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REVIEW OF US FILTER CORPORATION SALTON RIVER PROPOSAL FINAL REPORT

March 2003

Prepared for:

Salton Sea Authority
Plaza La Quinta
78-401 Hwy 111, Suite T
La Quinta, California 92253

Prepared by:

Tetra Tech, Inc.

In cooperation with:

Salton Sea Science Office
and
Citizens Advisory Committee

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FOREWORD

US Filter proposed a solution to problems at the Salton Sea that would create a Salton "River" around the perimeter ring of the current Salton Sea. The "river" would flow from south to north, providing moderately saline water for treatment at a desalination treatment facility to be constructed at the north end of the Sea, and creating a new source of fresh water. While the shoreline of the current Salton Sea would be stabilized at current levels, the interior of the Sea would shrink through natural evaporation allowing for development of new wildlife habitat of grasses and wetlands on the exposed internal seabed. US Filter presented their concept at a number of meetings and posted it on their website at http://www.usfilter.com/water/water.asp?wid=593.

The proposal generated significant interest and the agencies involved in projects at the Sea determined that further investigation of the concept was warranted. Therefore, the Salton Sea Authority contracted with Tetra Tech to prepare this report, with additional funding provided by the US Bureau of Reclamation. This report was prepared in cooperation with a diverse group of individuals, including technical specialists convened by the Salton Sea Science Office, engineering consulting companies, and technical specialists with the Bureau of Reclamation. Other agencies were also invited to comment on the proposal. In addition, the Salton Sea Authority convened a Citizens Advisory Committee to provide input on economic and recreational aspects of the concept. Input from these diverse groups is discussed in this report.

ACKNOWLEDGEMENTS

The author of this report, William R. Brownlie, PhD, PE (Tetra Tech, Inc.), compiled information from a wide range of sources and gratefully acknowledges the contributions of all of the individuals that supported the preparation of this paper.

The US Filter proposal includes key components that are similar to a project proposed by the Pacific Institute for Studies in Development, Environment and Security located in Oakland, California in October 200. The U.S.D.I. Salton Sea Science Office coordinated an evaluation of that proposal. A report that summarizes the consensus opinion of the nearly thirty scientists regarding the Pacific Institute proposal has been used liberally as a source for the present report. The author of the present report acknowledges and appreciates the effort of all of the individuals that completed the earlier review.

In addition to the above-mentioned contributions, the author acknowledges and greatly appreciates the efforts of a number of technical specialists who directly contributed material in this report. Joseph Zuback of US Filter was very helpful in providing data and cost estimates related to the proposal. Dike and dam engineering and cost evaluations were completed by Leo Handfelt (URS), Michael Clinton (Consultant to the Salton Sea Authority) and Jack L. Delp (Consultant to the US Bureau of Reclamation) with assistance from Steve Fitzwilliam (URS), Paul Weghorst (Bureau of Reclamation Technical Service Center [TSC] in Denver, CO) and Mike Gobla (Reclamation TSC). In addition, Mr. Weghorst provided support for salinity and elevation evaluations and the associated graphics. Arthur Streifel (Reclamation TSC) prepared the piping and pumping cost evaluation, and Kevin Price and Harry Remmers (both with Reclamation TSC) provided consultation on cost factors for water treatment. Frank Stradling and Carla Scheidlinger of Agrarian Research assisted in the development of cost estimates for dust control mitigation. Louis Yu of Tetra Tech provided an assessment of nutrient control costs, and David Argo of Black & Veatch provided an independent assessment of water desalination costs.

A critical technical review of the first draft of this paper was organized by the Salton Sea Science Office. A list of participants and summary of their comments is provided in section 1.3 of this report. A complete set of comments of the review team is provided in Appendix E. In addition, a Citizen’s Advisory Committee was convened and provided comments on the proposal and its alternative and variations. This committee focused on recreational and economic aspects of the proposal. The list of participants in the Citizen’s Advisory Committee and their comments are provided in section 1.4 of this report.

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EXECUTIVE SUMMARY

This report provides a review of a copyrighted proposal that was submitted by the US Filter Corporation for shallow water shoreline dike integrated with desalination, water transfer, seabed reclamation, and salt storage. U.S. Filter Corporation submitted a proposal that would essentially provide for a stable freshwater shoreline near the current elevation of the Sea. The analysis is based on the proposal as described on the US Filter web site. Since that original proposal was posted, US Filter has further developed a number of aspects of their proposal and conceived a number of variations, partly to address some of the concerns that are expressed in this review. Variations proposed by US Filter were not available when this review was initiated, and may subject to further evaluation later.

The basic US Filter proposal included the following components:

- A dike around the Sea constructed in approximately 10 feet of water to create the "Salton River" that would convey water to the north end of the Sea

- A water treatment plant would be constructed at the north end of the Sea and treated water would be pumped to the Colorado River Aqueduct

- The central portion of the Sea would become a hypersaline sink for residual brines

US Filter Corporation anticipated that the design would be based upon the assumption that 500,000 acre-feet per year of high quality desalinated water would be removed from the surface water inflows to the Salton Sea via desalination and transfer. The remaining surface water entering the Sea that would not be lost to evaporation in the peripheral diked surface water impoundment would contain approximately 5,000 milligrams per liter (mg/L) of total dissolved solids. This remaining water would be returned to the central Sea (inside the ring created by the diked surface water impoundment), which would gradually reduce in size from evaporation. As the central Sea would shrink and eventually reach equilibrium (central Sea water level at approximately the –270 ft elevation), the water entering the central Sea would be used for environmental mitigation and restoration of the exposed seabed.

Engineering and Cost Evaluation. US Filter Corporation estimated that capital recovery for the dike construction and for the desalination plant, desalinated water transfer pump and pipeline, and seabed plants, the net cost per acre-foot for the major components would be about $388 per acre-foot of desalinated water available for transfer. The current evaluation suggests that the cost of producing water would be on the order of $750 and $930 per acre-foot of water produced.

Benefits. The US Filter proposal is expected to have the following key benefits:

- The plan would provide a substantial benefit to California in providing for re-use of a significant amount of diverted Colorado River water. The plan could possibly reduce California's dependence on diversions from the river.

- It would also provide a stable shoreline that could be beneficial to local residents, except that there would be many concerns associated with the quality of the water along the shoreline of the impoundment.

Concerns. Some of the key concerns associated with the US Filter proposal would include the following:

- The Salton River impoundment would serve as a very slow sluggish extension of the existing rivers.

- Sedimentation problems would occur near the river mouths and turbidity would likely be high throughout the impoundments.

- Variations in water surface could create rising levels in some areas and reduced depths in other areas. The average depth throughout the impoundment would be only about 5 feet.

- Contaminants in the inflowing waters would not be diluted as they are in the present Sea and would tend to be concentrated by evaporation and other processes in the impoundment.

- Temperature ranges would generally be similar to those in the inflowing rivers, and would be more extreme than in the present Sea and oxygen depletion problems could be expected. These factors could lead to fish kills in the narrow impoundment, particularly winter kills of tilapia.

- The food web would change to a fresh water web with algae as the major food base and extensive growths of vascular vegetation would occur along the shoreline.

- Fish, bird and human diseases associated with water borne parasites, contaminants, and mosquitoes would be a concern.

- Although air quality mitigation measures have been included, it is likely that these measures would not be able to fully mitigate the potential dust problems that could occur from exposure of 190 square miles of sediments.

Constructing the impoundment dikes at 15-foot water depths would lessen some of the problems listed above, but would also be more costly. The upper limit of the costs discussed above is based on dike construction in 15-feet of water.

Alternatives and Variations to the US Filter Proposal. An alternative to the US Filter proposal was proposed by the staff of the Salton Sea Authority working with other experts and stakeholders. This alternative would not include a 95-mile dike or the Salton River, but it would include a desalination plant that would produce water that could be used within the Salton Basin. This water could be sold or it could facilitate a transfer which in turn could help provide funding for the project. Because the total surface area of the Sea would still need to be reduced to allow exports of water, a single dam, 8.5 miles in length is proposed to divide the Sea, creating a salt water lake on the north and a residual brine pool on the south.

The North Lake alternative would offer some benefits to the ecological conditions in the Salton Sea area, and in some cases would avoid the problems listed above for the US Filter proposal. In addition, the costs could generally be less than those discussed above. A comparison of some of the features of the US Filter proposal and the North Lake alternative, including cost, is provided in Table 1.

Variations of both the US Filter proposal and the North Lake alternative suggested by the Regional Water Quality Control Board are also discussed in this report. The variation to the US Filter proposal would involve a salt river in place of the fresh water river. The variation to the North Lake alternative would involve a lower lake elevation, and add some additional features aimed at water quality improvements.

Recommendation. While the US Filter proposal as discussed above has many unresolved issues, the concept of coupling water reuse with structural measures at the Sea has many potential benefits. The North Lake alternative incorporates key concepts from the US Filter proposal, while avoiding some of its pitfalls. The North Lake proposal would result in a smaller, cleaner Sea than under present conditions, with salinity stabilized at ocean water levels and a stable water surface near the current shoreline elevation. It would also preserve key habitat areas. In addition, it would provide for reuse of agricultural drain water for sale or transfer to help fund the project. Tetra Tech recommends that further work be done on the North Lake concept or variations thereof to better understand its feasibility and costs.

Table 1. Comparison Between US Filter Proposal and North Lake Alternative

	Current Conditions	Reduced Inflow (1 MAFY)	US Filter Proposal	North Lake Alternative
Physical Attributes and Hydrology				
• Configuration	Open lake	Smaller Lake	River-like annulus	Open lake
• Shoreline	100 miles	About 85 miles	100 + 95 mi. dike	About 60 miles
• Surface Area (sq mi)	365	280	40	160
• Water level	-227 msl	-246 msl	-230' msl	-230' msl
• Dilution factor	5.8	2.8	<1	About 5
• Sedimentation and Turbidity	High	High	High	Reduced
• Oxygenation	Variable: 0 to sat	Variable: 0 to sat	Uncertain	Improved[1]
• Salinity	44ppt	>85ppt	~3 ppt	35 ppt
• Nutrient loading	High	High	High	Reduced
• Temperature	$50^{o}F$ - $90^{o}F$	Wider range	Wider range	Same
• Odor	Often Unpleasant	Same	Likely the Same	Improved[1]
Biological Attributes				
• Habitat type	Saline	Brine fly	Fresh	Saline
• Algae	High	High	High	Reduced
• Vascular plants	Few	None	Many	Few
• Invertebrates	Many	Some	Many	Many
• Fish				
a. Endangered pupfish	Connectivity	Reduced Con.	Connectivity	Connectivity
b. Sport fish	High salt water	None	Fresh water	High salt water
• Birds				
a. Pelicans	Abundant	Reduced	Reduced	Abundant
b. Other fish-eating birds	Abundant	Reduced	Reduced	Abundant
c. Shorebirds	Abundant	Reduced	Abundant	Abundant
d. Waterfowl	Abundant	Reduced	Abundant	Abundant
e. Marsh birds	Abundant	Reduced	Abundant	Abundant
Disease/Parasite Consideration				
• Fish	Low-moderate	Loss of fishery	Concern	Low-moderate
• Birds	Moderate-high	Moderate-high	Concern	Moderate-high
• Humans	Insignificant	Some concern	Concern	Insignificant
• Toxic algal blooms	Insignificant	Unknown	Concern	Insignificant
Contaminant Consideration				
• Selenium	Low-moderate	Moderate	High	Moderate
• Other metals	Low	Low-moderate	Concern	Low
• Pesticides and other contaminants	Low	Low-moderate	Concern	Low
Air Quality				
• Exposed lakebed (1,000 acres)	None	48	95-150	45
• Fugitive dust	None	Serious concern	Concern	Concern
• Control potential	NA	Fair	Fair	Good
Engineering/Cost Consideration				
• Engineering Challenge	NA	NA	95-mile dike	8.5-mile dam
• Cost Estimate ($/acre-foot)[2]	NA	NA	$750-930	$470-590

[1] Based on nutrient and sediment controls on inflow streams.

[2] Based on assumed inflow of 1.3 MAFY and treatment and transfer of 500,000 acre-feet/year.

1.0 SCOPE AND PURPOSE OF THIS DOCUMENT

This report provides a review of a copyrighted proposal that was submitted by the US Filter Corporation for shallow water shoreline dike integrated with desalination, water transfer, seabed reclamation, and salt storage. U.S. Filter Corporation submitted a proposal that would essentially provide for a stable freshwater shoreline near the current elevation of the Sea.

1.1 Evaluation Process

The US Filter proposal includes key components that are similar to a project proposed by the Pacific Institute for Studies in Development, Environment and Security located in Oakland, California in October 200. The U.S.D.I. Salton Sea Science Office coordinated an evaluation of that proposal for conversion of the Salton Sea ecosystem. The evaluation of that proposal included workshops held during December 2001 and January 2002 at Riverside, San Diego and Indian Wells, California. A report of the findings of the workshop was submitted on February 2002 and is available on the Salton Sea Science Office website. That document summarizes the consensus opinion of nearly thirty scientists and engineers familiar with the Salton Sea as to the properties the system proposed by the Pacific Institute would be likely to have.

Similarities between the Pacific Institute and US Filter proposals:

- Both involve construction of dikes that would run parallel to the current Salton Sea shoreline.
- In both proposals, the dikes would create shallow water impoundments that would have a stable water surface elevation at about –230 feet, relative to mean sea level (ft, msl).
- In both proposals, the concentration of salinity in the impoundments would be around 4,000 to 5,000 milligrams per liter (mg/L) of total dissolved solids (TDS).
- In both proposals, the average water depths in the impoundments would be five to eight feet.
- In both proposals, the central part of the Sea would become smaller and hypersaline, and separated from the impoundments along the current shoreline.

This review of the US Filter proposal relies heavily on the conclusions presented in the Salton Sea Science Office paper regarding the Pacific Institute proposal for those components listed above.

The Pacific Institute proposal and the US Filter differ in several aspects:

- The Pacific Institute proposal would involve construction of impoundments roughly around 1/3 of the current shoreline of the Sea while the US Filter proposal would involve construction of impoundments around the entire Sea

1.2 The Present Salton Sea

The present-day Salton Sea (Sea) is a body of water that currently occupies the lower elevations of the Salton Basin, but it is not the first to do so. Historical evidence and geologic studies have shown that the Colorado River has spilled over into the Salton Basin on numerous occasions over the last thousand years, creating intermittent lakes that, in some cases, lasted decades to centuries. For example, Lake Cahuilla is believed to have formed around A.D. 700, when the Colorado River silted up its normal egress to the Gulf of California and swung northward through two overflow channels. Evidence of an ancient shoreline suggests that Lake Cahuilla occupied the basin until about 300 years ago. From 1824 to 1904, Colorado River flows flooded the Salton Basin no fewer than eight times.

The present-day Sea was formed in 1905, when Colorado River flood flows breached an irrigation control structure and were diverted into the Salton Basin for about 18 months. Since then, agricultural drainage flows from nearby Imperial, Coachella, and Mexicali Valleys and smaller contributions from municipal effluent and storm water runoff have sustained the Sea. Over the years, the Sea has developed into a recreation area, wildlife refuge, and sport fishery.

The Salton Basin extends from Banning, California, on the north to near the international border of Mexico on the south. The Sea itself is about 35 miles long and 15 miles wide. Recently, the elevation of the Sea has been about -227 feet mean sea level (msl) (228 feet below sea level), with annual fluctuations of about 1 foot. At this elevation, the Sea has a maximum depth of 51 feet, with an estimated surface area of 234,000 acres (366 square miles). The lowest seafloor elevation is about -278 feet msl. Throughout most of the past decade, the Sea has had a storage volume of approximately 7.6 million acre-feet. The Salton Sea is California's largest lake.

The Sea's recent salinity concentration has been about 44,000 milligrams per liter (mg/L) (25 percent saltier than ocean water). Annual inflows in the recent past have been in balance with the water that has evaporated, or about 1.34 million acre-feet per year. Inflows add about 4 million tons of salt each year. Since the Sea has no natural outlet, the salinity in the Sea continues to rise each year as salts (or total dissolved solids—TDS) are left behind when the water evaporates.

The salinity in the Sea has the potential to rise substantially if salinity control measures are not implemented. The rise in salinity could increase by several thousand mg/L each year, because of an imbalance between inflow and evaporation, if inflows to the Sea are reduced due to increasing demands for water in Southern California.

Rising salinity is threatening the highly productive fishery in the Sea. The Sea's fishery is important for ecological reasons, as well as for recreational reasons. The Salton Sea and nearby wetlands are an integral part of the Pacific flyway, providing habitat and seasonal refuge to millions of birds and hundreds of bird species. The fish in the Sea are a primary source of food for many of those bird species. In addition to salinity, other issues are of environmental concern at the Sea, including high levels of nutrients.

1.3 Science Office Review

A critical technical review of the first draft of this paper was organized by the Salton Sea Science Office. A list of participants in the review process is provided in Table 2. A complete set of comments of the review team is provided in Appendix E.

Comments by the review team indicated that the scientists generally agreed with the conclusions in the draft review document. The majority of comments provided in Appendix F expand upon information contained in the body of this document. However, a few reviewers did recommend specific changes that have been incorporated in the present document, including comments on avian diversity by Kathy Molina and a comment by Rex Sohn on the West Nile virus. Also, partly in response to the science team review, the North Lake with Desalination proposal, which was originally considered as a variation to the US Filter proposal, is now identified as a different alternative.

1.4 Citizens Advisory Committee Review

A Citizen's Advisory Committee was convened and provided comments on the proposal and its alternative and variations. This committee focused on recreational and economic aspects of the proposal. The citizen participants were Larry Anderson, Mary Belardo, Mac Brinegar, Ted Deckers, Roland Gaebert, Debi Livesay, Norm Niver, Bill Power, and Dick Schall. The citizens commented on the base US Filter proposal, a salt water river variation suggest by the Regional Water Quality Control Board (RWQCB) and the North Lake with Desalination Alternative.

Table 2. Participants in the Salton Sea Science Office Review

Discipline	Team Leader	Reviewers
Hydrology	Tim Krantz Director, Center for Environmental Management Redlands Institute	Paul Weghorst Hydraulic Engineer, USBR
Biology	Glenn Black Senior Biologist	Kathy Molina Ornithologist Natural History Museum of Los Angeles County
	Jack Crayon	Mike Saiki Fishery Biologist, USGS
Avian Disease	Doug Barnum Science Coordinator	Theresa Presser Research Chemist, USGS
		Rex Sohn Veterinary Medical Officer, USGS/NWHC
		Tonie Rocke Wildlife Biologist, USGS/NWHC
Water Quality	Jose Angel, RWQCB Watershed Protection Division Chief	Chris Amrhein Professor of Soil & Environmental Sciences, UCR
	Nadim Zeywar Environmental Scientist	Mike Anderson Associate Professor/Soil Chemist, UCR
		Maria de la paz Carpio-Obeso Environmental Scientist
		Jim Setmire Hydrologist, USGS/USBR
Air Quality	Cheryl Rodriguez Environmental Protection Specialist	Theodore D Schade P.E. Senior Project Manager Great Basin Unified Air Pollution Contol District
		Grace Holder, PhD, RG Geologist Great Basin Unified Air Pollution Contol District

A meeting with the citizens was convened on 6 February 2003. The meeting included a presented of the US Filter proposal, the RWQCB variation and the North Lake with Desalination alternative. After each part of the presentation, the Citizen's group was invited to ask questions and commented on various aspects of the projects, particularly as related to recreation and economics. At the end of the meeting, the group informally rated the proposals on a scale of 1 to 10, with 10 being best. They rated the US Filter and RWQCB proposals at about 3 or 4 and the North Lake Alternative at about and 8 or 9. Comments on each of the proposals are summarized below.

US Filter Proposal. The citizens were concerned about a number of the recreational aspects of the basic US Filter proposal. They were concerned that it could further depress already low property values around the Sea. Some of the comments included:

- Property owners on west side of Sea would have the New River in their front yard
- It would be bad for property values in the long run, but could have an initial increase on the news that the Salton Sea was being restored
- Negative impact on motorized boating (5-10 mph no wake zones)
- Negative impact on swimming
- Negative impact on camping (bugs, smell)
- Problem with vegetation in channel, for example, Eurasian milfoil
- Not saving the Sea but creating a new body of water
- Maintenance of channels could be a problem
- There would be a potential for flooding
- There would be a problem if steel sheet pile was used

Specific comments from several participants included, "it would be better than doing nothing" and that the "stable shoreline would be a plus," and that the "negatives would outweigh the positives."

RWQB Salt Water River Variation. The citizens were not in favor of this proposal and generally felt that it had many of the negative aspects of the basic US Filter proposal. In particular temperature extremes and elevated bacteria levels were cited. It was also noted that Torres-Martinez lands would be impacted. Overall the group expressed that the "negatives outweigh the positives."

North Lake Alternative with Desalination Plant. There was a favorable reaction to this proposal. There would be open water boating with a stable shoreline and the marine fishery would be preserved. Control of odor was expressed as a critical factor, and if the water quality control measures incorporated in this proposal were effective, that would be very positive. Concerns were expressed about the need to accommodate Bombay Beach, and that the FWS refuge and the State management area could be negatively impacted. Overall the group expressed that the "positives outweigh the negatives."

1.5 Agency Review

Agencies that have been cooperating or coordinating on the Salton Sea project were invited to review the preliminary final review paper. The agencies involved were the California Department of Fish and Game, California Department of Water Resources, Regional Water Quality Control Board, Torres Martinez Band of the Desert Cahuilla Indians, US Bureau of Reclamation, US Environmental Protection Agency, and US Fish and Wildlife Service. A review meeting with agencies representatives was conducted on March 18, 2003 to review the proposal and its alternative and variations. Agency representatives identified the following areas that deserve further attention:

US Filter

- Concerns about pupfish connectivity in the agricultural drains around the south end of the Sea – there would be a potential for reduced connectivity under the Salton River concept.
- Nature of freshwater fishery – there is a question about whether bass would survive in the high temperatures and low oxygen levels in the Salton River.
- There could be increases in salt cedar and possible biological effects and costs associated with salt cedar control.

North Lake

- Possible need to re-establish fishery or that the fishery might change.
- Low quality water would be flowing into habitat areas in the south – this concern would need to be addressed.

RWQCB Variation on North Lake Concept

- Concern about loss of delta habitat at south end and shorebird habitat overall
- Transitional impacts to fish eating birds during the transition/loss of fishery/re-establishment of Salton Sea ecosystem maybe for 10 to 20 years

Common to All Alternatives

- Ecological issues at residual sea / brine pools
- Groundwater / hydrogeologic issues associated with possible groundwater seepage through exposed sediments, particularly in salt crust areas of dust mitigation in the North Lake alternative
- Water treatment costs – are they reasonable
- Land use compatibility and ownership, particularly at the Wildlife Refuge and other federal and state lands, including lands that are now submerged
- Selenium concerns throughout the various areas that would be affected by the project

2.0 U.S. FILTER PROPOSAL

An overview of the US Filter proposal is provided below followed by engineering and cost assessments of the proposal.

2.1 Overview of U.S. Filter Proposal

According to the US Filter Corporation website, the proposal, posted at http://www.usfilter.com/water/water.asp?wid=593 would include the following components (see Figure 1 and Table 3):

1. **10-foot dike creates Salton "River" ring** - A shallow water 10-foot elevation dike that runs parallel to the entire shoreline of the Salton Sea would be built, creating a brackish area between the dike and the shore. The dike creates a 40,000-acre ring of water at the edge of the Salton Sea with a salinity level of approximately 3,000 ppm, far below the current salt content of 44,000 ppm. Excess water would overflow the dike into the central Sea.

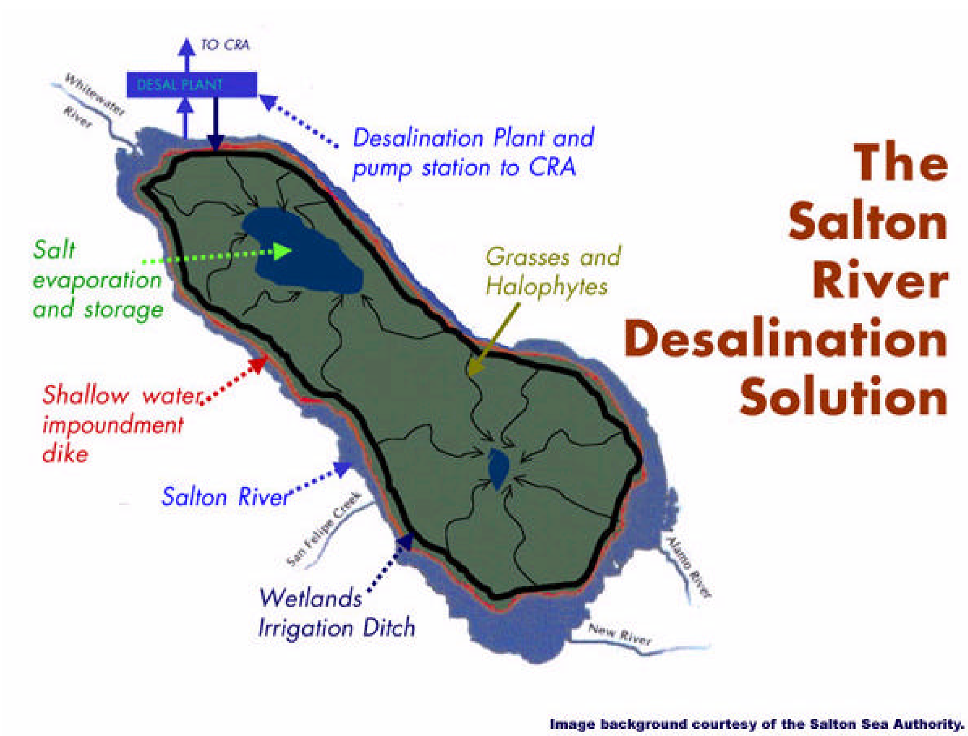

Figure 1. Graphic representation of proposal prepared by US Filter.

2. **A desalination plant as a new source of fresh water for Californians** - A desalination reverse osmosis plant and pumping station would be constructed at the northern end of the Salton Sea. The desalination plant would take water out of the "river," or impoundment between the dike and the shore, remove the salt, and make freshwater available for potential urban or groundwater recharge uses. Water from this treatment facility could be pumped to the Colorado River Aqueduct, improving the quality of the water coming from the Colorado River, and providing additional water quality benefits which would help meet the State's Water Use Plan as well as regulatory requirements. Following the treatment process, the salt removed from the water would be returned to the deepest part of the central Sea within the dike.

3. **Salton Sea shrinks through natural evaporation** - The water level of the Sea within the dike would drop through evaporation. The Sea is currently evaporating at the rate of about six feet of water per year. Because most of the water inflow would be caught in the outer ring, natural evaporation would shrink the interior of the Sea to a size of about 59 square miles.

Table 3. Salton River Concept Basic Information.

	Dikes at 10' Depth	Dikes at 15' Depth
Volume of Salton River (ac-ft)	140,000	376,300
Surface Area of Salton River		
-- Area (ac)	25,400	44,160
-- Area (sq mi)	39.7	69.0
Average Depth (ft)	5.5	8.5
Length of Dikes (mi)	94.5	92.0
Average Width		
-- Width (ft)	2,220	3,960
-- Width (mi)	0.42	0.75
Interior Area Within Dikes		
-- Interior Area (ac)	202,400	183,600
-- Interior Area (sq mi)	316	287

4. **Internal irrigation ditch allows for environmental improvements** - When the water level inside the dike drops enough to expose the Sea bed, an internal irrigation water ditch would be built to distribute water around

the periphery of the Sea bed to control dust and allow for environmental improvements. The irrigation ditch would be used to distribute fresh water to displace salt in exposed soil and support new plant life.

5. **Salt tolerant grasses are planted** - Gradually (over nine years) salt tolerant grasses and plants would be planted as the interior seabed is exposed.

6. **Salt from desalination plant is stored in lowest part of the remaining Sea** - Salt would be stored at the lowest elevation of the central Sea to eliminate risk of salt contamination of any fresh water resources. Even in the event of an earthquake, freshwater resources would be protected from potential contamination by the stored salt.

The US Filter website shows the dike constructed in water depths of 10-feet, but preliminary conceptual cost assessment information provided by US Filter has also indicated the dikes could be constructed in 10- to 15-foot water depths. For the purpose of this analysis, the 10-foot water depth has been evaluated as the base case, but the costs and benefits associated with constructing dikes in 15-foot water depths have also been considered. Basic information about the Salton River Concept at both depths is displayed in Table 3.

2.2 Engineering Design Factors and Costs

The impoundment and appurtenant structures, the treatment plant, and other components of the project would require significant annual investment in maintenance and management activities. The engineering design and cost evaluation includes consideration of dikes and related appurtenances, water treatment, piping and pumping, and irrigation systems. Conceptual cost estimates for dikes and piping and pumping have been combined with rough order of magnitude estimates of other components to develop a range of cost estimates. Low, middle and high estimates for each component.

2.2.1 Dikes

A team of three engineers was convened to evaluate engineering concepts and conceptual costs for the perimeter dike as well as several mid-Sea dam concepts that are being evaluated as alternatives to the basic US Filter proposal. The team's report is provided in Appendix A.

The perimeter dike would need to serve as a hydraulic barrier that would act as a dam as the Sea recedes. It would also need to be resistant to earthquakes because the Salton Basin is located in a highly seismic area. The concept for the dike includes a hydraulic barrier constructed of vinyl sheet piles. These sheet piles would be suitable for the lower hydraulic heads involved with the perimeter dike and would be corrosion resistant. The top of the sheet pile wall would be at elevation of –225 feet MSL to allow for the 5 feet of freeboard. For the base case, the dike would be constructed in 10 feet of water and a cost estimate was also prepared at 15 feet of water. The concept for the Salton Sea perimeter dike at a 15-foot water depth is shown in Figure 2. The concept for a 10-foot water depth would be similar.

The sheet pile wall would be buttressed with rock to provide stability. An over excavation of 5 feet of soft sediments below the seafloor was assumed. The rock would be placed by barge with side slopes of 2:1 and should be seismically resistant. A minimum crest width of five feet has been assumed. The length of the perimeter dike would be 94.5 miles at the –240 foot MSL contour (10 feet of water), and 92 miles at the –245 foot MSL contour (15 feet of water). It was assumed that a sheet pile embedment below the over excavation equal to the height of the dike as sufficient to mitigate potential piping failures. Overflow weirs could easily be incorporated into the dike by having the tops of the sheet piles at elevation –230 feet MSL at various locations around the perimeter.

Since the Salton Sea is located in a highly seismic area, estimates have been included in the cost evaluation to provide for routine maintenance as well as rebuilding of the dike structures should they be damaged by earthquake activity.

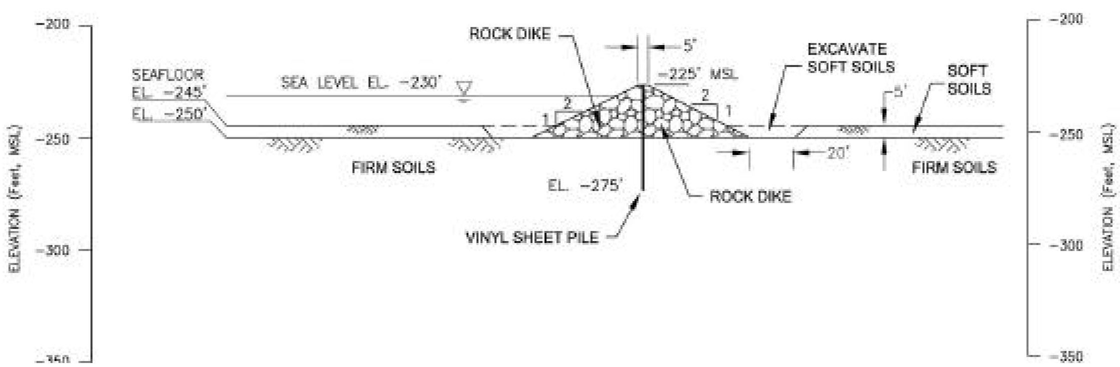

Figure 2. Perimeter Sheet Pile Dike.

