP's shallow wetlands, and may occasionally cause the elevation of the north lake to drop below target levels. Several of the workshop participants also expressed concern that inflows are subject to annual variation, or that the projected reductions in flows to the Sea may be too conservative, and therefore there may be even less water available than anticipated. Additionally, participants noted several potential challenges posed by the design of the IWMP. Specific concerns included:

- There may be seasonal shortages of inflows, decreasing the size of the southern ponds;
- Inflows vary annually and might not be sufficient to meet the needs of the IWMP in all years;
- Agricultural drainage from land near the southern ponds will need to be pumped into the river extensions;
- The mixing of river water and north lake water in the southern ponds is poorly conceptualized; and
- Sedimentation rates and loads may be higher than estimated by the plan, requiring additional maintenance.

Biota

The additional risk posed by exposure to increased concentrations of selenium, and changes to the size and shape of the Salton Sea, will affect fish and wildlife. By decreasing and stabilizing salinity at a lower concentration, the IWMP would preserve a fishery in the north lake, in turn supporting large populations of fish-eating birds. However, the evaluators identified several concerns:

- Desert pupfish (an endangered species) may be negatively impacted, due to the loss of habitat connectivity;
- Eutrophication will continue to adversely affect ecosystem health and recreational/ economic potential;
- More frequent mixing events in the north lake could bring anoxic water to the surface more often, resulting in additional fish kills;
- The steeper shoreline of the north lake may provide inferior habitat for fish and wading birds;
- More extreme water temperature fluctuations in the various water bodies, due to reduced volumes, may stress fish; and
- Sediments from the riparian sedimentation basins are likely to have elevated levels of pesticides and other contaminants.

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INTRODUCTION

This report presents the conclusions generated by an experts workshop that evaluated a proposal to rehabilitate the Salton Sea. This proposal, known as the *Integrated Water Management Plan for the Salton Sea* ("IWMP") (also known as the 'North Lake Plan'), would divide the Sea by means of a retention structure or causeway. The northern portion of the Sea would remain an open marine environment; the southern portion would be converted to a series of constructed shallow-water impoundments, with a terminal brine pool. The U.S. Geological Survey's Salton Sea Science Office and the Pacific Institute, with the generous financial support of the U.S. Bureau of Reclamation and the Salton Sea Authority, convened the workshop of more than twenty scientists and engineers, from November 15-17 in Riverside, California.

The objective of the evaluation process was to develop a credible description of the future physical and biological conditions created by implementation of the IWMP. The objective of the evaluation process was not to support or reject the proposal. Economic and recreational impacts generated by implementation of the proposal, although important, were beyond the scope of this evaluation process and were not addressed. The evaluation did not concern itself with regulatory, policy, political or agency positions. Based on the scientific expertise of the participants, the evaluation sought to identify any critical flaws in the proposal, as well as major beneficial outcomes, major questions to be resolved, and considerations of importance in judging the effectiveness of the proposal. Because of the uncertainty about conditions in the watershed fifty years in the future, and because the general objective of the workshop was to generate information rather than render a final decision, this report also presents the non-consensus and dissenting opinions raised during the evaluation process, to provide the reader with a better understanding of the range of potential outcomes and impacts implementation of the proposal might have.

A recent water transfer agreement and other actions will decrease inflows to the Salton Sea; future conditions at the Sea will be very different from current conditions, whether or not the IWMP is implemented. Comparing the benefits and drawbacks of the IWMP with the current Salton Sea is therefore not appropriate. For a better understanding of potential conditions at the Salton Sea in the absence of any rehabilitation plan, and to provide a basis for comparison of the IWMP, please refer to *Projection of Future Conditions at the Salton Sea With No Project Implemented* (posted at www.pacinst.org/topics/water_and_sustainability/salton_sea/).

BACKGROUND

The Salton Sea

South-eastern California's Salton Sea lies 56 km (35 miles) north of the U.S.-Mexico border, in one of the most arid regions of North America (Figure 1). The Sea is a terminal lake, with a

Figure 1. Salton Sea locator map.

January 1, 2005 provisional surface elevation of 69.8 meters (228.86 feet) below mean sea level. Currently, the Sea is about 56 km (35 miles) long, 14 to 24 km (9 to 15 miles) wide, and has roughly 190 km (120 miles) of shoreline. At its current elevation, the Sea has a maximum depth of about 15 meters (50 feet) and average depth of 9 meters (30 feet), with a total surface area of 95,750 hectares (230,000 acres) and a volume of 7.2 million acre-feet (MAF) of water.[1]

Maximum temperatures in the basin exceed 38° C (100° F) more than 110 days each year; temperatures drop below freezing only in unusual years. The Sea's surface temperatures varies seasonally, with winter lows of ~10° C (~50° F) and summer highs of ~35° C (~95° F). The Salton Sea is slightly alkaline, with a surface pH of about 8.2, while the pH near the lakebed is about 7 (Holdren and Montaño 2002).

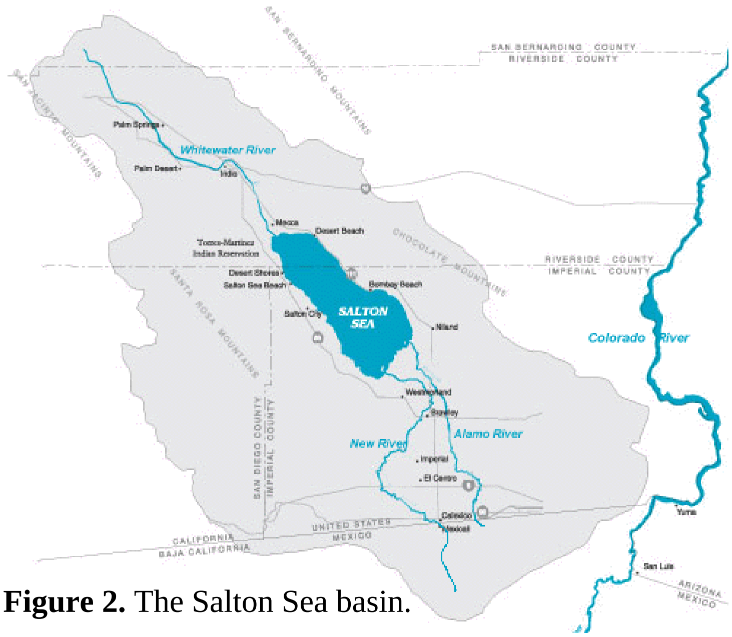

Figure 2. The Salton Sea basin.

Annual precipitation on the Sea averages less than 7.6 cm (three inches); net evaporation rates from the Sea's surface exceed 1.68 m (66 inches)/year. The Sea's watershed (see Figure 2) encompasses some 21,700 km^2 (8,360 square miles), extending from San Bernardino County south into the Mexicali Valley, in Baja California, Mexico, but more than 90% of the Sea's inflows come from the drainage from fields irrigated with imported Colorado River water.

Hydrology

Currently, about 1.3 MAF flow into the Salton Sea each year. About 80% of these inflows come from the Imperial Valley, 7.4% from Mexico, 8.6% from the Coachella Valley, and the remainder from direct precipitation and local run-off. The Sea reaches its maximum annual elevation from March through June each year, dropping to its minimum elevation (about 0.3 meters lower) in October and November, reflecting irrigation practices in the Imperial Valley. The Sea's January 1 elevations (used in this report) average 9 cm (0.3 feet) higher than its lowest annual end of month elevation.

Water flows into the Salton Sea from the Alamo (~46% of total inflows) and New (33%) rivers in the Imperial Valley, from the Whitewater River (5.6%) in the Coachella Valley, from irrigation drains discharging directly to the Sea (10%), and from direct precipitation and ephemeral washes draining the nearby mountains. Alamo River water contains a blend of surface and sub-surface agricultural drain water. New River water

[1] By convention, large volumes of water in the western United States are measured and allocated in acre-feet. One acre-foot equals 1,233 cubic meters; one cubic km equals 810,700 acre-feet.

contains a blend of agricultural drainage and municipal effluent from Mexico (~20%), and agricultural drainage from the Imperial Valley. Surface drainage from agricultural fields, also known as tailwater, has higher concentrations of nutrients and pesticides, and lower concentrations of salts and minerals such as selenium, than does sub-surface drain water (also known as tilewater). Tailwater flows from individual fields can vary dramatically day-to-day and hour-to-hour, based on irrigation practices; tilewater flows, modulated by percolation, are more constant. Contaminant concentrations in blended agricultural drainage can therefore vary dramatically, with higher proportions of tilewater especially during October and November, when surface irrigation decreases.

The following table displays concentrations of certain contaminants in water entering the Sea from the Imperial Valley:

Table 1. Concentrations of select water quality constituents in Salton Sea inflows.

Parameter	Irrigation Delivery	New River			Alamo River		
		Border	Drains	Outlet	Border	Drains	Outlet
Total dissolved solids (TDS) (mg/L)	771	3,894	2,116	2,997	3,191	2,375	2,458
Total suspended solids TSS (mg/L)	86	117	193	313	360	318	479
Selenium (Se) (µg/L)	2.5	3.0	7.4	3.9	5.9	7.9	7.7
Nitrate (NO_3) (mg/L)	0.28	0.84	7.49	4.37	1.87	8.14	7.81
Total phosphorus (mg/L)	0.05	1.42	0.78	0.81	0.47	0.84	0.63
DDT (µg/L)	0.001	0.088	0.013	0.016	0.011	0.020	0.016
Diazinon (µg/L)			0.025				0.025
Chlorpyrifos (µg/L)			0.025				0.025
Boron (µg/L)	170	1,600	804	1,172	1,798	683	695

Source: IID (2002) June final EIR p. I-6.

The salinity of the Salton Sea is currently about 46 g/L (about 33% saltier than ocean water). At this salinity, the Sea contains roughly 450 million metric tons of salts. About four million metric tons of salts enter the Salton Sea each year. Because the Salton Sea lacks an outlet, the various contaminants entering the Sea tend to concentrate there. However, Amrhein et al. (2001) estimate that some 0.7 to 1.2 million metric tons of salts (and as much as 1.5 million metric tons), primarily calcium salts in the form of carbonate and sulfate, precipitate out of the Sea's water column each year, slowing the rate at which the Sea's salinity increases.

As shown in Table 1, the Sea's inflows also contain elevated levels of nitrogen and phosphorus. Holdren and Montaño (2002) estimate the Sea's annual total phosphorus loadings at 1,385 metric tons, and the annual total nitrogen loadings at 14,300 metric tons. They note that total phosphorus concentrations in the rivers are about an order of magnitude greater than those in the Sea. However, despite these continued phosphorus inputs and a doubling in annual loadings, the Sea's phosphorus concentration is about the same as it was 40 years ago. These findings suggest that the Sea is a phosphorus sink, possibly due to biological sequestration of phosphorus, chemical precipitation, and sedimentation (Holdren and Montaño 2002).

The Alamo and New Rivers also have much higher (30-120 times) concentrations of total nitrogen than the Sea, indicating that nitrogen also leaves the Sea's water column. Even so, samples of Sea water in 1999 had ammonia concentrations of 1.15 mg/L, nearly twice the state's acceptable level (Holdren and Montaño 2002). Setmire et al. (2000) report summer average ammonia concentrations as high as 2.8 mg/L. Surface seasonal nitrogen to phosphorus ratios range from 24:1 to more than 190:1, indicating that phosphorus concentrations are the limiting factor for biological productivity in the Sea (Setmire et al. 2000).

Irrigation water applied to fields in the Imperial Valley has a median selenium concentration of approximately 2 μg/L, while Alamo River water (draining many of these fields) has a median selenium concentration of approximately 8 μg/L (Setmire and Schroeder 1998). The median dissolved selenium concentration of 304 samples of Imperial Valley tilewater taken from August 1994 - January 1995 was 28 μg/L, with a range[2] of 1 - 311 μg/L (Setmire and Schroeder 1998). The median dissolved selenium concentration of biweekly samples of Imperial Wetlands input water,[3] taken from January 2001 - February 2004, was 6.3 μg/L, with a range of 3 - 94 μg/L. The median dissolved selenium concentration of biweekly samples of Brawley Wetlands input water,[4] taken from January 2001 - February 2004, was 10.5 μg/L, with a range of 4 - 73 μg/L.

Dissolved concentrations of selenium in New River water at its outlet to the Sea consistently measures less than 5 μg/L.[5] Yet selenium concentrations in the water column of the Salton Sea are much lower, ranging from 1.1 - 2.1 μg/L (Holdren and Montaño 2002). The Salton Sea's sediments currently act as a selenium sink (Selenium Fact Sheet, undated).

The Sea is a wind-driven system, with a counter-clockwise gyre in the southern portion of the Sea. These wind-driven currents may be affecting patterns of selenium deposition; the slower-moving water in the northern portion of the Sea may be precipitating selenium in the detrital foodchain, increasing selenium concentrations in the

[2] One evaluator noted that Wilber (1980. Toxicology of selenium: a review. Clin. Toxicol., 17:171-230) emphasizes that the biology of extremes is much more important for selenium than the biology of means. Even a brief spike in selenium concentrations can set foodchain contamination at a higher level than would be expected based solely on the mean concentration.

