Evaluation of a Proposal for Conversion of the Salton Sea Ecosystem

Analysis of a project proposed by the Pacific Institute for Studies in Development, Environment and Security
Oakland, California, October 2001

By participants in workshops coordinated by the U.S.D.I. Salton Sea Science Office and held during December 2001 and January 2002
Riverside, San Diego and Indian Wells, California

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EXECUTIVE SUMMARY

Nearly 30 scientists and engineers were asked to assist in an evaluation of a proposal by the Pacific Institute. The origin of the proposal must be put into proper context to understand the total review contained herein. The proposal calls only for creation of freshwater (10-15 ft maximum depth, 3-4 g/L salinity) impoundments at the northern (2010 ac) and southern (26,800 ac) ends of the Salton Sea, with their surface elevations stabilized at -230 ft. Outflows from these impoundments would flow into a residual Salton Sea. This specific proposal was predicated on the assumption that a major transfer of water from the Imperial Valley to San Diego County and the Coachella Valley would take place, thus causing the level of the residual Salton Sea to drop significantly. The proposal was developed in an attempt to salvage many of the components of the existing Salton Sea Ecosystem recognizing that these components would likely cease to exist with the advent of a water transfer. This important point should not be lost during the reading of this document. ***This review did not attempt to separate out those effects due to a water transfer from those due to development of freshwater impoundments. Thus this document contains review and comment on ecosystem effects from both a transfer of water resulting in a drop in water levels of the Salton Sea, and the development of freshwater wetlands as proposed by the Pacific Institute.*** This review document delineates these effects in most cases by using the terms "Residual Sea" for the lake level with reduced water inflows, and "impoundments" for the freshwater areas proposed by the Pacific Institute.

The overall review indicated clearly that this proposal is very unsatisfactory. The Science Office views this as an iterative process of which this is the first step. We expect further iterations of this review process and interactions with these expert teams to produce a more workable proposal and greatly refined cost estimates. However, the consensus view of the workshop participants was that even with substantial modifications, the proposal would result in freshwater impoundments incapable of supporting the diversity and magnitude of biological resources supported by the current Salton Sea.

On the assumption that impoundment dams would be completed in 2007 and that total inflows to the Salton Sea basin would soon drop to 1.0 maf/yr and remain at that level indefinitely, the residual Sea would drop about 30 ft, stabilizing at an elevation of -257 ft and an area of about 147,000 ac (37 percent smaller than the present Sea) by 2025. The salinity of this residual Sea would increase indefinitely, reaching 100 g/L by 2015 and 200 g/L just prior to 2030. By 2025 about 57,200 ac of exposed lake bottom would exist around the margins of the Sea and between it and the impoundment dams due to water level drops. Artificial wetlands along the New and Alamo rivers are proposed for removal of sediments, pathogens, pesticides, nutrients and other contaminants from flows prior to their entry into the southern freshwater impoundment. In order to remove >90 percent of the sediment loads of these rivers, about 9000 ac of these treatment wetlands would be needed. This document does not attempt a rigorous evaluation how well these treatment wetlands might accomplish these functions.

Impoundment dams would have to be designed for seismic and hydraulic stability and might cost about $1,040,000,000. Treatment wetlands might cost up to $450,000,000 Annual maintenance and operation costs of this complex of systems were not estimated but clearly would be in the millions of dollars.

The impoundments would be less well mixed than are the corresponding areas of the Sea at present. They might be more subject to periods of anoxia and would experience greater temperature extremes. Impoundments would be isolated, however, from the consequences of summer overturn events that generate anoxic, reducing conditions in surface waters that then are occasionally carried into near shore zones by currents.

The ecological and recreational values of the impoundments would be determined primarily by salinity and contaminant levels and the fact that they would represent only about 12 percent of the area of the present Sea. As freshwater systems, they would quickly be colonized by large numbers of freshwater plants, invertebrates, and fish, with carp, tilapia, catfish, threadfin shad, and possibly largemouth bass dominating among the latter. These fish would be much more heavily infested with parasites than are present Salton Sea fish. As the impoundments would effectively be sluggish extensions of the rivers that feed them, they would have contaminant levels similar to those of the rivers. Selenium levels in impoundment waters would be roughly six times those in the present Sea. Fish and invertebrates in impoundments thus would be likely also to have much higher selenium concentrations than do fish and invertebrates of the present Salton Sea. These would pose significant increased risk to both sport fisherman and to fish- and invertebrate-eating birds, such as pelicans, grebes, ducks and shorebirds. The fish-eating birds would have fewer but more contaminated fish available to them than they do now.

Even after flowing through treatment wetlands, inflow waters would have higher concentrations of microbial pathogens than does the present Salton Sea. These would further inhibit or advise against various types of recreational use of the impoundments. Dense aquatic and terrestrial vegetation would colonize possibly 50 miles of now barren shoreline within the impoundments. This would serve as excellent habitat for certain birds but also for mosquitoes, including *Culex tarsalis*. The latter is a known vector in the region of western equine encephalomyelitis, St. Louis encephalitis, and, potentially, West Nile encephalitis, as soon as that gets to California from eastern U.S. The 9000 ac of treatment wetlands could also serve as major new mosquito-producing habitat and might also be sites of selenium concentration in the food web. Other biting insects (horseflies, biting midges) would also likely increase in abundance.

The residual Salton Sea would soon go fishless as salinity rose. The current aquatic invertebrate assemblage would also die out. For some years afterward, high densities of brine shrimp, brine flies and water boatmen would be found here and serve to attract large numbers of invertebrate-eating waterbirds. However, with increasing salinity the production of even such salinity tolerant species drops rapidly. A residual Salton Sea at a salinity of 200 g/L would be as barren of birds as is most of The Great Salt Lake of Utah. Selenium levels in these salinity tolerant invertebrates would also be much higher than those in invertebrates of the present Salton Sea.