2.2.2 Appurtenances

For the impoundment, chief appurtenances to be constructed would be the outflow structures. Rough order of magnitude cost estimates have been developed for these structures along with estimates for the cost of maintenance and monitoring of these outflow structures.

Other ancillary costs may be associated with vegetation control to maintain access to open water at certain points along the shoreline, mosquito control along roughly 50 miles of newly vegetated shoreline, and possibly security patrols if dikes are to be made off limits some or all of the time.

2.2.3 Water Treatment

It has been assumed that a reverse osmosis (RO) plant would be constructed at the north end of the Sea to provide the water treatment. With a product water capacity of 558 MGD, the Salton Sea plant would be nearly twice the size of the largest desalting plant in the world, the 250-MGD thermal desalting plant at El Jebel in Saudi Arabia.

Cost estimating factors for constructing and operating a reverse osmosis or micro-filtration plant proposed by US Filter were reviewed by staff at Tetra Tech and Black and Veatch, two consulting engineering companies, and were found to be reasonable. In addition US Bureau of Reclamation technical personnel were also consulted and provided factors that bracketed the numbers used by US Filter. Therefore, US Filter cost estimates for the desalination component have been retained in the current cost estimates.

2.2.4 Piping & Pumping

Water would need to be pumped from the Salton Sea to the Colorado Aqueduct, a distance of 12.7 miles, with an elevation gain of 1,984 feet, from -227 feet below sea level to 1,757 feet above sea level. The Water Conveyance Section of the Bureau of Reclamation Technical Service Center in Denver, CO prepared conceptual-level estimates for the costs of construction, operation, maintenance and energy for such a pipeline. These cost estimates along with the costing assumptions are provided in Appendix B.

2.2.5 Air Quality Mitigation

It is not likely that weirs along the 92-95-mile dikes and a trench along the inside of the dikes would be sufficient for irrigating and providing dust control for almost 200 square miles of exposed sediments. Estimates for dust control costs were developed for irrigation and vegetation management, based on experience from Owens Lake. Frank Stradling and Carla Scheidlinger of Agrarian Research assisted in the development of cost estimates for dust control mitigation, and recommended using a factor of $5,000 per acre for salt grass or low shrub treatments. Experience at Owens Lake has shown that the entire exposed area may not need to be treated. In developing cost estimates, it has been assumed that about 40 percent of the exposed area would need to be treated.

2.2.6 Conceptual-Level Cost Assessment

As previously mentioned, the cost evaluation includes consideration of dikes and related appurtenances, water treatment, piping and pumping, and irrigation systems. Low, middle and high conceptual cost estimates for dikes and piping and pumping have been combined with rough order of magnitude estimates of other components to develop a range of cost estimates. Cost estimates were developed for the following assumptions:

- Inflow conditions of 1.3 million acre-feet per year (MAFY) and 1.0 MAFY
- Federal and non-federal construction programs, using different factors for the non-contract costs and discount rates. The federal estimates assume it is a federally funded program and standard assumptions for these two factors are applied. The non-federal estimates assume lower non-contract costs and a lower discount rate.
- Dikes constructed in 10 or 15 feet of water.

Estimates for the capital cost of construction as well as OMER are presented in Table 4. As shown in Table 4, the estimated cost for producing and delivering drinking quality water ranges from $750 per acre-foot to almost $960 per acre-foot for the case where the dikes would be constructed in 10-foot water depths. If the dikes were to be constructed in 15 feet of water, these costs would increase by about $100/acre-foot. These values can be compared to US Filter's estimate of $388 per acre-foot. Note that the US Filter cost estimate did not include all items that are included in the current cost estimate. In addition to these costs there may be ancillary costs associated with delivering the water. For example, it is likely that the Colorado River Aqueduct would not have sufficient capacity to handle the full 500,000 acre-feet per year each year. Costs associated with expanding the Aqueduct have not been estimated.

Table 4. Cost Estimate Summary for the US Filter Proposal.

Cost Elements with Dikes at 10' Depth	US Filter Estimate	Inflow = 1.3 MAFY Non-Fed Estimate	Inflow = 1.3 MAFY Federal Estimate	Inflow = 1.0 MAFY Non-Fed Estimate	Inflow = 1.0 MAFY Federal Estimate
Capital Construction ($M)					
Dikes (10' water depth)[1]	$600	$1,414	$1,414	$1,414	$1,414
Appurtenances (weirs, etc.)		$140	$140	$140	$140
Pretretment wetlands/settling ponds		$3	$3	$3	$3
Water Treatment (558-MGD plant)	$600	$600	$600	$600	$600
Piping & Pumping (1,984' el. gain) see Appendix 2	$500	$361	$361	$361	$361
Air Quality Mitigation	$100	$206	$206	$304	$304
Subtotal	$1,800	$2,721	$2,721	$2,819	$2,819
Noncontract costs		12%	33%	12%	33%
Subtotal Capital Construction	**$1,800**	**$3,051**	**$3,623**	**$3,161**	**$3,753**
Operation, Maintenance & Energy ($M/Yr)					
Dikes		$14	$14	$14	$14
Appurtenances		$7.0	$7.0	$7.0	$7.0
Water Treatment	$86	$86	$86	$86	$86
Piping & Pumping		$68	$68	$68	$68
Air Quality Mitigation		$21	$21	$30	$30
Subtotal		**$196**	**$196**	**$206**	**$206**
Present Value ($M)					
Dikes		$1,828	$2,073	$1,828	$2,073
Appurtenances		$278	$281	$278	$281
Water Treatment		$2,159	$1,966	$2,159	$1,966
Piping & Pumping		$1,587	$1,409	$1,587	$1,409
Air Quality Mitigation		$587	$554	$866	$817
Total Present Value Cost ($M)		**$6,439**	**$6,283**	**$6,718**	**$6,546**
Annualized Costs Amortized Over 30 Yrs ($M/Yr)	**4.00%**	**4.00%**	**6.13%**	**4.00%**	**6.13%**
Annual Payment for Construction Loan		$176	$267	$183	$276
Operation, Maintenance & Energy		$196	$196	$206	$206
Total Annualized Cost		**$373**	**$463**	**$389**	**$482**
Cost Per Acre-Foot of Water Produced	**$388**	**$750**	**$930**	**$780**	**$960**

[1] Cost estimate based on perimeter dike cost estimate provided in Table 1 of Appendix 1, prior to application of non-contract costs, which are included as a line item on this table.

Table 4 (continued). Cost Estimate Summary for the US Filter Proposal.

Cost Elements with Dikes at 15' Depth	US Filter Estimate	Inflow = 1.3 MAFY Non-Fed Estimate	Inflow = 1.3 MAFY Federal Estimate	Inflow = 1.0 MAFY Non-Fed Estimate	Inflow = 1.0 MAFY Federal Estimate
Capital Construction ($M)					
Dikes (10' water depth)[1]	$600	$1,983	$1,983	$1,983	$1,983
Appurtenances (weirs, etc.)		$200	$200	$200	$200
Pretretment wetlands/settling ponds		$3	$3	$3	$3
Water Treatment (558-MGD plant)	$600	$600	$600	$600	$600
Piping & Pumping (1,984' el. gain) see Appendix 2	$500	$361	$361	$361	$361
Air Quality Mitigation	$100	$190	$190	$174	$174
Subtotal	$1,800	$3,334	$3,334	$3,318	$3,318
Noncontract costs		12%	33%	12%	33%
Subtotal Capital Construction	**$1,800**	**$3,737**	**$4,438**	**$3,720**	**$4,417**
Operation, Maintenance & Energy ($M/Yr)					
Dikes		$20	$20	$20	$20
Appurtenances		$10.0	$10.0	$10.0	$10.0
Water Treatment	$86	$86	$86	$86	$86
Piping & Pumping		$68	$68	$68	$68
Air Quality Mitigation		$19	$19	$17	$17
Subtotal		**$203**	**$203**	**$202**	**$202**
Present Value ($M)					
Dikes		$2,564	$2,907	$2,564	$2,907
Appurtenances		$397	$402	$397	$402
Water Treatment		$2,159	$1,966	$2,159	$1,966
Piping & Pumping		$1,587	$1,409	$1,587	$1,409
Air Quality Mitigation		$541	$511	$496	$468
Total Present Value Cost ($M)		**$7,248**	**$7,194**	**$7,203**	**$7,152**
Annualized Costs Amortized Over 30 Yrs ($M/Yr)	**4.00%**	**4.00%**	**6.13%**	**4.00%**	**6.13%**
Annual Payment for Construction Loan		$216	$327	$215	$325
Operation, Maintenance & Energy		$203	$203	$202	$202
Total Annualized Cost		**$419**	**$530**	**$417**	**$527**
Cost Per Acre-Foot of Water Produced	**$388**	**$840**	**$1,060**	**$830**	**$1,050**

[1]Cost estimate based on perimeter dike cost estimate provided in Table 1 of Appendix 1, prior to application of non-contract costs, which are included as a line item on this table.

2.3 Sediments and Sedimentation

Sediment in the south end of the Sea is currently delivered to the Sea almost entirely by the New and Alamo rivers and amounts to about 20-ac ft/yr. In the north, some sediment also flows in from the Whitewater River. While 20-acre-feet per year of sediment would be a negligible volume relative to the total volume of the proposed impoundment, it would likely create clogging problems in the vicinity of the river mouths. The sediment is mostly in the form of suspended clay particles, though it is not clear that estimates have been made of the amount of sand transported as bed load.Without any treatment of inflowing waters, phosphorus and pesticides adsorbed on clay particles would be precipitated out with the sediment near the mouths of the rivers. This sediment and the associated contamination would be concentrated in the newly confined areas at the south end of the Sea and could have an adverse effect on the biota.

The type and distribution of bottom sediments in the impoundment might show some gradual changes relative to present conditions. Silt and clay that now is suspended by wave action and then eventually falls permanently to the bottom in deeper waters would be trapped within the impoundment. There would also likely be a large increase in particulate organic matter content of impoundment near shore sediments. This would derive from production of the continuous band of vascular plant vegetation that would occupy the shoreline and shallow waters of the impoundment.

The Imperial Irrigation District has a dredging program for maintaining channel depth near the river mouths. This likely would need to be continued if impoundment were constructed, although to the extent that the impoundment surface elevation is set at a level lower than the present surface of the Sea, there initially would be a lessened tendency for sediment buildup in these lower portions of the rivers. Eventually, however, channel maintenance would be required to the same extent as it is today.

2.4 Hydrology and Physical Limnology

Hydrology and physical limnology characteristics considered include the water budget, hydraulic characteristics and residence time along with factors such as currents and wave action, dilution factors, salinity, temperature and oxygen, and turbidity. The characteristics of the residual Sea are also discussed.

2.4.1 Water Budget

The water budget below shows that the Salton River could be sustained with minimal inflows to balance evaporation. Although US Filter suggested that 500,000 acre-feet per year would be treated for reuse, some of the water shown below as being available for dust control could also be treated. Increasing the treatment amount would decrease the average cost of water expressed as cost/acre-ft.

A water budget was calculated for two inflow conditions, 1,300 KAFY and 1,000 KAFY, and for constructing the primary dikes to create the Salton River at either a water depth of 10 feet or 15 feet. The water budget is as follows:

Water Depth at Dike (ft)	10	10	15	15
Starting Inflow (1,000 acre-feet/year, KAFY)	1,300	1,000	1,300	1,000
Evaporation from River (KAFY)	(150)	(150)	(264)	(264)
Desalination Product Water (KAFY)	(500)	(500)	(500)	(500)
Brine Reject (KAFY)	(150)	(150)	(150)	(150)
Water Available for Dust Mitigation (KAFY)	(500)	(200)	(386)	(86)

2.4.2 Hydraulic Characteristics and Residence Time

Hydraulic calculations have been prepared to determine if there would be potential for backwater or flooding problems at the south end of the Sea, or conversely depletion of flow problems at the north end. These calculations were also used to estimate residence times. Residence time is the time elapsed between entry of a water mass into the impoundment and its departure via outflow or evaporation. It is a function of inflow rates, outflow rates, impoundment volume, and impoundment evaporation rates, and is calculated for the average water mass, i.e. on the assumption that all water masses entering an impoundment have the same residence time.

Approximate residence time calculations are shown in Table 5. These calculations were performed to estimate the water surface slope and flow velocities from the south end of the Sea to the north, using a simple application of the Manning equation, a standard equation used for hydraulic calculations. This simplified approach can be considered conservative since it does not take into account the variations in channel geometry along the proposed Salton River or the effect of side weirs and evaporation. These effects would tend to increase the water surface slope and increase residence time. To partially compensate for these factors, a relatively high Manning n resistance factor has been assumed, assumes that shallow water vegetation would be present that would tend to retard flow.

The Salton River would essentially form two rivers – one around each side of the Sea. The calculations show that the impoundment around each side of the Sea would form a sluggish extension of the rivers and drainage canals feeding into it, with flow velocities on the order of 0.02 to 0.07 feet per second (fps). Each side would be a river of about 45 miles in length with no bed slope.

The effect of switching to deeper dikes is illustrated by the calculations shown in Table 5. With the dikes constructed in 10-feet of water, the residence time could be on the order of 40 to 50 days; whereas, the residence time could be on the order of 105 to 137 days if the dike is constructed in 15-feet of water.

Table 5. Approximate Hydraulic Characteristics of US Filter Proposal.

	Dikes at 10' Depth		Dikes at 15' Depth	
Assumed Inflow (ac-ft/yr)	1,300,000	1,000,000	1,300,000	1,000,000
Flow Rate (cfs)	1,796	1,381	1,796	1,381
Half of Flow on Each Side (cfs)	898	691	898	691
Width (ft)	2,220	2,220	3,960	3,960
Average Depth (ft)	5.5	5.5	8.5	8.5
Cross Sectional Area (sq ft)	12,210	12,210	33,660	33,660
Flow Velocity (fps)	0.07	0.06	0.03	0.02
Assumed Manning n	0.2	0.2	0.2	0.2
Water Surface Slope	9.92E-06	5.87E-06	7.28E-07	4.31E-07
Distance (mi)	47	47	46	46
Elevation Decrease, south to north (ft)	2.46	1.46	0.18	0.10
Residence Time (days)	39	51	105	137

Note: These calculations are intended to show possible order of magnitude changes in water surface from the south to the north based on standard open channel flow calculations. Side weirs for irrigation have not been considered. More detailed modeling would be needed to develop more precise predictions.

For the 10-foot deep dike, the water surface could be on the order of 2 or 3 feet lower in the north than the south for hydraulic reasons. Evaporative losses and side releases of water for irrigation could add another 1 or 2 feet to the elevation difference. Thus the difference in elevation could be on the order of

4 to 5 feet. Unless designed properly, this effect could create backwater or flooding problems at the south end of the Sea. In addition, the design of side weirs or other mechanisms for releasing water for irrigation or wetting of interior sediments would be complicated by variations in water surface. It is possible that simple side weirs would be ineffective in releasing evenly distributed water along the dikes for irrigation purposes. With the dikes in 15-feet of water, the elevation difference between north and south would likely be much less than for the 10-foot dikes. Detailed flow modeling would be needed to better understand the flow characteristics. The Corps of Engineers HEC-RAS computer model would probably be an appropriate tool for this application.

Physical mixing in the impoundment would be predominantly wind-driven just as it is in the present Sea. However, current speeds, turbulence, and wave action would be reduced relative to present conditions. Winds now have fetch of up to 40 miles over which to exert their influence on water movements in the Sea. With 10-foot deep dikes, wave action along the shoreline of the impoundment would be greatly reduced from what it is now. With 15-foot deep dikes, wave action along the shoreline would be reduced to a lesser extent, particularly in the southern area where fetches of a few to several miles in that impoundment would still be sufficient for significant waves to be generated. Additionally, the high ratio of shoreline (including dam margins) to surface area would have a dampening effect on current speeds. Several consequences would follow from this.

Vertical mixing of the water column would be reduced in the southern area of the impoundment relative to what it is now in this part of the Sea. This tendency to poorer vertical mixing would be mitigated to some extent by elimination of vertical salinity gradients now often detectable along the southern shoreline and many miles east and north of the Alamo River mouth. Lower shoreline wave action and near shore turbulence action would be significant factors influencing sediment composition, impoundment turbidity and establishment of aquatic vegetation.

2.4.3 Dilution Factor

Related to residence time is the dilution factor, the degree to which properties, such as contaminant concentrations, of inflow waters would tend to be overwhelmed by corresponding properties of the receiving waters by simple dilution, ignoring biogeochemical processes that operate to alter these properties further. This dilution factor is a function of inflow rates and impoundment volumes.

For the present Sea the capacity of the Sea is more than five times the annual inflow. If dikes were constructed in 10-foot water depths, the entire Salton

River would not be much more than 10 percent of the annual inflow. Therefore, the dilution factor is now roughly 50 times greater than what it would be for the proposed impoundment. If dikes were constructed in 15-foot water depths, the current dilution factor would be roughly 20 times greater than what it would be for the impoundment. In either case, contaminants in the inflowing waters would not be diluted by the large receiving water, and instead would be concentrated in the new impoundment.

2.4.4 Salinity

Salinity would be the single most important factor causing impoundment biotic communities to differ from those of the present Sea. Because of the short impoundment residence times, salinity would drop quickly from Salton Sea salinities (around 45,000 mg/L) to salinities only slightly higher than salinities of the inflowing rivers.

The Bureau of Reclamation's Salton Sea Accounting model was adapted by Reclamation to evaluate the salinity and elevation for the US Filter proposal. Figure 3 illustrates the projected salinity both within the proposed Salton River impoundment and in the residual Sea. The model shows that upon completion of construction, the salinity in the impoundment is projected to rapidly decrease to about 4,000 mg/L, while the residual Sea would rapidly become hypersaline and would become saturated with salts in only a few years.

Certain factors could cause the salinity of the inflows to increase. These include reduction of low salinity tailwater runoff from agricultural fields, and reduction in input of low salinity municipal wastewaters from Mexicali (if and when Mexico chooses to reclaim this water). Salinity of Whitewater River (Coachella Valley Flood Control Channel) inflows could increase slightly over time if additional amounts of Colorado River water are transferred to the Coachella Valley, in part to replenish its aquifer. Taking all these factors into account, it is predicted that the Salton River impoundment would within a few months achieve an equilibrium salinity level of about 4,000 mg/L.

Two additional factors for which the influence has not been quantified might increase slightly the equilibrium salinity levels expected. First, greatly increased abundance of shoreline and shallow water vegetation would likely result in water losses from the impoundment via evapotranspiration that would be in excess of evaporative losses calculated simply from impoundment surface areas. Second, a slight, transitory elevation of salinity above the predicted level might result from dissolution of gypsum, or calcium sulfate, which is abundant in sediments in many places. As the impoundment waters freshen, this would tend to go back into solution, slowing the rate of salinity decline in the impoundment. Gypsum dissolves slowly, however, and much of it is well below the sediment surface where even slower dissolution would occur.

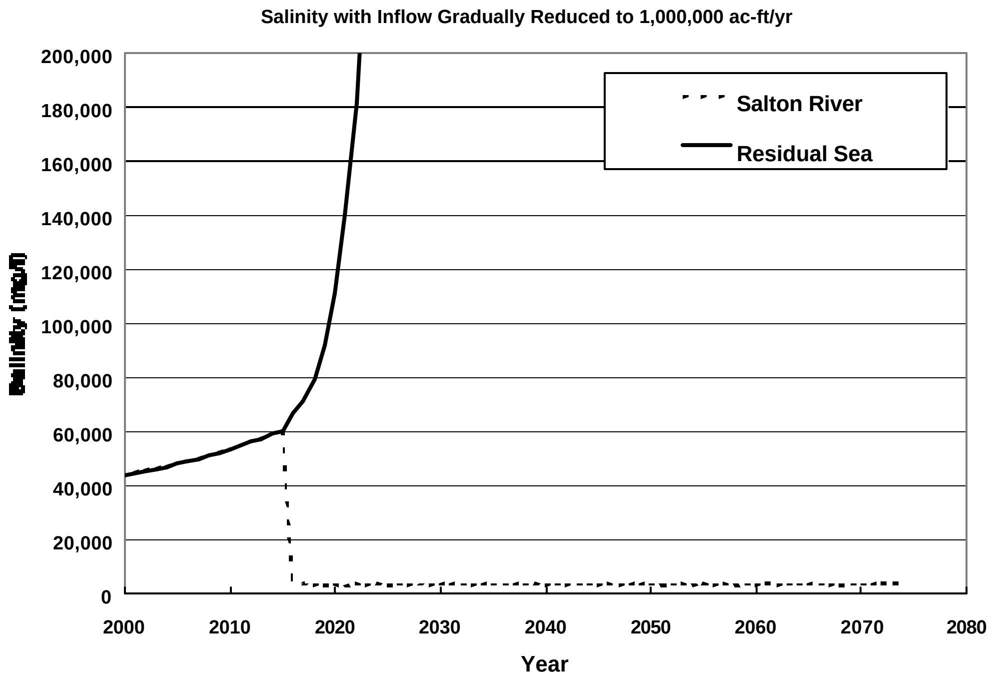

Figure 3. Predicted Salinity with Inflow Reduced to 1,000,000 Acre-Feet per Year.

The predicted equilibrium salinity level of about 4,000 mg/L is of particular biological significance. Limnologists conventionally set 3,000 mg/L as the dividing line between fresh and brackish waters. This is not entirely arbitrary. Most of the world's fresh waters have salinity less than 1,000 mg/L and most of its inland saline waters have salinity greater than 5,000 to 10,000 mg/L. The nature of lake biota correspondingly changes rather abruptly as one goes from 1,000-2,000 mg/L to 6,000-8,000 mg/L. Slight differences in this salinity range can cause large changes in the nature of the system, and much larger changes than might be produced by going from, say, 8,000 mg/L to 20,000 mg/L. Some species of aquatic vascular plants that would colonize the impoundment would find themselves near the upper limits of their salinity tolerance.

With the change in salinity, with the exception of tilapia, it is not likely the current populations of marine fish would survive, including the orange-mouth corvina (*Cynoscion xanthulus*), bairdiella or Gulf croaker (*Bairdiella icistia*), and sargo (*Anisotremus davidsoni*). It is even questionable whether the current population of tilapia could withstand such a rapid and drastic change in salinity. Fresh water fish species that are tolerant of brackish water would need to be introduced. Carp, which are present in the rivers, would be introduced naturally.

2.4.5 Temperature and Oxygen

Water in the proposed Salton River impoundment is likely to experience higher maximum water temperatures in summer and lower minimum temperatures in winter than the corresponding parts of the Sea now experience. The impounded water would be isolated from the protective thermal inertia provided by the main water mass of the Sea that now continually mixes with near shore waters. The case where the dikes would be constructed in 10 feet of water would likely experience greater extremes of temperature than a deeper and larger impoundment that would be created by dikes constructed in 15 feet of water.

The main consequence of lower winter water temperature would be for tilapia. Even in the present Sea, these fish experience winter water temperatures that, in combination with other stresses such as high salinity, occasionally drop to lethal levels. Massive winterkills of tilapia in the impoundment thus might occur more frequently than they do now in the Sea. Other fish likely would not be directly affected, though indirect effects would be likely to the extent that these other fish fed on or competed with tilapia.

Higher summertime temperature maxima in combination with altered mixing and current regimes, would likely affect a broader spectrum of fish and invertebrates. Increased water temperature reduces the solubility of oxygen at the same time it tends to increase metabolic rates, and hence oxygen demand, by fish and invertebrates. Other things being equal, the lower salinity of impoundment would cause the solubility of oxygen to be higher than in the Sea. However, in eutrophic water bodies, as the Sea is and as the impoundment would be, salinity effects on oxygen levels are likely to be obscured by the strong control of oxygen levels by biological factors, namely the intensity and daily variations of photosynthesis and respiration by autotrophs and heterotrophs, and by mixing regimes.

How impoundment oxygen levels would respond to altered hydrographics is difficult to predict, especially for the warmer half of the year. In the present Sea in summer the near shore waters often have higher oxygen levels than do waters at the same depth in the center of the lake. The dikes would slow currents and reduce vertical mixing. This would increase the likelihood of frequent or prolonged periods of anoxia in the deeper waters of impoundment. Even brief anoxic events, if pervasive in an impoundment, could cause such depletion of fish or macroinvertebrate populations for which recovery could take more than a year.

On the other hand, the impoundment would be completely isolated from the deeper anoxic waters and highly reducing bottom sediments found over the main part of the Sea. The impoundment would thus be less affected than are current near shore waters by major overturns of the water column in summer.

These overturns create anoxic, reducing conditions over the whole water column in the center of the lake, and currents sometimes then bring those lethal waters into the near shore zones.

2.4.6 Turbidity

Turbidity is a function of the amount of particulate matter in suspension. It would be a critical determinant of the nature of the impoundment ecosystems primarily via its influence on the depth to which submergent and emergent vascular plants would colonize the impoundment. Secondarily it is important as a determinant of how deep benthic algae may occur, of interactions between visual predators and their prey, and of biogeochemical processes mediated by or involving suspended particulate matter.

Turbidity is primarily due to two components – plankton and suspended sediments. Turbidity is very high in the areas of the Sea that would be occupied by the impoundment. Disturbance by turbulence, wave action and currents in these areas results in constant resuspension of fine bottom sediments. Shallowness and proximity to the nutrient-laden inflows also cause plankton densities to be higher in these areas than in mid-lake.

In the southern area of the impoundment in the immediate vicinity of river mouths, turbidity would be high. Over most other areas of the impoundment turbidity would also likely be high. It would probably be higher than in the present near shore waters of the Sea because of the limited potential for dilution. However, a number of factors would cause turbidity to be high, a number of other factors would cause it to be low, and it is uncertain how these would balance out.

Favoring lower turbidity would be: reduced turbulence, wave action, and currents; suspension-feeding on phytoplankton by the Asiatic clam (Corbicula) if it densely colonizes the impoundment; uptake of nutrients by benthic algae and by epiphytic algae coating the surfaces of submerged vascular plants (thus inhibiting phytoplankton growth); secretion of phytoplankton-inhibiting compounds by vascular plants; and grazing on phytoplankton by zooplankton, tilapia and threadfin shad.

Favoring higher turbidity would be: dense phytoplankton owing to high nutrient inputs; disturbance of sediments by carp and other bottom-feeding fish if they were to densely colonize the impoundment; and much more limited dilution.

2.4.7 The Residual Sea

Under the proposed plan, within about 20 years the present Salton Sea would decline in elevation by about 40 feet and the area would be reduced to less than

100,000 acres (less than 160 square miles). As shown in Figure 4, the resulting Sea would be more than 200 square miles smaller than the current Sea. If the dikes were constructed in 10 feet of water, about 190 square miles of sediments would be exposed between the dikes and the residual Sea. If the dikes were constructed in 15 feet of water, about 160 square miles of sediments would be exposed between the dikes and the residual Sea.

As illustrated in Figure 3, the residual Sea would become hypersaline in a few years, and would rapidly approach saturation, at which point salts would begin to crystallize. These exceptionally high rates of salinity increase for the residual Sea represent the combined effect of high salinity of inflow waters and decreasing lake volume.

The residual Sea would likely experience slightly colder mean water temperatures in winter and warmer ones in summer, as a result of its increased shallowness. Oxygen levels in the water column would tend to be reduced because of the low solubility of oxygen in highly saline water, but bottom waters might be completely anoxic less often as a result of the shorter water column being mixed to the bottom more easily. It is uncertain how these two factors would balance out.

2.5 The New Food Webs

The proposed Salton River impoundment would become the largest freshwater lake in California south of Lake Tahoe. New vascular plant vegetation along impoundment shorelines would be greater than that now occupying the entire length of the U.S. portion of the New River. Vascular plant growth does not represent a “new” habitat in the Salton Sink. Much of the state and federal wildlife areas, which directly abut the Sea, already provide areas with vascular plant growth. Increasing the extent of emergent vegetation along the shoreline of the Salton River and dike, and the certain eventual increases of salt cedar encroachment in the proposed residual Sea will not result in increases in bird diversity (i.e. species richness). To the contrary, it would likely result in decreases in species richness and in the abundance of shorebirds and other waterbirds (hundreds of thousands of individuals representing over 50 species) that forage and loaf in the extensive tracts of shallowly flooded and open mudflats that exist currently, particularly along the southeastern stretch (where shorebird density in any season greatly exceeds that of any other section of shoreline) but also along the northern, southwestern, and southern stretches of today’s Salton Sea. Abundant invertebrate populations in the residual Sea that would be attractive to relatively few species of birds would not provide a viable food resource in the long term.

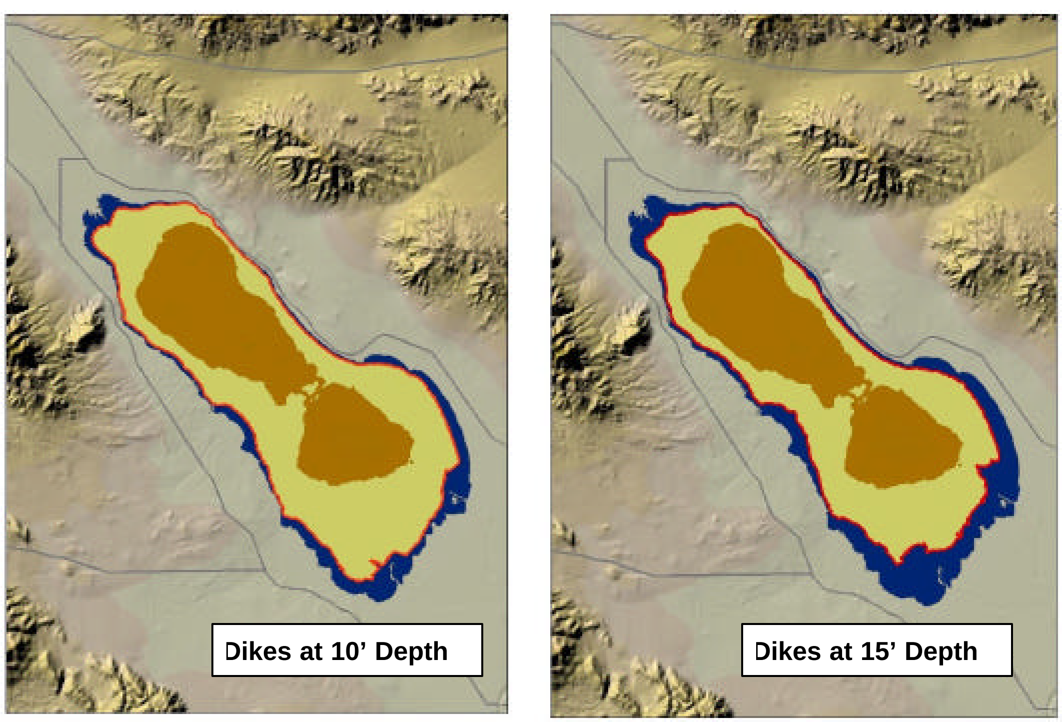

Figure 4. Graphics Depicting Residual Sea.

The following paragraphs briefly address some of the changes expected and kinds of organisms likely to dominate the food webs or biotic communities of the proposed impoundment and other new habitats that would be created. A more detailed discussion, modified from the Salton Sea Science Office review of the impoundments proposed by the Pacific Institute, is provided in Appendix C.

2.5.1 New Food Webs in the Salton River Impoundment

Algae would remain the major base of the food webs in the impoundment, though strongly supplemented by production by vascular plants and with macroalgae assuming a more important role than they have in the present Sea.

Now almost absent from the Sea and its shorelines, vascular plants would become abundant in the impoundment and along their shorelines. Vegetation would form along the 95-mile length of shoreline and along the 95-mile length of dikes, although full development of this vegetation would take some years. These vascular plants would contribute large amounts of plant detritus to the shoreline ecosystem and new habitat for birds in particular. These plants would probably boost overall production of the system and represent an increased food supply for decomposers and detritivores. The detritus would also increase the organic matter content of sediments making them softer, 'muddier,' and more subject to anoxia. If the dikes were constructed in 15-feet of water rather than 10-feet of water, clogging by vascular vegetation would be less of a concern.