[3] Input water is drawn from Rice Drain No. 3.

[4] Input water is drawn from the New River.

[5] Selenium concentrations in New River water diverted to the Brawley wetland site are higher than those observed at both the International Boundary and at the New River's outlet. One evaluator observed that poorly mixed water at the wetland's intake point could be influenced by a drain discharging to the New River and thus responsible for these results and their high temporal variability. Alternatively, there could be massive biological uptake of selenium from the water column of the New River between the Brawley Wetland intake point and the New River's outlet to the Salton Sea, such that much more of the selenium is in the unmeasured particulate fraction at the outlet. Or, the accuracy of the analytical chemistry might be at fault.

Sea's northern sediments. An alternative explanation for lower selenium concentrations in southern basin sediments is that the higher sediment loads of the New and Alamo Rivers may be diluting selenium concentrations in the lakebed in the southern basin. Figure 3 shows the concentrations of selenium in the Sea's deeper sediments. Figure 4 shows selenium concentrations in near-shore sediments, based on late 2004 assessments of sediment samples Agrarian Research took in 2003.

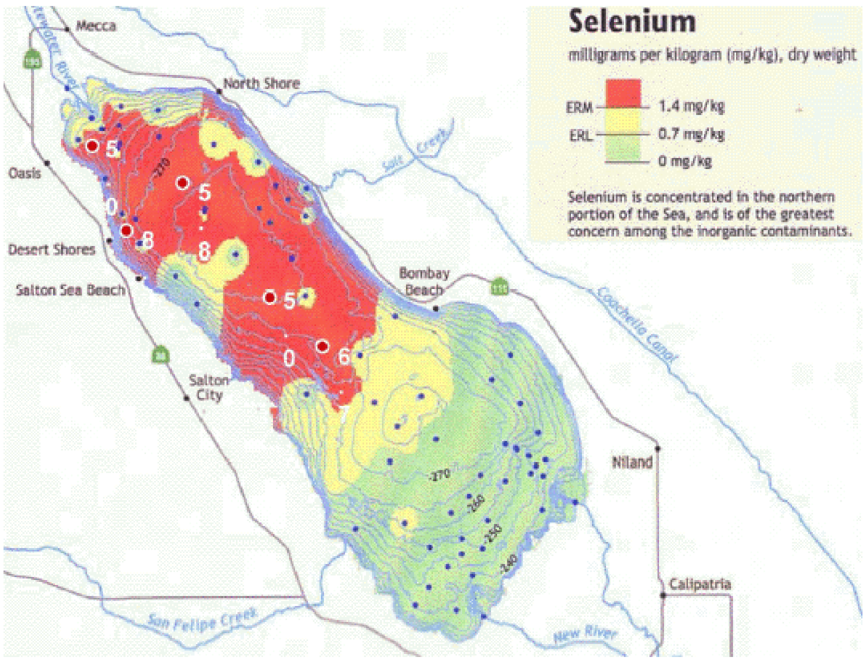

Figure 3. Selenium concentrations in Salton Sea sediments. Source: USGS Salton Sea Science Office

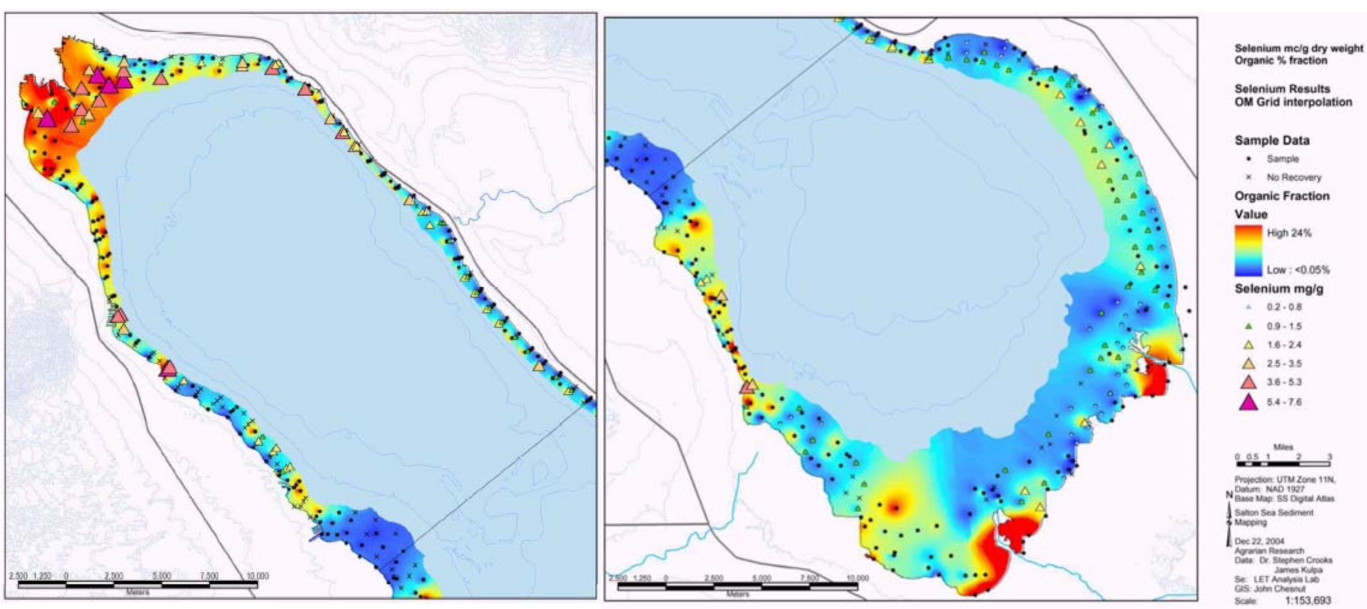

Figure 4. Selenium concentrations in near-shore sediments. Source: USGS Salton Sea Science Office

Biota

Short food chains, eutrophic conditions, and high avian abundance and diversity characterize the Salton Sea's ecosystem. Shuford et al. (2002) call the Sea "the most important site for waterfowl in the interior of southern California." More than 400 species of microscopic life have been identified in the Sea. Planktonic dinoflagellates, diatoms and cryptomonads co-dominate the Sea year-round, with a raphidophyte and green algae abundant in summer (Tiffany et al., no date). Fourteen species of macro-invertebrates have been identified in the Salton Sea. Of these, pileworm (*Neanthes succinea*) and barnacle (*Balanus amphitrite*) larvae, as well as a rotifer and a copepod (*Apocyclops dengizicus*), are the most abundant primary consumers. Tilapia has also been an important primary consumer the last few decades, as it feeds on larger phytoplankters as well as zooplankton and benthic invertebrates. The detrital food chain also plays a prominent role at the Sea. Dead plankton and other organic material sinks to the lakebed, to be consumed by adult pileworms, bacteria, and amphipods, which are in turn preyed upon by fish and birds (Redlands 2002).

Ten species of fish are found in the Sea, of which four introduced fish species – predominantly tilapia, Gulf croaker (bairdiella), orangemouth corvina, and sargo – were the most abundant.[6] These fish historically sustained an important sport fishery and provided the food base for fish-eating birds. Recently, fish populations have declined from their former abundance by more than an order of magnitude, likely due to poor water quality, especially rising salinity.

The Salton Sea supports tremendous avian abundance and diversity, and provides an important link on the Pacific Flyway. More than 400 species of birds have been recorded at and around the Sea, one of the most diverse avifaunas of the U.S. Shuford et al. (2002) report a total December, 1999 population at the Sea of 583,000 waterbirds, of 107 species, and documented breeding by 14,000 pairs of colonial waterbirds. April shorebird counts at the Salton Sea average 90,000 individuals. Adjacent agricultural fields also support large populations of wading birds (such as egrets) and shorebirds (such as plover); many of these birds return to the Sea at night to roost. Shuford et al. (2002) note that

> Various studies indicate the Salton Sea is of regional or national importance to pelicans and cormorants, wading birds, waterfowl, shorebirds, and gulls and terns. Important taxa are the Eared Grebe, American White Pelican, Double-crested Cormorant, Cattle Egret, White-faced Ibis, Ruddy Duck, Yuma Clapper Rail, Snowy Plover, Mountain Plover, Gull-billed, Caspian, and Black terns, and Black Skimmer.

More than 50 species of special status birds (threatened, endangered, or species of concern) have been observed at and around the Sea, including the endangered brown pelican, more than 90 percent of the North American population of eared grebes, 23-30% of the entire North American breeding population of white pelicans, about 40% of the U.S. population of the endangered Yuma Clapper Rail, and up to half of the world's population of mountain plovers (Shuford et al. 2002).

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[6] The California Dept. of Fish and Game began its current fish sampling protocol in 2002. As of Fall, 2004, these surveys have detected no sargo since July 2002, and no bairdiella or corvina since May 2003. Reproductive pulses of tilapia were recorded in 2003 and in 2004.

Morbidity & Mortality

The Salton Sea's nutrient-rich inflows have created eutrophic to hyper-eutrophic conditions, with characteristic high biological productivity, low water clarity, and very low concentrations of dissolved oxygen, leading to massive fish kills and noxious odors (Setmire et al. 2000). Low water temperatures in winter are another source of stress to tilapia, the most abundant fish in the Salton Sea, which suffer mortality below 13° C (55° F) (Cohen et al., 1999). Strong wind events can create currents that disturb the Sea's anaerobic sediments, dramatically depleting dissolved oxygen concentrations in the water column, generating huge fish kills. In August 2003, such an event reportedly killed more than five million fish.

The Sea also suffers from recurrent avian mortality events, primarily due to avian botulism, avian cholera, salmonellosis, and Newcastle disease (Friend 2002). During the 1990s, there were a number of such events involving eared grebes, white and brown pelicans, double-crested cormorants and various duck species. The cause of the death of approximately 150,000 eared grebes in 1992 was partly due to avian cholera and partly due to an unidentified agent. More than 1,200 endangered brown pelicans were killed by type C avian botulism in 1996 after feeding on tilapia containing botulinum toxin, the first major instance of such botulism in fish-eating birds. Most of the cormorant mortalities at the Sea have been attributed to Newcastle disease. Duck mortalities, especially ruddy ducks, have been due mostly to avian cholera (Friend 2002). Selenium's ability to suppress the immune system may affect the susceptibility of birds to these diseases.

Hamilton (2004) reports that dietary intake, rather than simply aquatic exposure, appears to be the primary source of selenium uptake in fish and birds. Setmire et al. (1993, p.64) note that:

> The most important selenium food-chain pathway in the Salton Sea begins with accumulation by benthic invertebrates, particularly pileworms, and includes subsequent uptake by benthic-feeding fish and fish- eating birds. Selenium is transferred from sediment through successive trophic levels in the food chain at increasing concentrations, which shows that biomagnification occurs.

Table 2. Arsenic and Selenium concentrations in tilapia tissue

Tilapia	whole body		fillet	
(in µg/g)	wet weight	dry weight	wet weight	dry weight
Arsenic	0.7	2.8	1.2	5.7
Selenium	2.2	8.3	1.9	9

Source: Moreau et al. 2005.

A recent study (Moreau et al. 2005) assessed Salton Sea tilapia tissues for several contaminants, including selenium and arsenic. Table 2 summarizes their findings for these two elements. According to the authors, these tissue concentrations, while still at levels of concern, would cause negligible problems to fish, birds, or humans. However, these dry-weight selenium concentrations are above the ecological dietary threshold of 3 ppm, dry-weight for marginal risk and of 7 ppm, dry-weight, for substantive risk (Presser et al., 2004). These concentrations also exceed the ecological thresholds for risk to fish of 4 and 6 ppm, dry-weight, whole-body. If the human health advisory limit of 2 ppm, wet-weight, fillet (or 8 ppm, dry-weight) that was used to develop fish consumption limitations for the Salton Sea is applied to these data, then fish consumption would be restricted.

Air Quality

Wind speeds measured by an anemometer 10 meters above the ground in Niland, 2 km east of the Salton Sea, exceeded 11 m/sec (25 mph) about one percent of the time in both 2000 and 2001. At this station, high wind events generally blew from the west, although southeast winds were the most frequent (IID 2002). Dust can be emitted from unstable exposed lakebed surfaces by wind velocities of 7.6 - 8.9 m/sec (17 - 20 mph), measured at a 10 meter height. Furthermore, surface stability can change with changes in soil moisture and temperature: nearly all exposed, unprotected surfaces potentially can become unstable.

Both Imperial County and the Coachella Valley are currently classified as “serious non-attainment areas” for the federal PM_{10} standard (for inhalable particulate matter) for air quality. PM_{10} (a measure of dust particle size) can lodge deeply in the lungs, creating a health risk, irrespective of the nature of the material; toxic materials can increase this health risk. Violation of the PM_{10} twenty-four-hour standard occurs when there have been more than three exceedances of the standard in three years (the current federal 24-hour standard is 150µg/m^3). Wind events from the west and northwest currently cause exceedances of the PM_{10} standard in the Salton Sea area (northern Imperial County). Imperial County’s childhood asthma rates, as measured by hospital discharge records, are the highest in California.