Though under the project proposed by the Pacific Institute the ecosystems in the region would initially continue to be as attractive to birdwatchers as the present ones, by most other criteria they probably would be less valuable for wildlife or human recreation and have negative economic repercussions for the region. Fishing, boating, swimming, and camping at the Sea would be less attractive options than they are now. Increased particulate matter air pollution would occur, might affect human health over a large region, and might affect agriculture as well.

Scope and Purpose of This Document

This 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.

This system would be a multi-component one consisting of large freshwater impoundments at the northern and southern ends of the Sea, extensive treatment wetlands along the courses of the New and Alamo rivers, a large area of exposed lake bottom, and a residual Salton Sea in the center of the basin that would be much saltier and smaller than the present one.

We describe the expected salient features of these systems, trying to be clear about where uncertainties lie.

We focus especially on predicting the general nature of the impoundment ecosystems, which would be more complex than the highly saline residual Salton Sea that would still occupy most of the lakebed.

We do not attempt many predictions about particular species, fine spatial and temporal variations in the system properties. We also do not attempt to characterize the transitional states the system would pass through during the years required for dam construction and during the several months required for the impoundments to reach initial equilibrium salinity levels after dam closure.

We omit value judgments about the overall desirability of the proposed project. Weighing of the pluses and minuses requires attaching of a value to each one of them that is primarily a subjective, non-scientific process. Project desirability would also depend on the political and engineering feasibility of alternative possibilities, and we do not analyze those here.

Workshop and Evaluation Process

The possibility of creating freshwater impoundments with abundant fish at the northern and southern ends of the Sea and letting the main body of the Sea become highly saline and fishless was suggested by the Pacific Institute in comments it submitted on the draft EIS/EIR for the Salton Sea Restoration Project. This idea captured the imagination of some people concerned with the future of the Sea and with the need for California to finalize various agreements relating to water transfers and allocation of Colorado River water. The project seemed to represent an engineering option with low annual operating costs once built, did not depend on maintenance of current inflows to the Sea, and postulated some positive ecological aspects. Questions were soon put to relevant authorities – the Salton Sea Authority (SSA) and the USDI Salton Sea Science Office (SSSO) – as to the desirability and feasibility of this option.

To facilitate a scientific review, the Pacific Institute prepared a 7-page, prospectus on the features such impoundments might have and how the converted systems might at least partially meet the stated objectives of the Salton Sea Restoration Project as articulated by the SSA. The purpose of this Pacific Institute prospectus was to provide a concrete, if preliminary, proposal that could be evaluated by scientists and engineers.

In November 2001, the SSSO invited nearly 70 experts to carryout this evaluation, and organized four 1-day workshops covering the topics of hydrology, water quality, biology, and disease and contaminants. Given the short notice and being just before a major holiday, about 30 scientists and engineers convened on December 17 and 19, 2001 in San Diego and Riverside. The deliberations and conclusions of each group were recorded by a focus group member who also agreed to present the group findings at a later public workshop. Participants are listed in Appendix A.

On January 8, 2002, a public workshop on the Pacific Institute proposal was held at the Miramonte Resort in Indian Wells. At this workshop the Pacific Institute proposal was summarized by Michael Cohen of the Pacific Institute. Focus group members from each subject matter workshops presented the conclusions reached by their group and additional presentations were made on engineering and design considerations, on hydrologic modeling, and on the probable dimensions of the proposed impoundments, the residual Sea, and the lake bottom that would be exposed. The presenters collectively functioned as a panel. Following presentations the panel discussed among themselves and reached consensus on major issues that had been raised. Conclusions and commentary were recorded on flip charts in a facilitated discussion and in personal notes of the person assigned to write up the present document. All presenters also provided handouts of text, notes, and graphics used in their presentations. The agenda and procedural guidelines for this general workshop are given in Appendices B and C, respectively.

The Present Salton Sea

The most salient features of the Sea as it now exists are as follows. Its surface lies at an elevation of about -228 ft. Its area is 231,973 ac (362 sq miles), its volume is 7,391,803 ac-ft, and its maximum depth is 50 ft. It is saline (41-44 g/L, depending on season), rich in nutrients (ca. 5 mg N/L and 0.1 mg P/L), and with dense phytoplankton populations year round. Midlake mean water column temperature ranges from about 13˚C in January to about 32˚C in summer, though shallow near shore waters commonly go to >40˚C. During the warmer half of year, full mixing is only occasional and bottom waters are usually anoxic. Occasionally large overturn events render the whole water column anoxic, and there is heavy mortality of algae, invertebrates and fish. Fish populations vary from year to year and seem to be in a severely stressed state, though corvina up to 20 lb and tilapia up to 3 lb are still being caught. Millions of water birds use the Sea every year as a wintering area or a stopover point during their migrations. It is the most important habitat for such birds in southwestern United States. Large mortalities of certain species - pelicans, grebes, ducks, and cormorants - have occurred in recent years due to avian botulism, avian cholera, Newcastle disease, and still unidentified factors. The Salton Sea continues to be heavily used for human recreation. In decreasing order of popularity, principal activities probably would be bird watching and nature study, fishing and boating, and camping.

Pacific Institute Proposal

This is attached as Appendix D. Some of the estimates given below were developed after the original proposal was presented. Time prevented us from considering all possible alternatives for implementing the proposal. In order to standardize the assumptions used by all focus groups, several assumptions were made as to how the impoundments would be built and function. Although the proposals suggest building dikes at two different elevations, with or without treatment wetlands, *we based our review on the assumptions that a dike would be built at the –245 foot elevation at the south end, at the –240 elevation at the north end, and the process would include treatment wetlands*. The proposal did not specify where the dikes would tie into the shoreline, thus the mapping group made this decision and it is reflected in the maps used for discussion. Similarly, the proposal did not specify where and to what extent the dikes would have discharge points for the overflow water going to the residual Sea. The basic assumption was made by the hydrology group, and carried into the other group discussions, that there would be a discharge point near landfall at both ends of the dike and somewhere along the dike there would be a spillway capable of withstanding a 100 flood event.

The essence of the proposal is to build dams that will impound low salinity waters in the northernmost and southernmost portions of the Sea, recognizing that with a water transfer the main body of the lake will become, eventually, a highly saline, fishless lake. Water level in both impoundments would be maintained at the -230 ft level, about two feet lower than the current elevation of the Sea.