In the impoundment, the species-poor invertebrate assemblage of the Salton Sea would be quickly replaced by a much more diverse assemblage. Key elements of the present food chain, such as the pileworm (Neanthes) and barnacle (Balanus) would disappear completely, while a few elements might persist, e.g. the copepod (Apocyclops), the rotifers (Brachionus, Synchaeta), and the amphipod (Gammarus). Large numbers of new species of crustaceans, insects, oligochaete worms, mollusks, flatworms, rotifers and nematodes would colonize the water column, the sediments, and the surfaces of aquatic plants.

The fish assemblages that would develop in the impoundment would be radically different from the present one in the Sea. Corvina, sargo, bairdiella, and long-jaw mudsucker would disappear. Mozambique tilapia would persist as would threadfin shad, mosquito fish, mollies and mullet. Almost all of the freshwater exotics found in the Coachella, Imperial, and Mexicali valleys would eventually find their way into the impoundment and establish permanent populations. These include common carp, catfish, largemouth bass, sunfish, Zill's tilapia, and shiners. The triploid sterile grass carp used for weed control in agricultural drains could also invade though they should not be able to reproduce. It might be predicted that the fish assemblage would be dominated by the tilapias, threadfin shad, carp and catfish, as these feed predominantly near the bottom of the food web. Large mouth bass could become one of the more popular sportfish.

2.5.2 The Residual Sea

The residual Sea would continue to receive nutrients via overflow waters from the impoundment, algae and cyanobacteria tolerant of high salinities would persist, often in bloom conditions. These would serve as food for the few invertebrate species - protozoans, copepods, water boatmen, brine flies, and brine shrimp - that would dominate in the Sea once salinities exceeded 60-70 g/L and all or almost all fish had disappeared.

The overall productivity of the residual Sea would decline fairly rapidly as its salinity increased. This is because all those organisms - bacteria, algae, invertebrates - capable of surviving high salinities do this in large measure by dedicating more energy to maintenance functions, such as osmoregulation, and less energy to growth and reproduction.

Certain invertebrates such as brine shrimp and brine flies may become conspicuously abundant as their predators and competitors are eliminated by rising salinity. These invertebrates also possess unique sodium pumps allowing them to survive extremely saline waters. Food supplies for particular bird species – such as Eared grebes, phalaropes, avocets, stilts, certain gulls – that feed on such invertebrates can indeed become much more abundant than they were at lower salinities where overall system productivity was higher but was being utilized by other components of the food web (fish, predaceous invertebrates).

Even those invertebrates that tolerate high salinities grow and reproduce best at salinities lower than those of the present Salton Sea. Physiologically their populations would be in a state of decline from the moment they establish themselves in the Sea. Their abundance would also be influenced by oxygen conditions. Uncertainty as to oxygen conditions at the sediment surface, where larvae of brine fly larvae live, makes it unclear what percentage of the bottom of the shallower, saltier Sea could be used by such invertebrates, especially during the warm part of the year.

The most important point is that salinity increases would cause greatly decreased system productivity. Once salinities approached and exceeded 90-100 g/L there would be a rapid decline in the production of the very invertebrates most favored by birds that frequent salt lakes. Highly saline water bodies such as The Great Salt Lake of Utah have very low rates of production per unit area, and many of the principal bird feeding areas at them are actually the lower salinity areas or subsystems around their margins where freshwater flows into the lake.

The residual Salton Sea would not function as a giant, well-stocked bird feeder for more than a few years, given the projected very rapid increase in its salinity.

2.6 Disease, Parasites and Contaminants

The project proposed by the US Filter would create or exacerbate a number of problems relating to disease, parasites and contaminants.

2.6.1 Disease and Water-Borne Parasites and Contaminants

The potential problems concerning disease and parasites reflect the fact that the salinity of the Salton Sea functions as a prophylactic: neither its present salinity, nor one closer to ocean water, can be tolerated by certain pathogens, disease vectors and parasites that would become abundant in freshwater impoundment.

With respect to contaminants, the general problem is that the proposed impoundment would represent sluggish extensions of the inflowing rivers.

Consequently they would have contaminant levels closely reflecting those in the rivers themselves. The diluting and metabolizing power of the volume of the whole Salton Sea would no longer be available in these new freshwater ecosystems.

A detailed discussion of potential fish, bird and human disease issues associated with the proposed impoundment is provided in Appendix D. Appendix D also provides a discussion of concerns about toxic algal blooms and concentrations of phosphorous and nitrogen, selenium, and pesticides and other contaminants.

2.6.2 Particulate Air Pollution

Pollution of the atmosphere with particulate matter is already a problem in the Coachella and Imperial valleys with the PM_{10} standard being exceeded many days every year. That standard refers to the concentration in the air of particles smaller than 10 microns in diameter. These cause respiratory problems in humans.

By allowing the level of the Sea to decline and exposing 160 to 190 square miles of former lakebed, a worsening of air quality in the region is likely. This would depend largely on the physical structure, particle size distribution, and moisture content of the soil surface. The exposed Salton Sea lakebed would be greater in extent the exposed lakebed at Owens (Dry) Lake in northern 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 assist in mitigating this problem. However, it is difficult to predict how effective such measures would be, and there is not enough water to treat the entire exposed area. The cost estimates include treatment of 10 to 25 percent of the exposed area. At Owens Lake mitigation is needed for about 25 percent of the exposed area.

2.6.3 The Residual Sea

The residual Sea would likely pose no disease or parasite problems for birds, and toxic algal blooms are unknown in such highly saline systems. It would continue to receive nutrients and contaminants via overflow waters from the impoundment. Phosphorus would be less likely to be immobilized in sediments than it is in the present Sea and might thus be superabundant relative to demand by algae. In any case it would be unlikely to cause any problems.

The selenium loading per unit area of the residual Sea would likely be greater than it is for the present Sea. Selenium levels in brine shrimp and brine flies in the residual Sea thus would likely be higher than those in invertebrates in the present Sea. However, as the residual Sea would approach saturation levels for salts within about 10 years. Effects on biota would be short lived as the residual Sea would no longer support brine flies or brine shrimp.

2.7 Recreation and Economics

Recreational aspects of the impounded Salton Sea River that are considered are bird watching, fishing, boating and swimming, and camping. In addition, possible effects on regional economics are also briefly considered.

2.7.1 Bird Watching

This is an activity engaged in at the Sea by many thousands of individuals a year, especially at the southern end of the Sea. Construction of the proposed impoundment could have a few negative impacts on the quality of the area for bird watching.

The encroachment of vegetation along the shoreline would negatively affect access to traditional shoreline and open water points of interest for birdwatchers. The expected actual loss of vast stretches of open water and mudflat to encroaching vegetation and decreases in the visibility of such remaining substrate could discourage the number of birdwatchers to the Salton Sea, which are typically interested in the entire range of birdwatching opportunities that the Salton Sea has historically offered. The residual Sea, which may initially serve to concentrate a few species of birds, would generally not be accessible to the public.

Since the Salton Sea is already an excellent, nationally and internationally recognized location for bird watching, it would not likely experience even greater popularity in that regard even if certain bird species did become more abundant there or if others disappeared. It seems less certain that large increases in biting insects might not reduce the area's popularity for bird-watchers.

2.7.2 Fishing

Fishing could be quite good in the proposed Salton River for tilapia, largemouth bass, carp and catfish, though it is unpredictable just which of these would establish good numbers of good-sized individuals. Special attractions might include the fact that tilapia sport fisheries do not exist elsewhere in the state and the possibility that largemouth bass would reach large sizes in the impoundment. However, freshwater-type fisheries, except for the tilapia, can be found in many other water bodies in southern California, and whether many fishermen would be willing to travel long distances to take advantage of it is questionable. It would no longer be a special, unique marine fishery capable of offering 30-pound corvina.

It would likely become a fishery where contaminant levels were higher than elsewhere for the same species and higher than in the former Salton Sea. Selenium levels in fish could be six times greater or more than those in fish of the present Sea. Such a case would cause the state to warn against any consumption of fish. Detection of microbial pathogens or indicators of fecal contamination in the impoundment would lead to the same warning. The perception that the impoundment would create a sluggish extension of wastewater drains would probably discourage fishing.

2.7.3 Boating and Swimming

Boating in the Salton River impoundment, because of reduced current speeds and wave size, would probably be safer than in the current Sea, and the entirety of the impoundment area would be accessible to smaller boats. On the other hand, contaminant levels in fish, invasion by aquatic vegetation, and, unless removed during construction, the considerable number of obstructions (rocks, tree trunks, old man-made structures) in the shallow northern and southern ends of the Sea would render the impoundment much less attractive to boaters in general than is the present Sea. There would be no need for pontoon boat tours for birdwatchers, such as the State Recreation Area currently conduct. Persons with larger, faster boats interested in quasi-oceanic boating excursions would no longer be attracted.

The Salton River would probably not be very attractive for swimming. Softer sediments, aquatic vegetation, absence of beaches, more biting insects, and the presence of swimmer's itch and microbial pathogen levels higher than those in the present Sea would likely discourage potential bathers.

2.7.4 Camping

Currently there is a fair bit of both tent camping and mobile home camping around the edges of the Salton Sea, much of which is associated with bird watching, desert nature study, scientific excursions by university classes, and relaxation. The slow moving Salton River would likely increase the abundance of biting insects as well as non-biting insects such as chironomid midges, likely to swarm to campsite lighting fixtures. The presence of such insects could make shoreline areas even less attractive than they are now for camping, unless campsites were a considerable distance – perhaps hundreds of yards - from the water's edge.

2.7.5 Economics

It is difficult to assess the overall effect of implementing the US Filter proposal on the regional economy. It would be a very large construction project that would generate a large number of jobs in the engineering and construction sectors. In, operation of the treatment and pumping plants would also generate many long-term employment opportunities.

The values of most shoreline properties around the Salton Sea are currently depressed. In the absence of any other measures to control salinity or address other issues at the Sea, it is likely that the values of these properties would continue to be depressed. However, if this alternative were to create an unattractive recreational opportunity, it is possible that additional problems for local residents could be created. For example, it is possible that fewer people would come to the Sea for fishing, boating, and camping, although it is likely that the numbers coming for bird watching would remain high. If the dust control measures are not effective, then increased particulate matter and associated air pollution could exacerbate already high levels of airborne particulates and thus increase medical and public health costs. These air quality problems might also affect agriculture if much of the particulate matter consisted of salts. The cost to Imperial and Riverside counties of mosquito control along the nearly 100 miles of new shoreline mosquito habitat could be high.

2.7.6 The Residual Sea

The US Filter proposal does not provide for any access to the residual Sea. The shorelines of the receding residual would not be an attractive recreational option. Even with mitigation, air pollution from particulate matter would be higher than on the present shoreline especially during breezy or windy weather. In addition, the residual Sea would rapidly become hypersaline and would likely be brown in color, subject to unpleasant odors, and be an attraction for large swarms of brine flies.

3.0 NORTH LAKE ALTERNATIVE

The North Lake alternative is illustrated on Figure 5. This variation would involve constructing the treatment plant at the south end of the Sea instead of the north, a mid-Sea dam, and only enough dikes to convey water from the south end of the Sea to just north of the dam. The North Lake would be sustained at an elevation of about -230' msl and at a salinity of 35,000 mg/L.

3.1 Engineering Design Factors and Cost

This alternative would allow several cost savings measures over the base proposal. For example, the piping and pumping costs, as well as the diking costs could be reduced substantially. In lieu of pumping the water out of the basin, a transfer of water rights or some other mechanism for exchange would need to be arranged to provide water to the coastal region of California. The use of geothermal energy as applied in Vertical Tube Evaporator (VTE) technology may offer the opportunity for cost savings relative to other processes for desalting river waters. However, this is not certain and should be studied in detail before such technology is included the river water desalting plan. The Bureau of Reclamation's water treatment experts have suggested that VTE technology is only cost competitive in desalting waters at ocean salinity levels and above. A significant additional cost would be associated with construction of the mid-Sea dam.

A technical challenge for this alternative would be ensuring that sufficient water is available to sustain the northern recreation fishery area. Sustaining the North Lake would limit the amount of water than can be produced for sale. This can be illustrated from the following calculation:

Starting Inflow (KAFY)	1,300	1,000	1,300	1,000
Evaporation from North Lake (KAFY)	(570)	(570)	(570)	(570)
Discharge from North Lake (KAFY)[1]	(90)	(90)	(90)	(90)
Desalination Product Water (KAFY)[2]	(500)	(200)	(700)	(400)
Losses in Channel and Wetlands (KAFY)	(50)	(50)	(50)	(50)
North Lake Inflow from CRA RO Reject[3]	0	0	200	200
Extra Water for Habitat Areas (KAFY)	(90)	(90)	(90)	(90)
Inflow to North Sea to sustain -230' msl (KAFY)	660	660	460	460

1. Water from North Lake would flow through shorebird ponds and then be used for dust mitigation.
2. Each case facilitates a water transfer of the amount shown in this line.
3. An additional 200,000 AFY with a salinity of 4,100 mg/L may be available from a proposed RO treatment plant on the CRA.

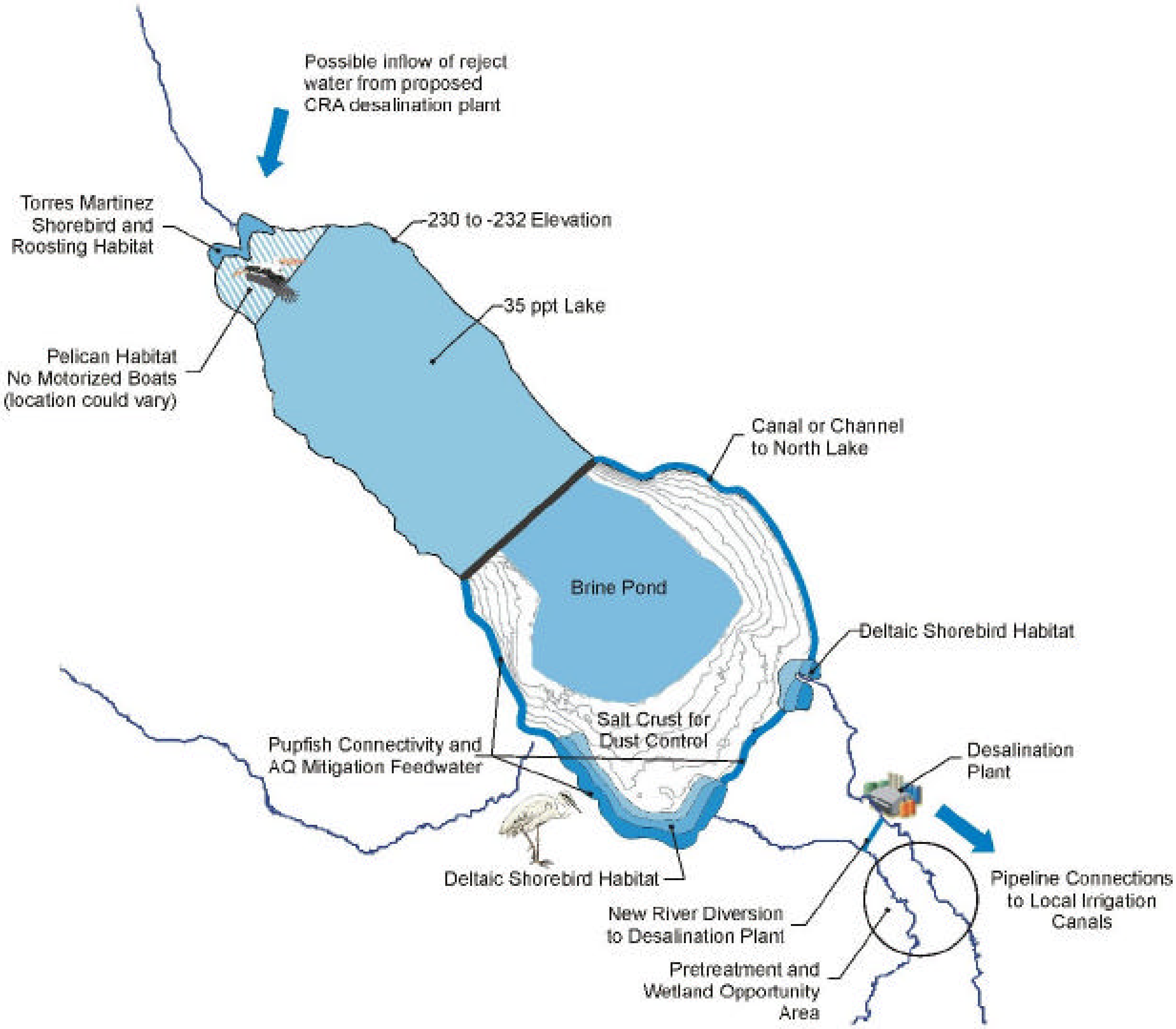

Figure 5. Conceptual Layout for North Lake Alternative.

This calculation illustrates how much water would be available for treatment and sale under various inflow alternatives. For the case where inflow to the Sea would have been 1 million acre-feet per year (MAFY), the amount of water that could reasonably be treated and sold would be 200 thousand acre-feet per year (KAFY), less than half the amount treated under the US Filter proposal. If the inflow were 1.3 MAFY, the amount of water that could be treated and sold would be 500 KAFY, the same as for the value used in the US Filter proposal. The estimated treatment volumes have been used in the cost estimates prepared for the different inflow assumptions.

Salinity in the North Lake could be managed by regulating the percentage of flow diverted through the canal along the east shore to the North Lake. It is expected that, on average, diverting most of the flow to the North Lake would provide for a stable salinity of 35,000 mg/l. The percentage diverted would vary in later years depending on how reductions in inflow to the system may occur in the future. The remaining flows would be discharged to the south to help sustain habitat areas.

Conceptual-level cost estimates for this alternative are provided in Table 6. Cost estimates were developed for the following assumptions:

- Inflow conditions of 1.3 MAFY and 1.0 MAFY
- Federal and non-federal construction programs, using different factors for the non-contract costs and discount rates. As with the estimates for the US Filter proposal, the federal estimates assume it is a federally funded program and standard assumptions for these two factors are used. The non-federal estimates assume lower non-contract costs and a lower discount rate.
- With and without a desalination plant proposed to be constructed on the Colorado River Aqueduct (CRA) that would provide reject stream that could be used as supplemental inflow to the North Lake, in the amount of about 200,000 acre-feet per year.

The estimated costs, expressed as an annual amount per unit of water produced, range from $470 to $590 per acre-foot for the 1.3 MAFY inflow case where 500,000 acre-feet per year of product water could be produced. The unit cost increases substantially for the lower inflow case, and decreases for the cases where CRA water would be available.

3.1.2 Habitat Features

This proposal includes a number of habitat features designed to provide bird habitat and connectivity for pupfish. As shown on the map, these features are located at the north end of the map and around the south basin. Around the south basin, these areas would be supplied by water discharged from the North Lake at a salinity of about 35,000 mg/L. The water would flow through a series of terraced habitat ponds, increasing in salinity, because of evaporation. From these ponds it would flow to concentrator and crystallizer ponds to be used to build a salt crust to cover exposed sediments and control dust. As the brine pool in the south basin would recede over time, the salt crust could be built downward toward the residual pool over time. The habitat ponds are expected to include the following features:

Table 6. Cost Estimate for North Lake Alternative.

	1. Inflow = 1.3 MAFY		2. Inflow = 1.0 MAFY	
	Non-Fed Estimate	Federal Estimate	Non-Fed Estimate	Federal Estimate
Capital Construction ($M)				
Mid-Sea Dam	$788	$788	$788	$788
Appurtenances (weirs, etc.)	$80	$80	$80	$80
Dike to Convey Water to North	$153	$153	$153	$153
Shorebird & Pupfish Ponds	$25	$25	$25	$25
Pretretment wetlands/settling ponds	$2.8	$2.8	$1.1	$1.1
RO Water Treatment	$446	$446	$178	$178
Nitrate and Phosphate Removal	$49	$49	$20	$20
Piping & Pumping (260' el. gain over about 13 mi.)	$237	$237	$166	$166
Air Quality Mitigation	$25	$25	$25	$25
Subtotal	$1,576	$1,576	$1,238	$1,238
Noncontract costs	12%	33%	12%	33%
Subtotal Capital Construction	**$2,023**	**$2,402**	**$1,609**	**$1,911**
Operation, Maintenance & Energy ($M/Yr)				
Dam & Dike	$9	$9	$9	$9
Appurtenances	$4.0	$4.0	$4.0	$4.0
Shorebird Ponds	$1.0	$1.0	$1.0	$1.0
Water Treatment	$93	$93	$37	$37
Piping & Pumping	$9	$9	$4	$4
Air Quality Mitigation	$1	$1	$1	$1
Subtotal	**$116**	**$116**	**$55**	**$55**
Annualized Costs Amortized Over 30 Yrs ($M/Yr)	**4.00%**	**6.13%**	**4.00%**	**6.13%**
Annual Loan Payment for Treatment & Dist.	$44	$67	$22	$34
Annual Loan Payment for All Other Items	$73	$110	$71	$107
Annual OM&E for Treatment & Distribution	$95	$95	$38	$38
Annual OM&E for All Other Items	$21	$21	$17	$17
Total Annualized Cost	**$233**	**$293**	**$148**	**$196**
Annual Water Delivery (KAFY)	**500**	**500**	**200**	**200**
Cost Per AF of Water Trearment and Distribution	**$280**	**$320**	**$300**	**$360**
Cost Per AF of All Other Items	**$190**	**$270**	**$440**	**$620**
Total Cost Per Acre-Foot of Water Produced	**$470**	**$590**	**$740**	**$980**

[1]Cost estimate based on mid-Sea dike with slurry wall cost estimate provided in Table 1 of Appendix 1, prior to application of non-contract costs, which are included as a line item on this table.

Table 6 (continued). Cost Estimate for North Lake Alternative.

	3. Inflow = 1.3 MAFY		4. Inflow = 1.0 MAFY	
	Non-Fed Estimate	Federal Estimate	Non-Fed Estimate	Federal Estimate
Capital Construction ($M)				
Mid-Sea Dam	$788	$788	$788	$788
Appurtenances (weirs, etc.)	$80	$80	$80	$80
Dike to Convey Water to North	$153	$153	$153	$153
Shorebird & Pupfish Ponds	$25	$25	$25	$25
Pretretment wetlands/settling ponds	$4.0	$4.0	$2.3	$2.3
RO Water Treatment	$625	$625	$357	$357
Nitrate and Phosphate Removal	$69	$69	$39	$39
Piping & Pumping (260' el. gain over about 13 mi.)	$274	$274	$216	$216
Air Quality Mitigation	$25	$25	$25	$25
Subtotal	$1,792	$1,792	$1,466	$1,466
Noncontract costs	12%	33%	12%	33%
Subtotal Capital Construction	**$2,288**	**$2,717**	**$1,888**	**$2,242**
Operation, Maintenance & Energy ($M/Yr)				
Dam & Dike	$9	$9	$9	$9
Appurtenances	$4.0	$4.0	$4.0	$4.0
Shorebird Ponds	$1.0	$1.0	$1.0	$1.0
Water Treatment	$130	$130	$74	$74
Piping & Pumping	$13	$13	$7	$7
Air Quality Mitigation	$1	$1	$1	$1
Subtotal	**$157**	**$157**	**$96**	**$96**
Annualized Costs Amortized Over 30 Yrs ($M/Yr)	**4.00%**	**6.13%**	**4.00%**	**6.13%**
Annual Loan Payment for Treatment & Dist.	$58	$88	$37	$56
Annual Loan Payment for All Other Items	$74	$112	$72	$109
Annual OM&E for Treatment & Distribution	$133	$133	$76	$76
Annual OM&E for All Other Items	$24	$24	$20	$20
Total Annualized Cost	**$289**	**$357**	**$205**	**$261**
Annual Water Delivery (KAFY)	**700**	**700**	**400**	**400**
Cost Per AF of Water Trearment and Distribution	**$270**	**$320**	**$280**	**$330**
Cost Per AF of All Other Items	**$140**	**$190**	**$230**	**$320**
Total Cost Per Acre-Foot of Water Produced	**$410**	**$510**	**$510**	**$650**

[1]Cost estimate based on mid-Sea dike with slurry wall cost estimate provided in Table 1 of Appendix 1, prior to application of non-contract costs, which are included as a line item on this table.

- Water in impoundments would generally be designed to be not be greater than 2 to 3 feet deep.
- Levees or berms would be built to have about 2 feet of freeboard. South facing side of levee would have minimum 8:1 slope, north facing will have very gradual slope as constructed. Crown of levee should be flat and be min 3 m wide. Alternating levees would be constructed for light vehicle traffic (maintenance and observation).
- Levees would be constructed in a series of terraces, with provision for multiple overflows into the next sequential terrace. Terminal terrace overflows into canal (or structure) leading directly to residual brine pool.
- Terminal terrace would have salinity of 120,000 mg/L or less.
- At intervals of about 0.5 mile along vehicle accessible levees the levee would be expanded to allow vehicle turnaround point. At intervals of about 1.5 to 2 miles these turnaround points could be widened at the crown to provide nesting “islands”. Some of these “islands” could have a dirt base overlaid with rocks, boulders, broken concrete, and expanded to make artificial nesting/roosting sites for cormorants, pelicans and other species.
- In initial terraces and spaced through out all terraces artificial roosting sites would likely be constructed.
- All terraces would have levees with crossing locations for airboats.
- Access to all levees could be controlled with solar-powered electrical fencing/gates to deter terrestrial predators.
- Artificial islands could be constructed within the terraces themselves, surround on all sides by water. These islands can be of compacted earth, with dimensions of 8:1 slopes, rising about 2 feet above water line, placed perpendicular to prevailing winds, length of 300 meters x width 10 m.
- All terraces need not be flooded at all times and it would probably be better for invertebrate productivity to plan for periods of dryness. Important periods for flooding would be to have some terraces available at all times, and to have at least 75 percent of them filled during migration periods and breeding.

3.1.3 Ecological Factors

The benefits, concerns, and possible mitigation of concerns associated with this variation to the US Filter proposal are discussed in the following paragraphs.

Benefits. North Lake alternative to the US Filter proposal is expected to have the following key benefits:

- Like the US Filter proposal, the North Lake alternative would produce drinking water, which would provide a substantial benefit to California in providing for re-use of a significant amount of diverted Colorado River water. The plan could possibly reduce California's dependence on diversions from the river .However, the water would be used within the basin and a transfer would need to be arranged to provide water to coastal California. Some institutional hurdles may be associated with such a transfer.

- North Lake alternative would provide a stable shoreline in the northern basin that could be beneficial to local residents and recreational users.

Concerns and Possible Mitigation of Concerns. Some of the key concerns associated the US Filter proposal could be at least partially mitigated by North Lake alternative:

- The Salton River impoundment in the base US Filter proposal would serve as a very slow sluggish extension of the existing rivers. The presence of treatment wetlands and the fact that much of the water would be comprised of the brine stream from the water treatment plant would greatly mitigate issues associated with contaminants in the canal component of North Lake alternative. The north basin fishery/recreation area would provide a stable shoreline in lieu of the Salton River, assuming the concern regarding insufficient water could be mitigated as discussed above.

- Sedimentation and turbidity problems in the north basin would be minimal, but they would occur in the shorebird ponds near the river mouths.

- Variations in water surface in the Salton River concept would not be a factor in North Lake alternative.

- Contaminants in the inflowing waters would not be diluted as they are in the present Sea and would tend to be concentrated by evaporation and other processes in the shorebird ponds. Removal of some of these materials would be accomplished by the treatment wetlands. In addition, pretreatment of inflows to the desalting plant would remove contaminants that would then not be present in the brine stream.

- Temperature ranges would be more extreme in the shorebird ponds and to a lesser extent in the northern basin than in the present Sea and oxygen depletion problems could be expected. These factors could lead to fish kills in the shorebird impoundments, particularly winter kills of tilapia.

- The food web in the canal would change to a fresh water web with algae as the major food base and extensive growths vascular vegetation would occur along the shoreline. This issue would not be a problem with the northern basin.

- Fish, bird and human diseases associated with water borne parasites, contaminants, and mosquitoes would be a concern in the canal, but this would be much more limited in area than in the 95-mile Salton River component of the base proposal.

- Air quality mitigation for this alternative would likely be easier than for the US Filter proposal. First, the area of exposed sediments would be smaller than for the US Filter proposal. Second, brine discharge from the North Lake could be used to create a salt crust to control dust formation. Saline water discharged from the North Lake would first be used to create habitat areas along south west shoreline areas. From there it would flow by gravity to concentrator and crystallizer ponds. The crust could be created gradually over a number of years as the south brine pool would shrink by natural evaporative processes. For the US Filter proposal, it has been assumed that vegetative controls of dust would be required since the water for dust mitigation would be nearly fresh.

- Shorebird and pupfish ponds in the southern area would provide bird habitat and connectivity of pupfish habitat. However, while this alternative addresses some bird habitat issues, key foraging and resting areas for all wading species in the south end of the Sea would not be addressed and only one of three key areas at the north end, the Whitewater Delta/Torres Martinez Shorebird and Roosting Habitat would be addressed. The deltaic shorebird habitats at the south end of the Sea, and the Torres Martinez habitat plan at the north end as proposed in this alternative appear to be subject to the same physical conditions and to encroachment by vegetation, as does the base proposal. The vast majority of breeding colonies of waterbirds are located at the south end of the Sea in patches of dead tree snags or on small islets isolated by water from the shoreline. Loss of these sites could occur under this alternative, and modifications should be considered during more detailed design phases to address these issues.

3.1.4 Recreation and Economics

Preserving the fishery in the northern basin would have recreational benefits for fisherman, campers and other recreational users. In addition, a stable shoreline would have significant benefits for both recreation and regional economics. Shorebird ponds in the southern area would be recreational assets to both bird watchers and hunters.

4.0 Variations to the US Filter Proposal and North Lake Alternative

The California Regional Water Quality Control Board proposed a variation to the US Filter proposal, and a variation to the North Lake alternative. Each is discussed in the following sections.

4.1 Variation to the US Filter Proposal

This variation, illustrated in Figure 6, would involve the following differences from the base US Filter proposal:

- The treatment plant would be constructed at the south end of the Sea instead of the north end and treated water would be used within the Salton Basin. Therefore, a transfer would need to be arranged rather than directly pumping water out of the basin to the Colorado River Aqueduct. In addition, other treatment plants are included for ecological purposes.
- A mid-Sea dam would be constructed similar to North Lake alternative; however, in this case it would be a smaller dam constructed after the residual Sea would recede and the north basin pool area would be much smaller than the one in North Lake alternative.
- Water contained by the perimeter dikes would be saline and thus could support a marine fishery.
- Pupfish refuges, freshwater marsh habitats, and a corvina hatchery would also be included.

4.1.1 Engineering Design Factors and Cost

This variation to the US Filter proposal would allow several cost savings in eliminating the piping and pumping costs to the Colorado River Aqueduct. In addition, the mid-Sea dike would be considerably less expensive than that proposed for North Lake alternative. Other added features would add cost such that the estimated cost of producing water for this variation is expected to be about 25 percent greater than for the basic US Filter proposal.

A technical challenge for this alternative would be creating the marine fishery in the north basin. After creation of the peripheral dikes and construction of the primary treatment plant, the residual Sea would begin to shrink rapidly. This residual Sea would rapidly become hypersaline and salts would begin to precipitate. Restoring this body of water to salinities that could support a marine fishery would likely take many years.