FUTURE CONDITIONS

Until the implementation of the Quantification Settlement Agreement (QSA) in late 2003, the size of the Salton Sea was in dynamic equilibrium between inflows and evaporation, with a gradual trend toward rising salinity. For the purposes of this report, the most notable component of the QSA is the water conservation and transfer agreement between the Imperial Irrigation District (IID) and the San Diego County Water Authority. This agreement calls for an annual increase in the volume of water effectively moved from the Imperial Valley to San Diego, from 10,000 acre-feet in 2003 to almost 200,000 acre-feet in 2020. A related agreement will move water from the Imperial Valley to the Coachella Valley, rising from 4,000 acre-feet in 2008 to 103,000 acre-feet in 2026.[7] The QSA, and various other actions in Mexico and the U.S. (see Table 3), will decrease inflows to the Sea, reducing its size and, absent any intervention, increasing the rate at which the Sea’s salinity will exceed the tolerance of the aquatic biota currently present. Note that the rate of many of these changes, most notably the quantity of water transferred out of the Imperial Valley, will occur gradually over time. In the initial years of the QSA, these

[7] Please see Appendix A for the QSA delivery schedule and projected annual decreases in Salton Sea inflows.

decreased inflows may be buffered by other changes, such as fluctuations in local precipitation events and Colorado River flows. These reduced inflows provide the context in which any rehabilitation plan, including the IWMP, must be evaluated.

Table 3. Projected Changes in Salton Sea Inflow

Action	*Changes in Inflow by Year 2026 (af/yr)*
QSA / IID Transfer	-303,000
Mexicali Power Plant Operations	-10,500
Mexicali Wastewater Treatment Plant Operations	-22,500
Reduced Colorado River flows to Mexico	-50,000
Wetland Projects on New & Alamo rivers (1000 acres)	-5,500*
All-American Canal lining & reduced returns from Mexico	-20,000*
CVWD Groundwater Management Program	+29,500*
Total	**-382,000**

Source: U.S. Bureau of Reclamation. *Revised from original Reclamation projections.[8]

These and other planned and probable future actions will affect the quality of the water flowing into the Sea. The implementation of the Regional Water Quality Control Board's *Total Maximum Daily Load* (TMDL) program[9] for the Salton Sea watershed, for pollutants such as suspended sediments, nutrients, salt, and selenium, among others, will likely improve the quality of water flowing into the Salton Sea. Projected population growth in the Imperial and Mexicali valleys may increase pollutant loadings in the New and Alamo rivers. Projected population growth in the lower Coachella Valley may also increase pollutant loads in the Whitewater River. Additionally, the means by which water is conserved in the Imperial Valley will affect water quality, potentially decreasing nutrient loadings while increasing the concentration of salts and selenium.

EVALUATION PROCESS

The USGS Science Office experts workshop included more than twenty scientists and engineers (please see Appendix B for a list of participants). After a series of background presentations about the Sea and the IWMP, participants broke into five topical groups: hydrology, water quality, biology, disease and contaminants, and air quality. Each of these groups discussed a series of questions about the likely impacts of implementation of the IWMP (please see Appendix C for 'Instructions for Evaluators' and

[8] AAC lining was not included in the Reclamation estimate (assumes that ~1/3 of the water conserved by lining would have returned to the New River and discharged to the Sea); wetland acreage revised downward by 90%, reflecting limited available acreage and funding; CVWD groundwater returns decreased to reflect time required to reverse overdraft. The Coachella Valley Water Management Plan of 2002 notes that lower Coachella Valley groundwater overdraft in 1999 was 41.7 kaf. The population of the lower valley is projected to increase from an estimated 141,000 in 2005 to 211,000 in 2025. By 2026, IID will transfer 103 kaf to CVWD annually. For CVWD to meet its objective of eliminating the lower valley GW overdraft, meet the demands of its projected population increase, and increase its discharge to the Sea by 50 kaf/yr by 2026, it would effectively have to spill 50 kaf of the transferred water directly into the Sea.

[9] See www.swrcb.ca.gov/rwqcb7/tmdl.html and related links for more information on the TMDL program.

the list of questions posed to each group). Each topical group reported its findings back to the group as a whole, clarifying or modifying these findings based upon the group's feedback. The group as a whole developed final comments about the plan, and developed a list of major issues and questions requiring further information. The notes from each topical group, and from the group as a whole, formed the basis for this report. Each of the participants had the opportunity to review an initial draft of this report and submit comments, which were incorporated into this report. Interested evaluators, and the Salton Sea Science Office and Bureau of Reclamation staff, also reviewed a final draft of this report. Disagreements and lack of consensus have been preserved, to provide the reader with a better understanding of the range of potential outcomes and impacts the implementation of the proposal might have.

THE INTEGRATED WATER MANAGEMENT PLAN (IWMP)

Salton Sea Restoration: Preferred Project Report (Salton Sea Authority 2004),[10] describes the IWMP and provided the basis for this evaluation. The IWMP includes a seven to eight-and-a-half mile causeway across the Salton Sea near Bombay Beach, creating a north lake of 85,000 to 95,000 acres, with an elevation of -235' or -240' and a salinity roughly that of the ocean (~35 g/l) (see Figure 5). For the purposes of this

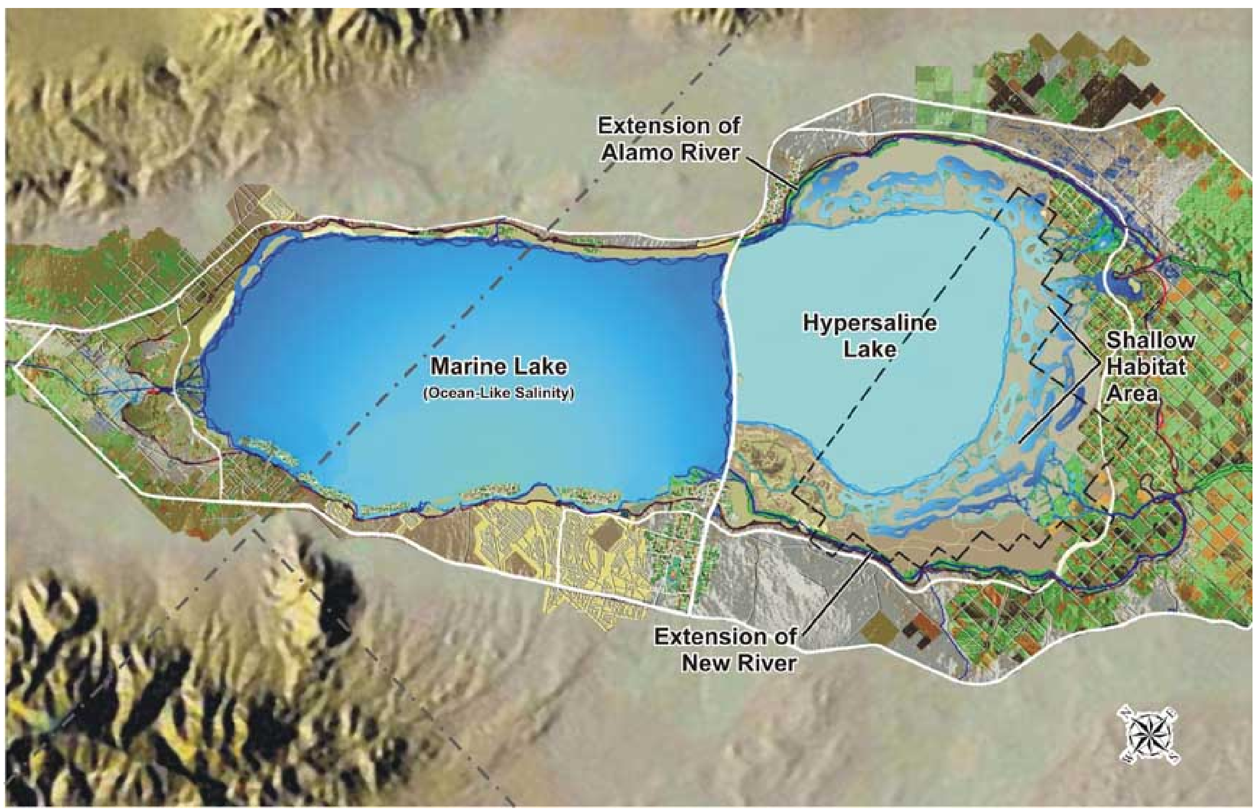

Figure 5. The Integrated Water Management Plan (IWMP).

[10] Posted at www.saltonsea.ca.gov/media/ppr_summary.pdf

evaluation, the elevation of the north lake was assumed to be -235’, with a total extent of 95,000 acres. The Alamo and New rivers would each be extended about 21 miles from their current location at the -227’ contour, to drain into the north lake. The lake would have two or more outlets, controlling salinity and elevation and providing feed water for a proposed series of 20,000 acres of shallow habitat areas in the southern portion of the existing Sea. These shallow habitats would eventually drain via gravity into a hypersaline lake. Figure 5 shows the general features of the proposal, including the causeway, river extensions, constructed wetlands, and hypersaline lake.

The IWMP also includes components to enhance local recreation and economic development, including recreational lakes and dredging near existing shoreline communities, and notes the potential for reclaiming land that is currently underwater. Additionally, the IWMP notes the potential for exploiting geothermal resources in the southern, inundated portion of the Salton Sea. Although each of these components merit assessment, they were beyond the scope of this evaluation and are not addressed in this report.

The IWMP lists three measures that could be undertaken to address air quality concerns at the Salton Sea: shallow water habitat areas; salt crusts from evaporated brines, which could be used to cover fine sediments; and salt tolerant vegetation. Aside from the shallow water habitats, the IWMP does not provide estimates of the extent of these remediation measures.

The following table describes the characteristics of the major hydrologic features of the IWMP, in the order in which water moves from feature to feature.

Table 4. IWMP Features and Characteristics

Feature	*Extent*
Upstream wetlands	1376 acres
Sedimentation basins	20 units, 110 acres total
New & Alamo River extensions	~21 miles each
Greenbelt channels along river extensions	2500 acres
North (Marine) Lake	90,000 acres at -235’
Southern (shallow habitat area) wetlands	20,000 acres
Brine pool	~60,000 acres

IWMP EVALUATION

The comments and conclusions of the five topical evaluation groups (hydrology, water quality, biology, disease and contaminants, and air quality) have been integrated in the following. Comments are offered on the various components of the IWMP, in the order in which water moves from feature to feature (see Table 4), followed by general comments and questions requiring further information.

Upstream Wetlands

The IWMP report (Salton Sea Authority 2004, p.59) describes its upstream wetlands and sedimentation basins:

> Created wetlands and sedimentation basins would be installed to help remove fine sediments and nutrients from the waters that flow into the main lake. Locations of wetland habitats and sedimentation basins include areas along the New and Alamo rivers, extensions of those rivers that may be associated with the creation of a smaller marine lake, and areas near the mouth of the Whitewater River. In addition to having benefits for water quality, created wetland areas would provide a variety of habitats for birds as well as recreational opportunities for hunting, bird watching, and possibly fishing. Wetlands could also be designed to preserve snag habitat used by wildlife in the northern and other portions of the Sea.

The biology group recommended coordinating program management and scientific oversight of the IWMP constructed wetlands along the New and Alamo rivers and along their extensions to the north lake, with the management and oversight of the wetlands created by the Citizen's Congressional Task Force on the New River. They noted that contaminant sampling of the entire wetlands structure should be a high priority. They predicted that fish probably would not tolerate the high summer temperatures and low levels of dissolved oxygen in these wetlands. Fish (likely to be introduced species such as *Gambusia*) would probably seek refuge upstream and downstream during extreme environmental events within the wetlands. Seepage areas adjacent to the constructed wetlands could attract Yuma clapper rails and Black Rails; the IWMP could include measures to create and enhance seepage habitat. Such habitat would also be attractive to migrant passerines.

The biology group noted that wetlands can be constructed either for treatment or for habitat, though they noted that wetlands can serve both purposes if sampling and monitoring do not indicate any problems. Given the potential for selenium toxicosis in these wetlands, the group recommended that a continual monitoring and management program be implemented. Managers will need to decide whether to encourage or discourage bird use of the wetlands, based on the threat posed by selenium. To encourage use, they will need to manage for multi-layered vegetation. To discourage use, no vegetation should be present, and the ponds should be steep and deep, to discourage waders. Active sediment maintenance will be required in these wetlands.