At the northern end the dam would be constructed along the -240 ft elevational contour (current water depth of about 12 ft), and at the southern end it would be constructed along either the -240 ft or -245 ft (current depth of about 17 ft) contour. It is proposed that the water level in both impoundments would be maintained at about -230 ft.

The northern impoundment would have a surface area of about 2010 ac and a volume of about 9000 ac-ft. These represent about 0.87 percent of the surface area and 0.12 percent of the volume of the current Sea (at -228 ft), respectively. The northern impoundment would be fed by the Whitewater River and nearby agricultural drains.

The southern impoundment with a dike at –245 ft would have a surface area of 26,800 ac and a volume of 181,000 ac-ft. These would represent about 12 percent of the surface area and 2.4 percent of the volume of the present Sea (at -228 ft). With the dike at –240 ft, this impoundment would have a surface area of 10,500 ac and a volume of 47,000 ac-ft. These would represent about 4.5 percent of the surface area and 0.64 percent of the volume of the current Sea at –228 ft, respectively. The southern impoundment would be fed by the New and Alamo rivers and nearby agricultural drains.

To improve water quality of the inflows to the southern impoundment, it is proposed that artificial wetlands be created along the New and Alamo rivers. These could function to remove silt, nutrients, pathogens, pesticides and selenium to varying degrees from the rivers. They would also function as wildlife habitat. Approximately 9000 ac of such wetlands would be needed to meet the objective of removing >90 percent of the silt load.

Outflows from the freshwater impoundments would be carried by channels, lined or unlined, to the main body of the Sea. Initially this would be at the same elevation (-230 ft) as the impoundment surfaces. If total inflows to the basin are reduced to 1.0 maf/yr and no less, this main body of the Sea would eventually stabilize at an elevation of about -257 ft and its salinity would increase indefinitely.

Drop of the residual Sea's elevation to -257 ft would leave exposed about 57,200 ac (89 sq miles) of the present lakebed of the Sea. This would include broad strips a few miles wide between the bases of the dams and the margins of the shrunken Sea and about 8300 ac between the present margins of the Sea at -228 ft and the impoundment shorelines stabilized at -230 ft.

According to the Pacific Institute, the proposed project would offer the following benefits:

1. Compatible with water re-allocation efforts
2. Sustainable over the long term

3. Increases diversity of habitats at the Salton Sea
4. Preserves and enhances fisheries in impounded areas
5. Promotes increased recreational and economic development opportunities
6. Compatible with other off-site actions

Comparison Systems

The project proposed by the Pacific Institute ideally would be evaluated against specific alternative possibilities and the ecosystems they would produce. However, possible alternatives are numerous, most have not been put forward in any detail, and consideration of all salient variables under the various alternative scenarios would require more time and information than is available.

Nevertheless, it is useful to briefly list some of the major alternative scenarios against which this proposal can be evaluated and that decision makers will need to consider.

These include:

1. The Sea as it has been over the last 10-20 years but with salinity and lake level stabilized or slightly reduced by one of the engineering schemes under evaluation by SSA. Because this is the state for which we now have much concrete scientific information, it is the state most readily compared with the systems proposed by the Pacific Institute. It is also the state that has been the goal of the Salton Sea Restoration Project as defined by the SSA with stakeholder input.

2. A No Action alternative that assumes no further reduction in inflows.

3. A No Action alternative that assumes inflows will soon be reduced to 1.0 maf/yr and will remain at that level for the next 74 years. Those inflow assumptions were ones used by the Bureau of Reclamation in modeling the system that would result from implementation of the Pacific Institute proposal.

4. A No Action alternative that assumes inflows will soon be reduced to 1.0 maf/yr and that, once the precedent of water transfers from the Salton Basin to the coast has been set, larger transfers and further reductions in inflow would take place over the coming decades. This alternative has received little discussion but is arguably the most realistic of the No Action alternatives.

Dams and Wetlands: Designs and Costs

The Pacific Institute proposal considered two primary options for the southern impoundment, one with the dam built along the -240 ft contour and one with it built along the –245 ft contour. There was consensus among all the evaluation teams that we should focus the evaluation on the latter option. The first option would result in a smaller, shallower impoundment that would be markedly less attractive as wildlife habitat or for fishing and other recreational activities.

Thus in the remainder of this report all references to the southern impoundment are to one built on the –245 ft contour.

Dams

Though the Pacific Institute proposal refers to the impoundment-retaining structures as *dikes*, the California Division of Safety of Dams is likely to classify them as *dams* because they would be greater than 6 ft in height and impound more than 50 ac ft of water. This means dam safety would be a major concern at the regulatory level.

The dams would need to be designed to withstand safely the 'project flood'. They would need spillways or weirs and channels to convey water to the new Sea, would require break risk analysis, and would need to be designed for seismic stability.

The least expensive design would involve uncompacted underwater berm construction. This would be subject to potential failure from internal erosion due to seepage and pressure resulting from the 15 ft hydraulic head that would exist after the elevation of the Sea had fallen. Costs for the two dams are estimated at $370,000,000 to $450,000,000.

Quite likely it would be necessary to go to a sheet pile design to achieve the required seismic and hydraulic protection. With that type of construction, the cost for the two dams is estimated at about $1,040,000,000.

The Pacific Institute proposal offered a rough preliminary estimate of total dam costs of about $382,000,000. This was based on the assumption that dike-type structures would be sufficient, an assumption that now appears unrealistic.

The Pacific Institute proposal did not suggest where the outflows from the impoundments were to be placed. The evaluation team thought the best locations would be at the extremities of the impoundments where the dams joined the shoreline. That positioning would minimize development of stagnant areas within the impoundments.

A case could also be made for placing multiple outflow points along the dikes. Once the level of the Sea had fallen each of these would create a channel crossing the exposed lakebed. These channels would quickly evolve into corridors of salt cedar vegetation that could diminish wind speeds and entrainment of particulate matter from the lakebed, thereby potentially reducing air pollution.