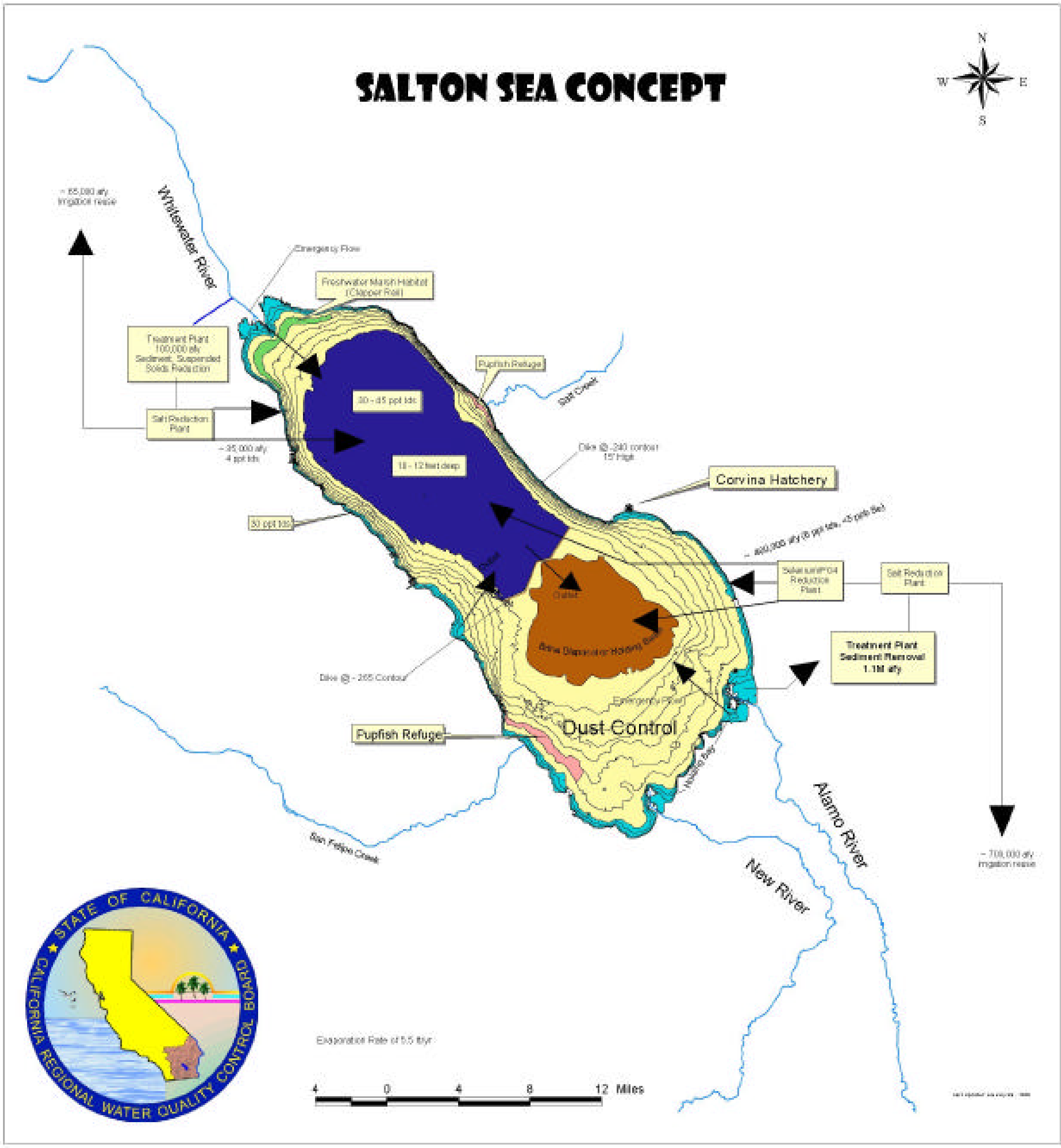

Figure 6. Conceptual Layout for Variation to the US Filter Proposal.

4.1.2 Ecological Factors

The benefits and possible mitigation of concerns associated with this variation to the US Filter proposal are discussed below.

Benefits. This variation to the US Filter proposal is expected to have the following key benefits:

- Like the base proposal, this variation would produce drinking water, which would provide a substantial benefit to California in providing for re-use of a significant amount of diverted Colorado River water. However, the water would be used within the basin and a transfer would need to be arranged to provide water to coastal California. Some institutional hurdles may be associated with such a transfer.

- This variation would provide a stable shoreline around the entire Sea that would be beneficial to local residents and recreational users. Unlike the base proposal, this variation would provide a marine environment in the impoundment and would include treatment to improve the water quality.

Concerns and Possible Mitigation of Concerns. Some of the key concerns associated the US Filter proposal could be at least partially mitigated by the North Lake proposal:

- The Salton River impoundment in the base US Filter proposal would serve as a very slow sluggish extension of the existing rivers. In this case the impoundment would have a marine environment.

- Sedimentation and turbidity problems at the south end of the impoundment would be similar to the base proposal.

- Variations in water surface in the Salton River concept could occur in the impoundment for this variation.

- Contaminants in the inflowing waters would not be diluted as they are in the present Sea and would tend to be concentrated by evaporation and other processes in the shorebird ponds. However, various water treatments are being considered for this alternative to combat this issue.

- Like the base proposal, temperature ranges would be more extreme in the impoundment than in the present Sea and oxygen depletion problems could be expected. These factors could lead to fish kills in the shorebird impoundments, particularly winter kills of tilapia.

- The food web in the impoundment would not change to a fresh water web and extensive growths vascular vegetation would not occur along the shoreline.
- Fish, bird and human diseases associated with water borne parasites, contaminants, and mosquitoes in the impoundment of the base proposal would be less of a concern in the marine environment in the North Lake proposal.
- Although air quality mitigation measures have been included, it is likely that these measures would not be able to fully mitigate the potential dust problems. Without measures such as the North Lake proposal, if the inflow to the Sea were reduced, large areas of sediment would be exposed in any case; however, with the North Lake proposal, the area exposed would be substantially greater.
- Shorebird and pupfish ponds in the southern area would provide bird habitat and connectivity of pupfish habitat. The retention of a marine environment in the central impoundment and in the Salton River impoundment may provide higher quality habitat for waterbirds and shorebirds, respectively, than those in the base proposal. However, from the information provided it is unclear how water depth could be effectively controlled in the narrow, peripheral band of the Salton River, to maintain adequate areas for shallow-flooded (0-10 cm of water) mudflats suitable for shorebird foraging and waterbird roosts. The loss of all existing breeding colony sites of waterbirds is not considered in this proposal.

4.1.3 Recreation and Economics

The peripheral impoundment would support a marine fishery, which would be directly accessible residents and others seeking recreational opportunities in the Salton Sea area. In addition, a stable shoreline would have significant benefits for both recreation and regional economics. Similar to North Lake alternative, preserving the fishery in the northern basin would have recreational benefits for fisherman, campers and other recreational users. The freshwater marsh habitat in the northern area would be a recreational asset to both bird watchers and hunters.

4.2 North Lake Variation

Since the first draft of this report was prepared, the RWQCB has proposed the variation to the North Lake shown in Figure 7. The northern lake component would offer the same advantages over the Salton River concept as those discussed for the North Lake alternative. However, the lake would be about 15 feet lower than the current elevation of the Salton Sea. It is likely that this reduced elevation would be unpopular with local residents. The lower lake level would save costs on the dam construction, and make the dam height lower and less susceptible to seismic failure. Some additional water quality improvements features are included in this variation. The additional cost of these features may offset the savings associated with a lower dam height, so that the costs would be comparable.

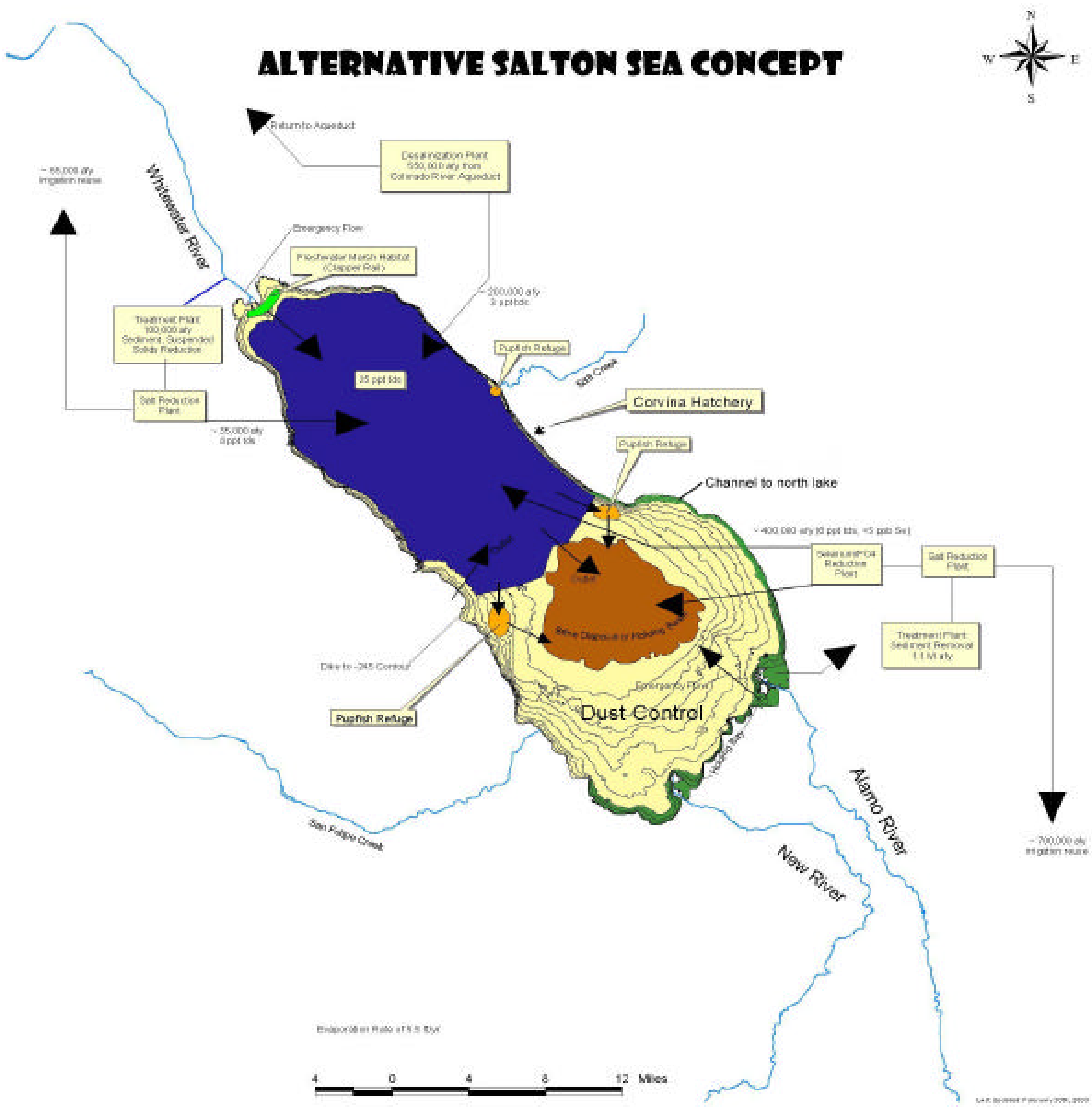

Figure 7. Conceptual Layout for Variation to the North Lake Proposal.

At the current conceptual level of analysis, this variation is similar enough to the North Lake alternative to make distinguishing comments difficult. It does, however, offers some variations that are worthy of further considerations should a more detailed engineering analysis and design be conducted.

4.3 Other Variations

Other variations to the US Filter proposal have been suggested. One suggestion involved placing the treatment plant at the south end of the Sea so that the water in the peripheral impoundment around one side of the Sea would contain fresh clean drinking quality water. The water in the impoundment around the other side of the Sea would convey the brine from the treatment plant and could be managed as a marine environment. The biggest challenge with this arrangement would be that there would be evaporative losses in the channel from the south to the north. In addition, there would likely be water quality degradation in the freshwater impoundment because of local agricultural runoff and re-entrainment of salts or other contaminants in the sediments.

Other variations will be evaluated as they emerge, including a proposal from staff of the US Fish and Wildlife and several variations proposed by US Filter.

APPENDIX A: ENGINEERING AND COST EVALUATION OF DIKES

January 22, 2003

Salton Sea Authority
Mr. Tom Kirk
La Quinta, California

Bureau of Reclamation
Salton Sea Project Manager
Mr. Michael Walker

Yuma, Arizona

Reference: December 17, 2002, Salton Sea Work Shop Assigned Action Item – Appraisal Grade Cost Estimates for Salton-Sea Mid-Sea Impervious Dam and Impervious Perimeter Dike

Gentlemen:

The individuals (Group) assigned to the Action Item, Mr. Leo Handfelt (URS), Mr. Michael Clinton (Consultant to Authority) and Mr. Jack L. Delp (Consultant to Reclamation) with assistance from Steve Fitzwilliam (URS), Paul Weghorst (Reclamation TSC) and Mike Gobla (Reclamation TSC) followed the guidelines as written in the Action Item in Attachment A. The Action Item requested our Group make appraisal grade estimates for costs to construct a Salton Sea Mid-Sea Dam and Perimeter Dike.

Our Group considered three different Mid-Sea Dam Design Concepts; the estimated costs for these concepts range between $1.0 billion and $2.5 billion. The Perimeter Dike cost is estimated at $3,800 to $5,400 per foot or $1.8 billion to $2.6 billion for constructing it along the entire perimeter of the Salton Sea.

Described below is an explanation of the means and methods the Group followed to achieve the above cost estimates.

Background

Because of the short duration of the study, no in depth review of previous materials or information compiled on the Salton Sea was undertaken. However, it was noted that the 1974 Salton Sea Alternatives Report, Final Reappraisal Report (1974 Report) included geologic and geotechnical information based on drill holes completed in the southern portion of the Sea, which was obtained in 1972. This information indicated that the materials encountered below the bottom of the Sea included a top layer of organic muck ranging up to 16 feet in depth. Below this material were Lake Cahuilla lacustrine deposits of soft to hard clay with interbeds of silts and sands to the maximum depths explored. This information was given consideration during development of conceptual designs by the Group.

Another Report that was of interest was the Salton Sea Alternatives Final Pre-appraisal Report, dated November 12, 1998, which include Reclamation's conceptual designs for Static Dike Design and

Seismic Dike Design, both designs for a mid-sea barrier. It was noted that both of these design concepts were developed with understanding the dam would see minimum differential between the Sea level on the north and south sides of the dam. The Report also included a statement that the Static Dike Design, which considered construction in the wet, involves a high degree of risk of failure. The Seismic Dike Design required the section of the Sea be dewatered during construction.

Defining Mid-Sea Dam and Perimeter Dike Concepts

December 30, 2003, our Group convened in San Diego at the URS office to brainstorm different design concepts for construction of a mid-sea dam near mid-point of Salton Sea and for construction of a perimeter dike that would be located at an elevation that would retain a 10- or 15-foot depth of water, similar to the US Filter concept. Because of the short time period to complete the Action Item, our Group set the objective to have concepts identified by the end of the meeting and allow the development of cost estimates and preparation of report for remainder of scheduled time.

The Group acknowledged that the soil foundation conditions below the Salton Sea at the proposed location for the Mid-Sea Dam are an undefined and critical design element. The Mid-Sea Dam conceptual designs assumed that soft foundation conditions similar to those identified in the 1974 Report are present throughout the Salton Sea. The ultimate Sea design elevation is considered to be Elev. -230 feet MSL and the Sea bottom elevation at lowest point considered to be Elev. –271 feet MSL. Minimum road width will be 30 feet and the top of the dam or dike will be at elevation –225 feet MSL, allowing for 5-feet of freeboard. The design was to consider the dam and dike to be impervious. After construction of the proposed dam, the Sea should be considered to maintain a Sea elevation of -230 feet MSL on one side of the dam and the other side of dam the Sea elevation should be considered to reduce to an elevation near – 270 feet MSL in about a 10 year period.

The Group selected a tentative location for the Mid-Sea Dam (Figure 1), which is from the west shore of the Sea, about ¼-mile south of the City Limits of Salton City, to the east shore of the Sea, about two miles north of Bombay Beach, a total length of about 45,000 feet, or over eight miles in length. This location minimizes the length of the structure as well as the evaporation area of the remaining part of the Sea.

At the conclusion of our Group's brainstorm session, three Mid-Sea Dam Concepts were developed and one Perimeter Dike Concept was selected. These concepts would be taken forward and related appraisal grade cost estimates developed. Mid Sea Dam Concepts consisted of (1) Reclamation's Seismic Dike Design presented in the 1998 Report; (2) Steel Sheetpile Cellular Dam with a Compacted Earth Dam constructed on one side of the cellular dam when that side of the Sea becomes dewatered; and (3) Dumped Fill Dike with Slurry Wall. The Perimeter Dike Concept would be a Vinyl Sheet Pile buttressed with dumped rock for stability.

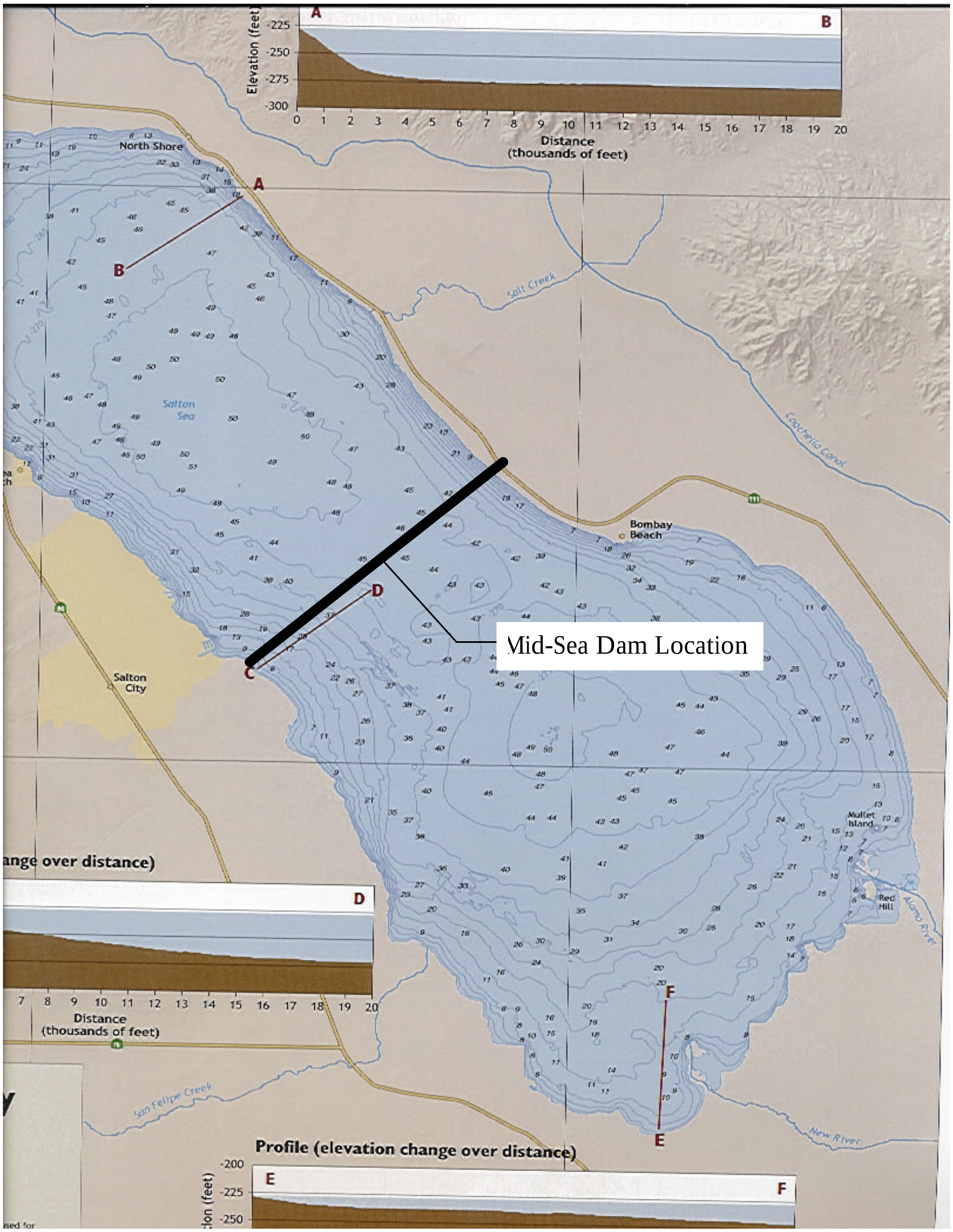

Figure 1. Location of Mid-Sea Dam

Brief Description of Concepts

Mid-Sea Seismic Dike Design

This concept consists of a conventional dam embankment built "in the dry" with the embankment materials compacted to a density high enough to withstand earthquake loading. Initially a 10-foot thick layer of soft "muck" would be hydraulically excavated from the work area. Next, two rows of sheet-pile cofferdams would be installed from barges and their ends connected to enclose a 2,000-foot long by 800-foot wide work area. After placing the steel sheet-pile, the cells would be filled with sand and gravel to establish the temporary cofferdam. The 2,000 foot long enclosed segment of the Sea and the cofferdam cells require one billion gallons of water to be removed to allow access to a dry work area. Next, an additional 15 to 25 feet of soft foundation material would be removed to limits exceeding the foundation area of the dam.

A thick mat foundation (roller compacted concrete or soil-cement) would be placed to fill the initial over excavated area and to provide a firm foundation for dam embankment construction. The top of dam will be at elevation –225 feet MSL, allowing for 5 feet of freeboard, and have 3:1 (horizontal: vertical) side slopes. A conventional zoned embankment consisting of sand and gravel with a silt / clay core and filter would be placed in 1 foot thick horizontal layers and be compacted. The process would be repeated in "leap frog" fashion by placing additional cofferdams out ahead of the initial one. Once all construction is completed in the first cell, cofferdam steel would be reused and the work area around the new dam segment would be flooded. Three 2,000 foot long cell segments would be required to allow the various activities to operate without interruptions. It is anticipated that the sheet pile could only be reused twice and then new steel is required. At the end of construction, all remaining sheet pile and the sand and gravel cell filling would be removed from the Sea and disposed of.

The embankment would be instrumented and monitored. The embankment would be expected to experience some settlement requiring periodic rises to the crest of the dam.

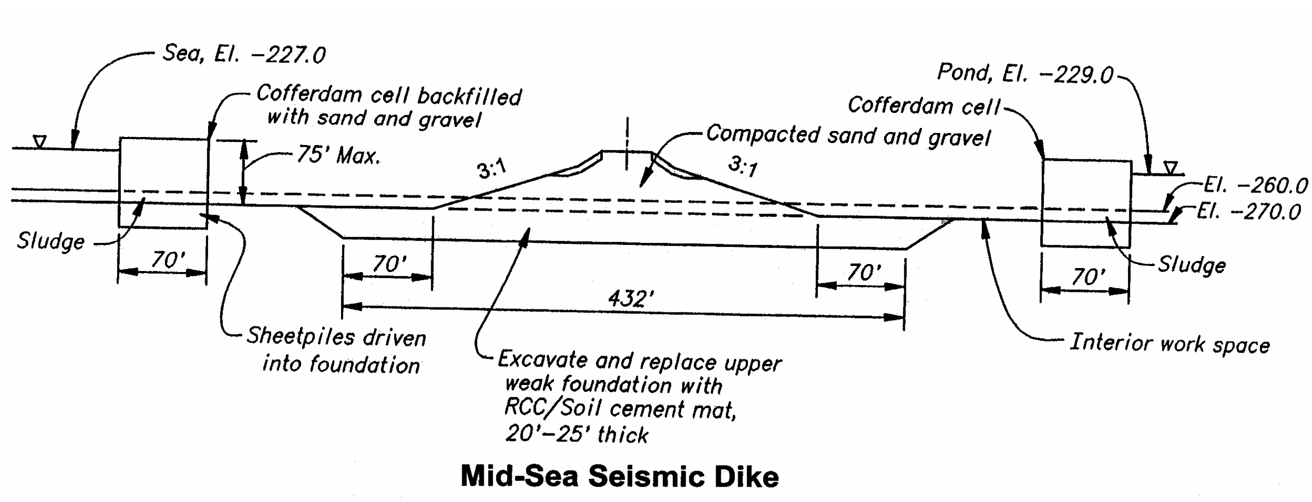

Figure 2. Cross Section of Mid-Sea Seismic Dike

Mid-Sea Compacted Earth Dam

This concept is shown in Figure 3. Initially, a sheet pile dam would be constructed by driving sheet piles in arcs with connecting sheet piles. The interior of the cells would be backfilled with either hydraulically-placed or end-tipped fills. These fills (and the underlying soft/loose seafloor sediments) would then be densified to increase their shearing resistance and mitigate their seismic liquefaction potential. We would anticipate this could be done using vibroreplacement (also known as stone columns). The cofferdam was sized to be stable with a top elevation of –225 feet MSL (allows for 5 feet of freeboard above a Sea level of –230 feet MSL) and an over-excavation of soft soils on the "dry" side as discussed below.

This structure would then serve as a temporary dam while one side of the Sea is allowed to dry out. However, due to the corrosion potential of the steel sheet piles, there is a concern on the longevity of this design. Therefore, a compacted earth fill embankment would be constructed against the cofferdam on the "dry" side of the cofferdam. A geomembrane placed between the cofferdam and the compacted embankment would serve as the permanent hydraulic barrier. The compacted embankment would be constructed with a downstream inclination of 2½:1 (horizontal: vertical). We had discussed using roller compacted concrete (RCC) for this embankment but had decided on the compacted earthen embankment with geomembrane due to its potential to better accommodate foundation settlements and possible lateral fault displacements.

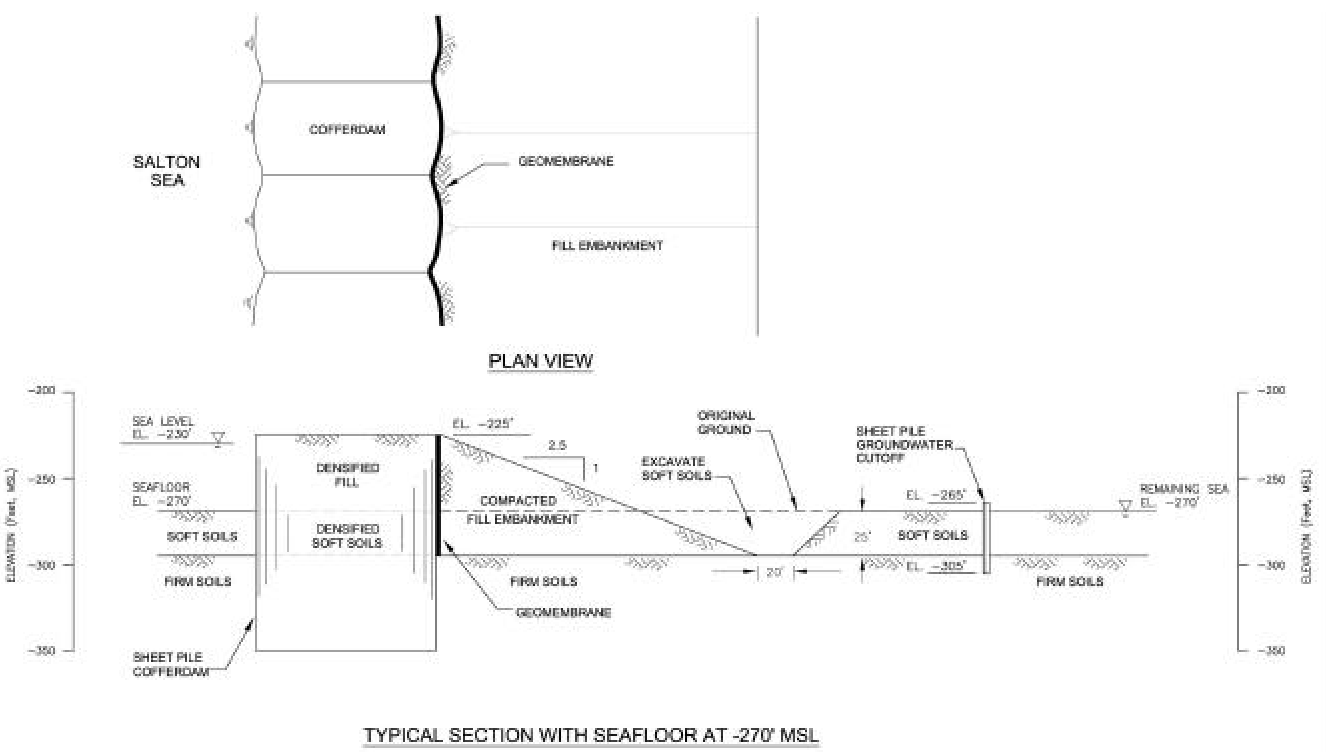

Figure 3. Mid-Sea Compacted Earth Dam

We have assumed typical sections with seafloor elevations of –245, -260 and –270 feet MSL with corresponding over excavations of soft sediments of 5, 15 and 25 feet, respectively. These depths are consistent with assumptions that have been used for previous conceptual designs, but are not based on any site-specific subsurface information.

The Group estimates that the Sea surface on the "dry" side will never actually be lower than elevation –270 feet MSL. We have allowed that a line of sheet piles will need to be driven as a ground water cutoff for the conceptual designs that require an over excavation below elevation –270 feet MSL. The over excavation and embankment construction would then be completed in the dry with dewatering by sumping the infiltrating ground water.

Mid-Sea Dumped Fill Dike with Slurry Wall

This concept is shown in Figures 4. This concept consists of an earthen dike constructed by dumping fill into the Sea. The crest of the dike would be 30 feet wide (consistent with previous conceptual designs for in-Sea embankments) with a top elevation of –225 feet MSL (allows for 5 feet of freeboard above a Sea level of –230 feet MSL). Again, three typical sections have been assumed with seafloor elevations of –245, -260 and –270 feet MSL with corresponding over excavations of soft sediments of 5, 15 and 25 feet.

End-tipping the fills would result in embankments with side slopes at the angle of repose (i.e. incipient failure). The embankment side slopes are designed to be 6:1 to mitigate seismic instabilities and wave erosion. This will require placement of the fill materials beyond the angle of repose with barges or gantry conveyors. With such flat slopes it is anticipated that strong seismic shaking would induce a slumping of the embankment rather than a catastrophic failure. The upstream side of the dike would be rip-rapped for wave protection.

Before one side of the dike is allowed to dry out, a soil-cement-bentonite slurry wall would be constructed along the centerline of the embankment as the hydraulic barrier. We have assumed a slurry wall 3 feet thick and extending 20 feet below the bottom of the embankment as sufficient to mitigate potential internal erosion (piping) failures.

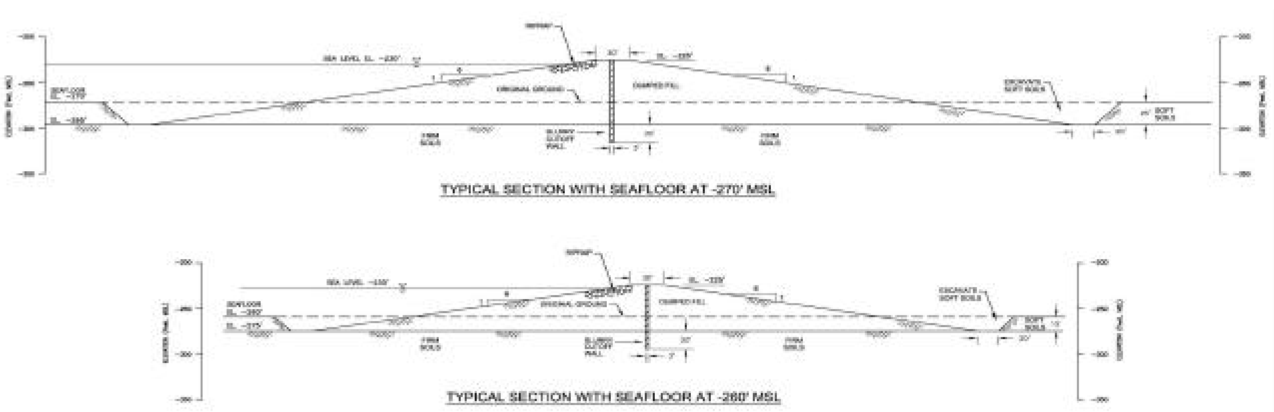

Figure 4. Mid-Sea Dumped Fill Dike with Slurry Wall

Perimeter Sheet Pile Dike

The concept for the Salton Sea perimeter dike at a 15-foot water depth is shown in Figure 5. The concept for a 10-foot water depth would be similar. This concept includes a hydraulic barrier constructed of vinyl sheet piles. These sheet piles would be suitable for the lower hydraulic heads involved with the perimeter dike and would be corrosion resistant. The top of the sheet pile wall would be at elevation of –225 feet MSL to allow for the 5 feet of freeboard.