The treatment wetlands are not sized adequately to remove anything but sediment, because of low residence times. They will not achieve significant reductions of microbial pathogens. With selenium loading at 8 µg/L or higher,[11] these wetlands are at great risk of selenium contamination, with potential for classic avian selenosis syndrome (embryonic malformations, etc.) similar to that seen at Kesterson. The risk-benefit ratio does not seem to justify these riparian wetlands. If treatment wetlands result in form changes of selenium (e.g., organo-selenium, which is more bio-available), it might result in an even higher risk, even though total selenium concentration may have decreased. More data on opportunities for biological transformation are needed before these wetlands are constructed. Managers should also recognize that there will be contaminant-related costs associated with the maintenance of the treatment wetlands, such as harvesting and disposal of selenium-contaminated vegetation.

Nitrogen and phosphorus are important in determining the productivity and abundance of algae and higher plants, and hence the productivity and abundance of the higher levels of the food web as well. When present in high concentrations, however, they lead to such high levels of production that the respiration and decomposition of this production leads to anoxia and other water quality problems, such as high ammonia or high sulfide levels. Fully developed treatment wetlands might remove, via denitrification, significant amounts of nitrogen from river flows. This nitrogen tends to be lost rapidly via the same process in the Sea. Treatment wetlands are not efficient at removing phosphorus. The most that might be expected would be about a ten percent removal. Though phosphorus is the nutrient in shortest supply in the present Sea, and would be in the north lake, a ten percent reduction in loading would not be likely to reduce the frequency or magnitude of algal blooms or the frequency of anoxia in the north lake.

Available information indicates that most pesticides and other water-borne contaminants, though often detectable in river inflows, are undetectable or present in very low concentrations in the water, sediments and biota of the present Sea. Probably of greatest significance is DDE, a metabolite of DDT, which is found in Salton Sea fish at concentrations of 0.08 µg/g wet weight, and may still contribute to egg shell thinning that has been noted over recent decades in colonial nesting birds at the Salton Sea. This DDE is presumably derived entirely from soil residues dating from prior to 1972, when DDT ceased being used in the United States, and is declining over time. Treatment wetlands would have the potential to remove these contaminants, though again, possibly at the expense of increasing their concentrations in the wetlands' food webs and in the wildlife that inhabit them.

The incidence of mosquito-borne diseases is not likely to increase in the north lake, but there is a possibility it could increase in any freshwater or brackish component (e.g. the treatment wetlands, the initial shallow water ponds, and in the created 'Redhill Lake'). Some of these mosquitoes would merely be annoying as biters, but others, such as *Culex tarsalis*, are vectors of serious viral diseases of man and other animals. The viruses that cause St. Louis encephalitis and western equine encephalomyelitis are known from birds in the Imperial and Coachella valleys, although at present cases of human disease are rarely

[11] Inflows to the Brawley and Imperial pilot wetlands on the New River have mean dissolved selenium concentrations of 6.3 – 10.5 µg/L, with maximum concentrations of 73 µg/L or greater.

reported. If much recreational use were made of the proposed impoundments, there would be increased likelihood of transmission of these viruses by mosquitoes from the avian reservoir species to humans. *Culex tarsalis* likely could also serve as a vector for the West Nile virus, another agent of human encephalitis. West Nile virus has been reported in many counties of California.

Sedimentation basins

The hydrology group noted the significant sediment loads of the Alamo and New rivers: the TMDL target suspended sediment load for these rivers is 200 mg/L (currently 280 mg/L for the Alamo River). In the extended river channels discharging into the north lake, stream “bed load” sediment would add to the regulated suspended sediment. The group had doubts over the effectiveness of the sedimentation basins planned to be placed along the “Greenbelt” shown in Figure 6-9 of the Salton Sea Authority’s *Preferred Project* report. The proposed 110 acres of sedimentation basins proposed along the course of the extended rivers will only remove large sand particles, but not the finer materials. The group agreed that upstream sediment management facilities would be necessary to avoid clogging and burdensome maintenance at downstream facilities. Facilities designed to remove this and higher sediment loads, and the strategy to dispose of accumulated sediment, were the principal features needing specific descriptions.

The group recommended that:

- a sediment management plan for the life of the project be developed;
- sediment be removed before entering the river extensions, or sediment removal in the river extensions would be required;
- sedimentation basins be placed at/before the diversions;
- an IWMP sediment management plan be integrated with TMDL sediment controls upstream;
- real sediment load estimates be developed in the creation of an IWMP sediment management plan.

The siltation basins and the implementation of sediment TMDLs will delay the formation of deltas in the north lake, limiting the availability of this key avian habitat. Sediments from the riparian sedimentation basins are likely to have elevated levels of pesticides and other contaminants. The IWMP should describe how these sediments will be tested or monitored, and if contaminated, how and where they will be disposed of.

River extensions

In addition to the sedimentation problems, the group identified several potential issues with the river extensions themselves. Under the IWMP, the New and Alamo rivers would be diverted at the -227 foot contour and would be extended to the north basin. Agricultural drains that currently discharge directly to the Salton Sea from the Imperial Valley would need to be configured for this revised system. For most direct drains, discharge into the extended rivers would likely require pumping. Alternatively, the direct drains could cross the extended rivers by gravity through constructed siphons. The design of this alternative would need to consider the potential for silt to clog the siphons. The need to accommodate these direct drains is also related to the need to provide conductivity of desert pupfish habitat in these drains. However, as noted by the disease and contaminants group, direct discharge of drain water into shallow habitats should be discouraged, due to its high selenium concentrations (potentially greater than 15 µg/L) and the potential for selenium toxicity in the birds using this habitat.

The IWMP notes the potential for reclaiming currently inundated farmland in the southern portion of the Sea (see Figure 5, above). Irrigators in this area would need to be able to drain to the Salton Sea as a repository, without having to resort to pumping drainage water up-gradient into the river extensions (draining directly into the shallow ponds could pose an unacceptable risk of selenium toxicity), yet it appears that a considerable acreage of reclaimed farmland may be down-gradient of the river extensions.

The group predicted that the velocities in the river extensions (particularly with the north lake at elevation -235') would likely not exceed those in the existing delta areas where vegetation control is necessary. Local experience indicates that vegetation growth along banks will significantly impede channel maintenance and sediment removal from the river extensions and sedimentation basins. To maintain flow, ongoing vegetation removal will be required from these areas.

The extended rivers would cross several drainages, including Salt and San Felipe creeks, requiring long siphons under these and possibly other washes, to avoid storm-generated damage to the extended river channels. The group also questioned whether the extended rivers would provide sufficient connectivity between the north lake, Salt Creek, and San Felipe Creek, for the endangered desert pupfish.

Greenbelt channels along river extensions

The groups noted that the greenbelt channels would face the same challenges and obstacles that were described for the upstream wetlands (see above). The biology group questioned whether the river extensions would permit pupfish connectivity, because flow rates in these rivers would tend to permit only a downstream dispersion of pupfish. However, such connectivity could be designed into the extensions, via slack, off-channel water areas. Otherwise, these river extensions will offer poor fish habitat. Seepage from the unlined river extensions could benefit certain bird species. However, the group noted that diverting water from the existing New and Alamo river deltas could negatively impact colonial nesting birds that use these delta habitats, if breeding habitat is left exposed to predators or is destroyed. The group also expressed concern with plant growth along the river extensions, which might affect water velocity, and create mosquito habitat. They noted that active sediment maintenance will be required in the river extensions, though periodic high velocity flows may scour the bottom of the channel, creating deltas at the river mouths in the north lake. Aggressive saltcedar (*Tamarix ramosissima*) management and removal will be necessary.

North (Marine) Lake

The central feature of the IWMP would be the 85,000-95,000 acre north lake, with an elevation of -235’ or -240’ and ocean-level salinity. The north lake would be impounded by a causeway running from near Bombay Beach across the relatively shallower middle of the Sea, with outlet structures to manage elevation and salinity. “Access to communities would be provided by dredging channels to local communities which would also create islands and peninsulas that would have new recreation and development opportunities.” (Salton Sea Authority 2004, p.55)

The hydrology group calculated that the projected reductions in flows would challenge efforts to maintain the north lake at the -235’ elevation, especially when dust control efforts are factored in. Potentially, the causeway could be moved farther north to reduce the size of the impounded area, though even this may not address the potential loss of elevation due to the seasonal variability of inflows. The group also noted that the lake outlet/control structures will require regular maintenance, to minimize barnacle fouling. The discharge control structures on the north lake will need to function at lower elevations, so that in years with lower inflows it would still be possible to get water to the shallow ponds and/or reduce salinity in the lake by releasing water.

The water quality group noted that on-farm sediment control to meet TMDLs will reduce the suspended sediment load to the Sea, which may in turn reduce phosphate loadings and eutrophication. Additionally, re-suspension of sediments in the Sea may decrease due to changes in morphometry. However, they noted that the role of sediment re-suspension in the current Sea and in all proposed designs is not known; data and model results suggest that re-suspension is important in driving phosphorus dynamics in the Sea now, and will vary with alternative designs. They noted the need to examine the IWMP’s impacts on areal nutrient loadings relative to loadings from re-suspension. However, they predicted that total loadings will increase (with more phosphorus loading per unit area)[12], despite the implementation of TMDLs, because the north lake will be much smaller than the current Salton Sea. They also expected that the north lake will still have high ammonium concentrations, which could be a significant problem given that current NH_3 concentrations are likely toxic to fish.

The water quality group predicted that the frequency of complete vertical mixing of the water column will increase due to the shallower depth of the north lake, mixing hypolimnetic (lakebed surface) water with surface water more frequently. This hypolimnetic water is frequently low in oxygen and high in ammonium and hydrogen sulfide. However, some participants noted that the north lake will still be about 40' deep, more than enough to set up stable stratification, complete with anoxia in the bottom waters, on a frequent basis. While mixing may occur more frequently, the smaller north lake will not eliminate the current problem of stratification and periodic mixing of anoxic bottom water with the rest of the water column. The likelihood of anoxia is based on temperature,

[12] An evaluator from a different group questioned the prediction of increased phosphorus loadings in the north lake, stating that this projection neglects the fact that the north lake will have an outflow that will reduce net phosphorus loadings. If north lake inflows are decreased during the transition to maintain salinity near ocean levels (rather than closer to river salinity), phosphorus loadings will also be decreased.

salinity-controlled mixing, nutrient loading, re-suspension of sediments, and biomass. The group predicted that the surface temperature of the north lake will be about the same as the current Sea.

The water quality group expressed concern that the proximity of the mouths of the river extensions to the outlet structure for the north lake could lead to 'short-circuiting' the system and preclude full mixing, rather than flushing the north lake. Aside from this design flaw, they noted that the north lake's salinity could be readily controlled by the IWMP, to 35 mg/L, though they suggested that decreasing the Sea's salinity to 42 mg/L might be sufficient. The biology group, however, recommended that the north lake be managed for low salinity (~ 20 g/L) in its initial years, to reduce sulfide production. However, the water quality group expressed uncertainty about the impacts of chemical precipitation or dilution on the salinity of the north lake. There was considerable uncertainty about how the proposed alternative might affect the ability of the sea to effectively reduce selenium concentrations. Dividing the Sea will alter wind- and water-driven water circulation, which might affect mixing and the ability of the north lake to reduce selenium concentrations.

Dredging the Salton Sea lakebed, especially in near-shore areas (see Figure 4), could resuspend selenium and other elements that have precipitated, dramatically increasing their concentrations in the water column.

The IWMP does not appear to improve dissolved oxygen levels in the water column. This has implications for both fish and bird health. Potential changes in dissolved oxygen levels have implications for redox potentials for selenium. Re-suspension of particulates should be modeled in terms of bioavailability of selenium and inputs to food chain. It is not clear that nutrients will be reduced with this plan, which could lead to algae growth, including potentially toxic algae.

The north lake, with its steeper shoreline, would present fewer shallow foraging areas for birds that feed at or near the lake's surface, and fewer flats for those that forage within the wet margin of the lake's shore, making it less suitable than a southern lake would be for fish and fish-eating birds that either plunge- or pursuit-dive, or dip from the surface, wading birds (herons, egrets), and shorebirds. The group expressed concern about potential human disturbance of wildlife, and suggested the development of a management plan to include wildlife sanctuaries in the north lake, to minimize recreational interference with wildlife. The maintenance of wildlife habitat at the delta of the Whitewater River was also identified as a critical issue. The group recommended that the IWMP build upon the plans of the Torres Martinez tribe to develop Whitewater River wildlife habitat. The effects of IWMP implementation on eared grebe and ruddy duck populations will depend on how the restoration affects their primary prey items (primarily pileworms), as well as the amount of habitat available for feeding.

The group noted that the Sea has suffered significant and massive decreases in fish populations in the past several years. They expected that the mouths of the rivers will serve as refuges for fish. Fish will likely be more abundant once the IWMP lowers the salinity of the north lake sufficiently for a restocking program to be implemented, and for recruitment to occur from the remnant population. A larger portion of the north lake bottom, because it will be more shallow in the future, will be oxic and support invertebrates and fish, thereby affecting nutrient and contaminant cycling. However, some of the participants noted that the north lake will still be more than forty feet deep, so it is not clear how much more oxygen will be available at the lake bottom. Barnacles (larvae and adults) are an important food source for some birds and fish and are likely to be the main species benefiting from the rocky face of the causeway, though this will also provide substantial habitat for pileworms and other invertebrates. Some previous studies (Thiery 1999) suggest that pileworms may be able to tolerate the north lake's projected maximum transitional salinity of ~ 65 g/L (at the -235' surface elevation), and thus would likely rapidly recolonize the north lake as salinity decreased. However, if the Sea is permitted to drop to -240', the transitional salinity could peak at ~80 g/L, well above the expected maximum tolerance of pileworms and many other invertebrates. Additionally, the steeper shoreline of the north lake may provide less habitat for birds that prey upon pileworms.