Treatment Wetlands

Treatment wetlands have been proposed as a desirable component because of their ability to remove sediment, improve quality of water coming into impoundments, and provide habitat for wildlife. It has not been established, however, that they would provide a net positive benefit.

For example, Total Maximum Daily Loads (TMDLs) for sediment have been established for the Alamo and New Rivers. The water quality issue here is not turbidity *per se* or the potential for sediment accretion, but rather the phosphorus and pesticides that are adsorbed to the sediment particles. Sediment accreting in wetlands would concentrate the pesticides and make them more available. Likewise, it has not been demonstrated in the pilot project on the New River that wetlands reduce concentrations of selenium reaching the Sea. Instead, by slowing the flow of selenium-containing drainwater, the wetlands may become another aquatic habitat (in addition to the irrigation drains) where the element is available to be concentrated through the food chain.

Finally, the extensive acreage of the proposed wetlands will increase water loss by evaporation and reduce by 6-8 percent the amount of water, but not the amount of salts, flowing into the impoundments and the residual Sea, accelerating salinity increase in the latter.

Those questions aside, it is estimated that 9000 ac of treatment wetlands would be needed to remove all or most sediment from the New and Alamo river flows. As only about 2000 ac of suitable river bottom lands are available for wetland construction, the remaining 7000 ac needed would have to be constructed on bluffs many feet above the rivers. Assuming appropriate land could be found, the need to locate wetlands on bluffs would add significant additional costs in terms of piping, pumping, and maintenance.

Design details would be critical because the optimal design for one wetland function often will be suboptimal for other functions. Desired functions would need to be clearly prioritized.

Capital costs for developing the 9000 ac of wetlands are estimated to be $450,000,000 based on a per acre cost of $50,000. This is a rough figure based on costs of setting up the small scale pilot wetlands already in operation along the New and Alamo rivers. Economies of scale would likely result in lower actual costs if extensive wetlands were constructed, although such economies might be offset to some extent by the need to locate most of the artificial wetlands on bluffs.

Maintenance and Management

The dams, impoundments, and treatment wetlands would require a significant annual investment in maintenance and management activities.

For the treatment wetlands, chief needs would be pumping operations, periodic sediment removal, vegetation control and removal, and insecticide applications for mosquito control.

For the impoundments, chief needs would be dam maintenance, monitoring of outflow structures, 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 dams are to be made off limits some or all of the time.

If it were desired to create additional habitat diversity and manipulate impoundment water levels in a manner similar to the way artificial wetlands on many wildlife refuges are managed for waterfowl, then internal dikes within one or both impoundments would be needed as well. This would involve increased capital costs and increased costs associated with water management and was not evaluated further by any of the groups

The evaluation team made no effort to estimate maintenance and operation costs, but given the scale of these systems, these costs would be at least in the millions of dollars per year, and possibly greater than the maintenance and operation costs for systems under evaluation for control of salinity of the Sea.

Sediments and Sedimentation

Sediment is currently delivered to the Sea almost entirely by the New and Alamo rivers and amounts to about 20 ac ft/yr. This is a negligible volume relative to the 181,000 ac ft volume of the proposed southern impoundment. So sediment removal would not be needed to prevent filling in of the impoundment. 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.

The treatment wetlands would be designed to remove >90 percent of sediment present in inflows to the wetlands. A benefit of this would be that phosphorus and pesticides adsorbed on clay particles would be precipitated out with the sediment. If these remained immobilized in the wetland sediments until they were scraped up and hauled to some disposal area that does not drain into the Sea, then there would be potential for slight improvement in water quality related to these contaminants.

If the wetlands remove 90 percent of the sediment in wetland inflows, the sediment loading to the Sea would *not* be reduced to the same degree, at least not initially. There are two reasons. First, as relatively sediment-free water comes out of the wetlands back into the rivers, it would tend to recharge itself with sediments from the bed of the river channel until the equilibrium sediment load dictated by current speed is reacquired. Second, if the impoundment level is established at –230 ft, the gradient of the lower river channels would steepen slightly relative to what they are now with the Sea at –228 ft, and current speed would be higher.

The type and distribution of bottom sediments in the impoundments might show some gradual changes relative to present conditions. With reduced loading of fine sediments, there might be a shift to slightly coarser, sandier sediments in shallow waters. Silt and clay that now is suspended by wave action and then eventually falls permanently to the bottom in deeper waters will no longer be replaced by much new sediment from river inflows. 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 will occupy the shoreline and shallow waters of the impoundments.

The Imperial Irrigation District has a dredging program for maintaining channel depth near the river mouths. This likely will need to be continued if impoundments 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.

Hydrology and Physical Limnology

Residence Time

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, 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.

Residence times for the two impoundments would be short, on the order of 3-6 weeks for the northern impoundment and 9-16 weeks for the southern impoundment. The impoundments thus would essentially be sluggish extensions of the rivers and drainage canals feeding into them.

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 dilution factor is roughly 50 times greater than what it would be for the proposed northern impoundment and roughly 200 times greater than what it would be for the southern impoundment.

Salinity

Salinity will 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 will drop quickly from Salton Sea salinities (> 42 g/L) to salinities only slightly higher than salinities of the inflowing rivers.

Exact trajectory for salinity during the first months following dam completion is unpredictable at the moment – and perhaps not of much importance. It would depend a great deal on mixing rates, impoundment configurations, and positioning of outflow points.

Equilibrium salinity (S_e) in impoundments, however, would be a simple function of inflow salinity (S_i), inflow rate (F, ac-ft/yr), and impoundment evaporation rate (E, ac-ft/yr), viz.

$$S_e = S_i F /(F - E)$$

In general this predicts that these impoundment systems would have salinities 15-20 percent higher than the waters flowing into them.

Certain factors might or would cause the salinity of the inflows to increase. These include reduction of low salinity tailwater runoff from agricultural fields, reduction in input of low salinity municipal wastewaters from Mexicali (if and when Mexico chooses to reclaim this water), and evaporative concentration of New and Alamo river flows as they pass through 9000 ac of treatment wetlands.