The sheet pile wall would be buttressed with rock to provide stability. We have assumed an over excavation of 5 feet of soft sediments below the seafloor. The rock would be placed by barge with side slopes of 2:1 and should be seismically resistant. A minimum crest width of five feet has been assumed. The length of the perimeter dike would be 94.5 miles at the –240 foot MSL contour (10 feet of water), and 92 miles at the –245 foot MSL contour (15 feet of water).

We have assumed a sheet pile embedment below the over excavation equal to the height of the dike as sufficient to mitigate potential piping failures. Overflow weirs could easily be incorporated into the dike by having the tops of the sheet piles at elevation –230 feet MSL at various locations around the perimeter.

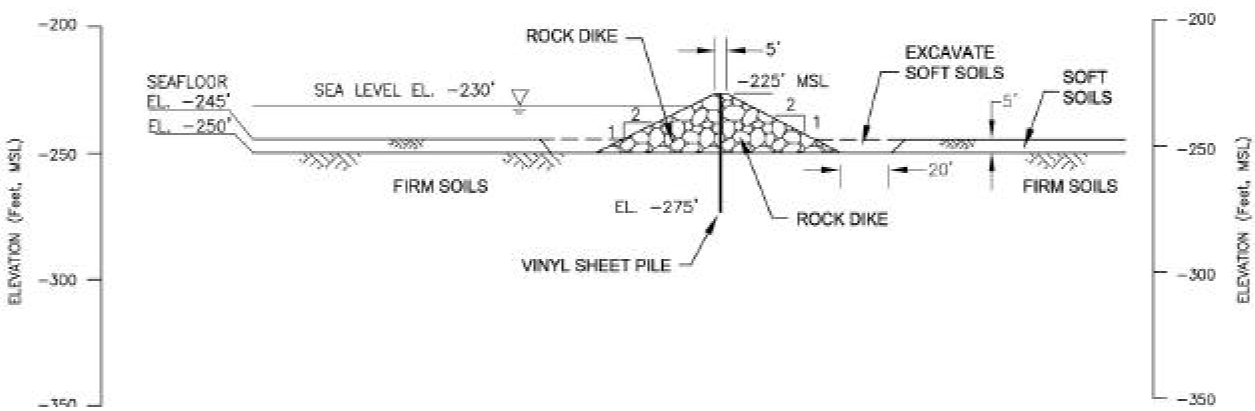

Figure 5. Perimeter Sheet Pile Dam (in 15 feet of water)

Estimated Appraisal Level Costs for Each Concept

Appraisal level cost estimates were developed for the above conceptual designs of the mid-Sea dams and perimeter dikes. Quantities of the major components of the construction were estimated by multiplying the quantity in a typical section by the applicable length of the dam or dike. A summary of these quantities is shown in Table 1.

Unit costs for earthwork similar to those used in appraisal level cost estimates of other alternatives were applied to the quantities to estimate the appraisal level costs. Unit costs for other items (e.g. cofferdam, roller compacted concrete, slurry wall, etc.) were based on discussions with specialty contractors, bid prices from recent similar projects, and published cost information. The appraisal level cost estimates (in present day dollars) for the concepts studied are also shown in Table 1. The construction costs shown include mobilization (at 5 percent) unlisted items (plus 15 percent), contingencies (plus 25 percent), and non-contract costs (plus 33 percent). This is consistent with what has been applied to previous appraisal level cost estimates.

It is anticipated that the Mid-Sea Compacted Earth Dam would be constructed about 10 years after the cofferdam had been completed. This is to allow for one side of the cofferdam to dry out. A net present value of this concept was calculated by separating the costs associated with the earthen dam in this concept and delaying their expenditure until Year 10 of a 30 yr design life. This net present value is shown in Table 1. No operating and maintenance costs have been included in any of the alternatives.

Table 1. Summary of Conceptual Designs and Appraisal Level Cost Estimates

Item	Mid-Sea Seismic Dike	Mid-Sea Compacted Earth Dam	Mid-Sea Dike with Slurry Wall	Perimeter Dike (in 10' water)	Perimeter Dike (in 15' water)
Length (feet)	45,000	45,000	45,000	499,000	485,900
Length (miles)	8.5	8.5	8.5	94.5	92.0
Sheet Piles (sq ft)	20,073,000	19,494,000	na	na	na
Cofferdam Backfill (cy)	15,552,000	5,695,000	na	na	na
Ground Improvement (cy)	na	8,633,000	na	na	na
Dewatering (months)	60	na	na	na	na
Over excavation (cy)	29,700,000	6,002,000	27,022,000	12,012,000	13,496,000
Embankment (cy)	12,700,000	7,293,000	37,800,000	na	na
Geomembrane (sq ft)	na	2,516,000	na	na	na
Rip Rap (cy)	535,000	na	500,000	na	na
Slurry Wall (sq ft)	na	na	3,416,000	na	na
Rock Fill (cy)	na	na	na	16,632,000	24,743,000
Vinyl Sheet Pile (sq ft)	na	na	na	19,958,000	24,293,000
RCC Cement Pad (cy)	18,165,000	na	na	na	na
Construction Costs	$2,527,000,000	$1,381,000,000	$1,048,000,000	$1,881,000,000	$2,637,000,000
Cost/lineal foot	$56,000	$31,000	$23,000	$3,800	$5,400
Net Present Value[a]	$2,527,000,000	$1,165,000,000	$1,048,000,000	$1,881,000,000	$2,637,000,000
NPV/lineal foot	$56,000	$26,000	$23,000	$3,800	$5,400

Conclusions

The three Conceptual Designs developed for the Mid-Sea Dam and the single Conceptual Design for the Perimeter Dike for the Salton Sea were developed from information made available in conjunction with the experiences brought to the Group by each member and assistance provided by associates in the subject matter. The costs generated for each concept must be considered to be appraisal grade estimates.

The costs estimated for the perimeter dam are much higher than the $480 million estimated by US Filter for the dikes in their concept. They had used a cost of $6 million per mile and 80 miles of dike constructed in 10 feet of water based on a previous estimate by Parsons. However, that dike design had assumed no differential water head across the dike. The Group's conceptual design for a hydraulic barrier along a 92 to 95 mile perimeter is $20 to $29 million per mile.

Any refinement of these costs will require geotechnical investigations at potential sites and further feasibility level engineering studies. A major unknown is the embankment foundation conditions below the Salton Sea. This unknown has a major impact on the amount of over excavation that would be required, and the long term performance of the dam embankments. The costs for the over excavation and backfill account for 44, 15, and 64 percent of the construction costs for the Mid-Sea Seismic Dike, Compacted Earth Dam, and Dumped Dike concepts, respectively. The over excavation and backfill costs account for 26 to 30 percent of the perimeter dam costs.

Submittal of Report

The information and appraisal grade estimates included in this document are being submitted to the Salton Sea Authority, Mr. Tom Kirk and to the Bureau of Reclamation Salton Sea Project Manager, Mr. Michael Walker, as requested December 17, 2002, at Salton Sea Work Shop held at McCarran Airport Conference Room 6B. This report is hereby submitted jointly by the following:

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ATTACHMENT A

SALTON SEA RESTORATION PROJECT
DECEMBER 17, 2002 WORKSHOP
MEETING ROOM 6B McCARRIN AIRPORT

Assignment of Action Item For

Development of cost estimates for Dam Construction
and for dike construction within Salton Sea Waters

Completion date January 15, 2003

1. Salton Sea Authority Manager Mr. Tom Kirk and Reclamation's Project Manager assigned to Salton Sea Project, Mr. Michael Walker jointly assigned action item to Mr. Leo Handfelt (URS), Mr. Michael Clinton (Consultant to Salton Sea Authority) and Mr. Jack L. Delp (Consultant to Reclamation) to develop and provide cost studies for the construction of a dam that will divide the Salton Sea and for construction of perimeter containment dikes along the Sea Shoreline. Jack L. Delp assigned to coordinate the effort.
2. Proposed Salton Sea Dam. The location of the Dam, for estimating purposes, shall be located approximately near the mid-point of the Sea looking in a north-south direction. The proposed Dam construction shall be considered with assumption the Sea elevation will be at elevation -230 feet. Function of the Dam will be ultimately to allow the containment of Sea waters to the north and allow south portion of Sea to lower to a full dewatered state. Dam design assumptions to be consistent with established design standards for the location and conditions anticipated at the sight based on current information known. Alternative solutions to construction of the proposed Dam invited.
3. Proposed Salton Sea containment Dikes. The locations of these dikes for estimating purposes are to be initially constructed within the Sea along the shoreline up to a maximum depth of 15-feet. As the Sea recedes the dikes will become exposed on the Salton Sea side and waters received from inflow sources will accumulate and be able to flow to a point the inflow water may be delivered to a Desalting facility (Anticipated to be at the north or south end of Salton Sea) or to an overflow structure where the water may continue to flow to the Sea, at an estimated elevation of -257 or for other uses (irrigation of exposed Sea bottom). Alternative solutions to construction of proposed dikes invited.
4. Documentation shall be included in the report that defends assumptions, criteria, and estimates generated and included in report.
5. Deliverable shall be in the form of a report providing estimated costs for the construction of a Dam near the north-south center of the existing Salton Sea and for the construction of shoreline containment dikes. The cost for the containment dikes will be such that cost may be generated based on length of dikes proposed (Linear Foot Price).

APPENDIX B: EVALUATION OF PIPELINE AND PUMPING COSTS

Water would need to be pumped from the Salton Sea to the Colorado Aqueduct, a distance of 12.7 miles, with an elevation gain of 1,984 feet, from -227 feet below mean sea level to 1,757 feet above sea level. Arthur Streifel with the pipeline group at the US Bureau of Reclamation office in Denver, CO prepared a conceptual-level estimates for the costs of construction, operation, maintenance and energy for such a pipeline. The cost estimate worksheet is provided on the following page.

CODE:D-8140

ESTIMATE WORKSHEET

SHEET__1__ OF __1___

FEATURE: **25-Jan-03**

Salton Sea to
Colorado River Aqueduct
500 kaf/year (691 cfs)

PROJECT:

DIVISION:

UNIT:

C:\Data 2002\Excel\Salton\Mid Sea & US Filter\[USF Pumping Costs.xls]Costs

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization and preparatory work	8140		LS		$ 12,000,000.00
		Pumping Plant, 691 cfs, 500 ft. TDH	8140	4	EA	$31,100,000.00	$124,400,000.00
		Pipe, 144B500 (no special liner)	8140	67,000	FT	$1,600.00	$107,200,000.00
		Excavation, common	8140	1,900,000	CY	$2.50	$4,750,000.00
		Compacted Backfill, common	8140	360,000	CY	$3.00	$1,080,000.00
		Backfill, common	8140	1,200,000	CY	$1.25	$1,500,000.00
		Backfill, bedding	8140	200,000	CY	$12.00	$2,400,000.00
		Subtotal					$ 253,330,000.00
		Unlisted Items	+/-	15%			$36,670,000.00
		Contract Cost					$290,000,000.00
		Contingencies	+/-	25%			$70,000,000.00
		Field Cost					$360,000,000.00
		Noncontract Costs	+/-	33%			$120,000,000.00
		Construction Cost					$480,000,000.00
		ANNUAL COSTS					
		O.M, & R Pumping Plants					$1,860,000.00
		Pipelines					$80,000.00
		Energy					$66,500,000.00
						Total OMER	$68,440,000.00

QUANTITIES		PRICES	
BY Art Streifel	**APPROVED**	**BY** K. Copeland	**CHECKED**
DATE PREPARED 25-Jan-03	**DATE**	**DATE** 01/25/03	**PRICE LEVEL**

APPENDIX C: NEW FOOD WEBS

The discussion of food webs in the Salton Sea Science Office review of the Pacific Institute proposal is relevant to the US Filter proposal. The discussion from that paper has been modified slightly to apply to the US Filter proposal and to remove references to treatment wetlands that were part of the Pacific Institute proposal, but not part of the US Filter proposal. That modified discussion is presented below.

C.1 Algae

Algae would remain the major base of the food webs in the impoundment, though strongly supplemented by production by vascular plants and with macroalgae assuming a more important role than they have in the present Sea.

Phytoplankton. Phytoplankters that now dominate in the Sea are dinoflagellates, diatoms, and raphidophytes. The impoundment would likely be dominated by chlorophytes (green algae) and cyanobacteria (blue-green 'algae'). This shift in composition would result from the fact that few dinoflagellates and raphidophytes tolerate salinities as low as 2-4 g/L, and the fact that reduced turbulence in the impoundment would make it more difficult for diatoms to remain suspended in the photic zone. Their silica frustules make them susceptible to sinking in quiet waters.

In general the short residence times would tend to favor dominance by small phytoplankton species capable of rapid growth. Species present in inflow waters would be especially favored as they would be continuously being inoculated into the impoundment.

Total phytoplankton abundance, measured as biomass per liter, could be either lower or higher in the impounded areas than in the corresponding areas of the present Sea. As discussed in the section on turbidity, some factors would tend to favor higher levels and others lower. At present, phytoplankton densities in these shoreline areas are typically much higher than in offshore waters.

Macroalgae. Abundance and diversity of macroalgae would be greater in the impoundment than in the present Sea, as a consequence of lowered salinity, reduced wave action, and increased areas of hard substrate. These would include green algae such as Enteromorpha, Cladophora and other filamentous forms that would form floating mats in quieter areas, attach to solid substrates, including dam faces, and possibly accumulate as drift on shorelines when they die or are pushed there by waves. Stoneworts such as Chara or Nitella, with rhizoids anchoring them to sediments, may also appear. And microbenthic cyanobacteria would also be able to form thin algal mats on soft and hard substrates just as they do now in the Sea.

Abundance of these macroalgae would likely be strongly influenced by turbidity, which limits the depths at which they can grow, by wave action, and by grazing by certain fish, water birds and invertebrates. Faces of the new dams would presumably be of rock or concrete and their great linear extent would tremendously increase the abundance of attached macroalgae. The inner sides of the dams generally would experience much less strong wave action than do the dikes along the present southern shoreline of the Sea, allowing larger masses of macroalgae to develop on these inner sides than are now observed on the dikes.

Microperiphyton. This refers to the small algae of various sorts that are found growing on the surfaces of aquatic vascular plants, loosely or tightly attached to them. Such algae represent a food supply for a variety of aquatic invertebrates than cannot feed on the vascular plants themselves. Though inconspicuous, these small algae can take up nutrients rapidly from the water, thus competing with phytoplankton, macroalgae, and the vascular plants themselves. If abundant on plants in the impoundment they would tend to have a clarifying effect on the water column by reducing phytoplankton densities.

C.2 Vascular Plants and Shoreline Vegetation

Now almost absent from the Sea and its shorelines, vascular plants would become abundant in the impoundment and along their shorelines. An additional 100 miles of shoreline would become vegetated, although full development of this vegetation would take some years. These vascular plants would contribute large amounts of plant detritus to the shoreline ecosystem and new habitat for birds in particular. These plants would probably boost overall production of the system and represent an increased food supply for decomposers and detritivores. The detritus would also increase the organic matter content of sediments making them softer, 'muddier,' and more subject to anoxia.

Vascular plants are a group especially sensitive to salinity variations in the vicinity of the 3 g/L dividing line between fresh and saline systems. Many species that can thrive at 2 g/L cannot tolerate 5 g/L. Thus precise prediction of the new assemblages of vascular plants would require precise prediction of impoundment salinities and review of the literature on the ecophysiology of aquatic vascular plants in the region.

Three principal categories of vascular plants would be involved in this increase: submergent, floating, emergent, and terrestrial. These are discussed in turn.

Submergent vegetation. These are plants that are rooted in sediments and have all or most of the plant body beneath the water surface. Among species likely to colonize the impoundment would be those in the genera Ruppia, Potamogeton, Zannichellia, Hydrilla, Najas, and Myriophyllum. Ruppia and Potamogeton serve as food for some waterfowl species. Ruppia beds occurred in the Sea a few decades ago and were favored habitat of the sargo. Submerged vegetation serves as a substrate often colonized by microalgae and by invertebrates. It also creates structural complexity that provides invertebrates and smaller fish some protection from predation by larger fish.

Abundance of submergent vegetation would likely be sharply limited by turbidity, and by disturbance or grazing by common carp and the plant-eating Zill's tilapia (Oreochromis zilli) now restricted to freshwater influents. Some submergent species can root in sediments tens of feet deep and grow to the surface there if turbidity is low enough and light levels sufficient.

Invasion of the impoundment by the fast growing exotics Hydrilla (Hydrilla verticillata) and Eurasian watermilfoil (Myriophyllum spicatum) would be likely. Both species already occur in the region. The Imperial Irrigation District controls Hydrilla in canals and ditches in the Imperial Valley with sterile, triploid grass carp, and the California Department of Food and Agriculture and U.S. Department of Agriculture have a program to eradicate it from the state. Both are primarily freshwater species, but Hydrilla grows at salinities up to 7-10 g/L and watermilfoil in salinities up to 15 g/L. Once established in the proposed impoundment, neither species could ever be eradicated, given the great size of the impoundment. In the past, some California water bodies invaded by Hydrilla have been closed to recreational boating in order to prevent plant fragments from accidentally being transferred to other water bodies on boats or boat trailers.

Emergent vegetation. Emergent aquatic plants are those that are rooted in the lake bottom or on damp shorelines and whose photosynthetic and reproductive structures extend well above the water surface. Common types are cattails (Typha), bulrush (Schoenoplectus), common reed (Phragmites), and giant reed (Arundo). Some such plants can grow in water more than 10 ft deep, if they can get established, can extend more than 10 ft above the water surface, and can grow so densely as to form impenetrable thickets separating open water from terrestrial habitats. The dense emergent vegetation that grows along the edges of the lower portions of the New and Alamo rivers is rooted in water often 5-6 ft deep.

Now restricted to the immediate vicinity of the deltas and other inflow points of rivers and streams, emergent vegetation would start colonizing all impoundment shoreline areas with sandy or muddy substrates very soon after dams were completed. These vegetation beds would then tend to expand into deeper water, in large part by vegetative reproduction. This would probably be a slow process that went on for years before plants reached some depth beyond which they could not grow. This emergent vegetation could come to occupy up to 5 percent of the total areas of this shallow impoundment, tremendously increasing the extent of marsh habitat in the region.

The history of Ciénaga de Santa Clara in the Mexican portion of the delta gives an idea of what can happen. Once an apparently barren, 25 mile long, saline depression periodically inundated by ocean water, the whole northern end of the Ciénaga became a densely vegetated marsh of Typha, Schoenoplectus, and Phragmites once large volumes of 3 g/L wastewaters from Arizona agriculture began being diverted into this basin. Of course, this is a much shallower system, with maximum water depths on the order of 3 ft, than would be the Salton Sea impoundment.

As with submergent vegetation, the depths that emergent vegetation can colonize are likely to be limited by turbidity and the feeding and sediment-disturbing activities of carp. Some feel that this vegetation is unlikely to occur in water more than 3 ft deep. Even so limited, there would be important consequences.

For example, with the water surface of the southern impoundment set at –230 ft, the deepest water between Mullet Island and the southern shoreline would be about 4 ft. It seems likely that eventually a broad band of dense emergent vegetation would completely connect Mullet Island with the mainland. Over time this might become traversable by mammals, allowing access to this bird nesting island by foxes and coyotes. A major dredging operation could presumably prevent such access from developing.

Terrestrial vegetation. The shoreline of the Salton Sea is mostly devoid of terrestrial vegetation, with the exception of shorelines near points of surface or groundwater inflow. The primary reason for this undoubtedly is the high salinity of soils and soil porewaters near the lake’s edge.

Once the impoundment is created, their fresher waters, together with the occasional rainfall events of the region, would greatly reduce soil salinity along the shores of impoundment. This would lead to great increases in the abundance of terrestrial vegetation, which would abut or intermingle with the emergent aquatic vegetation developing in adjacent shallow water areas. Various grasses (e.g. Distichlis) and shrubs (e.g., Salicornia, Atriplex, Pluchea, and Baccharis) would colonize these shore habitats. Salt cedar (Tamarix) likely would be the tree species that would most successfully establish in these freshened areas, but other trees such as cottonwood (Populus) and willow (Salix) might succeed in some areas as well, especially if planted.

Taken together, the submerged, emergent and terrestrial vegetation that would develop along the impoundment shorelines would represent a great ‘greening’ of the shoreline ecosystem. There would be new forms of animal life, especially invertebrates and birds that could use this vegetation as physical habitat for roosting, nesting, or hiding, as food, or as a place to find food.

A band of vegetation, probably dominated by salt cedar, would develop along every channel connecting an overflow point on a dam to the margin of the residual Salton Sea. This assumes that these channels would be unlined except in the immediate vicinity of the outer faces of the dams. With numerous overflow points and channels, the vegetation bands created could reduce wind shear at the ground surface and entrainment of particulate matter into the atmosphere. The vegetation bands would also increase evapotranspirative water loss and reduce inflows to the residual Sea, however. That would accelerate salinity increase in the residual Sea and cause its equilibrium elevation and surface area to both be lower than predicted by current USBR models.

C.3 Invertebrates

In the impoundment, the numerically abundant, but species-poor invertebrate assemblage of the Salton Sea would be quickly replaced by a much more diverse assemblage. Key elements of the present food chain, such as the pileworm (Neanthes) and barnacle (Balanus) would disappear completely, while a few elements might persist, e.g. the copepod (Apocyclops), the rotifers (Brachionus, Synchaeta), and the amphipod (Gammarus).

Large numbers of new species of crustaceans, insects, oligochaete worms, mollusks, flatworms, rotifers and nematodes would colonize the water column, the sediments, and the surfaces of aquatic plants. A long species list could be compiled from studies of other marshes and lakes in California or the Southwest with salinities of 2-4 g/L. It would not be possible to predict the absolute and relative densities of these new invertebrate species. They would depend in part on complex food web interactions, such as predation on invertebrates by fish and birds in the new ecosystem.

Increased abundance and diversity of shoreline vegetation would be accompanied by large increases and diversity in the abundance of terrestrial invertebrates, especially insects and other arthropods (e.g. spiders, mites), relative to what now can be found along the mostly barren shorelines. Some of these arthropods may feed directly on green plant tissues. Others may be detritivores. Detritus produced by this vegetation would create shallow water sediments and shoreline soils rich in organic matter, and this can serve as the base for detritus-based modules of the overall food web.

The impoundment likely would increase abundance of biting insects in the vicinity of the Sea. These could include mosquitoes (Culicidae), biting midges (Ceratopogonidae), and horse flies (Tabanidae). Aquatic larvae of the mosquito

Culex tarsalis are common at the margins of vegetated water bodies in the Salton Sea region, including shallow pools among salt cedar and salt grass on the margin of the Sea itself. This mosquito is a vector of western equine encephalomyelitis and St. Louis encephalitis. Another local mosquito species, Culex erythrothorax, is a very aggressive biter and found abundantly in cattail beds, but is not a known disease vector.

The structural complexity provided by the stems and foliage of submerged and emergent vegetation would provide mosquito larvae and other invertebrates significant refuge from fish predation. In general fish-inhabited marshes are major breeding grounds for mosquitoes, both in coastal and inland areas. Slight fluctuations in water level as occur seasonally or as a result of seiches or wave action at the Sea are significant creators of mosquito breeding pools free of fish and other predators.

Biting midges and horseflies breed in damp soils with moderate to high levels of organic matter, often near the margins of bodies of fresh water. Their increase would seem highly probable, but it is not possible to predict whether or not this would be to levels representing a significant nuisance to persons visiting or living near the impoundment areas.

C.4 Fish

The fish assemblages that would develop in the impoundment would be radically different from the present one in the Sea. Corvina, sargo, bairdiella, and long-jaw mudsucker would disappear. Mozambique tilapia would persist as would threadfin shad, mosquito fish, mollies and mullet. Almost all of the freshwater exotics found in the Coachella, Imperial, and Mexicali valleys would eventually find their way into the impoundment and establish permanent populations. These include common carp, catfish, largemouth bass, sunfish, Zill's tilapia, and shiners. The triploid sterile grass carp used for weed control in agricultural drains could also invade though they should not be able to reproduce. It might be predicted that the fish assemblage would be dominated by the tilapias, threadfin shad, carp and catfish, as these feed predominantly near the bottom of the food web. Large mouth bass could become one of the more popular sportfish.

The abundances of the different species would exert strong influences on each other and on other components of the impoundment ecosystems via predation, disturbance of the sediments, and, in the case of carp and Zill's tilapia, grazing of macroalgae and aquatic vascular plants.

Fish production on a per unit area basis might be lower in the impoundment than in the corresponding portions of the present Sea. The major reason for this is that fish presently in these near shore areas are recipients of advected food supplies, e.g. plankton, that are produced over the entire area of the Salton Sea. During the warmer half of the year, these food supplies are not consumed in the central 80 percent of the lake because almost all fish move into the near shore areas.

On the other hand, some factors would tend to offset the above to some extent. These would be the greater variety of fish present, and hence of foods utilized, feeding modes, and microhabitats utilized, and less physiological stress caused by salinity, leading perhaps to greater and more regular reproductive and recruitment success.

Total fish production for the region (excluding aquacultural production) would be drastically reduced as the proposed impoundment would represent, at most, only 12 percent of the area of the present Sea.

Habitat of the Desert pupfish, an endangered species, might be somewhat compromised. Retreat of the margin of the residual Sea would make impossible movement through the Sea of individuals moving from one drain or creek to another, though it is uncertain how important such movements are. The high diversity of exotic freshwater species in the impoundment might increase the likelihood of some of them invading pupfish habitats such as San Felipe Creek and reducing their numbers via predation or competition.

C.5 Amphibians and Reptiles

Soft-shelled turtles have been seen in the New and Alamo rivers and doubtless would colonize the impoundment. Bullfrogs occur in the region, and used to be collected for food in the Rio Hardy when it was in better condition. The African clawed frog is now widespread in southern California and doubtless would colonize the impoundment. Toads and tree frogs might use the impoundment for breeding. Abundance of amphibians would be closely tied to the nature of aquatic vegetation present, as this would be needed as critical refuge from piscine and avian predators. Amphibians especially are likely to be sensitive to many aspects of water quality.

C.6 Birds

The avifauna of the region would be markedly affected by the creation of impoundment and by the rise in salinity of the residual Sea that would ultimately preclude the presence of fish. Some types of birds would become more abundant, others less abundant. Changes would reflect changes in available habitats and food supplies. The discussion below focuses on predicting changes for four major categories of birds.

Users of shoreline vegetation. The predicted large increases in shoreline and shallow water vegetation could lead to increased abundances of some species of birds that could use this habitat type for nesting, roosting, or feeding, such as passerines (blackbirds, wrens, warblers, and sparrows), waterfowl and coots, and perhaps rails and bitterns. Tall salt cedar stands might be attractive to nesting herons and egrets provided that they were sufficiently isolated by water and inaccessible by predators. There might be pressure from duck hunters to manage vegetation and water level so as to create optimal waterfowl habitat.

All arboreal nesting waterbirds (herons, egrets, cormorants, ibis) except one species, the Cattle Egret, are highly unlikely to utilize stands of mature trees not isolated by water, and therefore accessible to terrestrial predators and other disturbances at the Salton Sea. Stands of landlocked trees, unless very mature and dense, may even fail to attract roosting herons and egrets. While increases in some aquatic and terrestrial vegetation types along the Salton Sea shoreline may provide additional resting and feeding habitat for species that are migratory, only a limited number of species (Yuma Clapper Rail, Least Bittern, Black-crowned Night-heron, Abert's Towhee, Song Sparrow, Marsh Wren, Verdin, Common Yellowthroat, Red-winged Blackbird, and Yellow-headed Blackbird) would use the vegetation for nesting. The gain in aquatic and terrestrial vegetation favored by passerines, rails and waterfowl would hardly offset the loss of the open and shallowly flooded mudflats usurped by this new growth, and of the species rich and abundant shorebirds that require it.

Aerial feeders. Production of insects with aquatic larvae and aerial-terrestrial adults is now essentially zero in the Sea. This production would likely be high in the impoundment though strongly influenced by fish predation. Adults of non-biting midges (Chironomidae) and perhaps mosquitoes (Culicidae) would be especially abundant and likely to attract more flycatchers, swallows, swifts, and nighthawks to the skies above the impoundment.

Feeders on aquatic invertebrates. We distinguish three categories: wading shorebirds (e.g. avocets, stilts, dowitchers, godwits, etc.), beach runners (e.g. sandpipers, plovers), and open water feeders (eared grebes, Wilson's phalaropes, shovelers, ruddy duck, etc.).

We would expect to see reduced abundances in the impoundment of the first two categories as the open shoreline and mudflat areas they utilize would eventually be taken over by dense shoreline vegetation. The open water feeders would probably also be less common as we would predict that the diverse fish assemblage in the impoundment would result in lower overall density of macroinvertebrates of the types these birds feed on.

At least some of these feeders on aquatic invertebrates would be likely to find, at least for a many years, increased food supplies in the residual Sea that would be left to become fishless. Once it was fishless, the dominant invertebrates there would be copepods (Apocyclops), water boatmen (Trichocorixa) and brine flies (Ephydra). Only after salinity became high enough (> 80-100g/L) to eliminate the copepods and waterboatmen would brine shrimp (Artemia) become abundant, as the first two are predators on the latter.

Fish-eating birds. In general these would become very much less abundant in the region, even though some individual species might come to have higher densities in the impoundment than they do in the current corresponding portions of the Sea. Fish-eating birds, such as egrets and herons that like quiet water and are willing to use vegetated marshy areas might become more abundant in the impoundment than they are now along the Sea's southernmost and northernmost shorelines.

The Double-crested cormorant and the two pelicans would be likely to become less abundant even in the areas to be impounded, once the main part of the Sea became fishless, even if fish production per unit area were high in the impoundment.

The cormorant would be affected by loss of Mullet Island as a nesting area, if this became connected to the mainland by filling in of shallow water areas with vegetation, as described earlier.

For the Brown pelican, the Salton Sea is a novel and not critical habitat. This species is essentially marine and nests on islands in the Sea of Cortez, though it has unsuccessfully attempted to nest at the Salton Sea in recent years. With reduction in abundance of fish in the region and elimination of attractive nesting areas, this species would likely occur in fewer numbers and might tend to abandon the area altogether. Though this would represent a loss of diversity, it would not necessarily represent significant damage to that species.

The scenario would be different for the White pelican. This species is severely reduced in number in the West perhaps because of disappearance and degradation of shallow lakes in the western U.S. and northern Mexico in general. The Salton Sea is one of the most important wintering and stopover points on the migration route of this species. Thus, significant negative impacts on the species could follow the elimination of 88 percent of the Salton Sea as fish-producing habitat. Also, areas that the pelicans currently use for loafing – small islands, sand spits, etc., though not Mullet Island – would no longer be suitable for this purpose once these areas are occupied by dense vegetation following freshening of impoundment and soil porewaters. Though vegetation beds offshore or around islands can be used for loafing, and even nesting, by pelicans, most of the new vegetation beds would be near the shoreline and accessible by terrestrial predators.

Greater diversity of small fish – mosquito fish, shiners, mollies, and young of the numerous larger species, especially tilapia – would likely represent a more diverse food supply for smaller fish-eating birds, such as terns, black skimmers, and western grebes. The balance expected among species and size classes would be difficult to predict. Predation by the larger fish present, such as large mouth bass, would have much influence on this. Whether overall abundance and availability of small fish would be greater or lesser than in these shallow areas of the present Sea would also be difficult to predict.

Nesting habitat. Mullet Island, currently isolated by water from the mainland and therefore inaccessible to mammalian predators, has been an important nesting site for several species of colonial breeding ground nesters. Species such as Caspian and Gull-billed Terns (two federal species of concern) and Black Skimmers frequently breed on the island in addition to Double-crested Cormorants and occasionally, the Brown Pelican.