The disease and contaminants group noted that if there is going to be a road on the causeway, the volume of traffic should be projected and the routing of runoff will need to be addressed.

At present the fish in the Salton Sea are known to host only a single metazoan parasite, a monogenean fluke (*Gyrodactylus*), and this only rarely. A few microbial ectoparasites (*Amyloodinium*, *Cryptobia*, *Ambiphrya*) are known to infest large percentages of fish, especially juvenile tilapia, at certain times of year. On rare but significant occasions, botulism has been found in moribund tilapia, often associated with *Vibrio* infections. Low dissolved oxygen is probably the biggest mortality factor in fish. These issues are likely to remain in the proposed north lake.

Avian botulism is likely to remain an issue in fish-eating birds in the saline north lake, particularly if tilapia remain the dominant prey fish in the Sea and the nutrient loading/low dissolved oxygen problem is not resolved. This problem may also extend to some of the shallow water habitats that have fish in them.

It is difficult to predict what may happen with the unidentified source of grebe mortality; it may continue in the north lake, or perhaps the reduction of salinity may alleviate the problem. Salmonellosis could be a problem if there are large increases in colonial nesting birds in vegetation on the margins of the impoundments or on top of the dams. Newcastle disease is mainly associated with ground-nesting, as carried out by cormorants at the Sea. Though the factors initiating outbreaks are unknown, once present the frequency of this disease would probably be a function of the numbers of cormorants nesting on Mullet Island or the dam/causeway surfaces.

Cyanobacteria can create blooms that are toxic to fish and wildlife, including terrestrial mammals. Such blooms occur frequently in other shallow, eutrophic freshwaters, though not in waters as saline as the current Sea. However, toxic species of cyanobacteria could appear in the biota without having harmful effects. Some of the cyanobacteria in the Sea now, as well as some of the dinoflagellates and raphidophytes there, are capable of producing toxins. But there is no hard evidence to date that these have harmed fish or wildlife.

The New River has received, on a regular basis, large quantities of untreated or poorly treated (e.g. only primary treatment) municipal wastewater from Mexicali. On an irregular basis, the New and Alamo rivers have received municipal wastewater from Imperial Valley towns. More than two dozen bacterial and viral pathogens have been detected in the New River. The group noted that the construction of new wastewater treatment plants, and discharging treated effluent to new areas, means that sewage flows will decrease in the future. This will decrease the human health risk from pathogens in the north lake and should further expand recreational opportunities, although other potential sources, such as urban runoff, may increase with economic development around the lake.

Southern (shallow habitat area) wetlands

The IWMP would create as much as 20,000 acres of shallow habitat in the south basin, phasing in construction of wetlands as the lake level in the south basin recedes. Some of these habitats could be less than one foot deep. These shallow habitat areas would offer the added benefit of dust suppression and reducing wind fetches.

The hydrology group recommended that the design and hydraulics for mixing river and north lake water in the southern shallow ponds be further developed and refined. This mixing will likely require many miles of additional conduits, possible small lakes for mixing, and/or mixing manifolds. They projected that the IWMP's project construction and O&M costs would likely increase as further attention is paid to this project element. However, the disease and contaminants group recommended that river water never be added to the shallow habitats, because of its elevated concentrations of selenium.

Monthly and annual variability in inflows (see Figure 6) will cause variability in the size and salinity of the shallow ponds and the brine pool from month to month, and from year to year. Note that discharge of the Alamo River doubles from a low of ~560 cfs in mid-January (and only 440 cfs on December 26), to a high of 1160 cfs in late April. This variability in inflows may result in times when there is insufficient water to maintain a significant proportion of the shallow ponds; at times, there may be insufficient water to maintain the north lake at its target elevation. A member of the group suggested that the north lake be allowed to fluctuate one and a half to two feet, to stabilize the elevation of the southern ponds. The IWMP does not describe the control of inflow into the southern ponds and the control of the water elevation in the ponds themselves; these controls need to be described in detail.

Several of the participants thought that future inflows to the Sea would likely be even lower than projected. They noted that many reasonable forecasts (including decreased basin yield under climate change, increased evapotranspiration due to higher local temperatures, further decreases in irrigation return flows from changing land use and open market water allocation, etc.) would produce substantially less than the projected reductions in inflows. They noted that assuming further reductions of just one to two percent could leave several of the IWMP project elements, especially the shallow wetlands, without sufficient water in most years. Hydrologic calculations suggest that the water supply is very close to being insufficient for the proposed plan. Seasonal and inter-annual variation will produce substantially fluctuating conditions somewhere in the overall IWMP system, even if the IWMP had a reliable water right for the projected inflow.

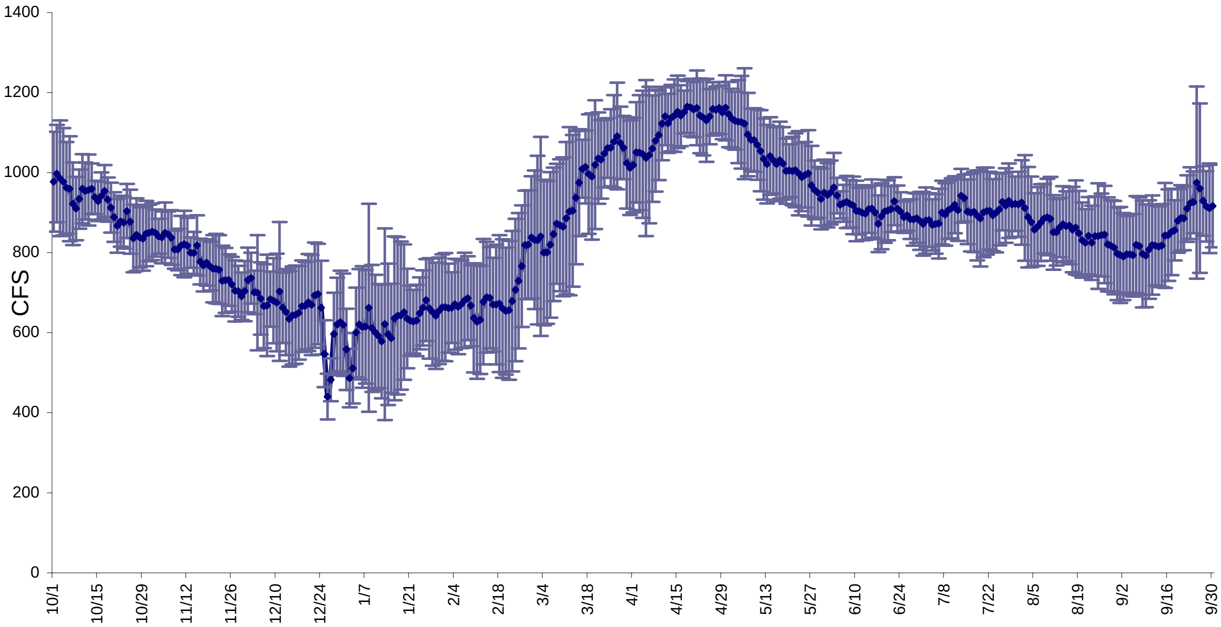

Fig. 6. Mean annual daily discharge of the Alamo River, 1991-2003 (with standard deviation).

The water quality group expressed concern over the potential for selenium toxicosis in the saline shallow water habitat constructed upon old Sea lakebed. Data (Agrarian 2004) from the Authority's test evaporative basins indicate that selenium concentrated in these evaporation basins, suggesting that 2 µg/L north lake water could pose a problem in shallow water habitat constructed on old Sea lakebed. The water quality group recommend that neither river water nor drainage water be added to the shallow water habitat impoundments because of selenium issues.

The mechanisms that keep water selenium concentrations in the current Salton Sea (and the proposed north lake) well below inflow concentrations are unlikely to operate strongly in the proposed 20,000 acres of South Basin wetlands. In fact, these wetlands have several warning signs (very shallow, intermittently exposed surfaces) for selenium concentration and toxicity. It is not clear whether these wetlands are a desirable component of the plan, and it is not clear how the plumbing (gravity drains, mixing basins, pumping) would be configured and operated in conjunction with the use of water for dust control.

The biology group recommended that the lower end of the range of salinities for these wetlands should begin at or near the north lake concentration, and that river water not be used for these wetlands. However, they noted that although the higher salinity water will reduce the threat of selenium toxicosis in the shallow water habitats, the availability of fresh water for young birds is critical during the breeding season. These southern wetlands will be conducive both to bird watching and to hunting activities, so an active program will be required to coordinate these different recreational activities. The influence of geothermal development and activity will also be a concern for birds: lights at night on structures and power lines pose bird strike issues. The group recommended that the IWMP incorporate islands into the pond designs.

The biology group recommended that the upper tier of the shallow water wetlands be managed for some type of fishery with deep water habitat, even if that means that these wetlands could have problems with vegetation encroachment. These ponds might be too warm in summer to support sport fish, though they would likely support new fish populations that are not part of a sport fishery. There still would be more small fish available for fish-eating birds than there are now, according to one evaluator. Control of invasive vegetation, such as *Tamarix*, will be an important management objective if these wetlands receive lower salinity inflows directly from the drains or the rivers, as will maintaining unvegetated habitat.

The source and quality of the water feeding the southern shallow water wetlands should be carefully evaluated. Feed water from the north lake will have to be evaluated from both a chemical and biological perspective, because it may have both disease and contaminant issues – e.g., a significant load of organo-selenium in algae. River feed water, if used in high amounts (60%+), will result in higher selenium concentrations in these wetlands, with potential for classic avian selenosis syndrome (embryonic malformations, etc.) similar to that seen at Kesterson.

Agricultural tile drain water has significantly higher levels of selenium than does surface (tailwater) runoff; several of these drains currently discharge directly into the Sea. The proposed plan needs to explicitly state where these drains will be directed. They should not drain directly into the shallow water ponds or to the river extensions if they lead to the treatment wetlands.

The southern shallow-water habitats are not designed for fish management, but fish will probably inhabit them, at least at the lower salinity levels. Disease issues in these habitats are probably similar to those identified above for the north lake. These wetlands are likely to have low levels of dissolved oxygen and high temperatures, which will stress fish, leading to mortality and/or opportunistic infections.

Brine Pool (Hypersaline Lake)

The IWMP projects that the salt pond would occupy about 60,000 acres and would provide for salt storage for at least 300 years to preserve the function of the Sea as a repository for agricultural runoff.

The brine pool will lose less water to evaporation than was estimated by the IWMP, but the pool will also be smaller than predicted, due to greater water use by the other components of the IWMP. The brine pool will have elevated sulfate concentrations and conditions favorable for sulfate reduction. However, the water quality group was uncertain about the potential toxicity of ammonia and hydrogen sulfide on wildlife or human health. One evaluator speculated that sulfide and ammonia degassing from the brine lake was likely to be minimal, given that its shallowness would result in the whole water column being oxic most of the time.

As the salinity of the terminal brine pool transitions from 100-200 g/L (according to the hydrology projections provided for the workshop, this will only take 5-6 years after the causeway is closed), it will teem with brine flies and brine shrimp. The group expressed concern that selenium could pose a threat during this transitional period. Brine flies and brine shrimp are an excellent food source for many birds, particularly eared grebes, ruddy ducks, and phalaropes. The perimeter of the brine pool during the transition period potentially will be good for birds, for nesting and foraging. Islands are beneficial in many areas, but several evaluators suggested that they should be avoided in the brine lake, because they would be attractive as nesting areas, but would not offer a source of fresh water for young birds. However, a reviewer noted that white pelicans, great blue herons and California gulls nest on islands in the Great Salt Lake, some in the north part of that lake, where salinity can exceed 220 g/L. The islands of Mono Lake (salinity ~85 g/L) hold about 50,000 nesting gulls, as well. Several evaluators questioned whether adults, and especially the young, of some colonial ground nesters (terns and skimmers, perhaps cormorants) would be able to effectively use the waters of the brine pool to regulate nest and body temperatures when coping with the extreme ambient temperatures experienced at the Sea during the breeding season, as they now do in the saline or brackish waters that are presently available. Because these breeders and many other species typically loaf directly in shallow water during the day in summer, there may be a small risk of salt encrustation in the brine pool.

Exposed Lakebed

Assuming that the IWMP would include about 5,000 acres of infrastructure atop exposed lakebed (including the causeway and shallow habitat impoundment structures), the total January 1, 2003 lakebed exposed with full implementation of the IWMP would be about 60,000 acres. However, the IWMP would not expose any additional lakebed relative to a ‘no action’ alternative, in which the elevation of the Salton Sea would stabilize at about -247’ (though it is important to note that different portions of the lakebed would be exposed in the IWMP and under a ‘no action’ projection).