Salinity of Whitewater River (Coachella Valley Flood Control Channel) inflows is projected to increase slightly over time as additional amounts of Colorado River water are transferred to the Coachella Valley, in part to replenish its aquifer. This transferred water will be more saline than the well water that constitutes the water supply for domestic uses in the Valley. As the Coachella aquifer is replenished, in part via percolation of municipal wastewaters, more saline groundwater will discharge into the Whitewater River.

Taking all these factors into account, it is predicted that the southern impoundment would within a few months achieve an equilibrium salinity level of about 4 g/L and that the northern impoundment would initially have a salinity of 1.2 g/L that would rise gradually over 15-20 years to an equilibrium salinity of about 2.8 g/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 impoundments via evapotranspiration that would be in excess of evaporative losses calculated simply from impoundment surface areas. By reducing impoundment overflows, this would also accelerate salinity increase in the residual Sea.

Second, especially in the southern impoundment, a slight, transitory elevation of salinity above the predicted level might result from dissolution of gypsum, or calcium sulfate, that is abundant in sediments in many places. As the impoundment waters freshen, this will 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.

The predicted equilibrium salinity levels of 2.8-4.0 g/L are of particular biological significance. Limnologists conventionally set 3 g/L as the dividing line between fresh and saline waters. This is not entirely arbitrary. Most of the world's fresh waters have a salinity of < 1 g/L and most of its inland saline waters have a salinity of > 5-10 g/L. The nature of lake biota correspondingly changes rather abruptly as one goes from 1-2 g/L to 6-8 g/L. A difference of just a few g/L in this salinity range can cause large changes in the nature of the system, much larger changes than might be produced by going from, say, 8 g/L to 20 g/L. Some species of aquatic vascular plants that would colonize the impoundments would find themselves near the upper limits of their salinity tolerance.

Currents, Turbulence, Vertical Mixing and Wave Action

Physical mixing in the impoundments 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 in this part of the Salton Sea. Winds now have fetch of up to 40 miles over which to exert their influence on water movements in the Sea. In the impoundments winds would have much shorter fetches. 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 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.

The long, narrow shape of the southern impoundment would tend to increase inflow-driven currents in proportion to the degree that inflow/outflow rates were high. Current speed and direction within the impoundment would be influenced by the number and position of the overflow points. For maximum homogeneity of water quality within the impoundment, overflow points would be located at either end of the dikes. For maximum heterogeneity, they would be located on the dam about halfway between the New and Alamo river mouths.

Wave action along the shoreline of the northern impoundment would be greatly reduced from what it is now when wind is from the south. Wave action along the shoreline of the southern impoundment would be reduced to a lesser extent, as fetches of a few to several miles in that impoundment would still be sufficient for significant waves to be generated. Shoreline wave action and near shore turbulence action are significant as factors influencing sediment composition, impoundment turbidity and establishment of aquatic vegetation.

Temperature and Oxygen

The impoundments are 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 impoundments will 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 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 winter kills of tilapia in the impoundments 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 impoundments 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 impoundments 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 diel variations of photosynthesis and respiration by autotrophs and heterotrophs, and by mixing regimes.

How impoundment oxygen levels wound 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 dams would slow currents and reduce vertical mixing. This would increase the likelihood of frequent or prolonged periods of anoxia in the deeper waters of impoundments. 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 impoundments would be completely isolated from the deeper anoxic waters and highly reducing bottom sediments found over the main part of the Sea. The impoundments 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.

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 impoundments. 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 impoundments. 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 impoundment in the immediate vicinity of river mouths, turbidity would be low because so much suspended mineral matter would be removed by the treatment wetlands. Over most of both impoundments, however, turbidity would likely be high. It is difficult to say whether it would be higher or lower than in the present near shore waters of the Sea. 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 inputs of sediments by rivers; reduced turbulence, wave action, and currents; suspension-feeding on phytoplankton by the Asiatic clam (*Corbicula*) if it densely colonizes the impoundments; 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 even if some nutrients were removed by treatment wetlands; and disturbance of sediments by carp and other bottom-feeding fish if they were to densely colonize the impoundments.

The Residual Sea

Under the proposed plan, the present Salton Sea would decline in area and elevation until about the year 2025. Its area would drop from 235,000 ac to 147,000 ac, its maximum depth would drop from about 51 ft to about 28 ft, and its mean depth from 25 ft to perhaps about 17 ft.

Salinity would rise to 100 g/L prior to 2015, to 200 g/L just prior to 2030, and still increase gradually thereafter, according to USBR models. These exceptionally high rates of salinity increase for the residual Sea increase represent the combined effect of high salinity of inflow waters and decreasing lake volume. Salton Sea inflows have much higher salinities than are typical of streams feeding more natural saline lakes. For example, Salton Sea inflows are 80-100 times saltier than waters flowing into Mono Lake, California's second largest saline lake.

The lake 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.

The New Food Webs

The overall project would increase habitat diversity and biotic diversity in the region. The southern impoundment would become the largest freshwater lake in California south of Lake Tahoe. New vascular plant vegetation along impoundment shorelines would roughly equal to that now occupying the entire length of the U.S. portion of the New River. The treatment wetlands would represent the second largest marsh habitat in the Colorado River delta region, the largest being Ciénaga de Santa Clara in Mexico. The residual Salton Sea would remain the largest lake in California but would lack fish and would have increased densities of certain macroinvertebrate species over some period of time.

It should be kept in mind that diversity per se is not necessarily good and should not be an automatic objective, mantras in the literature, both scientific and popular, notwithstanding. There would be ways of increasing bird diversity in the Salton Basin that could result in severe damage to particular bird species. Would that be an acceptable trade-off? The quality of a sport fishery bears little relation to the diversity of fish species present. Greater diversity and abundance of parasites, diseases, and disease vectors is unlikely to benefit fish, wildlife or humans in the region.

Here we summarize some of the changes expected and kinds of organisms likely to dominate the food webs or biotic communities of the proposed impoundments and, more superficially, other new habitats that would be created.