Snags, the remains of trees killed decades ago by rises in level of the Salton Sea, are found in shallow water at many locations around the margins of the Sea. They are used for nesting and perching by herons and cormorants, because like Mullet Island, they are isolated from the mainland and largely protected from predation by mammals. These snags would be stranded far from the water if the level of the Sea dropped as predicted, and the loss of this protective isolation would probably herons and egrets to abandon these sites.

The margins of the residual Sea and/or the upper surfaces of the dams potentially could be used as nesting areas by species that are not strongly colonial. These species include Snowy plovers, Black-necked stilts, American Avocet and Killdeer. However, Caspian terns, Black Skimmers, Double-crested cormorants, and other colonial species would be less likely to establish nest sites on these surfaces, unless they were free from disturbance by predators and humans during the nesting season.

APPENDIX D: DISEASE AND WATER-BORNE CONTAMINANTS

The discussion of diseases, parasites and contaminants in the Salton Sea Science Office review of the Pacific Institute proposal is relevant to the US Filter proposal. The discussion from that paper has been modified slightly to apply to the US Filter proposal and to remove references to treatment wetlands that were part of the Pacific Institute proposal, but not part of the US Filter proposal. That modified discussion is presented below.

D.1 Fish Diseases and Parasites

At present the fish in the Sea are known to host only a single metazoan parasite, a monogenean fluke (Gyrodactylus), and this only rarely. A few microbial ectoparasites (Amyloodinium, Cryptobia, and 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.

In freshwater impoundments Vibrio infections might be greatly reduced if in fact their present occurrence is due in part to stress on tilapia immune systems created by present high salinities. If Vibrio infections, combined with other stresses, have been responsible for the development of tissue anoxia in tilapia and subsequent production in their guts of type C avian botulism toxin, then fewer moribund, toxic tilapia would be available to pelicans and other fish-eating birds. This role for Vibrio infections remains only a working hypothesis, however.

It is difficult to predict how the types or degrees of infestation by microbial parasites might change in the impoundment relative to the Sea. Cryptobia and Ambiphrya are known to occur in freshwater habitats, aquaria and aquaculture operations. Many other species of microbial parasites may be capable of tolerating a salinity of 2-4 g/L and could appear in the impoundment as well.

In the proposed impoundment, fish would be more heavily infested with metazoan parasites (flukes, cestodes, roundworms, crustaceans). The life cycles of most of these parasites require an intermediate host, usually an insect, crustacean or snail. Few species of such potential invertebrate hosts are found in the present Sea, but many-fold more such host species would establish populations in the freshwater impoundment. This would lead to greater diversity and higher infestation rates of parasites on and in impoundment fish. The lower salinity water itself would also facilitate survival of the free-swimming stages that some of these parasites have.

One such parasite would be the introduced Asian fish tapeworm Bothriocephalus acheilognathi This has been found in shiners and mosquito fish in creeks draining into the Sea. It is a harmful parasite of commercial and recreational significance. It uses freshwater copepods as an intermediate host, spreads rapidly, can cause high mortality of juvenile cyprinids in particular, and could become common in fish in the impoundment. With increasing abundance in the area it might also soon infect local Desert pupfish populations.

Black-spot disease is caused in North American freshwaters by infestation of fish by a fluke (Uvulifer ambloplitis) that requires snails as intermediate hosts. The flukes are visible to the naked eye as black spots on the skin, fins and flesh of fish, making them less attractive for human consumption.

Whether parasite loads would be heavier in impoundment fish than they are in these same fish species where they occur in other freshwater ecosystems in southern California is not certain. In freshwater systems in general, however, parasite loads for fish, amphibians and reptiles are higher in eutrophic water bodies than in meso- or oligotrophic ones – and the impoundment would be highly eutrophic.

D.2 Bird Diseases and Parasites

During the 1990s there were a number of large mortality events involving Eared grebes, White and Brown pelicans, Double-crested cormorants and various duck species. Cause of the death of ca. 150,000 Eared grebes in 1992 was never determined, the pelicans were almost all killed by type C avian botulism after feeding on tilapia containing the botulinum toxin, the biggest cormorant mortalities were due to Newcastle disease, and duck mortalities have been due mostly to avian cholera.

Some tentative predictions as to how the disease situation would differ on the impoundment can be made.

Smaller populations of Brown pelicans might lead to reductions in botulism mortality of pelicans, although if tilapia populations persist in the impoundment and the fish are stressed by high temperature and low dissolved oxygen, botulism would probably continue to afflict fish-eating birds.. Classical type C avian botulism, however, would likely become more common because aquatic vegetation would attract larger numbers of ducks to the impoundment than are currently found in these parts of the Sea now. Moreover, fresher, quieter waters, increased levels of sediment organic matter, higher summer water temperatures, and lower oxygen levels would represent conditions much more favorable to development of botulism-loaded insect larvae or other invertebrates than are present conditions in the Sea. Classic type C avian botulism is most commonly associated with freshwater systems, and in salt water systems is usually associated with areas of freshwater inflows.

Increased waterfowl densities would also likely result in increased mortalities due to avian cholera, as waterfowl are the primary carriers of this disease in the wild.

Salmonellosis would also likely become more common if there are large increases in colonial nesting birds in vegetation on the margins of the impoundment 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 surfaces. The dependence of those numbers on accessibility of those areas to predators has been mentioned.

The increased number of invertebrate and fish species in the impoundment that could serve as intermediate hosts for parasitic helminths would likely increase infestation of birds by those parasites. The importance of this to the health of the bird populations is difficult to judge, however. Most birds would be exposed to these parasites in many of the other aquatic systems they visit for food during the course of a year’s travels.

D.3 Human Diseases and Parasites

The proposed impoundment would cause increased exposure of humans to water-borne pathogens, to vector-borne viral diseases, and to swimmer's itch, especially if the impoundment and adjacent areas were heavily used for recreation.

Water-borne Pathogens. In the recent past the New and Alamo rivers have received on a regular basis from Mexicali and on an irregular basis from Imperial Valley towns, large quantities of untreated or poorly treated (e.g. only primary treatment) municipal wastewaters. More than two dozen bacterial and viral pathogens have been detected in the New River. At present the Salton Sea functions as a large diluter and digester of such pathogens, and there is no evidence that the Sea is an unsafe environment for swimming and other water-based activities.

The proposed impoundment, with its much-reduced capacity for dilution and digestion, would not be deemed safe for many recreational activities. Microbial contaminants are expected to be present at unacceptable levels. Without a continuous, expensive monitoring program for pathogens, public health advisories on recreational use of impoundment would have to err on the conservative side.

Though progress is being made toward the objective of providing secondary treatment for all municipal wastewaters in the region, this is slow. Most of the human population in the Salton Sea watershed lives in Mexicali, this city has a population growth rate of a few percent per year, and wastewater treatment infrastructure is not keeping up with this growth.

Vector-borne Viral Diseases. These could become a serious problem if the US Filter proposal were implemented. The regional abundance of mosquitoes would increase greatly in response to the large increase of heavily vegetated, shallow water and marsh habitat that would form on impoundment margins. 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. Though not yet reported in the Salton Sea area, this virus has become epidemic in wildlife, domestic livestock and human populations in areas of eastern and central North America.

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 reported. If much recreational use were made of the proposed impoundment, 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. Though not yet reported in California, this virus was only first detected in the U.S. in 1999, now is widespread in avian reservoirs in eastern North America, and is likely to be in California soon.

Parasites. If the impoundment were used for swimming, swimmer's itch, or schistosome cercarial dermatitis, might become a problem. This is caused by penetration of human skin by the aquatic larval stage (cercaria) of certain flukes that have life cycles involving snail, fish and bird hosts. High densities of snails and waterfowl in the impoundment would favor the presence of these parasites. Though the larvae die soon after penetration and do not actually parasitize humans, they nevertheless cause serious welts and rashes that are highly irritating, can last for some weeks, and would thereby diminish the recreational value of the water body during the seasons the fluke larvae are present.

D.4 Toxic Algal Blooms

Lower salinities and higher nutrient levels, especially of phosphorus, in the impoundment would lead to greater abundance of cyanobacteria than in the present Sea.

Cyanobacteria have potential for creating blooms 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. Toxic species of cyanobacteria could appear in the biota without having harmful effects, of course. Indeed some of the cyanobacteria in the present Sea now, as well as some of the dinoflagellates and raphidophytes there, are capable of producing toxins. But there is no hard evidence so far that these have harmed fish or wildlife.

Short water residence times in the impoundment would diminish the likelihood that cyanobacteria could achieve dense enough blooms to affect fish or wildlife. On the other hand, portions of an impoundment partially isolated from the rest of the impoundment by shoreline embayments or by stands of aquatic vegetation could have effective residence times much longer than the impoundment as a whole. These could become sites of dense bloom formation.

D.5 Phosphorus and Nitrogen

These nutrients 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.

Nutrient levels in New and Alamo rivers are somewhat higher (9 mg N/L, 0.3 mg P/L) than mean levels in waters of the Sea itself (5 mg N/L, 0.1 mg P/L). Nutrient levels in the southern portion of the impoundment would be similar to the higher levels in river inflows. This would tend to create higher phytoplankton densities than are found in at least the offshore waters of the present Sea. Moderating such effects would be the short residence time of water in the impoundment and loss of nutrients via the outflows, uptake of nutrients by periphyton and vascular plants, and self-shading of the phytoplankton. Exacerbating such effects would be increased recycling of nutrients from bottom sediments back into the water column by benthic invertebrates and bottom-feeding fish such as carp and catfish.

Phosphorus is the nutrient in shortest supply in the present Sea, and would be in the proposed impoundment. However, in the impoundment, as in the present Sea, phytoplankton production is likely to be light-limited most of the time and not limited by shortage of phosphorus. Large reduction of phosphorus inputs via other processes – such as improved management of tailwater drainage and improved municipal wastewater treatment – would diminish the likelihood of impoundment becoming severely hypereutrophic. But evaluation of the efficiency and feasibility of those other projects is outside the scope of this evaluation.

Un-ionized ammonia (NH3) would have a higher probability of reaching toxic levels in the impoundment. Ammonia is excreted by fish and invertebrates and released by decomposition of proteins. It normally exists in the form of the ammonium ion (NH4+). In that form it is non-toxic to animal life and actively taken up by some algae. As pH increases, however, an increasing fraction of the total ammonia would be in the form of un-ionized ammonia. Daytime pH values would be expected to be higher, up to 10 or higher, in the impoundment than in the present Sea. Such high pH values would result from rapid photosynthetic uptake of CO2 from the water by dense phytoplankton. High photosynthetic CO2 uptake occurs regularly in the present Sea, but pH values are rarely greater than 8.8 because the present high concentrations of dissolved salts have a buffering effect.

D.6 Selenium

The importance of selenium in current bird disease and reproductive success issues and to human health at the Sea is unknown. But selenium concentrations in the inflows already are at levels of concern, and those levels would be increased by the proposed project.

In general, 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 effects on fish and bird reproduction and embryonic development, and 4) its potential effects on human health.

In the present system, selenium concentrations average about 6 micrograms per liter (µg/L) in inflows to the Salton Sea (8 µg/L in Alamo River, 4 µg/L in New River), about 1 µg/L in the Salton Sea water column, about 2 µg/g wet weight of Salton Sea fish, and < 1 µg/g dry weight of sediments in area of proposed impoundment. Most selenium entering the present Sea is possibly entombed in the deeper sediments where it is minimally available to the biota.

The EPA criterion for water 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.

Fish and other organisms in the proposed impoundment would be exposed to selenium levels roughly 6 times greater than now experienced by fish and other organisms in the Sea. The concentrations expected in impoundment fish and invertebrates might thus be expected to be much higher than those in present Salton Sea fish and invertebrates. If that transpired, it is likely that an advisory would be issued by the state recommending no human consumption of impoundment fish.

Water conservation measures underway, such as reduction of tailwater drainage and operational losses, could in the future cause selenium concentrations in river inflows to increase by as much as 30 percent.

Selenium-related problems for birds might be exacerbated by resuspension of sediments during dam construction. This, however, would be a less important mechanism for increased selenium exposure of birds than would be the accumulation of higher selenium levels in the impoundment fish and invertebrates after the dam was completed. It should also be noted that selenium deposited in impoundment sediments would not be immobilized there but would be recycled back into the food web by benthic invertebrates and bottom feeding fish such as carp and catfish.

Other actions that could reduce selenium loading to the system are being considered. These include steps being proposed in the state of Colorado to reduce input of selenium-rich agricultural wastewaters into the river and the fallowing of poorer quality Imperial Valley land where soils are relatively high in salts and selenium. However, even if over a number of years such projects could reduce selenium levels in New and Alamo rivers by 50 percent, that would still result in the southern area of the impoundment having selenium levels 3 times greater than those in the present Sea.

The Salton Sea Science Office hosted a meeting of 13 selenium experts on March 11, 2003, in Sacramento, California. The goal of the meeting was to assess what is known about selenium in the Salton Sea and predict potential changes if any of the restoration proposals are implemented. Specific objectives were: 1) review what is known about selenium in the Salton Sea; 2) predict fate and impact of selenium resulting from the restoration scenarios; and 3) review technologies for removal of selenium from aquatic systems. The group documented current selenium levels in various components of the Salton Sea ecosystem and predicted levels for the various restoration proposals. Results are provided in the attached table.

General consensus of the group concerning selenium in the Salton Sea follows:

- Current inflows to the Sea contain low-moderate levels of selenium. However, total selenium burden to the Salton Sea annually is equivalent to that of Kesterson Reservoir, a selenium contaminated 1,200 acre wetland in California's Central Valley.

- The existing Sea appears to accommodate selenium. Water borne levels are lower than the inflows (either by dilution, incorporation into sediments, or some unknown process).

- Phytoplankton and algae take up selenium, but the absence of vascular plants in the Sea reduces its bioavailability. However, selenium levels in fish (human health advisories) and some birds are of concern.

- Selenium is currently bioavailable through invertebrate and fish consumption of bacteria and algae in the water column or in shallow sediments. However, the greatest portion of this selenium appears to become incorporated into deep anoxic sediments as the algae and bacteria die, becoming a detrital rain. These deep sinks have with little or no biological activity, and thus for all practical purposes the selenium is biologically unavailable once it reaches these areas so long as the deep water and anoxic sediment conditions are maintained.

- Increased levels of selenium in most components of the ecosystem are expected as a result of the three restoration proposals because of the reliance on desalination by reverse osmosis.

- Levels in the exposed sediment areas surrounding the brine pool would be expected to be very high, in some cases >1000 µg/L in puddle water from irrigation practices or rainfall. Group consensus was that irrigation practices associated with vegetation for dust control would create selenium remobilization conditions far exceeding Kesterson Reservoir conditions.

- Situations with a fresh-water component would support vascular vegetation and hence increase the bioavailability of selenium.

- For the restoration scenarios discussed in this document, selenium treatment and removal would be required.

- Selenium treatment and removal technology, either chemically or biologically, is available and currently being tested.

- Tailwater reduction along drains tributary to the New and Alamo Rivers will increase Se concentrations to roughly 12 µg/L, then desalination will concentrate some of that inflow by a factor of 3, to 36 µg/L flowing into the North Lake version, or at the 12 µg/L increasing to 15 µg/L (through evapo-concentration) for the US Filter version.

- Selenium is of concern in the water column and sediments, but is also of concern in exposed sediments which may become fugitive dust, in the exposed sediment areas irrigated for vegetation establishment and especially in areas of the northern ½ of the seabed if exposed

The general conclusions are: 1) Higher levels of selenium would be experienced in most elements of the ecosystem if any of the restoration scenarios are implemented; 2) some type of selenium treatment removal would be required; and 3) treatment and removal technologies are available for aquatic systems, but none are proven technologies scaled to the volume of water of the Salton Sea. Nanofiltration of waters post-desalination as well as combinations of nutrient reduction and selenium treatment appear promising.

D.7 Pesticides and Other Water-Borne Contaminants

Available information indicates most such 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. Of greatest significance probably 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 entirely derived from soil residues dating from prior to 1972, when DDT ceased being used in the United States, and is declining over time.

The impoundment and its food web would be exposed to the contaminant levels of the rivers themselves. Though low and possibly ecologically and toxicologically inconsequential in most cases, these levels would nevertheless be substantially higher than levels in the present Salton Sea.

APPENDIX E: SCIENCE OFFICE REVIEW COMMENTS

Review Comments Included in this Appendix

F.1 Hydrology Comments Compiled by Tim Krantz with Input from Paul Weghorst

- ❖ The -240 Dike Option:
- ➢ Assuming a design elevation of -230, Salton River will occupy 20,970 acres.

- ➢ The area exposed above Salton River (-227 to -230 elevation) will be 11,310 acres.

- ➢ The effect of changing inflow volumes and water transfers would be as follows:

- ▪ Assuming 1.3 million acre-feet of inflow and no water transfer, elevation of the remnant Salton Sea would be -230, yielding no additional exposure (this is the baseline).
- ▪ Assuming 1.0 million acre-feet of inflow and no water transfer, the elevation of the remnant Salton Sea would be -255, yielding an exposure area of 50,220 acres, or 78 square miles below Salton River.
- ▪ Assuming 1.3 million acre-feet of inflow and a 500,000 acre-feet water transfer, the elevation of the remnant Salton Sea would be -264, yielding an exposure area of 84,820 acres, or 133 square miles below Salton River.
- ▪ Assuming 1.0 million acre-feet of inflow and a 500,000 acre-feet water transfer, elevation of the remnant Salton Sea would be -271, yielding an exposure area of 136,720 acres, or 214 square miles below Salton River.

- ❖ The -245 Dike Option
- ➢ Assuming a design elevation of -230, Salton River will occupy 40,020 acres.

- ➢ The area exposed above Salton River (-227 to -230 elevation) will be 11,310 acres.

- ➢ The effect of changing inflow volumes and water transfers would be as follows:

- ▪ Assuming 1.3 million acre-feet of inflow and no water transfer, elevation of the remnant Salton Sea would be -230, yielding no additional exposure (this is the baseline for this sequence, as well).
- ▪ Assuming 1.0 million acre-feet of inflow and no water transfer, the elevation of the remnant Salton Sea would be -261, yielding an exposure area of 50,230 acres, or 78 square miles below Salton River.
- ▪ Assuming 1.3 million acre-feet of inflow and a 500,000 acre-feet water transfer, the elevation of the remnant Salton Sea would be -267, yielding an exposure area of 84,830 acres, or 133 square miles below Salton River.

- Assuming 1.0 million acre-feet of inflow and a 500,000 acre-feet water transfer, elevation of the remnant Salton Sea would be -273, yielding an exposure area of 136,730 acres, or 214 square miles below Salton River.

- Miscellaneous observations and comments:

- These water calculations account for surface area exposed to the sun, inflow volumes, and changing acreages with depth, and further assume a fairly constant salinity. These calculations do not account for water used to maintain pupfish or bird habitats, nor does it account for water requirements in controlling dust-emissive surfaces.

- The areas exposed between the 240 and 245 dike scenarios do not vary by much, because the larger impound within Salton River in the 245 dike scenario is reflected in a lower remnant lake level, whereas the smaller impound in the 240 dike scenario is reflected in a proportionally larger remnant lake.

- When the lake level declines below -265, chaos factors will take over, and actual lake conditions will be subject to change from factors that can not be anticipated.

- These figures are calculations using two assumed inflow rates, and 0.5 million acre-feet water transfers, but nothing has been stated about why the inflow will vary by 300,000 acre-feet.

- The water volume requirements for revegetating the lakebed, or at least watering it sufficiently to mitigate airborne dust hazards, is definitely at issue.

- The US Filter proposal suggested that 75% of the exposed surface might be emissive, and shallow flooding sufficient to mitigate this would be on the order of 4 acre-feet per acre per year.

- This averages out to 3 acre-feet per year per acre of exposed lakebed, or 151,000 acre-feet of water for 50,320 acres of exposure, 254,000 acre-feet for 84,830 acres, and 410,000 acre-feet for 136,730 acres, in the three scenarios listed for the 245 dike option. The 240 dike option does not vary much in the water requirements for controlling dust-emissive surfaces

- The water used to maintain vegetation to control emissive-surfaces may explain the 300,000 acre-feet of “lost” inflow volume.

- A likely scenario is for there to be 1.3 million acre-feet of inflow, a 500,000 acre-feet water transfer, and 254,000 acre-feet of water needed to control the emissive surface of over 84,000 acres of territory.

- Other species of plants can have different evapotranspiration rates, and therefore, utilize different volumes of water; we could select plant species that require less water which would still control the dust-emissive surfaces.

❖ Grainsize Distribution of Lakebed Sediments.

- The sediment grainsize distribution as modeled from the Levine-Fricke data is consistent with many expected patterns.

▪ The mouths of the New and Alamo Rivers show a high percentage of sand, which tapers to silt and clay with increasing distance from the mouth of the river into the slower moving currents of the Salton Sea.
▪ The Whitewater River, which is located quite far from its source area in the San Bernardino Mountains, shows only silt at its mouth in the Salton Sea.
▪ Salt Creek shows silt immediately offshore, which grades to clay within another mile.
▪ The floors of both the north and south basins within the Salton Sea proper display mostly silts and clays.
▪ The berm or sill between the two basins is dominated by sand, which is reasonable given the two circulation gyres present in the Sea.

- When the distribution of grain size is depicted with the varying elevations of the Salton Sea, as anticipated in the scenarios detailed above, in each case sandy areas with a significant wind fetch are found upwind from exposed clayey surfaces, which is a condition consistent with the prerequisites required to produce a dust-emissive surface once the sediments are exposed to subaerial conditions.

❖ What is not included here

- This does not yet have an evaluation of the RWQCB proposal and estimated water budget.
- This also lacks an examination of the Science Office's proposal, for which we need to be certain of several specific parameters.

F.2 Comments on Avian Biology by Kathy Molina

P. 23. Increased habitat diversity and biotic diversity in the region. Vascular plant growth does not represent a "new" habitat in the Salton Sink. Much of the state and federal wildlife areas, which directly abut the Sea, already provide areas with vascular plant growth. Increasing the extent of emergent vegetation along the shoreline of the Salton River and dike, and the certain eventual increases of salt cedar encroachment in the proposed residual Sea will not result in increases in bird diversity (i.e. species richness). To the contrary, it will likely result in decreases in species richness and in the abundance of shorebirds and other waterbirds (hundreds of thousands of individuals representing over 50 species) that forage and loaf in the extensive tracts of shallowly flooded and open mudflats that exist currently, particularly along the southeastern stretch (where shorebird density in any season greatly exceeds that of any other section of shoreline, see Fig 5-4b in Shuford et al. Avifauna of the Salton Sea) but also along the northern, southwestern, and southern stretches of today's Salton Sea. Abundant invertebrate populations in the residual Sea that would be attractive to relatively few species of birds would not provide a viable food resource in the long term.

P. 27-29. The development of vegetation around the shoreline will not result in increases in the diversity (i.e. number of species) of waterfowl, passerines or rails. Emergent and shoreline vegetation do not represent novel habitat types in the Salton Sink. The encroachment of vegetation along the shoreline will negatively affect access to traditional shoreline and open water points of interest for birdwatchers. The expected actual loss of vast stretches of open water and mudflat to encroaching vegetation and decreases in the visibility of such remaining substrate could certainly discourage the number of birdwatchers to the Salton Sea which are typically interested in the entire range of birdwatching opportunities that the Salton Sea has historically offered. The residual Sea, which may initially serve to concentrate a few species of birds, will apparently not be accessible to the public.

P. 34, Fig 5. While Variation 1 addresses a few bird habitat issues, key foraging and resting areas for all wading species in the south end of the Sea are not adequately addressed and only one of three key areas at the north end, the Whitewater Delta/Torres Martinez Shorebird and Roosting Habitat is addressed. The deltaic shorebird habitats at the south end of the Sea, and the Torres Martinez habitat plan at the north end as proposed in Variation 1 appear to be subject to the same physical conditions and to similar or perhaps even greater rates of encroachment by vegetation, as does the base proposal. The vast majority of breeding colonies of waterbirds are located at the south end of the Sea in patches of dead tree snags or on small islets isolated by water from the shoreline (see Fig. 4-6, Shuford et al. Avifauna of the Salton Sea). The loss of these sites that would apparently occur under Variation 1 is not considered by this proposal, nor is it adequately addressed by this review.

P. 39, Fig. 6- Variation 2. The retention of a marine environment in the central impoundment and in the Salton River impoundment may provide higher quality habitat for waterbirds and shorebirds, respectively, than those schemes proposed in the base and Variation 1 versions. However, from the information provided it is unclear how water depth could be effectively controlled in the narrow, peripheral band of the Salton River, to maintain adequate areas for shallowly flooded (0-10 cm of water) mudflats suitable for shorebird foraging and waterbird roosts. The loss of all existing breeding colony sites of waterbirds is not considered in this proposal (see Fig. 4-6, Shuford et al. Avifauna of the Salton Sea), and inadequately addressed by this review.

P. 51. All arboreal nesting waterbirds (herons, egrets, cormorants, ibis) except one species, the Cattle Egret, are highly unlikely to utilize stands of mature trees not isolated by water, and therefore accessible to terrestrial predators and other disturbances at the Salton Sea. Stands of landlocked trees, unless very mature and dense, may even fail to attract roosting herons and egrets. While increases in some aquatic and terrestrial vegetation types along the Salton Sea shoreline may provide additional resting and feeding habitat for species that are migratory, only a limited number of species (Yuma Clapper Rail, Least Bittern, Black-crowned Night-heron, Abert's Towhee, Song Sparrow, Marsh Wren, Verdin, Common Yellowthroat, Red-winged Blackbird, and Yellow-headed Blackbird) would use the vegetation for nesting. The gain in aquatic and terrestrial vegetation favored by passerines, rails and waterfowl would hardly offset the loss of the open and shallowly flooded mudflats usurped by this new growth, and of the species rich and abundant shorebirds that require it.

P. 52. Mullet Island, currently isolated by water from the mainland and therefore inaccessible to mammalian predators, has been an important nesting site for several species of colonial waterbirds, including Caspian and Gull-billed terns, (two species of federal concern), and Black Skimmers, in addition to the Double-crested Cormorant and Brown Pelican.

The colonization of dikes and dams by most ground nesting birds is not likely to occur unless these areas were sufficiently isolated from human disturbances and terrestrial predators.

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18 February 2003

Note by Tetra Tech

In consultation with Ms. Molina these comments have been integrated into the text. The page numbers identified here refer to an earlier draft.

F.3 Comments on Biology by Michael K. Saiki

Although the US Filter proposal is interesting, it does not contain sufficient details for an in-depth ecological or ecotoxicological critique. As a minimum, the authors of the proposal should be asked to provide detailed predictions (along with supporting data) on ecological and hydrological changes that are likely to occur in the Salton River during at least the first few years following its implementation. The authors should also identify situations or scenarios where data are inadequate or lacking.

If Tetra Tech is correct in their speculations on ecological conditions likely to occur in the Salton River, implementation of the proposal should result in a moderately brackish waterway characterized by shallow depth, sluggish currents, mucky (highly organic) bottom substrates, and abundant vegetation (cattails and other emergents along the shoreline; a mixture of submerged rooted macrophytes and filamentous algae in deeper waters). The high nutrient content of inflowing water and warm water temperatures should stimulate very high primary and secondary productivity, resulting in conditions that attract aquatic birds and possibly provide very good angling opportunities. However, these same conditions could foster bioaccumulation of selenium and other contaminants especially at the south end of the River. When the abundant stands of aquatic vegetation undergo senescence especially during fall months, it is likely that dissolved oxygen concentrations will decline to near anoxic conditions, possibly resulting in fish dieoffs. Site-specific data are needed to determine if selenium or other contaminants could cause toxicity among sensitive birds and fish. Even if the health of birds and fish are not directly impacted by contaminants, their body burdens of chemicals could make them unfit for human consumption.

Nonnative fishes (poeciliids, cichlids, cyprinids, ictalurids, centrarchids, and perhaps others) are expected to colonize the river and become very abundant. If largemouth bass and other piscivorous fishes establish themselves in the Salton River, they will undoubtedly prevent the endangered desert pupfish from using this habitat. The nonnative fishes will undoubtedly attempt to access the mouths of Salt and San Felipe creeks and the various agricultural drains flowing into the Salton River where remnant populations of desert pupfish are currently extant. Even though pupfish are highly vulnerable to predation and possibly to competition from nonnative fishes, the pupfish might still avoid extirpation particularly in the creeks if ambient water quality (especially high salinity and high summertime water temperatures) in the lowermost reaches are sufficiently stressful to curtail or prevent upstream penetration by nonnatives. However, comparative data on the water quality tolerance limits of pupfish and nonnative fishes are lacking so this possibility cannot be adequately assessed at present.

Jack, without more details on ecological and contaminant conditions predicted for the Salton River, I am not able to offer a more in-depth assessment of positive and negative assets of US Filter's proposal. Nevertheless, I hope my comments are helpful.

Feel free to contact me if you have questions.

Thanks,

Mike

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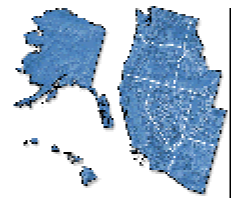
F.4 Comments on Selenium Issues by Theresa Presser



Water Resources Division
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345 Middlefield Road, MS 435
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February 20, 2003

TO: Doug Barnum, USGS, BRD, Salton Sea Science, La Quinta, California

FROM: Theresa Presser
U.S. Geological Survey, Water Resources Division, National Research Program, Menlo Park, California

SUBJECT: Technical Comments on Selenium Component of *US Filter Salton River Desalination Solution Proposal* (Version dated 11/20/02) and *Draft Review of US Filter Corporation Salton River Proposal* (containing *Variations #1 and #2*, 1/03)

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Selenium (Se) loading to the Colorado River is approximately 81,000 pounds (lbs) Se/year (Engberg et al., 1999). Estimates of the annual mass loading of Se to the Salton Sea is approximately 17,600 lbs Se (Skorupa, 1998), an amount equal to that which caused the eco-toxicity at Kesterson (discharge 1981-1985, 17,400 lbs Se, Presser and Piper, 1998). Understanding the biotransfer of Se is essential to evaluating the impact of proposed changes in Se discharges to the Salton Sea and associated mitigation wetlands. The *US Filter Proposal* does not address the ecology, food webs, hydrodynamics, or Se biogeochemistry in the Salton Sea and proposed mitigation wetlands. Successful integration of these sciences with the current understanding of factors that affect the environmental fate of Se would help quantify the transfer of risk that is associated with Se management in proposed solutions. Presented below are general and specific comments that address the contaminant Se in proposed remediation. In addition, I include information that will help to provide a scientific conceptual basis for restoration, which I found lacking in the proposal materials.

General Comments

Recognize Se-impairment of Salton Sea and Constructed Wetlands

Lack of comprehensive historical and current data for the fate of Se in the Salton Sea ecosystem and its tributaries is a major problem. Skorupa (1998) gives a compilation of Se concentrations in water, sediment, food chain fauna, fish tissue, bird tissue, and bird eggs for the

Salton Sea (see attached Table 1). If these data for Se concentrations in environmental media of the Salton Sea are used to rate the Salton Sea ecosystem based on the Lemly Index for Se hazard (Lemly, 1995 and 1996), the hazard score shows a high hazard.

The Salton Sea (1 –2 µg/L total recoverable Se in water) is currently posted because of Se with a health warning against consumption of fish (> 2 µg Se/g wet weight or 8 µg Se/g dry weight, filet). Selenium concentrations in fish muscle (see attached Table 2) also are above the dietary ecological risk threshold for aquatic life (> 7 µg Se/g, whole body; whole-body Se concentrations are usually greater than muscle Se concentrations). Concentrations of Se in grebe liver samples and egg samples (see attached Table 3) from the Salton Sea can be within the range of toxicity for acute effects and certainly are within the range at which sub-acute effects occur (e.g., suppression of the immune system).