The water quality group expressed concern over the potential for exposed lakebed to be periodically rewetted, either for dust suppression or by precipitation, potentially leading to selenium toxicosis in ephemeral pools. Concerns about aquatic selenium concentrations and contaminated dust from exposed former seabed would be magnified if inflows decrease below the 382,000 acre-foot reduction projected for the next 75 years.

The recession of the Salton Sea shoreline will likely increase the amount of potential habitat for reptiles. Additional amphibian habitat may become available as a result of the New and Alamo River extensions, unless velocities in these channels are too high, and through the development of treatment wetlands if vegetation is allowed to establish and water temperatures and conditions are favorable. Moving the outfall of the rivers may affect pathogen/human interactions. The biology group noted that establishing and maintaining a native vegetation program along the river extensions and exposed lakebed (to minimize the extent of saltcedar) could provide economic opportunity and a source of jobs.

By allowing the level of the Sea to decline and exposing at least 57,800 acres of former lakebed, a worsening of air quality in the region is likely. This will depend largely on the physical structure, particle size distribution, and moisture content of the soil surface. The exposed Salton Sea lakebed would be almost equal to the dry lakebed at Owens (Dry) Lake in eastern California, which has produced severe air quality problems in that region for many decades.

Use of overflow waters to create bands of wind-interrupting vegetation could mitigate this problem to some extent. However, to the degree that evapotranspiration of overflow waters is increased by these bands of vegetation, the residual Sea would have an even lower final equilibrium level, exposing an even larger acreage of former lake bottom.

An air quality assessment at the Salton Sea should address other factors besides PM_{10} (e.g agricultural productivity, animal health issues, suspension and aerial transfer of pesticide issues). The Aral Sea offers a disturbing example of potential problems due to exposing the Sea's lakebed, including dry deposition problems from airborne particulates, especially blowing salt.

Air quality at a reduced-sized Salton Sea will be a function of exposed lakebed. All of the reduced-inflow alternatives call for exposing significant amounts of lakebed. The air quality group stated that federal and state air quality laws require public health to be protected; the other objectives should be given secondary importance to the need for public health protection. Therefore, controlling dust emissions from the exposed lakebed must be one of the highest, if not the highest, objective of the IWMP or any other reduced-water alternative. Dust must be controlled as the lake recedes and exposes potentially emissive lake bed surfaces. The Clean Air Act will not allow the target level (-235' or -240') to be achieved before dust controls are implemented. This presents logistical challenges to the implementation of any reduced-water alternative.

The air quality group noted that both Imperial County and the Coachella Valley are classified as "serious non-attainment areas" for the federal PM_{10} standard. Violation of the PM_{10} twenty-four-hour standard occurs when there have been more than three exceedances of the standard in three years (the current federal 24-hour standard is $150 \mu g/m^3$). Wind events from the west and northwest are currently causing exceedances of the PM_{10} Standard in the Salton Sea area (northern Imperial County). The 1996 EPA's Natural Events Policy allows air districts to document the PM_{10} violations that are caused by a qualifying natural event (high wind event). This data is flagged in the U.S.EPA AIRS database and it can be excluded from the determination of PM_{10} NAAQS compliance. Both the Imperial County and Coachella Valley are currently documenting PM_{10} natural events. This policy requires that Best Available Control Measures (BACM) must be implemented at contributing anthropogenic sources of dust in order for a PM_{10} violation to be treated as due to uncontrollable natural event. The exposed lakebed would be considered an anthropogenic source; therefore, BACM to mitigate fugitive dust emissions from the exposed lakebed must be implemented. In addition, the Clean Air Act requires that PM_{10} "serious" non-attainment areas shall implement BACM to mitigate dust generated at all anthropogenic PM_{10} significant sources. Due to the serious non-attainment status of these areas, offsetting or emission trading is not an option.

The group stated that all significant sources of PM_{10} in the southern Coachella and northern Imperial areas must be controlled, including emissions from the exposed bed of the Salton Sea. Although there are two PM standards, PM_{10} and $PM_{2.5}$ (particles less than 10 microns and particles less than 2.5 microns), solving the PM_{10} problem will solve the $PM_{2.5}$ problem due to the small ratio of $PM_{2.5}$ to PM_{10}. $PM_{2.5}$ is typically associated with combustion materials (e.g. diesel exhaust).

The group noted that dust emissions can occur from any unstable surface sediment. Unstable lakebed surfaces are a concern regardless of particle size. Unstable is defined as any surface that is not wet, salt-crusted, protected with vegetation, or covered with larger, stable materials (i.e. gravel, barnacles, fish bones). Dust can be emitted from unstable exposed lakebed surfaces by wind velocities of 17-20 mph, measured at a 10 meter height. Furthermore, surface stability can change with changes in soil moisture and temperature: nearly all exposed, unprotected surfaces can potentially become unstable, and may require mitigation. Based on studies at Owens and Mono Lakes, soil particle size alone is a poor predictor of emissivity. Salt chemistry and crystallization conditions (moisture and temperature) impact salt crusting and therefore surface stability. Under certain conditions, very unstable surfaces can be created that lead to extremely high PM_{10} emission rates. Under other conditions, hard, stable, durable crusts may form that are not emissive. <u>These conditions are difficult, if not impossible, to predict.</u>

It is important to acknowledge that the impacts associated with exposing lakebed sediments down to -235 feet will not be mitigated as part of the IID Water Conservation and Transfer Project, as these impacts were considered to be the baseline condition. This area below the existing shoreline and above -235' is of particular concern, as the IWMP does not include dust controls for that area, encompassing some 19,400 acres relative to January 1, 2004 lakebed elevation. Exposure of sediments above -235 feet, and, depending on the timing, exposure of sediments above -240 feet would not be an impact of the IWMP.

However, soil salt levels will be lower at these higher elevations, and that <u>**may**</u> lead to lower emission rates. As the Sea recedes, the exposed surfaces will vary from less saline near the existing shoreline to hypersaline as the brine pool is formed. This will cause a gradient of soil salinities and, possibly, emissivities. Massive salt precipitation will occur at saturation in the brine pool and the lower shallow wetlands. These deposits typically protect the surface. Even if only portions of the exposed lakebed emit dust, it will be problematic to decide which portions need to be controlled. Dust controls must be applied before dust emissions start. <u>This may mean that all exposed lakebed areas will require dust controls.</u>

Drying down wetlands between February and June could create an air quality risk, if the soils become dry enough to be emissive, especially since the strongest winds typically occur from December-May. Additionally, dried algal mats can be a source of PM air pollution. Fine materials (clay, silt and salts) will create a PM_{10} problem as they are lofted by the wind. Wind-borne salt from exposed lakebed surfaces can also have a negative impact on crop production. Larger materials (sand) might not create an air pollution problem, but will create additional nuisance and possibly public safety problems such as impacts to farms, housing, road ways, railroads, geothermal facilities, etc. (as shown by the Algodones Dunes, southeast of the Salton Sea). Although the PM_{10} standard is material independent, contaminants in the lakebed sediments pose a toxic risk, in addition to the PM_{10} threat. Solving the PM_{10} problem also solves the toxics problem, as well as the threats posed by airborne diseases and contaminants.

All exposed lakebed surfaces can potentially become unstable and emissive, and may require mitigation. Even relatively small emissive areas (perhaps less than one square mile) can be significant sources of dust. The group identified several potential sources of dust remediation and control. They noted that emergent vegetation can stabilize otherwise emissive surfaces and may capture blowing sand (though blowing sand may have an adverse impact on vegetation health). Vegetation coverages of between 20 and 50 percent should provide sufficient protection against dust emissions. However, soil reclamation (i.e. salt flushing) is required when soil salt levels exceed tolerance of terrestrial vegetation.

Ponds can trap sand that blows off of unponded areas. This is beneficial from a sand control standpoint, but may have adverse impacts on the ponds, pond vegetation and pond wildlife. Dust control measures can include not only shallow habitat areas, but also other wet controls such as shallow flooding, or non-wet controls such as stable salt deposits, upland vegetation, rock covers or other controls. The size and configuration of the wetlands will be an important factor in determining the stability of the remaining exposed areas. Many small wet areas would be more effective in controlling dust than fewer large contiguous areas. For wet controls, based on measures at Owens Lake, approximately 75 percent of every square mile of exposed lakebed must have standing water or surface-saturated soil in order to adequately control dust emissions. Two to four acre-feet of water per acre per year will be required for dust control – 40-70% of the evaporative rate of the Sea itself. Emissions from exposed lakebed surfaces can be controlled with water of any salinity or quality. The proposed brine pool would be an excellent source of water for dust control, although its value for habitat would be minimal.

A continuous PM_{10} and meteorological research network (as opposed to a 1-in-6 compliance network) is necessary to identify the magnitude and location of any dust problem. The network should surround the Sea and particularly be installed where people live or work. This needs to be established now in order to collect baseline information, and continue until a stable condition is achieved. The group also recommended limiting surface disturbing activities, such as off-road vehicle recreation, on stable and unstable surfaces.

General Concerns

The evaluators noted several general concerns about the IWMP, which encompass more than one of the project elements, or the proposed plan in general. These concerns are discussed in the following , with special attention paid to the threats posed by selenium and increased lakebed exposure. The problem areas highlighted by the workshop – water supply and variability; plumbing and operation of shallow wetlands in the south basin; selenium concentration in shallow, fluctuating impoundments; and dust control – primarily center on the south basin and what will be done with the land exposed as the extent of the Salton Sea diminishes.

Several of the evaluators expressed the sentiment that the general objectives of the IWMP themselves were misplaced. One noted that creating an intermediate flow-through pool with a relatively stable volume and an intermediate salinity that would have many of the attributes of the Salton Sea of recent times represented the easy (though perhaps expensive) part of the challenge. The real problem is obtaining a desirable, sustainable long-term condition for the nearly1,000 square kilometers currently inundated by the Salton Sea. Another evaluator suggested that the whole idea of achieving a permanent water body with some of the desirable attributes exhibited by the Salton Sea as it has evolved over the last 90 years is an inappropriate definition of the problem, reflecting vestigial thinking about the Salton Sea as a stable water body with gradually increasing salinity. Instead, the problem should be framed as guiding a shrinking sea towards a situation in which the exposed surfaces avoid the kind of scenarios that have played out at Owens Lake and the Aral Sea. The kinds of fish that might inhabit open water areas will likely end up being one of the least of the challenges for the area over the next 50 years.

The biology group assembled a general set of principles to guide the development of any rehabilitation plan for the Salton Sea ecosystem:

- Maintain as much diversity of habitat as possible;
- Utilize adaptive management;
- Avoid exotic invasive vegetation, or at a minimum include an aggressive program of intervention and control for such species;
- Coordinate with the TMDL process;
- Maintenance, expansion and enhancement of surrounding upland habitats for key species should be included;
- Selenium and other contaminants must be managed as a high priority, on an on-going basis;
- Management options for selenium: biota safe or biota free.

The group as a whole identified a series of questions and potential problems with the IWMP. They noted that 90% of the inflow to the Salton Sea is controlled by man, and largely dependent on variable agricultural conditions. Monthly inflows should be assessed, for the potential for seasonal changes to limit the viability of IWMP components. It was unclear whether the IWMP could function with its future water supply, partly because dust control was not specifically addressed. Generally, water supply issues will need to be reconsidered. In particular, the acreage of the proposed shallow water wetlands will need to be adjusted, to accommodate flows from the north lake, or the IWMP will need to reduce salinity/elevation targets of the north lake.

The group questioned whether the IWMP could proceed without direct management of pupfish populations. Monitoring of fish, inverts, birds, etc., should be a priority effective immediately if restoration is to be managed in an adaptive manner.

The disease & contaminants group developed a major issue summary and set of recommendations for the IWMP (see Table 5 for their comparison of the IWMP with a no action alternative):

(1) Evaluate toxic equivalency of selenium outflow from wetlands.

(2) Evaluate salt encrustation and toxicosis issues at the hypersaline lake/brine pool.

(3) Evaluate the feed water from the north lake to the shallow wetlands for its geobiological load as well as its chemical load of selenium.[13]

(4) Account for the routing of water from agricultural drains that currently discharge directly to the Salton Sea, as well as the pupfish in these drains.

(5) Selenium concentrations in river feed water are likely to be substantially higher (> 10 µg/L, and potentially > 15 µg/L) than the plan is anticipating. Loads will not be reduced even though flow will be reduced, and increases in load will likely occur from re-routing of agricultural drains that currently discharge directly to the south sea (see Table D-1 in Appendix D).

(6) The north lake will continue to receive the full selenium load currently entering the Salton Sea, but in only 40% of the water volume currently receiving these loads. This will result in a greatly exaggerated selenium sink somewhere in the system, such as the water column, biota, and/or sediments, each of which will have important management implications (see Table D-1 in Appendix D).