Algae

Algae would remain the major base of the food webs in the impoundments, 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 impoundments 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 impoundments 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 impoundments.

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 impoundments 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 impoundments they would tend to have a clarifying effect on the water column by reducing phytoplankton densities.

Vascular Plants and Shoreline Vegetation

Now almost absent from the Sea and its shorelines, vascular plants would become abundant in the impoundments and along their shorelines. An additional 50 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 impoundments 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 impoundments 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 impoundments, neither species could ever be eradicated, given the great size of the impoundments. 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 these shallow impoundments, 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 impoundments.

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 impoundments were created, their fresher waters, together with the occasional rainfall events of the region, will greatly reduce soil salinity along the shores of impoundments. 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, 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 in which 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.

The vegetation of the 9000 ac of treatment wetlands would presumably be heavily managed but nevertheless represent significant additional aquatic vegetation habitat in the region. In present pilot scale wetlands, an attempt is being made to eliminate salt cedar, seeds of which are present in large quantities in river water and germinate in large numbers on the shorelines of the pilot wetlands. Dense salt cedar stands would make maintenance of wetlands difficult and cause increased water loss via evapotranspiration. The cost of keeping 9000 ac of wetlands free of salt cedar should be considered in estimating annual maintenance and operation budgets.

Invertebrates

In the impoundments, 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 (B*rachionus, 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 will 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 impoundments 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.

Freshwater invertebrates of many sorts, including mosquitoes, would also become very abundant in treatment wetlands. On a per unit area basis, their production might exceed that of invertebrates in the impoundments. Fish in the treatment wetlands are likely to be smaller and scarcer and their prey, such as mosquito larvae, will have more physical structure in which to hide.

Fish

The fish assemblages that would develop in the impoundments 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 impoundments 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 impoundments 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 impoundments 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 impoundments might increase the likelihood of some of them invading pupfish habitats such as San Felipe Creek and reducing their numbers via predation or competition.

Amphibians and Reptiles

Soft-shelled turtles have been seen in the New and Alamo rivers and doubtless would colonize the impoundments. 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 impoundments. Toads and tree frogs might use the impoundments and treatment wetlands 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.

Birds

The avifauna of the region would be markedly affected by the creation of impoundments and treatment wetlands and by the rise in salinity of the residual Sea that will 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. We focus on predicting changes for four major categories of birds.

Users of shoreline vegetation. The predicted large increases in shoreline and shallow water vegetation would lead to large increases in bird species that can use that habitat for nesting, roosting, or feeding. These would include particularly rails, bitterns, blackbirds, wrens and warblers. Once tall salt cedar stands had developed, various herons and egrets would be likely to nest in them. Passerines that glean insects from the foliage of such vegetation would also increase. Ducks, coots, and even geese that can feed on submergent aquatic vegetation would also be more abundant. There might be pressure from duck hunters to manage vegetation and water level so as to create optimal waterfowl habitat. Some of these same birds would be able to utilize the managed vegetation of the 9000 ac of treatment wetlands.

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 impoundments 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 impoundments.

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 impoundments 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 impoundments 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 becomes 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 impoundments 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 impoundments 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 impoundments.

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 impoundments 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 will 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.

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. These snags would be stranded far from the water if the level of the Sea dropped as predicted, and probably would no longer be used by these species. One reason would be the much higher heat loads these large birds would be subject to, absent the temperature-moderating effect of water surrounding the snags. Another might be the ability of terrestrial predators to patrol the immediate vicinity of the snags and, in some cases, climb into them.

The margins of the residual Sea and/or the upper surfaces of the dams potentially could be used as nesting areas by Snowy plovers, Black-necked stilts, Caspian terns, Black Skimmers, Double-crested cormorants, and other species. For the dams to be useful for this purpose an unpaved upper surface would be needed and there would have to be restrictions on access by predators, humans, and vehicles during the nesting seasons.

The Residual Sea

As this would continue to receive nutrients via overflow waters from the impoundments, 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, 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 posses 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 will 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.

Disease, Parasites and Contaminants

The project proposed by the Pacific Institute would create or exacerbate a number of problems relating to disease, 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 impoundments.

With respect to contaminants, the general problem is that the proposed impoundments 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.

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*, *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.

We cannot predict how the types or degrees of infestation by microbial parasites might change in the impoundments 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 impoundments as well.

In the proposed impoundments, 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 impoundments. 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 impoundments. 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 impoundments will be highly eutrophic.

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 impoundments can be made.

Smaller populations of Brown pelicans might lead to reductions in botulism mortality of pelicans, although if tilapia populations persist in the impoundments 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 impoundments 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 impoundments or on top of the dams.

Newcastle disease is mainly associated with ground-nesting, as carried out by cormorants at the Sea. Though the factors initiating outbreaks are unknown, once present the frequency of this disease would probably be a function of the numbers of cormorants nesting on Mullet Island or the dam 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 impoundments 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.

Human Diseases and Parasites

The proposed impoundments would cause increased exposure of humans to water-borne pathogens, to vector-borne viral diseases, and to swimmer's itch, especially if the impoundments 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.

Even with treatment wetlands processing the full flow of the New and Alamo rivers, the proposed impoundments, with their much reduced capacities for such dilution and digestion, would not be deemed safe for many recreational activities. Treatment wetlands might remove 90-99 percent of microbial contaminants, but that likely would still result in unacceptable levels of them in the impoundments themselves. Without a continuous, expensive monitoring program for pathogens, public health advisories on recreational use of impoundments 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 Pacific Institute 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 and in treatment wetlands. Some of these mosquitoes would merely be annoying as biters, but others, such as *Culex tarsalis*, are vectors of serious viral diseases of man and other animals.

The viruses that cause St. Louis encephalitis and western equine encephalomyelitis are known from birds in the Imperial and Coachella valleys, although at present cases of human disease are rarely reported. If much recreational use were made of the proposed impoundments, there would be increased likelihood of transmission of these viruses by mosquitoes from the avian reservoir species to humans.