Effects are likely to occur at the proposed levels for mitigation wetlands (7-10 µg Se/L) based the current USEPA criterion for the protection of aquatic life (5 µg Se/L) and on current research on Se exposure. Use of large-scale biological treatment technologies (e.g. wetlands or evaporation ponds) has generated serious ecological problems and hazardous Se wastes for disposal (Luoma and Presser, 2000; Presser and Piper, 1998; Skorupa, 1998a; Hamilton, 2000b). Further, Tulare Basin evaporation basins are regulated by the state and clean wetlands are required to mitigate for unavoidable toxic impacts to breeding waterbirds (Skorupa, 1998). The mitigation wetlands are not allowed to average more than 2.7 µg/L total recoverable Se in impounded water (Central Valley Regional Water Quality Control Board, 1993).

Vulnerable downstream water bodies should be considered when evaluating upstream source waters. Selenium impacts may not appear equally in all components of an ecosystem because some components may be more sensitive than others. Selenium-contaminated impoundments appear to present greater risks to wildlife than Se contaminated streams and rivers (Seiler, 1995; Skorupa, 1998). For example, a flowing system may be less sensitive to Se effects where selenate dominates, than adjacent backwaters or wetlands, where residence times and biogeochemical transformations of Se are more likely. As noted below, treatment could affect the speciation of Se, producing a more bio-available form of Se in downstream ecosystems.

Need for Protective Criteria Based on Food Webs

It seems clear from current research that significant scientific advances in regulation and technology are needed to control environmental Se concentrations within environmentally protective ranges to avoid adverse impacts from Se. It is now known that direct transfer of Se from solution to animals is a small proportion of exposures. Bioaccumulation and uptake via food is the most important route of Se transfer to upper trophic level species. For example, Se concentrations were well below water quality guidelines for the protection of aquatic life in the San Francisco Bay-Delta Estuary (Bay-Delta) in the latest surveys in 1996. Nevertheless, Se in the food web was sufficient to be a threat to some species and a concern to human health if those species were consumed. Cases such as this prompted the U.S. Environmental Protection Agency to re-evaluate Se standards for the protection of aquatic life to include diet and vulnerable species (USEPA, 1998). The U.S. Fish and Wildlife Service and the National Marine Fisheries Service through the California Toxics Rule also are asking for more stringent Se criteria than the current national criteria. Hence, consideration should be given to elevated Se concentrations currently occurring in the fish and birds of the Salton Sea, even though waterborne concentrations in the Sea are between 1 and 2 µg Se/L (i.e., less than the current 5-µg Se/L USEPA criterion for the protection of aquatic life).

Recognize Treatment is Problematic

Treatment technologies for Se have utilized both chemical and biological processes to remove Se from the water column, but with little operational success or cost-effectiveness (San Joaquin Valley Drainage Program, 1990a; Hanna et al., 1990; San Joaquin Valley Drainage Implementation Program, 1998; 1999a). Selenium removal is further hampered by the failure of traditional chemical methods to reduce Se to levels acceptable for remediation and, in arid regions, by the problem of disposal of associated salts (San Joaquin Valley Drainage Program, 1990a). Remediation has not been established other than that dependent on dilution in a larger body of water (San Joaquin Valley Drainage Implementation Program, 1998; U.S. Department of the Interior's National Irrigation Water Quality Program, 2000). Management plans for the western San Joaquin Valley that include drainage storage and reduction through source control have been developed, but systematic and comprehensive implementation has not taken place (San Joaquin Valley Drainage Program, 1990 and 1991; San Joaquin Valley Drainage Implementation Program, 1998; Environmental Defense Fund, 1994).

Treatment also may be important in determining Se-load impacts. Treatment technologies applied to source waters may affect both the Se concentration and Se speciation of the effluent. For example, a treatment process could decrease the concentration of Se in the influent, but result in enhanced Se food chain concentrations if speciation in the effluent changes to increase the efficiency of uptake.

Need for a Selenium Component to Proposals

Without information concerning selenium as an environmental toxicant as part of the proposals, the basis for understanding the adverse impacts or benefits of a proposed solution would be incomplete. To this end, a separate Se component equal in status to that of salt and water needs to be developed for each proposed remediation effort. This ecological analysis should be as detailed as that of engineering and economics. Models (e.g., bird-use, Se pathway bioaccumulation) are available (see below) that can be integrated into the analysis to aid in the development of realistic loading and concentration scenarios and the forecasting of biological effects.

Need for a Se Budget—Mass Balance Approach

In general, the fundamentals of food chain exposure, ecology, hydrodynamics, and the biogeochemistry of Se need to be integrated into proposals to provide consistent linkages of major processes leading from Se loading through consumer organisms to predators to protect fish and wildlife. Hence, recognition and monitoring of Se loading to the Salton Sea ecosystem on a mass balance basis (i.e., inputs; fluxes and storage within environmental media; and outputs, Presser and Piper, 1998) are essential to evaluating how to control Se concentrations within environmentally protective ranges. Monitoring plan components necessary for a mass balance approach include source loads of Se; concentrations of dissolved Se and suspended Se; Se speciation in water and sediment; assimilation capacities of indicator food chain organisms; and Se concentrations in tissues of prey and predator species. A linked or combined approach would include all considerations that cause systems to respond differently to Se contamination and would relate to source control limits.

Modeling of Biological Effects and Planning for Bird-Use

The USGS has recently published a Se bioaccumulation model specific to the ecosystem of the San Francisco Bay-Delta Estuary (Luoma and Presser, 2000; available on the web: http://pubs.water.usgs.gov/ofr00-416/). Summary pages also are available on the web: http://sfbay.wr.usgs.gov/access/bioavail/no_bay/. The fundamentals of the model are applicable to modeling effects of Se on other ecosystems. This pathway bioaccumulation model represents a new tool to predict ecological effects. Demand-driven Se loads as well as supply-driven management scenarios can be considered.

Specific protocols that include feeding relations and life cycles of vulnerable predators including migratory and mobile species also should be a part of the modeling effort. Bird-use models also are available as a result of planning for mitigation for the Tulare Basin evaporation ponds (U.S. Fish and Wildlife Service, 1996).

Bioavailability

In the Bay-Delta Se Model, we concluded that credible protective Se criteria should be based on 1) contaminant concentrations in sources that most influence bioavailability and 2) concentrations in media and organisms relevant to vulnerable food webs (Luoma et al., 1992; Luoma and Presser, 2000). As noted above, critical media are water, particulate material, and tissue of prey and predators. Existing criteria for these media could be used in-combination to evaluate risk or hazard (Lemly, 1995; USDOI, 1998).

The *US Filter Proposal* does not address Se bioavailablity in any of the proposed aquatic systems. The *Tetra Tech review* of this proposal and the review of the *Pacific Institute Proposal* state that “Most selenium entering the present Sea is possibly entombed in the deeper sediments where it is minimally available to the biota”. This statement is misleading and not based on data analysis. Data are needed to substantiate this statement (i.e., Se concentrations and speciation in suspended material and identification of food webs). Entombment of Se in deeper sediments does not necessarily equate to unavailable Se. Availability depends on food webs and sensitivity of species to Se (Luoma et al., 1992). Differences in speciation, transformation to particulate form(s), speciation on particulates and invertebrate bioaccumulation all influence how waterborne Se is transferred to a predator. These processes are affected by the nature of the source and the environmental conditions in receiving waters (e.g. Se in agricultural drainage water can be a different form than the Se in treated sources; Se discharged to a freshwater wetland is transformed differently than Se discharged to an estuarine water column). Physical processes like hydraulic residence time are also important. Particulate transformation of Se in a river may occur far downstream from the source of input; while transformations in a wetland or an estuary with a long residence time may occur near the input. Biological processes that affect exposure of the predator include differences among predator species in feeding, behavior, and physiology.

As noted in the *Tetra Tech review*, resuspension is a possibility. A change in water-column dynamics and chemistry as proposed could well reverse uptake phenomena. Recycling of Se within a surficial biologically active layer of the Salton Sea may be an important part of current conditions affecting Se transport in the Sea. Given the bioreactive nature of Se, the food webs of the current limited ecosystem of the Salton Sea (i.e., overwhelmingly dominated by introduced species having broad environmental tolerances) could be a result of past Se bioaccumulation, cycling, and toxicity effects.

Specific Comments (on *US Filter Proposal* and *Tetra Tech review* of 1/03 which contains *Variations 1 and 2*)

Based on available limited Se data, I agree with most of what was written on Se contamination in the review of *Pacific Institute Proposal* by the Salton Sea Science Office (see exception above on bioavailablity). The more in-depth version given on pages 28-29 should be added to the *US Filter Proposal* review. The synopsis in the *Tetra Tech review* is too short (page 59). A rebuttal of *Benefits* of the proposed remediation similar to that given in the *Pacific Institute Proposal* (page 33) should be developed for the *US Filter Proposal*.

Providing mitigation habitat for migratory birds is crucial to the success of any proposal for the Salton Sea. All three of approaches described in the *Tetra Tech review* of the *US Filter Proposal* (*US Filter Proposal* and *Variations 1 and 2*) are problematic because of potential impacts of Se on fish, wildlife, and aquatic resources. The *US Filter Proposal* is the most problematic in terms of Se because it creates an agricultural drain (Salton River) surrounding a dying Salton Sea that would receive seleniferous by-products from desalination. The agricultural drain (i.e., the shoreline impoundment fed by agricultural drainage) is proposed as wetland habitat. As part of this proposal, good-quality desalinated water would be sold for profit and used outside the project area. In terms of Se, Se concentrations could increase in the Salton Sea (through evaporation) and the Salton River (receiving more concentrated agricultural drainage).

Variations 1 and 2 are improvements in that they propose 1) returning some portion of treated water to the project area for mitigation of ecological effects and 2) separate Se treatment. For all three approaches, a Se budget (including Se in water, sediment, and biota) would quantify the potential increase in Se concentration in the proposed diminished marine areas, constructed wetlands, and impoundments. This budget also would include by-products such as reject water or solid salts from desalination. In addition to providing understanding of processes, the Se budget could identify options for splitting agricultural and desalination waste-streams to achieve benefits for bird habitat within the basin. In terms of Se concentrations and loads, a third variation could be developed that incorporates use of the desalinated water (not just reject water) for aquatic habitat, ensuring adequate mitigation for what appears to be unavoidable bird losses.

Thank you for asking for my input on identifying significant Se issues related to these proposals in connection with remediation of the Salton Sea. Let me know if you would prefer a more formal document than the *working document* I have provided. A formal document would need to undergo scientific review as part of administrative processes here at USGS in Menlo Park. I understand that this will be a cooperative review, which addresses all aspects of the proposal, not just contaminants. I look forward to seeing you at the meeting on March 11 to discuss these issues further. If you have any questions or if I can be of further assistance, please do not hesitate to call (Theresa Presser, 650-329-4512, tpresser@usgs.gov)

Comment Response by Tetra Tech

The reviewer suggested including expanded text on Selenium from the previous paper that documented the Science Office review of the Pacific Institute Proposal. This material is included in Appendix D, section D.6 of this document.

TABLE 1. Environmental media
(Compilation of data for Salton Sea from Skorupa, 1998)

Water source (µg Se/L) (selenate)	2-10	
Water system (µg Se/L)	1.5	
Sediment (µg Se/g, dry weight)	3.3	
Food chain fauna (µg Se/g, dry weight)	0.8-12.1	
Fish (µg Se/g, dry weight) Whole-body Muscle	 6.1-16 7.9-14	
Bird (µg Se/g, dry weight) Eggs Muscle hepatic	 1.6-35 2.7-7.2 2.7-42	 5% reduction of black-necked stilt nesting proficiency

TABLE 2. **Fish** (From *Analyses of organic and inorganic contaminants in Salton Sea fish* March 8, 2002 Revised Final Report to the California State Parks)*

Fish muscle (filet)	µg Se/g, wet weight	µg Se/g, wet weight	µg Se/g, dry weight @ 75% moisture	µg Se/g, dry weight @ 75% moisture
Mean (± standard deviation	Mouths of Alamo and New Rivers	Salton Sea near-shore	River Mouths	Salton Sea
	N = 2	N = 3	N = 2	N = 3
croaker (*Bairdiella icistia*)	2.10 ± 0.12	2.32 ± 0.56	8.4	9.3
	N = 2	N = 2	N = 2	N = 2
orangemouth corvina (*Cynoscion xanthulus*)	2.73 ± 0.07	2.30 ± 0.00	10.9	9.2
	N = 2	N = 3	N = 2	N = 3
hybrid tilapia (*Oreochromis spp*)	1.89 ± 0.61	2.39 ± 0.11	7.6	9.6
Consumption guideline (muscle, filet)				
2 µg Se/g, wet weight or approximately 8 µg Se/g, dry weight at 75% moisture				
Dietary Ecological guidelines				
	Low Risk < 3 µg Se/g, dry weight	Marginal Risk 3 - 7 µg Se/g, dry weight	Substantive Risk > 7 µg Se/g, dry weight	
Toxicity to fish (tissue, whole body)				
	Low Risk < 4 µg Se/g, dry weight	Marginal Risk 4 - 6 µg Se/g, dry weight	Substantive Risk > 6 µg Se/g, dry weight	

* no date given for fish collection

TABLE 3. Avian (From Tonie Rocke, National Wildlife Health Center, Madison WI: email to T. Presser, 3/25/02 concerning bird data for Salton Sea)*

Bird liver	μg Se/g, dry weight	μg Se/g, dry weight	μg Se/g, dry weight	μg Se/g, dry weight
Geometric mean	north Salton Sea	south Salton Sea	Salton Sea	control
grebe	27	30	--	15
ruddy ducks	--	--	12	--
Thresholds for Se effects in birds (liver, mg Se/g, dry weight)				
	14 - 19 embryo deformity	23 - 32 terata	> 30 reproductive impairment; juvenile and adult toxicity	
	Heinz et al., 1989; Heinz, 1996	Lemly 1998	Skorupa, 1998	

*Samples collected in 1992.

F.5 Comments on Wildlife Disease by Rex Sohn

In my opinion Tetra-Tech's application of the analysis provided for fish, wildlife, and human health impacts of construction of large areas of shallow freshwater or brackish water wetlands provided in the valuation of the Pacific Institute Proposal in 2002 is appropriate for evaluation of these new proposals. The degree of the disease and contaminant problems that will potentially occur in various proposed projects will be correlated to the area of shallow, freshwater wetlands created.

One correction that I believe needs to be made in the Tetra Tech draft report is in the section on Vector-borne Viral Diseases. The last sentence of the first paragraph in this section..."Though not currently present, West Nile Virus is also a potential concern." should be removed and the last sentence in the third paragraph of the section should be changed to read..."Though not yet reported in the Salton Sea area, this virus has become epidemic in wildlife, domestic livestock and human populations in areas of eastern and central North America."

Based on my assumption that the disease impacts of the various projects will reflect the amount of new shallow freshwater habitat created, I believe the most severe disease and contaminant threats would be associated with the US Filter proposal. It is difficult to compare the potential disease and contaminant threats posed by Variations 1 and 2 since there is little or no data provided on the total area of fresh and saline wetlands created, water chemistry, etc. It appears that Variation 2 would pose the least amount of shallow, freshwater habitat and therefore have the least fish, wildlife and human disease issues associated with shallow freshwater impoundments. However, the reduced level of fish and wildlife losses to freshwater diseases might be completely outweighed by potential population declines due to loss of saline fish and wildlife habitats in that proposal. I will have to withhold my ranking of Variations 1 and 2 regarding disease and contaminant concerns until more information is available.

One potential disease issue that was not addressed in the review of the Pacific Institute proposal is associated with hypersaline water areas that will result from the various proposals and the "no action alternative". If water salinity exceeds approximately 200,000 mg/L in the impoundments, the brine ponds, or the residual Sea there is the possibility of salt poisoning of waterbirds. Usually mortality involving salt poisoning involves relatively small numbers of birds under unique environmental circumstances at small isolated wetlands; however, the scale of the bodies of hypersaline water proposed under some of the Salton Sea proposals might occasionally result in mortalities greatly exceeding those previously experienced.

Rex Sohn, D.V.M.
Wildlife Disease Specialist
USGS National Wildlife Health Center
6006 Schroeder Road
Madison, WI 53711-6223

F.6 Comments on Avian Disease by Tonie Rocke

I am not in favor of the US Filter proposal to create a Salton River ring around the Sea. I am afraid the highly saline central Sea would eventually become a large attractive nuisance for birds similar to the potash mines in New Mexico where there is a big problem with salt poisoning in birds. Also, the less salty river would provide much greater habitat for mosquito production, a concern for arbovirus transmission, like West Nile Virus.

I am much more in favor of the second alternative that leaves the North basin essentially intact and, with desalination, creates more brackish water shorebird and waterfowl habitat in the South basin area (somehow I don't have any written materials on that, but I do remember what we discussed in CA). This alternative seems to maximize bird habitat without adding more disease problems than already exist in the Sea (presuming a method for Selenium treatment is also included in this alternative).

Tonie E. Rocke
Epizootiologist
National Wildlife Health Center
6006 Schroeder Rd.
Madison, WI 53711

Note by Tetra Tech

The second alternative identified above is now referred to as the North Lake alternative.

F.7 Summary of Water Quality Comments Prepared by Jose Angel

All review comments from members of the water quality team were received and transmitted to the Salton Sea Science Office. A consolidation of the comments follows:

- The review by Tetra Tech, Inc. regarding water quality was thorough and reasonable;
- Concentrations of selenium, nutrients (phosphorous and nitrates), and pesticides in the Salton River will increase by various degrees;
- The central portion of the Sea will become hypersaline very rapidly; and
- Increased sedimentation, turbidity, temperature ranges, and oxygen depletion in the Salton River are likely.

The following are specific quotations form the different reviewers:

General Comments

Setmire:

- While the Pacific Institute's proposal could be modified to have the impoundments maintained at ocean salinity thereby preventing many of the water-quality and biological issues that were identified, the current US Filter proposal does not offer solutions to these issues.
- It is clear from this review that the US Filter proposal does not take into account any of the water-quality issues that were raised during the review of the Pacific Institute's proposal. In addition, this proposal is not a Salton Sea Restoration Project, but will totally change the habitat and some of the wildlife of the current Salton Sea.

Amrhein:

- The U.S. Filter proposal has many similarities with the Pacific Institute proposal, as noted in the Tetra Tech review.
- The biggest concern I see with a large, shallow, fresh water lake in the Salton basin will be the poor clarity of the water due to algal growth, combined with weed-choked banks, and stagnant water full of mosquito larvae. In addition, environmental toxicity problems associated with Se could be substantial in this kind of environment.
- The water quality evaluation as presented in the TetraTech report is reasonable.

Carpio-Obeso:

- The information provided by US Filter regarding water quality improvements at the Salton River is unsubstantiated.
- Variations in the physical-chemical environmental (pH, T, depth, DO, vertical mixing, retention time, etc.) will effect aqueous concentrations of contaminants/constituents in the inflowing waters (i.e. increasing or decreasing concentrations depending on the

constituent). These physiochemical changes may affect sorption, solubility, thermodynamic equilibrium, precipitation and transport of some contaminants

Anderson:

- While the proposal improves upon the Pacific Institute's earlier concept, there are still some substantial water quality concerns. The Tetra Tech review of the US Filter proposal prepared by Dr. Brownlie underscores many of these concerns. The review is generally quite thorough and well-written; nevertheless, elaboration on some of the points is probably warranted.

THE SALTON RIVER

SELENIUM:

Setmire:

- The primary water-quality issue of concern for this project is elevated selenium concentrations in critical feeding areas along the southern end of the Salton Sea and in the habitat of the newly created Salton River.
- Increasing selenium concentrations by ten-fold (1 ug/L in the Sea to 10 ug/L or higher in the Salton River) could cause major reproductive impairment and possible teratogenic effects on the avian resources using these newly created habitats.

Amrhein:

- In addition, environmental toxicity problems associated with Se could be substantial in this kind of environment.
- The aerobic conditions and shallow depth of the fresh water impoundment will also keep contaminants (Se and DDT) in the food web.

Carpio-Obeso:

- The fate of the Selenium (Se) is not sufficiently addressed by US Filter, although discussed by Tetra Tech in their review.

NUTRIENTS

Setmire:

- The nitrogen and phosphorus loading that is currently diluted by the entire Sea or at least dispersed throughout will inundate the Salton River and southern impoundment. The result will be extremely dense algal blooms, areas of algal matts on the surface, major color shifts in the water from green to black, and periodic strong odors of decay. Fluctuations in dissolved oxygen concentration will be severe with high summertime DO concentrations during the day and very low to zero DO concentrations at night.
- Chlorophyll *a* concentrations could exceed 75 mg/L and Secchi depths likely will be less than 0.5 meters. These conditions are indicative of a hypereutrophic system.

Amrhein:

- Suspended algae growth within the Salton River will be high because of high P loading, residence times of 40-50 days, and shallow, slow moving water conditions.

Anderson:

- The high dissolved nutrient concentrations in the rivers will clearly promote a high algal production rate.
- High chlorophyll concentrations are expected across the entire length of the Salton River, with annual average chlorophyll concentrations of 72 – 100 μg/L. This compares typical chlorophyll concentrations of 30 μg/L and TN and TP concentrations of 3.80 and 0.065 μg/L presently in the Sea (Anderson and Amrhein, 2002)
- It seems likely that the Salton River will ultimately come to resemble the test wetlands in the area, which are characterized by high phytoplankton productivity, high aquatic vascular plant densities, at least near the margins of the Salton River, and high densities of attached algae.

PESTICIDES

Setmire:

- Sediments carrying DDE will be deposited in the impoundment along the southern end of the Sea and will be available to the benthic biota for uptake by fish and birds. Water-soluble pesticides also are present in the New and Alamo Rivers and will not be diluted by the large body of the Salton Sea, but will be present in the feeding areas along the southern end of the Sea and in the Salton River.

Amrhein:

- The aerobic conditions and shallow depth of the fresh water impoundment will also keep contaminants (Se and DDT) in the food web.

Carpio-Obeso:

- The occurrence of pesticides is expected given the agricultural activity in the region, and high pesticide use. US Filter should investigate the fate of common pesticides used in this region, as well as pesticides that cause adverse impacts to the ecosystem.

Anderson:

- The fate of pesticides and trace elements is also an important consideration. The fate of pesticides and trace elements in the Salton River could probably be reasonably predicted using a surface water quality model, although such calculations are beyond the scope of this review.

THE TWO VARIATIONS

Setmire:

- The variations to the US Filter proposal alluded to in the Tetra Tech review document might offer viable solutions that would maintain some of the current Salton Sea and its habitats – a partial Salton Sea Restoration Project; there was insufficient information presented for evaluation.

Amrhein:

- The extensive shallow-water habitat of Variation 2 does not seem as desirable as the lake in Variation 1. Variation 1 preserves the existing shoreline of the northern basin, while Variation 2 maintains it with the Salton River, which is isolated from the central marine lake. This isolates the benefits of deep-water burial of Se from the productive, eutrophic shallow habitat of the Salton River.

THE RESIDUAL SEA

Setmire:

- Since the residual Sea will receive reject water from the reverse osmosis process, it will contain very high concentrations of selenium and other potential contaminants and nutrients.
- For this 5 to 10 year period, the residual body of water would be producing brine shrimp and larval forms that would contain elevated levels of selenium that far exceed any dietary concentration considered protective for birds feeding on these food items.

Amrhein:

- The hypersaline salt repository would also be eutrophic, receiving substantial nutrients from the freshwater lake and wastewater flows from the desalinization plant.

F.8 Comments on Water Quality by Christopher Amrhein

Comments by: Christopher Amrhein
Professor of Soil and Water Sciences
Department of Environmental Sciences
University of California, Riverside

These comments are largely directed at water quality issues associated with remediation plans for the Salton Sea. The U.S. Filter proposal has many similarities with the Pacific Institute proposal, as noted in the Tetra Tech review. Both proposals include a shallow, fresh-water impoundment and a hypersaline salt lake in the center of what is now the current Salton Sea. In both proposals, dikes would be constructed in the current Salton Sea to isolate areas that could be maintained as flow-through systems. The Tetra Tech report offers two alternatives to the U.S. Filter project, both of which involve a deep-water, saline impoundment.

The biggest concern I see with a large, shallow, fresh water lake in the Salton basin will be the poor clarity of the water due to algal growth, combined with weed-choked banks, and stagnant water full of mosquito larvae. In addition, environmental toxicity problems associated with Se could be substantial in this kind of environment.

The water quality evaluation as presented in the Tetra Tech report is reasonable. Suspended algae growth within the Salton River will be high because of high P loading, residence times of 40-50 days, and shallow, slow moving water conditions. All of the input phosphorus (which is quite high) would be converted to algal biomass. The shallow water favors mixing and aeration, which allows for colonization of the sediments by fish, mollusks, worms, and insect larvae. Bottom-feeding ducks will stir the sediments also. The relatively short residence times, or high flushing rate, aerobic conditions in the water, and constant mixing of the sediments should keep internal loading of nutrients to a minimum. Nutrients will be lost to the saline pool, so nutrients are not likely to accumulate within the freshwater impoundment, keeping internal loading low. The aerobic conditions and shallow depth of the fresh water impoundment will also keep contaminants (Se and DDT) in the food web.

The recently constructed wetlands along the New River are a good example of how the Salton River would look and the kind of water quality that could be expected.

The hypersaline salt repository would also be eutrophic, receiving substantial nutrients from the freshwater lake and wastewater flows from the desalinization plant. Algae swept into the saline impoundment would settle to the bottom and decompose. If the saline lake is deep enough, anaerobic processes will dominate the bottom waters resulting in Se reduction and precipitation, sulfate reduction and hydrogen sulfide production, and precipitation of P as a coprecipitate with calcite. In a deep saline impoundment, the sediments will not be disturbed by burrowing insect larvae, worms, mollusks, fish, or bottom-feed birds. Mixing of the sediments in the shallow water by wading birds is possible, although the salinity will rapidly become too high for most invertebrates.

The first variation (developed by Tetra Tech and presented in their report) proposes a saline river transporting water to a deep-water, marine lake at the north end of the existing Salton Sea.

The only advantage of saline river over a fresh water river is shoreline effects (less weeds and mosquitoes). The water in the river will still be aerobic, eutrophic, and the bottom sediments well-mixed. It is possible that nutrients and Se concentrations would be significantly higher in the saline river system, as much of this water would be reject flows from the desalination plant, which would tend to concentrate nutrients, Se, and salts. Without the benefits of deep-water burial, the Se, DDT, and P could become a serious problem in the river.

One of the major advantages of the deep, saline impoundment is the potential for permanent burial of Se, DDT, and phosphorus. I like the idea of a relatively deep marine lake in Variation 1. The water quality in this saline impoundment would be similar to the existing Salton Sea, assuming the same P loading to volume ratio. If P loading does not decrease but the lake size does, algal blooms will be worse in the marine impoundment (Variation 1) compared to the current Salton Sea.

The second variation (proposed by the Regional Water Quality Control Board and presented in the Tetra Tech report) would make the Salton River saline. It is not clear from the proposal how this river will get salty water but it is likely that reject flows from the desalinization plant would be used. The drawing for Variation 2 shows a small box marked "Selenium-PO4 Reduction Plant" although no details are given for this process. Se and P removal prior to discharge into the saline river would be necessary if the desalinization brine flows are mixed into the Salton River. In variation 2, the marine impoundment at the central-north end would be 10-12 feet deep and much smaller than the impoundment in Variation 1. Variation 2 calls for both this central marine lake and a saline Salton River around the whole perimeter of the existing Sea. It is possible that the Salton River could be filled with water from the central marine lake, although the water would have to be pumped, which is not likely.

The extensive shallow-water habitat of Variation 2 does not seem as desirable as the lake in Variation 1. Variation 1 preserves the existing shoreline of the northern basin, while Variation 2 maintains it with the Salton River, which is isolated from the central marine lake. This isolates the benefits of deep-water burial of Se from the productive, eutrophic shallow habitat of the Salton River.

The following comments relate to a question concerning the relative eutrophication status of a shallow lake versus a deep lake. In general, a shallow lake will have greater amounts of algal production (be more eutrophic) than a deep lake. In a deep lake, there is a tendency for thermal stratification, which traps nutrients in the hypolimnion. This water is out of the photic zone, so does not produce algae. A shallow lake will be better mixed and all of the nutrients will be available for algae. For a constant influx of nutrients, a large volume lake offers a dilution advantage. However, the larger lake will have longer residence times, so settling of algae and internal loading of nutrients becomes more important.

F.9 Comments on Hydraulics by Michael Anderson

Michael A. Anderson
Dept. of Environmental Sciences
University of California, Riverside

The following are comments regarding the US Filter Proposal and accompanying documents. The proposal outlines creation of a freshwater "river" flowing at about 2 cm/s northward to an RO desalination plant that will deliver 500,000 af of drinking water to Colorado River Aqueduct. Brine will be discharged to the central portion of the existing Salton Sea. Two variations on the theme were also outlined in the Tetra Tech review. One involves construction of a mid-Sea dam, maintenance of the north basin of the Sea by fresh/brackish water flows, and desalination of New and Alamo River water. The 2nd alternative involves a mid-Sea dam and maintenance of saline conditions in the perimeter dikes.

While the proposal improves upon the Pacific Institute's earlier concept, there are still some substantial water quality concerns. The Tetra Tech review of the US Filter proposal prepared by Dr. Brownlie underscores many of these concerns. The review is generally quite thorough and well-written; nevertheless, elaboration on some of the points is probably warranted.

The hydraulics of the Salton River are an important consideration. The average flow velocities due to convection were estimated at about 2 cm/s for the 10' dike option and about 1 cm/s for the 15' dike option (TetraTech, Table 5). These advective velocities are comparable to, or smaller than, the expected wind-driven velocities that can reach 1-3% of the windspeed (Horne and Goldman, 1994). With a typical windspeed of around 2 m/s, this corresponds to a wind-driven current of about 2-6 cm/s, although high windspeeds (e.g., 10 m/s) could induce wind-driven surface currents as high as 10-30 cm/s. Thus, the Salton River will be a relatively slow-moving system that will be strongly influenced by winds. The direction of the wind will govern the amount of energy input into the system; a fetch as short as about 0.4 mi or 0.7 km will result when winds are approximately out of the west, although NNW winds or SSE winds will yield a fetch as long as 20-25 km. Under such conditions, a large amount of mechanical energy will be added to the Salton River.

A simple empirical relationship of the form:

$$h = 0.105 * Fetch^{0.5} \qquad (1)$$

has been shown to reasonably estimate the maximum wave height, *h* (cm), of a water body as a function of fetch (cm). Solution to this equation suggests that wave heights as large as 1.6 m may be present at the Salton River (Fig. 1), although bottom shear and other effects will probably lower somewhat the maximum wave height relative to that calculated from eq 1.

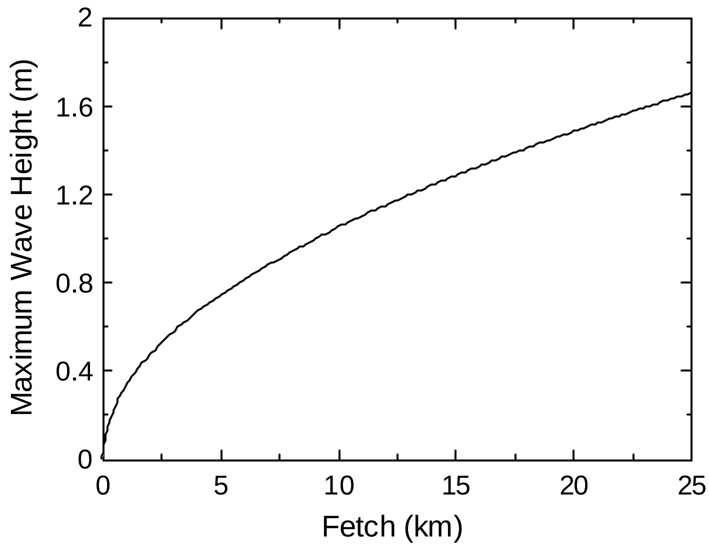

Fig. 1. Predicted maximum wave height vs. fetch.