(7) In addition to the PM_{10} issue, a critical issue requiring evaluation is the dry deposition of sulfate salts. Studies in the Aral Sea region have shown agricultural crops to be very sensitive to such deposition, with reductions in yield noted as far away as 500 km from the exposed bed of the Aral Sea. Other human health issues associated with dry deposition at Aral Sea include esophageal cancer and pesticide-related neonatal mortality.

(8) Evaluate sediment disturbance for dredging and causeway construction.

[13] The group recommended that data regarding the geobiological loading (sediment and non-sediment particulate matter associated with selenium) as well as the chemical loading (dissolved selenium) be considered by project planners (those two components together equal total selenium), which would require filling the current data gaps.

Table 5. Consideration of Specific Major Issues: No Project Alternative and Possible Proposed Actions. (Comparisons are keyed to items listed above.)

	No Project	modification possible
1.	+	+
2.	+	-
3.	N/A	+
4.	+	+/- (pupfish?)
5.	slightly +	+
6	=	-
7	=	+
8	+	-

+ = superior option or IWMP can be modified to be superior to no project;

- = worse option or IWMP cannot be modified to be superior to no project;

= means no difference

Selenium

In general, selenium is a concern because of:

6) its ability to bioaccumulate in the food web;
7) the narrow range between the concentration that is nutritionally beneficial and that which is toxic;
8) its effect on fish and bird reproduction and embryonic development;
9) its role in causing immune deficiency; and
10) its effect on human health from consumption of contaminated fish and birds.

The EPA's criterion for selenium concentration for protection of aquatic life is 5 µg/L, but lower limits such as 2 µg/L are being considered for areas where significant bioaccumulation has been noted. Selenium concentrations in water flowing in to the Salton Sea already are at levels of concern; future water conservation measures will increase those concentrations. Water conservation measures underway, such as reduction of tailwater drainage and operational losses, could cause selenium concentrations in river inflows to increase by as much as 30 percent in the future. Because of the reduced size of the north lake, selenium concentrations may increase there as well, because the total selenium load will remain the same (see Tables D-1 & D-2 in Appendix D).

The selenium situation at the Salton Sea is very complex and merits more detailed analysis than it received in the IWMP as presented to the study groups. The majority of participants stated that the threats of selenium toxicity posed by the plan, especially in the constructed wetlands and by the use of river and drainage water in the shallow habitat, approached the level of a fatal flaw. A minority of participants stated that potential losses due to selenium toxicity should be weighed in relation to other alternatives, such as losing all marine wetland habitats if no action is taken. Considerable analysis is needed to assess the risk posed by selenium; the design and implementation of a selenium management plan will be necessary for any alternative to restore Salton Sea habitats. In the absence of such an analysis, and with no identified selenium management plan, it would appear that selenium poses a fatal flaw for the IWMP as presented at the workshop.

The group noted that freshwater selenium habitats were extremely problematic, which is one of the strongest reasons to avoid designing freshwater wetlands or backwater habitats. Selenium toxicosis has been most clearly demonstrated for birds; for adults at higher concentrations, and for embryos and hatchlings at lower concentrations. Selenium drops out of the water column at the Sea, perhaps because of the high salinity. Since one of the objectives of the IWMP is to reduce salinity in the north lake, selenium equilibrium at lower salinities needs to be evaluated.

Selenium concentrations need to be linked to the food web to be meaningful. Selenium thresholds for sediment, diet, fish tissue, and bird eggs should also be considered. The fate of selenium in the different food web systems for the north lake, southern shallow water habitats, and riparian wetlands along the river extensions needs to be modeled as separate components. The disease and contaminants group compiled the following list of recommendations with respect to selenium management:

- Because selenium bioaccumulates in ecosystems, connect protective criterion to food webs;
- Concentrations of selenium in water need to be linked to food-web concentrations to be meaningful. Selenium thresholds for particulate matter, diet, fish tissue, and bird eggs are toxicologically relevant to assessing the ecological health of ecosystems;
- Assess protection of wildlife through ecological indicators, such as opportunities for transformation to organic selenium, diet, species sensitivity, and residency;
- Recognize that treatment wetlands are problematic when subjected to selenium discharges
    1) Selenium concentrations in river flows will be too high (> 2 µg/L) to use as feedwater for wetlands;
    2) If north lake-tiered wetlands are considered, source water and outflow must be considered for the toxic equivalency of selenium;
- Calculate a selenium mass balance budget for the components of the IWMP;
- Monitor the geobiological selenium load, measure selenium speciation, and model food webs on a seasonal basis, to assess the potential bioavailability and trophic transfer to vulnerable predators under proposed changes;
- Recognize the Salton Sea as a selenium reservoir (the storage term) in any analysis of source terms;

- The IWMP should give the same weight to managing selenium as it does to managing water and salt: selenium needs to be modeled, to determine if the IWMP's goals are achievable, particularly in the southern shallow wetlands;
- Consider the toxic waste accumulation and attractive nuisance hazard of the 60,000 acre salt pond (brine pool) functioning as storage for the next 300 years (in its role of federally designated agricultural sump), especially in terms of pools with elevated selenium concentrations during flooding and salt encrustation;
- Consider selenium effects to the immune system when addressing disease issues; and
- Consider interaction effects (e.g., mercury, immunobiology, toxic algal blooms) as important in determining risk.

The group noted that dust control and selenium management options are mutually exclusive, because wetting or saturating soils will be necessary to minimize soil emissivity and protect human health, but rewetting Salton Sea lakebed could pose a real threat of selenium toxicity to wildlife. Selenium also poses a threat in treatment wetlands, and in habitats created or conserved specifically for wildlife, raising the question of whether wildlife should be encouraged or discouraged from using these habitats. Selenium in freshwater impoundments will be problematic and should be avoided. Mixing freshwater and Salton Sea water is not a recommended option, since prior science indicates this could also be problematic.

However, some of the evaluators recommended that, at a management level, a decision be made as to what constitutes an acceptable or tolerable level of loss of biota, due to whatever source, but in particular due to selenium. If decision-makers determine that the acceptable loss is zero, then selenium must fall within the range for no impact, or the ponds must be bird-free or bird-safe. If, however, the IWMP has projected losses and they are considered to be unavoidable, then these losses must be mitigated. If the latter, and if some level of losses were determined to be acceptable, then the extent of mitigation habitat might be minimal, probably on the order of a few hundred acres or less.

The group identified several research needs relative to the movement of selenium in the Salton Sea. Information about how selenium moves through food webs should be modeled for the Sea. The group noted the importance of securing data on particulate-associated selenium in the Salton Sea, collected on a seasonal basis, to improve understanding of bioaccumulation of this toxicant. Samples of evapo-concentrated Salton Sea waters (from Naval Test Base brines) should be evaluated for selenium spikes.

Air Quality

The IWMP lists three measures that could be undertaken to address air quality concerns at the Salton Sea: shallow water habitat areas; salt crusts from evaporated brines, which could be used to cover fine sediments; and salt-tolerant vegetation. Aside from the shallow water habitats, the IWMP does not provide estimates of the extent of these remediation measures. The evaluators recommended that a more robust and detailed dust control plan for exposed surfaces be developed as part of the IWMP. They noted that a stable north lake can not be equated with a restored Salton Sea, especially if the IWMP ignores the exposed land under the current Sea, along with the associated human and wildlife health problems that will likely occur due to this exposure.

The group noted that Imperial County has the highest childhood asthma rates in California, and emphasized that public health concerns should be addressed as part of the IWMP, or of any rehabilitation plan. Although dust problems are inevitable in the basin, the question remains of who will pay for controls. They suggested that the use of gravel or other ‘dry’ controls be explored, as an alternative to wetting soils and increasing selenium risks.

Uncertainties and Research Needs

The evaluators identified a number of uncertainties, data gaps, and future research needs as part of the evaluation process.

The group noted a lack of information about:

- how currents in a smaller north lake might vary from current conditions;
- currents under stratified conditions;
- the relationships between wave action and re-suspension of sediments;
- uncertainty in meteorological forcing under future climate scenarios;
- how the rate of oxygen consumption varies with biomass; and
- the rate of re-aeration.

The group listed four unknowns relative to nutrient loadings:

- The degree to which nutrient concentrations will change in the future;
- Impacts of phosphorus TMDLs on in-Sea nutrient concentrations and algal blooms;
- The degree to which phosphorus output via the outflows from the north lake will affect phosphorus dynamics and eutrophication in the north lake; and
- Impacts of changes in salinity on nutrient dynamics.

The group listed several questions relative to fish in the north lake:

- What fish will be there?
- Are there any species that should be introduced or enhanced?
- Will all fish in the north lake be lost during the transition from current conditions to the stabilized north lake?
- What are the breeding habitat requirements of fish at the Salton Sea?

- What will the State of California want in terms of fish populations for the sport fisheries?
- What are the ecological interactions of the economically important biota, such as waterfowl and sport fish?

The group listed three unknowns relative to the shallow water habitat:

- the efficacy of selenium controls in solving selenium concentration problems;
- the risk selenium levels would pose to migrating birds and adult birds;
- whether biological removal would be necessary.

The disease & contaminants group identified the following data needs:

- What is the health risk of dry sediments contaminated with selenium?
- Would a “south lake” reduce contaminant issues? With a south lake, would there be a need for shallow habitat areas or river extensions?
- Can a selenium bioaccumulation model be developed for the current condition and proposed alternatives using existing data?
- What are the design characteristics of the proposed causeway road?
- How will projected air quality affect agricultural productivity, animal health, and suspension and aerial transfer of pesticides?

The group listed two unknowns relative to selenium:

- Whether there is any mechanism to effectively remove selenium from the food web; and
- The toxicity of selenium in the constructed wetlands.

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APPENDIX A – QSA TRANSFER SCHEDULE

Quantification Settlement Agreement Delivery Schedule By Conservation Method

QSA Year	Calendar Year	IID and SDCWA	IID and CVWD a,	IID and MWD	Total Delivery	Total Efficiency	Fallowing for Delivery	Mitigation Fallowing	Total Fallowing
1	2003	10	0	0	10	0	10	5	15
2	2004	20	0	0	20	0	20	10	30
3	2005	30	0	0	30	0	30	15	45
4	2006b	40	0	0	40	0	40	20	60
5	2007	50	0	0	50	0	50	25	75
6	2008	50	4	0	54	4	50	25	75
7	2009b	60	8	0	68	8	60	30	90
8	2010	70	12	0	82	12	70	35	105
9	2011	80	16	0	96	16	80	40	120
10	2012b	90	21	0	111	21	90	45	135
11	2013	100	26	0	126	46	80	70	150
12	2014	100	31	0	131	71	60	90	150
13	2015	100	36	0	136	96	40	110	150
14	2016	100	41	0	141	121	20	130	150
15	2017	100	45	0	145	145	0	150	150
16	2018	130	63	0	193	193	0	0	0
17	2019	160	68	0	228	228	0	0	0
18	2020	192.5	73	2.5	268	268	0	0	0
19	2021	205	78	5	288	288	0	0	0
20	2022	202.5	83	2.5	288	288	0	0	0
21	2023	200	88	0	288	288	0	0	0
22	2024	200	93	0	293	293	0	0	0
23	2025	200	98	0	298	298	0	0	0
24	2026	200	103	0	303	303	0	0	0
25	2027	200	103	0	303	303	0	0	0
26	2028	200	103	0	303	303	0	0	0
27 to 45	2029 to 2047	200	103	0	303	303	0	0	0
46 to 75c	2048 to 2077	200	50	0	250	250	0	0	0

All values in thousands of acre/feet

a If CVWD declines to acquire these amounts, MWD has an option to acquire them, but acquisition by MWD of conserved water in lieu of CVWD during the first 15 years is subject to satisfaction by MWD of certain conditions, including subsequent environmental assessment.

b In addition to the conserved amounts shown on this Table, additional amounts of up to 25,000 acre-feet in 2006, 50,000 acre-feet in 2009 and 70,000 acre-feet in 2012 could be conserved to meet the Interim Surplus Guidelines (ISG) benchmarks. IID has the discretion to select the method of conservation used to make the ISG backfill water. If fallowing is selected to conserve water to meet the ISG benchmarks, the total acres of fallowing would be within the amount originally evaluated in the EIR/EIS.

c This assumes that the parties have approved the extension of the 45-year initial term of the IID Water Conservation and Transfer Project.