Culex tarsalis likely could also serve as a vector for the West Nile virus, another agent of human encephalitis. 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 impoundments 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 impoundments 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.

Toxic Algal Blooms

Lower salinities and higher nutrient levels, especially of phosphorus, in the impoundments 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 impoundments 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.

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). In the absence of treatment wetlands, nutrient levels in the southern 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.

Fully developed treatment wetlands might remove, via denitrification, significant amounts of nitrogen from river flows. This nitrogen tends to be lost rapidly via the same process in the Sea. Treatment wetlands are not efficient at removing phosphorus. The most that might be expected would be about a 10 percent removal. Though phosphorus is the nutrient in shortest supply in the present Sea, and would be in the proposed impoundments, a 10 percent reduction in loading would not be likely to cause reduction in algal blooms or frequency of anoxia. In the impoundments, 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 impoundments becoming severely hypereutrophic. But evaluation of the efficiency and feasibility of those other projects is outside the scope of this evaluation.

Un-ionized ammonia (NH_3) would have a higher probability of reaching toxic levels in the impoundments. Ammonia is excreted by fish and invertebrates and released by decomposition of proteins. It normally exists in the form of the ammonium ion (NH_4^+). 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 will be in the form of un-ionized ammonia. Daytime pH values would be expected to be higher, up to 10 or higher, in the impoundments than in the present Sea. Such high pH values would result from rapid photosynthetic uptake of CO_2 from the water by dense phytoplankton. High photosynthetic CO_2 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.

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 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 impoundments. 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.

In the absence of treatment wetlands, fish and other organisms in the proposed impoundments 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.

The Pacific Institute proposal acknowledges that 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.

In principle it might be possible to design the treatment wetlands for removal of selenium by adding sediment basins ahead of the wetlands, but there are no even approximate estimates of the cost of doing this or of the reductions that might be expected. To the degree that treatment wetlands trapped selenium via accumulation in plants and other organisms, these wetlands themselves might become a potential problem for wildlife. Past use of large-scale biological treatment technologies (e.g. wetlands, evaporation ponds) has generated serious ecological problems and hazardous selenium waste. Selenium concentrations of 3 ug/g wet weight have already been found in algae in the pilot wetland near Imperial. Under certain conditions, selenium can be lost by volatilization from a system, but that process is not likely to occur at quantitatively significant rate.

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 southern impoundment selenium levels 3 times greater than those in the present Sea. More importantly, unless the selenium problem is dealt with at the source, the building of any number of selenium-removal wetlands upstream of the Salton Sea does not solve the selenium problem. It only makes it someone else's problem.

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.

Treatment wetlands would have the potential to remove these contaminants, though again possibly at the expense of increasing their concentrations in the wetlands food webs and wildlife that were part of them.

In the absence of treatment wetlands, impoundments and their food webs 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 many-fold levels in the present Salton Sea.

Particulate Air Pollution

Pollution of the atmosphere with particulate matter is already a problem in the Coachella and Imperial valleys with the PM10 standard being exceeded many days every year. That standard refers to the concentration in the air of particles smaller than 10 μm in diameter. These cause respiratory problems in humans.

By allowing the level of the Sea to decline and exposing at least 57,800 ac of former lakebed, a worsening of air quality in the region is likely. This will depend largely on the physical structure, particle size distribution, and moisture content of the soil surface. The exposed Salton Sea lakebed would be almost equal to the dry lakebed at Owens (Dry) Lake in 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 mitigate this problem to some extent. However, to the degree that evapotranspiration of overflow waters is increased by these bands of vegetation, the residual Sea would have an even lower final equilibrium level, leaving an even larger acreage of former lake bottom exposed.

The Residual Sea

The residual Sea could pose a serious hazard to wildlife in the form of selenium. It 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 impoundments. 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.

Selenium would be the big danger. Selenium probably would not be sequestered permanently in the sediments or biota of the impoundments. Rather it would cycle among the biota, sediments, and water column of those systems until eventually carried out of them in overflow waters. The quantity of selenium going into the residual Sea would thus be approximately the same as that entering the impoundments, roughly 7 tons/yr. The selenium loading *per unit area* of the residual Sea would therefore be greater than it is for the present Sea. Moreover, in the shallower residual Sea, selenium would also be less likely to be permanently sequestered in the sediments, especially if those sediments were more subject to burrowing and feeding activities of invertebrates. Selenium levels in brine shrimp, brine flies and water boatmen in the residual Sea thus would likely be much higher than those in invertebrates in the present Sea.

Recreation and Economics

Our evaluation of the Pacific Institute proposal focused primarily on the physical, chemical, and biological characteristics that the systems produced by implementation of the Pacific Institute proposal would be likely to have. Specialists in recreation and economics were not on the evaluation team only because of a lack of time to locate these experts.

Nevertheless, our findings have some direct and obvious implications for recreation at the Salton Sea and the regional economy. We briefly outline these below

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 impoundments would have a few negative impacts on the quality of the area for bird watching and a few positive ones.

Negative effects would include: reduced access to and visibility of northern and southern shoreline areas as a result of the extensive development of shoreline vegetation; reduction in abundance of fish-eating birds in general; and increased abundance of biting insects.

Positive effects would include: increased diversity of birds, especially of waterfowl, passerines, and rails as a result of development of aquatic and shoreline vegetation, and of fish- and invertebrate-eaters, as a result of greater diversity of fish and invertebrate prey in the impoundments; availability of dam surfaces both as loafing and nesting areas for birds, and as viewing areas for birders; and increased abundance of certain invertebrate-eating birds, at least for some years, on the residual Sea.

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.

Fishing

Fishing could be quite good in the impoundments 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 impoundments.

That sort of fishery, except for the tilapia, can be found in many other waterbodies in the region and in southern California, however, and fewer fishermen would be willing to travel long distances to take advantage of it. It will no longer be a special, unique fishery capable of generating tales of 30 lb corvina that got away.