Winds acting over a fetch of some distance will also set up orbital motion that can mix the water column and also resuspend bottom sediments. It has been shown that resuspension can occur when deep-water waves enter water shallower than one-half the wave length (Bloesch, 1995). The wavelength, L, of a deepwater wave is related to its period, T, by the relation:

$$L = \frac{gT^2}{2p} \qquad (2)$$

where g is the gravitational constant (Martin and McCutcheon, 1999). A wave's period can be estimated using the empirical equation developed by the US Army Coastal Engineering Research Center (Carper and Bachmann, 1984) that states:

$$T = \frac{2.4pU \tanh\left[0.077\left(\frac{gF}{U^2}\right)^{0.25}\right]}{g} \qquad (3)$$

where U is the wind speed and F is the fetch. Solution to equations 2 and 3 for the windspeeds and fetch lengths likely at the Salton River are presented graphically in Fig. 2. At a minimum fetch of about 0.7 km (corresponding to wind blowing perpendicular to the Salton River), wind-forcing is predicted to yield mixed layer depths of <2 m even at high windspeeds, although very large mixed depths (>8 m) are possible under high winds (8-10 m/s). Since the average water depth of the Salton River varies from 5.5 ft to 8.5 ft (or about 1.7 and 2.6 m) for the 10' and 15' dike options, respectively, typical afternoon-evening winds are expected to be able to mix the water column quite readily. That is, wind speeds of about 4 m/s would be sufficient to routinely mix heat and DO down to >2 m depth. In fact, simple empirical relationships indicate that the thermocline depth is about 2x the mixed layer depth. Thus, heat and DO can be expected to mix throughout the water column under both the 10 ft and 15 ft dike options; strong anoxia is unlikely to be a chronic problem in the system. This will be different than the current conditions at the Sea, where several months during the late spring and summer are characterized by negligible DO in the lower portions of the water column.

This will also change the biogeochemistry of the surficial sediments, since anoxia and strong sulfate reduction will be replaced by largely aerobic processes. The current biogeochemical reaction posited to help restrict SRP release from the sediments (alkalinity production from the sulfate reduction reaction, with concomitant coprecipitation of SRP with $CaCO_3$) will likely be lost. That is, lower Ca^{2+} and SO_4 concentrations due to the lower salinity, combined with aerobic conditions, will reduce substantially this reaction. Will the traditional $Fe(OH)_3$ phase found to regulate SRP flux ultimately control internal loading in the Salton River? That mechanism could be more or less effective than the hypothesized mechanism thought to be operating currently, so internal loading may or may not be be higher in the Salton River. Moreover, hydraulic flushing will be removing a substantial amount of nutrients, perhaps at a level comparable to that we feel is being buried with $CaCO_3$ each year currently.

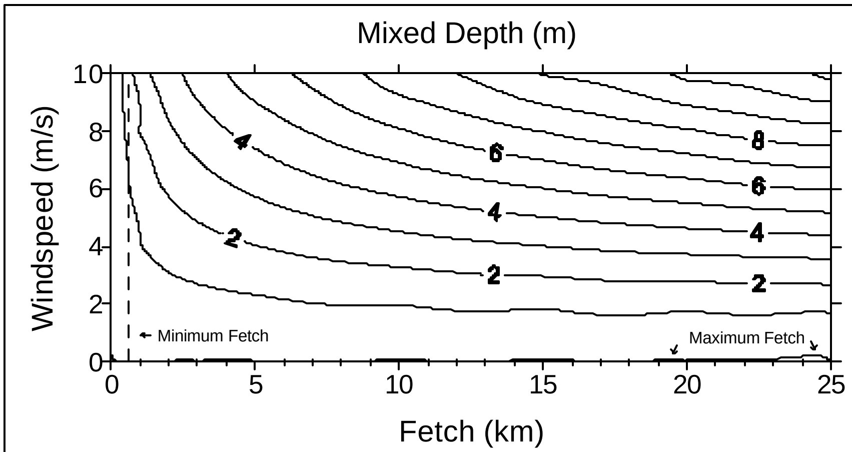

Fig. 2. Wind-mixed depth as a function of windspeed and fetch.

It can further be shown that the wind blowing across the Salton River surface would also result in wind setup (*i.e.*, a water surface slope due to wind forcing) (Fig. 3) that approaches or, for the 15' dike option, would exceed the water surface slope predicted for open channel flow (TetraTech, Table 5). Thus, potentially quite complex water surface elevations and circulation patterns will be present in the Salton River, with wind forcing and surface seiche effects resulting in flow "upstream" periodically.

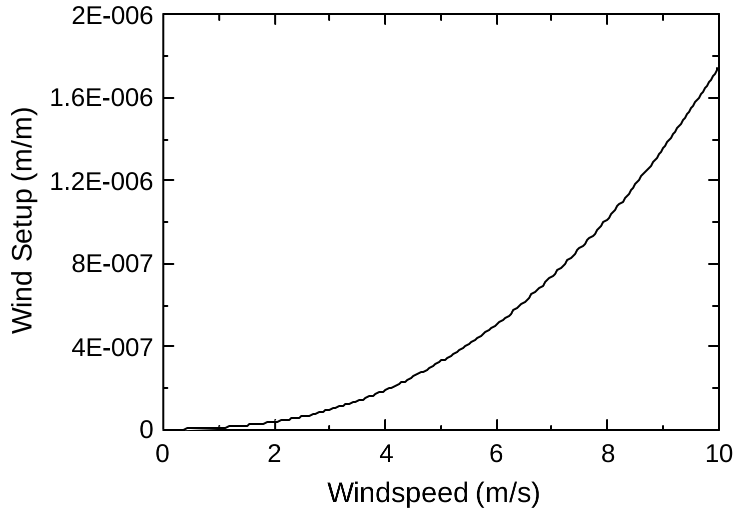

Fig. 3. Wind setup vs. windspeed.

Such turbulence may result in significant resuspension of bottom sediments that could limit macrophyte growth at depth due to light-limitations. The margins of the Sea possess comparatively low amounts of suspendable material presently, since wave action has already mobilized much of the fine material out of the sediment there. Nevertheless, the deeper areas of the Salton River may still periodically generate resuspended material. The lifetime of suspensiods in the water column then becomes a consideration. The suspended solids borne by the New and Alamo Rivers will also differentially settle out of the water column as the flow velocity slows due to the larger cross-sectional area of the Salton River as compared to the current river configurations. In the absence of substantial turbulence, the settling velocity of particles can be estimated from Stokes Law. The time for particles to settle out of the water column at the average depth of 5.5 ft varies from about 5.6 days for clay-sized particles (2 µm) to 0.2 days for a 10 µm silt particle to as short as 0.01 days for a 50 µm particle. Thus, only quite fine (clay-sized) particles will persist any period of time in the water column of the Salton River. The particle-size of the suspended solids in the rivers is not presently known, although observations indicate that silt-sized particles dominate the suspensoids.

The high dissolved nutrient concentrations in the rivers will clearly promote a high algal production rate. Brownlie (2003) correctly states that a new food web will be in place in the Salton River compared to the Sea. Questions remain, however, about the relative amount of nutrients/biomass partitioned to phytoplankton as compared to aquatic macrophytes and periphyton assemblages. It seems likely that the Salton River will ultimately come to resemble the test wetlands in the area, which are characterized by high phytoplankton productivity, high aquatic vascular plant densities, at least near the margins of the Salton River, and high densities of attached algae.

To help assess probable water quality in the Salton River, the BATHTUB model was used. Specifically, the west branch of the Salton River was simulated as a series of 5 identical, hydraulically-linked segments with an average width of 0.68 km, length of 15.1 km and average depth of 1.8 m. The 1st segment was fed by a flow of 898 cfs with a water chemistry equivalent to that reported by Holdren (2000) for the New River (*e.g.*, TN, inorganic N, TP and SRP concentrations of 8.20, 7.27, 1.11 and 0.70 mg/L, respectively). Nutrient sedimentation processes were represented using both the 2nd-order decay model and the 1st-order model, while chlorophyll was predicted using the P, N, light-model. The default model parameters were used for the simulations. It should be noted that internal loading and resuspension processes were not included in the model simulations, however.

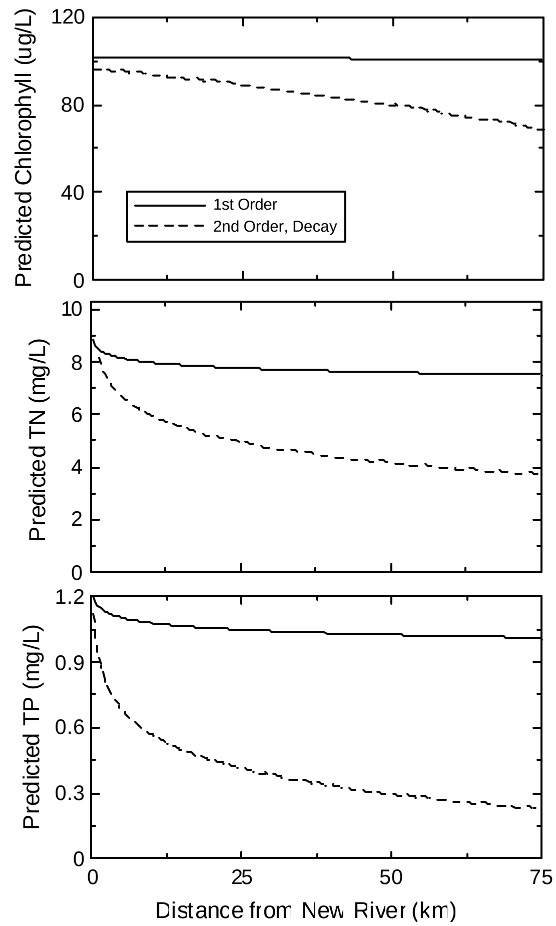

Fig. 4. BATHTUB-predicted water quality in the Salton River: (a) chlorophyll, (b) total N and (c) total P, comparing 1st and 2nd order nutrient sedimentation models.

The simulations indicate that the predicted water quality across the reach is strongly dependent upon the choice of model used to represent net particle settling (Fig. 4). Total P was predicted to decrease from 1.11 to 0.22 mg/L at the northern end of the Salton River (~75 km downstream) using the 2nd-order model, but to only 0.99 mg/L using the 1st-order model (Fig. 4). Total N was predicted to decrease from 8.2 to 3.55 or 7.39 mg/L depending upon sedimentation model (Fig. 4). Irrespective of the model used, high chlorophyll concentrations are expected across the entire length of the Salton River, with annual average chlorophyll concentrations of 72 – 100 μg/L. This compares typical chlorophyll concentrations of 30 μg/L and TN and TP concentrations of 3.80 and 0.065 μg/L presently in the Sea (Anderson and Amrhein, 2002). Thus, it seem clear that the claim by USFilter that "the Salton River would have lower levels of salt, nitrates and phosphates that the current Salton Sea" is not completely correct. While the Salton River would have a lower level of salt, it is likely that the River would, in fact, have *higher* levels of nitrates and phosphates than the Sea. Even with appreciable sedimentation losses, sufficient nutrients will be available to maintain a very high population of phytoplankton in the Salton River. Predicted Secchi depths averaged 0.3 m for the 1st-order model and 0.4 m for the 2nd-order model. Irrespective of resuspension effects, this high amount of algal turbidity will pose a substantial challenge to reverse-osmosis membranes without substantial pretreatment.

The fate of pesticides and trace elements is also an important consideration. The fate of pesticides and trace elements in the Salton River could probably be reasonably predicted using a surface water quality model, although such calculations are beyond the scope of this review.

References

Anderson, M.A and C. Amrhein. 2002. *Nutrient Cycling in the Salton Sea.* Draft Final Report submitted to SSA. 71 pp.+ Appendices.

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Carper, G.L. and R.W. Bachmann. 1984. Wind resuspension of sediments in a prairie lake. *Can. J. Fish. Aquat. Sci.* 41:1763-1767.

Martin, J.L. and S.C. McCutcheon. 1999. *Hydrodynamics and Transport for Water Quality Modeling.* CRC Press, Boca Raton, FL. 794 pp.

F.10 Comments on Water Quality by Maria de la Paz Carpio-Obeso

Date: February 6, 2003

To: Jose L. Angel
Division Chief, Watershed Protection Division

Subject: The Salton Sea River Desalination Solution, proposed by US Filter Corporation

I completed the review of US Filter's proposal, and the draft review by Tetra Tech, Inc. My comments focus on Water Quality aspects discussed in the documents I received and are as follows:

The information provided by US Filter regarding water quality improvements at the Salton River is unsubstantiated.

- Variations in the physical-chemical environmental (pH, T, depth, DO, vertical mixing, retention time, etc.) will effect aqueous concentrations of contaminants/constituents in the inflowing waters (i.e. increasing or decreasing concentrations depending on the constituent). These physiochemical changes may affect sorption, solubility, thermodynamic equilibrium, precipitation and transport of some contaminants.
- US Filter did not indicate the type(s) of membranes used for Reverse Osmosis (RO). This is very important because filters will determine the type and extent of contaminant removal hence water quality improvement. For instance, some filters remove most minerals and nutrients, but only a few dissolved pesticides or metals.
- The fate of the Selenium (Se) is not sufficiently addressed by US Filter, although discussed by Tetra Tech in their review. According to Tetra Tec, Se concentrations in fish and other organisms in the proposed impoundment will increase approximately 6 times the level currently observed or even more. To identify and comprehend the sink for Se, determine mechanisms for Se removal and potential environmental impacts, biogeochemical information should be evaluated, and mass balance calculations conducted.
- The potential impacts pesticides and other water-borne contaminates may have with implementation of US Filter's proposal is not sufficiently addressed. US Filter only addresses DDT, stating all DDT residues and metabolites are presumably derived from soil residues exposed to DDT prior to 1972. US Filter does not consider other potential DDT sources. The occurrence of pesticides is expected given the agricultural activity in the region, and high pesticide use. US Filter should investigate the fate of common pesticides used in this region, as well as pesticides that cause adverse impacts to the ecosystem.

Perhaps we should request more information to avoid confusion or assumptions. I would like to review more data that supports improvements to water quality, in particular for trace elements (Se and As) and pesticides.

Thank you for the opportunity to participate in this process. I look forward to working to improve Water Quality in the Salton Sea. If you have questions regarding my comments please let me know.

Sincerely

Maria de la Paz Carpio-Obeso, Ph. D

F.12 Comments on Water Quality by Jim Setmire

The focus of this review is on water-quality issues in the original proposal (although several other variations of the proposal are presented in the Tetra Tech review, insufficient information is presented to evaluate their effects on water quality).

The proposal details the creation of the Salton River, an extension of the Alamo River along the east side of the Salton Sea and the New River along the west side of the Sea to convey water from these two rivers to a desalinization plant located at the northern end of the Salton Sea. The river will be formed by placement of a dike at the –240 ft MSL contour (10 feet deep) along the periphery of the Sea. An impoundment will effectively be created in the southern end of the Salton Sea in the area between the deltas of the New and Alamo Rivers and extending laterally on both sides. The water delivered to the desalinization plant will be processed by reverse osmosis to generate 500,000 acre-ft of high quality water that will be piped to the Colorado River Aqueduct to augment the drinking water supply of southern California.

The overall area of the proposed Salton River is presented in the proposal to be 25,400 acres for dikes located at the 10ft depth contour. According to the U.S. Bureau of Reclamation's bathymetry study (1995), dikes constructed at a depth MSL of –237 ft (current level –227ft) would result in an area of 30,350 acres and a volume of 2.025 million acre-ft. Initially, it was unclear at what elevation the dikes would be placed. At the Salton Sea's current elevation of –227 ft, many areas along the southern end of the Sea are no longer covered by water. These lost areas represent major shorebird feeding habitat. If the water level elevation is reduced to –230 MSL, not only the above-mentioned areas will be dry, but many additional acres of critical habitat along the southern end of the Sea will be lost. A Salton River elevation that incorporates these areas is strongly suggested.

The Tetra Tech review of the proposal indicates that the Salton River will have an average width of 2,220 ft. Many areas along the northern half of the east side of the Sea (Salton Sea State Park, Corvina Estates, as well as areas along the western shore near Desert Shores and Salton Sea Beach) have very steep bottom slopes. A dike at the 10 ft contour would produce a very narrow channel in these areas. Since an average width was projected, it would be instructive to know how many measurements or sections were used to calculate this number. Additionally, the impact of inflow from the San Felipe River cannot be ignored. Flooding from rainfall runoff events such as Tropical Storm Kathleen in the 1970's could destroy large portions of the western Salton River including irrigation systems for the "dry" areas. Storm flows in the New and Alamo Rivers as well as the Whitewater River (Storm channel) could overwhelm many of the areas of the impoundments and Salton River dike. Additionally, the average water depth in the Salton River is listed as 5.5 ft. Section 2.4.1 of the Tetra Tech review reports that the water surface could be 2 to 3 feet lower in the north end due to hydraulic considerations and that evaporative and other losses could add an additional 1 to 2 ft loss. These reductions in depth describe a very shallow channel in the northern part of the Sea. These conditions would not only cause backwater or flooding problems in the southern end of the Salton River, they also will create areas that are largely impassable and likely inundated by aquatic vegetation.

Surface water inflow to the Salton River(s) and the impoundment created at the southern end of the Salton Sea by this project will have a total dissolved solids (TDS) concentration of about 2020 mg/L in the Alamo River and 3,000 mg/L in the New River. These are current concentrations. Mixing of water between these two rivers in the impoundment will be fairly minimal. Future TDS concentrations in the New and Alamo Rivers are likely to increase due to water conservation and reduction of flows from Mexicali. Since water conservation in the Imperial Valley will likely involve reduction in tailwater runoff and operational loss, the dissolved solids concentration of the water entering the new impoundment will likely increase. Along with an increase in TDS, selenium and other dissolved constituents in the water also will increase

The primary water-quality issue of concern for this project is elevated selenium concentrations in critical feeding areas along the southern end of the Salton Sea and in the habitat of the newly created Salton River. Water conservation is expected to increase selenium concentrations in the New and Alamo Rivers by as much as 30 percent. Selenium concentration in the Alamo River is about 8 ug/L, which already exceeds the current EPA criterion for the protection of aquatic life of 5 ug/L. A lower limit of 2 ug/L is seriously being considered because of selenium's ability to bioaccumulate in organisms and in the food chain under environmental conditions such as found in the Salton Sea. The selenium concentration in the water of the Salton Sea is 1 ug/L. Selenium in the water of the New and Alamo Rivers is quickly diluted from 4 and 8 ug/L respectively to 1 ug/L in the main body of the Sea and in those embayments along its southern end. These areas afford significant shorebird habitat as well as major habitat for large numbers of waterfowl and water birds. Even at its current concentration of only 1 ug/L, selenium is at concentrations in food items that make it an element of concern for birds feeding on fish and invertebrates in the Sea. Increasing selenium concentrations by ten-fold (1 ug/L in the Sea to 10 ug/L or higher in the Salton River) could cause major reproductive impairment and possible teratogenic effects on the avian resources using these newly created habitats. The effects are difficult to project since the entire food chain of the "Salton Sea" will be changed. The main body of the Salton Sea presently provides an environment where selenium is continuously removed from the water column via bacterial reduction and uptake by algae. The selenium is sequestered in the sediments of the deeper parts of the Sea as a result of bacterial reduction to reduced species such as selenite, selenides, and organic selenides. It is also deposited from the decay of algal biomass that has settled to the bottom. This sequestration means that much of the selenium entering the Sea is unavailable to the biota. In the proposed project, the entire 7 ton load of selenium will be concentrated in the Salton River and the impoundment created at the southern end of the Sea, which represent a volume of about 25% that of the current Sea. The biochemistry/dynamics of selenium will drastically change. This selenium will be incorporated as an analog to sulfate into algae that will be consumed by zooplankton, fish and some birds. Currently, the selenium concentration in bottom sediments of these areas is generally less than 1 mg/Kg. However, as the algae die and decay, the selenium will accumulate in the benthos and invertebrates inhabiting these shallow areas. Selenium concentrations in the bottom sediments will increase dramatically.

Additionally, water in the Salton River will be significantly affected by evaporation. If the area of the Salton River is 30K acres, an evaporation rate of about 6 ft/yr would cause the Salton River to lose about 180,000 acre-ft of water. Water loss of this amount will cause evaporative concentration of selenium and other elements in the Salton River, increasing the already elevated concentrations and perhaps placing at greater risk the biota inhabiting and feeding in the lower reaches Salton River toward the north end of the Sea. A project that knowingly creates a water body not only in violation of current EPA criterion for the protection of aquatic life but exacerbates current conditions will likely have trouble receiving federal backing and environmental support.

The current Salton Sea is strongly phosphorus limited. Coprecipitation of P with calcite effectively removes much of the P from the Salton Sea and, in reality, reduces algal blooms. The nitrogen and phosphorus loading that is currently diluted by the entire Sea or at least dispersed throughout will inundate the Salton River and southern impoundment. About 1.3 million kg of P enters the Salton Sea. Under flow reduction, this number will decrease somewhat, but nevertheless, a tremendous load of nitrogen and phosphorus will enter the Salton River. It is unlikely that the same coprecipitation will be effective in the Salton River as it is in the Salton Sea. The internal release of P from the sediments also will be significant from the decaying algae. The result will be extremely dense algal blooms, areas of algal matts on the surface, major color shifts in the water from green to black, and periodic strong odors of decay. Fluctuations in dissolved oxygen concentration will be severe with high summertime DO concentrations during the day and very low to zero DO concentrations at night. These diel fluctuations could be problematic for fish inhabiting the Salton River. The high DO concentrations also affect pH and could cause increased concentrations of unionized ammonia in the water column. The dense algal growth will cause the water to be quite turbid and will likely require substantial filtration prior to entering the reverse osmosis process. Chlorophyll *a* concentrations could exceed 75 mg/L and Secchi depths likely will be less than 0.5 meters. These conditions are indicative of a hypereutrophic system.

Current and previously banned pesticides are present in the water and sediment of the New and Alamo Rivers and for DDE, in the deeper parts of the Salton Sea. Sediments carrying DDE will be deposited in the impoundment along the southern end of the Sea and will be available to the benthic biota for uptake by fish and birds. Water-soluble pesticides also are present in the New and Alamo Rivers and will not be diluted by the large body of the Salton Sea, but will be present in the feeding areas along the southern end of the Sea and in the Salton River. The concentrations and effects of this contamination warrant further investigation.

Residual Body of the Salton Sea.

As described in the project proposal, the existing Salton Sea will quickly shrink and gradually stabilize. In addition to projected water losses to the Salton Sea, the project will remove an additional 500,000 acre-ft from the inflow. Evaporative losses in the Salton River and in the residual body of the Sea will cause salinity to increase drastically. Since the residual Sea will receive reject water from the reverse osmosis process, it will contain very high concentrations of selenium and other potential contaminants and nutrients. Although the residual Sea will eventually be too salty for even brine flies and brine shrimp, there will be a period between 5 and 10 years when algal growth will be extremely abundant and selenium concentrations at quite high concentrations in this water body. Additionally, these deeper areas are where the selenium discussed above is sequestered along with elevated levels of DDE. For this 5 to 10 year period, the residual body of water would be producing brine shrimp and larval forms that would contain elevated levels of selenium that far exceed any dietary concentration considered protective for birds feeding on these food items. No mention is made of a pipeline from the desalination plant to the center of the residual Sea. If the reject water is not piped to the deepest part of the Sea, then that stream will provide a unique habitat, one high in nutrients and very high in selenium. Although this flow does not represent a large habitat, it certainly will be a toxic one relative to selenium. Biota feeding on prey items in this water will be at significant risk to selenium toxicity. Although the residual Sea is supposed to become uninhabitable (food items) in ten years, what happens when periodic flooding and breaches in the dikes prevent the residual Sea from reaching this "uninhabitable" state? This contingency is not described, but is a very real possibility that will either restore or produce a very toxic body of water.

Aside from the potential for flooding, no mention was made of GW inflow to these deeper parts of the Salton Basin. Ground-water levels in the Imperial Valley are close to the soil surface requiring the installation of underground tile lines to maintain adequate salinity control in the soil horizon. Although GW inflow from the Imperial Valley is not considered to be a significant source of water relative to the current Salton Sea, with loss of the head pressure from the Sea and the Salton River on both sides, there is a possibility that seepage to the deepest parts of the Salton Trough might maintain a larger residual Sea than expected. Geothermal springs also are present in the area and are visible in the southern end of the Sea. The influence of this source of water also is not mentioned in the review. Ground-water samples in shallow (<200ft) wells collected during past DOI studies are indicative of shallow geothermal influence. Samples from these shallow wells had elevated levels of arsenic in excess of 60 ug/L. This geothermal source could also exert some influence on the impoundment created in the southern end of the Sea. Carbon dioxide can be seen rising from the bottom in the area near Mullet Island. The effect of this geothermal source on the water quality of the area created in the southern end of the Salton River is not clear.

It is clear from this review that the US Filter proposal does not take into account any of the water-quality issues that were raised during the review of the Pacific Institute's proposal. In addition, this proposal is not a Salton Sea Restoration Project, but will totally change the habitat and some of the wildlife of the current Salton Sea. While the Pacific Institute's proposal could be modified to have the impoundments maintained at ocean salinity thereby preventing many of the water-quality and biological issues that were identified, the current US Filter proposal does not offer solutions to these issues. The variations to the US Filter proposal alluded to in the Tetra Tech review document might offer viable solutions that would maintain some of the current Salton Sea and its habitats – a partial Salton Sea Restoration Project; there was insufficient information presented for evaluation.

The process of modification and creativity is finally beginning to take shape and I believe that a viable option is not far from development. Thank you for the opportunity to review this proposal and I look forward to participating in a process to piece together the best parts of these proposals to come up with the best possible solution to the problems facing the Salton Sea.

F.13 Comments on Air Quality by Ted Schade and Grace Holder

Ellen Hardebeck
Air Pollution Control Officer

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March 26, 2003

Cheryl Rodriguez, Environmental Protection Specialist
Bureau of Reclamation
Salton Sea Restoration Project Office
PO Box 61470
Boulder City, NV 89006-1470

Re: Review of the US Filter Corporation Salton River Desalination Solution Proposal

Dear Ms. Rodriguez:

The following are our comments on the US Filter Corporation Salton River Proposal received by the Great Basin Unified Air Pollution Control District (Great Basin) on January 30, 2003. We appreciate the opportunity to review the proposal and provide comments to the Bureau of Reclamation.

The US Filter Proposal received by Great Basin (and also found on the US Filter internet web site) is conceptual and very brief. The details of the project are not provided in the proposal. This lack of basic information makes it difficult to conduct a thorough review of the proposed project and the impacts it may have on air quality. The document from Tetra Tech, Inc. titled, *Review of the US Filter Corporation Salton River Proposal*, *Draft Report* dated January 2003, contains some of the details of the project that are needed for a review of the project, but a comprehensive detailed document discussing the proposed work is lacking. Thus, the comments provided here are not focused on specifics of the project but are more general in nature. The proposed project is based on a creative and interesting solution to an enormous developing environmental problem and has merit that should be seriously considered. However, the details of the work need to be presented before an in depth technical evaluation can be conducted.

Comments

1. Dust control area. From information given in the Tetra Tech review (Table 3), the percentage of area planned for dust control ranges from 10 to 25 % of the exposed lakebed area. There is no information given to support these percentages but based on experience on Owens and Mono Lake, it is probable that a larger percentage of the exposed area will need to be controlled to meet the particulate matter (PM-10 and PM-2.5) air quality standards. At Owens Lake the exposed playa from recession of the lake water is about 65 square miles of which about 30+ square miles (or 46% or more) need to be controlled to obtain air quality standards at the historic shoreline.

2. Dust control measure implementation. At Owens Lake, we were confronted with a lakebed that had been exposed for over 70 years. This makes it possible to move out onto large contiguous areas to implement dust control measures. At the Salton Sea, the lake will recede in a manner that exposes annular areas requiring immediate stabilization. The current air standards will not allow the lake to reach equilibrium before dust control begins. This means a series of dust control projects that will chase the exposed lake shore as it recedes. Work will always occur in very high groundwater areas (adjacent to the then current shoreline) and the exposed lake bed areas may not immediately have enough elevation above the groundwater table to allow them to be reclaimed and planted. A much more detailed analysis of dust control measure implementation methodology and logistics will be necessary before feasibility can be determined.

3. Water balance. A detailed water balance is not included in the proposal. Initial estimates based on values given in the Tetra Tech review suggest that there may not be enough water dedicated to controlling dust emissions (see table below). This needs to be looked at in more detail with well documented numbers to determine if there is enough water to support this proposal.

Rough Water Balance Without Estimates for Leakage, Infiltration, flows to Salton Lake etc. (units = acre-feet per year (AF/yr))

		15' Dike	10' Dike	
Inflow		1,000,000	1,000,000	From Tetra Tech document
Outflow				
1. drinking water		500,000	500,000	From Tetra Tech document
2. evaporation in Salton River		353,280	203,200	using 8 ac-ft/year evap rate (see Note 1 below)
3. Dust control measures				Assuming 46% of the exposed area for control
	Managed Vegetation	117,760	139,800	using 2.5 AF/ac water duty (see Notes 2 and 3)
	Shallow Flooding	188,416	223,744	using 4.0 AF/ac water duty (see Notes 2 and 3)
4. Leakage		unknown	unknown	
5. Infiltration		unknown	unknown	
6. Flow to residual lake		unknown	unknown	
	Inflow - Outflow 1	28,960	157,000	Using managed veg as sole dust control
	Inflow - Outflow 2	-41,696	73,056	Using Shallow Flooding as sole dust control

Note 1: surface water evaporation is likely going to be greater than the 6 F/yr value given in the proposal due to the fresher water quality in the Salton River and higher water temperatures. A value of 8 F/yr is used here. Even this value may be conservative.

Note 2: Area for dust control = 160 mi^2 for 15' dike and 190 mi^2 for 10' dike. Water duties calculated based on 75% water coverage for shallow flooding and 50% vegetation cover.

Note 3: water duty values from work on Owens Lake. These could be greater at the Salton Sea due to higher temperature conditions, longer growing season etc.

4. Soil survey. Is there information available on the sediments or soils that are present under the lakebed? This information is critical in the design and development of the dust control measures.

5. Leakage below ring dike. It appears that the initial design for the dike structure will minimize the leakage from the Salton River to the exposed lakebed. However, given the considerable length of the dike even a small amount of leakage could be significant. Are there estimates on this value?

6. Drainage system. The managed vegetation dust control measure will require a drainage system for leaching and operation. How much drainage water is anticipated and what will be done with it? Will it be incorporated into a shallow flooding measure or directed to the residual lake? Will there be enough elevation above the saline water table to allow fields to be drained?

7. Salt balance and salt chemistry. Has a salt balance been developed for the project? How much effluent will be directed to the remaining Salton Lake from the desalination plant? What is the anticipated chemistry of the effluent solution?

8. Evaporation. The evaporation numbers used in the documents appear to be conservative. In particular, the surface water evaporation rate from the Salton River is likely to be significantly greater than the 6 AF/yr value given in the proposal due to a lower salinity in the river water and warmer water temperatures. Using the 6AF/yr value, 15-25% of the inflow will be consumed by evaporation. Using a more reasonable value of 8 AF/yr evaporation rate up to 20 – 35% of the 1,000,000 AF inflow will be consumed by evaporation.

9. Salt flats for dust control. Given the high concentration of salts and suitable chemistry, the development of a stable salt crust over portions of the exposed lakebed might be a viable alternative for dust control. Implementation of salt flats could potentially significantly lower the water duty needed for dust control projects and provide a location for storage of salt in the system.

Sincerely,

Grace M. Holder, Ph.D., R.G.
Geologist

Theodore D. Schade, P.E.
Senior Project Manager

Comment Response by Tetra Tech

The air quality cost analysis has been revised substantially since these comments were prepared. For the US Filter analysis, we do not know how much sediment would need to be treated. It has been assumed for purpose of developing a cost estimate that about 40 percent would require treatment with vegetative cover. For the North Lake alternative it is assumed that the entire exposed area would be treated, but that a lower cost treatment of creating a salt crust would be used as suggested by comment 9 in this letter.