APPENDIX B – WORKSHOP PARTICIPANTS

(Affiliations are for identification purposes only)

Hydrology

Bill	Brownlie	TetraTech
Dan	Charlton	CVWD
Michael	Remington	IID
John	Scott	MWD
Paul	Weghorst	Reclamation

Water Quality

Chris	Amrhein	UC Riverside
Chris	Holdren	Reclamation
Robert	Jellison	UC Santa Barbara
Dale	Robertson	USGS
Geoff	Schladow	UC Davis

Biology

Zack	Bowen	USGS
Stuart	Hurlbert	San Diego State University
Eugenia	McNaughton	US EPA
Kathy	Molina	Natural History Museum of LA County
Nils	Warnock	Pt. Reyes Bird Observatory
Wayne	Wurtsbaugh	Utah State University

Disease & Contaminants

Rick	Gersberg	San Diego State University
Theresa	Presser	USGS
Tonie	Rocke	USGS
Joseph	Skorupa	US FWS

Air Quality

Cheryl	Rodriguez	Reclamation
Reyes	Romero	Imperial County APCD
Ted	Schade	Great Basin AQD

Floaters (moved among groups)

Greg	Auble	USGS
Doug	Barnum	USGS
Rey	Stendell	USGS

APPENDIX C – INSTRUCTIONS FOR EVALUATORS

Dear Evaluator,

Thank you for taking the time out of your busy schedule to assist us in the very important task of providing a preliminary evaluation of a new proposal to stabilize and rehabilitate the Salton Sea. We have sought your assistance because of your knowledge and because we feel you can objectively apply that knowledge to the task at hand of providing a highly focused evaluation.

The process you are involved with is a first level evaluation leading to the integration of various ecosystem components into a holistic understanding of the probable outcomes associated with the proposed project, if built as currently described. The potential for the evaluation workshop to achieve its goal of providing a defined understanding of the probable project outcomes is highly dependent upon how well the various small working groups are able to define their subject area outcomes.

The objective of the evaluation process is a credible description of the future physical and biological conditions created by implementation of the proposal. The objective is not to support or reject the proposal. The evaluation will not concern itself with regulatory, policy, political or agency positions. The evaluation will note any critical flaws in the proposal, as well as major beneficial outcomes, major questions to be resolved, and considerations of importance in judging the effectiveness of the proposal to achieve and sustain the stated objectives. A workshop facilitator will be used to maintain focus and control the amount of dialogue allocated for various issues that may arise, so that the full spectrum of issues can be addressed. However, the guiding principle of the facilitator will be to encourage dissenting opinions and creative thinking. The Pacific Institute will compile the findings and comments made by the expert panel and will draft a set of proceedings, which will then be circulated to the participants for review, prior to publication and distribution to decision-makers and interested parties. Because future conditions at the Salton Sea will differ from current conditions, workshop participants will also develop a credible future baseline, for comparison purposes.

The first afternoon of the workshop will be devoted to an overview of the Salton Sea and description of the proposed rehabilitation plan, followed by a description of the future hydrologic conditions with and without the implementation of the proposed plan. After these general presentations, workshop participants will break up into focus groups, to develop plausible descriptions of conditions at and around the Sea that are pertinent to their topic area. We expect that this focus group exercise will require all of Tuesday. On Wednesday, the focus groups will report back to the workshop as a whole, and participants will have the opportunity to speak on the interaction of the various elements. The workshop is scheduled to end by 4 pm on Wednesday, Nov. 17th. We will provide note-takers for the focus groups and for the general sessions. The note-takers will project their notes onto screens for the use of the group. These notes will also form the basis of each group's report back to the workshop as a whole.

The following guidance is provided for your task:

1. Physical and biological conditions at the Salton Sea are highly dependent on the quantity and quality of inflows. These inflows will change in the future, meaning that a credible evaluation must first describe plausible future conditions, as a basis for comparison. Using the 'no project' physical environment descriptive information provided as a basic foundation, describe the conditions likely to exist at and around the Sea at year 2050 from a perspective of your working group area (e.g., hydrology, biology, etc.). In doing so focus on the following key aspects:
    a) Develop detail relative to the reduced Sea and to the area surrounding the Sea, including exposed lakebed. These evaluations are restricted to your group area (e.g., biology-the following groups of birds will…).
    b) Identify major benefits that may result (e.g., biology-the invertebrate diversity will…).
    c) Identify issues deemed to be important (e.g., water quality-water temperatures will…).
    d) Identify unknowns that may result in significant changes (positive and negative) in 'no project' outcomes.
2. Make assumptions during your evaluations to avoid bogging down in unknowns. Assumptions should be reasonable and have a basis for the situation in question. Document the assumptions and basis for them. That will facilitate appropriate adjustments if the integration workshop or additional information at a later time suggests that adjustments should be made.
3. Using the project and physical environment descriptive information provided as a basic foundation, evaluate the function and outcomes of the inflow channels, large lake, wetlands, and brine pool from a perspective of your working group area (e.g., hydrology, biology, etc.). In doing so focus on the following key aspects:
    a) Develop detail relative to the results of the large lake and wetland environments that are created (may differ for the different areas) and for the area of the Sea outside of the wetland enclosures. These evaluations are restricted to your group area (e.g., biology-the following groups of birds will…).
    b) Identify major benefits that may result (e.g., biology-the invertebrate diversity will…).
    c) Identify issues deemed to be important (e.g., water quality-water temperatures will…).
    d) Identify unknowns that may result in significant changes (positive and negative) in project outcomes.

4. Prepare separate lists as key points for each of the categories identified in item 3 above. For each key point, highlight (as additional key points) why the item identified is a key point.
5. Separate lists should also be developed for questions/issues that arise relative to the interface of your work group subject area with that for other subject areas and for items considered, but discarded.
6. An especially difficult area to deal with is the transitions that will occur between current conditions and the proposal being in place if built. The best that can probably be done is to offer general comments of what needs to be considered during that interim period.
7. No formal report will be developed by the working groups. The critical key point lists for each group will serve as the record of discussions. Those same lists will be used by each group presenter as the primary presentation points for the general discussion on Wednesday, Nov. 17, and as a reference for the development of the proceedings report.
8. Initial thoughts for the working group presentations on Wednesday, Nov. 17th are:
    a. Maximum 20 minute presentation per group.
    b. Start presentation with identification of the subject area and who the evaluators were. Provide very brief highlights of their specific areas of expertise relative to the subject matter being evaluated.
    c. Follow with a brief overview of the process used by the group. Computers with projectors will be available for your presentation.
    d. Identify items considered but discarded, and why.
    e. Conclude by presenting pre-prepared powerpoint or other notes. Comment on items that need explanation and to provide additional highlights for specific items but do not comment on items that can be read from the list that do not need further explanation.
9. Clarification questions will be permitted during the presentations. General questions and discussion will be encouraged after each presentation.
10. Following a break, participants will integrate the information and make adjustments needed. The facilitator will keep the dialogue focused and use her discretion when to call upon others known to be in the group.
11. The basic objective of the workshop is to obtain general agreement that the key points identified or as adjusted provide a reasonable representation of the likely outcomes if the proposed project is completed to identify any major areas of disagreements, and to identify and include additional key points that may have been missed during the small working group evaluations.

APPENDIX D – SELENIUM LOADINGS

Table D-1. Salton Sea: Disease & Contaminants Group calculation of loading scenarios

	Alamo River	New River
(Imperial Valley drains average 25 µg/L (3 – 360 µg/L)		
2001-2002 data	?	8.4 µg/L Se (5-18 µg/L)
Assumed (NIWQP data)	8 µg/L Se X 598,358 AF X 0.00272 = 13,020 lbs Se/year	4 µg/L Se X 249,360 AF X 0.00272 = 2,713 lbs Se/year
Reduction of 382,000 AF @ 2 µg/L Se proportionately	2 µg/L Se X 269,633 AF X 0.00272 = 1,467 lbs Se/year	2 µg/L Se X 112,367 AF X 0.00272 = 611 lbs Se/year
	13,020 -1,467 = 11,533 lbs Se/year	2,713 – 611 = 2,102 lbs Se/year
	11,553 lbs/328,728 AF/0.00272 = **12.9 µg/L Se**	2.102/136,993 AF/0.00272 = **5.6 µg/L Se**
Add in 106,000 AF @ 25 µg/L Se proportionately	25 µg/L Se X 74,819 AF X 0.00272 = 5,088 lbs Se	25 µg/L Se X 31,180 AF X 0.00272 = 2,120 lbs Se
	11,553 + 5,088 = 16,641 lbs Se	2,102 + 2,120 = 4,222 lbs Se
	16,641 lbs/403,547AF/0.00272 = **15.2 µg/L Se**	4,222 lbs/168,173 AF/0.00272 = **9.2 µg/L Se**
Inflow to treatment wetlands (NIWQP Alamo and New River, assume 50:50) Assume more recent data	**Combined discharge 12.2 µg/L Se** **Combined discharge > 15 µg/L Se**	
Proportionality of river discharges	600,200 AF/year	512,000 AF/year
From Mexico	-1,842	-262,640
	598,358 AF	249,360 AF
If proportion 382,000	-269,633	-112,367
	328,728 AF	136,993 AF
If proportion 106,000	+74,819	+31,180
	403,547 AF	168,173 AF

Table D-2. Alternative selenium mass balance

Selenium Mass Balance of Imperial Irrigation District Drainage (IID) System

	(mg/L)
Selenium concentration of Colorado River water =	2
Selenium concentration of tilewater* =	28
Selenium concentration of Alamo River at Salton Sea =	8

*Median of data from August 1994 through January 1995 as reported in Setmire; 1996;*Selenium in Water, Sediment, and Transplanted Corbicula in Irrigation Drainage and Wildlife Use of Drains in the Imperial Valley, California 1994-1995*

Existing Setting Water Balance (volumes in thousand acre-feet)
As reported in Figure 3.1-16 of the Final EIR for the Imperial Irrigation District
Water Conservation Project

Surface inflow to drains

803	farm drainage
33	rainfall (deep percolation and runoff)
8	inflow from mesa storms
34	M&I "return flow" (closure value added to Jensen data for inflows to equal outflows)
99	main and lateral canal spill
165	New River from Mexico
2	Alamo River from Mexico

Non-farm subsurface inflow to drains

20	external subsurface inflow
114	canal seepage
4	recovery of seepage
1,274	Sum of inflows

Outflow from drains

1	subsurface to Salton Sea
604	Alamo River to Salton Sea
96	Direct drains to Salton Sea
448	New River to Salton Sea
125	evaporation from rivers and drains
1,274	Sum of outflows

Selenium Mass Balance Calculation
Baseline assumptions:
-subsurface drainage equivalent to tilewater
-tailwater is equivalent to canal water
-canal seepage is equivalent to tilewater
-Alamo River represents blended IID drainage

-20 percent of dissolved selenium is removed from the surface drains to the bottom sediments#

Source	Volume (kaf)	Selenium (µg/L)	Volume x (0.8)Selenium
tailwater†	603	2	965
tilewater†	200	28	4,480
ext. subsurface	20	28	448
canal seepage	110	28	2,464
rainfall/runoff	41	0	0
M&I return flow	34	2	54
canal spills	99	2	158
evaporation	(125)	0	0
IID flow to Sea	982	----	----
	Blended Concentration	8.73	µg/L

#Assumption based on discussion contained in Setmire; 1996; *Selenium in Water, Sediment, and Transplanted Corbicula in Irrigation Drainage and Wildlife Use of Drains in the Imperial Valley, California 1995-1995*

†Volume of tilewater based on the August 29, 2003 Bureau of Reclamation Document entitled, *Part 417 Regional Director's Final Determinations and Recommendations Imperial Irrigation District Calendar Year - 2003.* Volume of tailwater equal to the total farm drainage volume of 803 kaf less the tilewater volume.

Selenium Mass Balance Calculation

With 300,000 acre-feet of conservation:

Assumes all conservation is through reduced tailwater.

Source	Volume (kaf)	Selenium (µg/L)	Volume x (0.8)Selenium
tailwater	303	2	485
tilewater	200	28	4,480
ext. subsurface	20	28	448
canal seepage	110	28	2,464
rainfall/runoff	41	0	0
M&I return flow	34	2	54
canal spills	99	2	158
evaporation	(125)	0	0
IID flow to Sea	982	----	----
	Blended Concentration	11.86	µg/L
	Total Conservation	300	kaf

New River Calculation

Source	Volume (kaf)	Selenium (µg/L)	Volume x Selenium
IID*	170	11.86	2016
Mexico	82	2	164
Total	252	----	----
Blended concentration =		8.65	

*Based on Figure 3.1-26 of the Final EIR for the Imperial Irrigation District Water Conservation Project

Selenium Mass Balance Calculation

With 300,000 acre-feet of conservation and increased evaporation of 54 kaf:
Assumes all conservation is through reduced tailwater.

Source	Volume (kaf)	Selenium (µg/L)	Volume x (0.8)Selenium
tailwater	303	2	485
tilewater	200	28	4,480
ext. subsurface	20	28	448
canal seepage	110	28	2,464
rainfall/runoff	41	0	0
M&I return flow	34	2	54
canal spills	99	2	158
evaporation	(179)	0	0
IID flow to Sea	982	----	----
Blended Concentration		12.88	µg/L
Total Conservation		300	kaf

New River Calculation

Source	Volume (kaf)	Selenium (µg/L)	Volume x Selenium
IID*	143	12.88	1842
Mexico	82	2	164
Total	225	----	----
Blended concentration =		8.92	

*Based on Figure 3.1-26 of the Final EIR for the Imperial Irrigation District Water Conservation Project, and presumes that 50 percent of the increased evaporation of 54 kaf is from the New River.