Rather it would become known as a fishery where contaminant levels were higher than elsewhere for the same species and higher than in the former Salton Sea. Selenium levels we estimate would be six times greater than those in fish of the present Sea would cause the state to warn against any consumption of impoundment fish. Detection of microbial pathogens or indicators of fecal contamination in the impoundments would lead to the same warning. The accurate perception that the impoundments were sluggish extensions of wastewater drains would discourage fishing for many years even after contaminant levels had been reduced – if that ever were achieved.

In short, a sport fishery would not be compatible with the proposed project, at least not over the short or medium term.

Boating and swimming

Boating in the impoundments, because of reduced current speeds and wave size, would probably be safer than in the current sea, and the entirety of the impoundment areas would be accessible to smaller boats. On the other hand, contaminant levels in fish, invasion by aquatic vegetation, and 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 impoundments 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 conducts. Persons with larger, faster boats interested in a quasi-oceanic boating excursions would no longer be attracted.

Swimming would probably be non-existent in the impoundments. Potential bathers would be put off by softer sediments, aquatic vegetation, absence of beaches, more biting insects, the presence of swimmer's itch and microbial pathogen levels higher than those in the present Sea. Though swimming is less common than it once was along the exposed, coarser sediment shorelines of the present Sea, this has more to do with irrational fears of algal blooms and resultant turbidity and inaccurate press reports than it does with the reality of the situation. Naturally on those specific occasions when there is a moderate to large fish kill nearby or washing up on shore, or when there is a bloom of the surface film-dwelling alga *Pleurochrysis* in progress, or when heavy waves have stirred up sediments, swimming is not an attractive option. But for most of the year the present Salton Sea is an excellent place for swimming.

The main part of the Sea where salinity would be allowed to increase over time might remain suitable for both boating and swimming for some decades, though of course boating fishermen would not be interested in it. This possibility would be much influenced by the nature of shoreline and shallow water sediments along the margins of the receding residual Sea. If these were fine and muddy, little use would be made of the Sea for these purposes. However, once the level of the residual Sea stabilized access roads, docks and boat ramps could be put in, if expected boat use on the fishless Sea would justify such.

Camping

There is a fair bit of both tent camping and mobile home camping around the edges of the Salton Sea, and much of this is associated with bird watching, desert nature study, scientific excursions by university classes, and just relaxation under the desert stars. More than fishermen and boaters come to the Sea. Very little of this camping takes place along the shorelines of the areas to be impounded, and in general the impoundments – by increasing the abundance of biting insects as well as on non-biting insects, such as chironomid midges, likely to swarm to campsite lighting fixtures – would make these 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.

Camping on shorelines of the receding residual would not be an attractive option. Air pollution with particulate matter would be higher than on the present shoreline especially during breezy or windy weather. It would not make sense to provide much in the way of facilities (roads, parking areas, docks, restrooms) until the level of the residual Sea stabilized. Camping in the higher elevation, sandier spots would leave one far from the water.

New camping areas, or general centers of recreational activity, established near where impoundment dikes intersected the shoreline could enhance recreational values. These could provide easy access of boaters, birdwatchers or fishermen both to impoundments and to the residual Sea. These would be areas of high biotic diversity. Those on the west side of the Sea could be tranquil sites free of the hooting and rumbling of nighttime freight trains that run along the east side of the Sea.

Economics

In general the economic consequences of implementing the Pacific Institute proposal would seem quite negative. Value of most shoreline properties would drop precipitously. Many fewer people would come to the Sea for fishing, boating, and camping, though the numbers coming for bird watching would remain high. Increased particulate matter air pollution would exacerbate the above and increase medical and public health costs, and might affect agriculture if much of the particulate matter consisted of salts. The cost to Imperial County of mosquito control along 40 miles of new shoreline mosquito habitat and in 9,000 acres of treatment wetlands would be high.

Evaluation of Benefits Proposed by the Pacific Institute

We quoted at the beginning the benefits that the Pacific Institute claimed for the proposed impoundments, and they are repeated below, with our comments on each. We recognize that the intent of the Pacific Institute was, in part, to put these forward as benefits only relative to benefits or costs associated with No Action alternatives or with other proposed schemes for maintaining the environmental values of the Salton Sea.

Our comments take into account, however, that the Pacific Institute's proposed benefits will be interpreted by many as being *net* benefits defined in some more absolute sense.

Compatible with water re-allocation efforts. The impoundments would be compatible with these. However, there is an underlying presumption here that these "re-allocation efforts" are positive actions or at least politically inevitable. Many members of the evaluation team and others believe that some of them, such as the proposed water transfers from Imperial Valley to San Diego, are neither and that they will have high environmental and economic costs.

Sustainable over the long term. This is true only in the narrow sense that salinity increase over time would not be a problem as it is in the current Salton Sea and would be in a residual Salton Sea outside the impoundments. As presented the Pacific Institute Proposal is not sustainable. Only with substantial increases in infrastructure, operational and maintenance costs can it be said that once constructed, annual maintenance and operation costs *may* not be greater than those estimated for possible projects to restore the entire Sea involving evaporation and replacement waters. We suspect, however, that costs will be substantially higher and a more thorough review would bring this to light.

Increases diversity of habitats at the Salton Sea. This is true but diversity is not an automatic good. One major consequence of the increased habitat diversity will be increases in the diversity and abundance of biting insects, increases in diversity and abundance of parasites and pathogens, and increased extent of habitat where high selenium levels pose a threat to wildlife and humans.

Preserves and enhances fisheries in impounded areas. This might be more accurately stated as "Creates new fisheries in impounded areas", as neither preservation nor enhancement of what exists now is involved. From the point of view of sport fishermen and fish-eating birds the impoundment fishery would be greatly inferior to the existing fishery. The fish would not meet standards for human consumption, and their elevated selenium levels would make them more dangerous to fish-eating birds than are fish in the existing Sea.

Promotes increased recreational and economic development opportunities. This would not be true, for reasons given above. These opportunities would be diminished relative to those provided by the Sea even in its present unrestored state.

Compatible with other off-site actions. This is true of other possible restoration projects for the Sea, as well as of the No Project alternative, and does not constitute a benefit.