Chapter 2

Alternative Development Process

The preappraisal level alternatives are designed to reduce the salinity of the Salton Sea and maintain an acceptable water surface elevation. It is not known at what salinity level the Sea will become unproductive. Interim or phased projects may be considered for development that arrest salinity increases, do not preclude long term solutions, and do not increase water elevation levels.

Reducing salinity and maintaining the Sea level, alone, will not ensure a good biological habitat. However, the current biological habitats in the Sea will cease if the salinity of the Sea continues to rise. The Science Sub-Committee, established by the Secretary of the Interior, is examining the needs of the biological habitat and many other important science-related issues of the Sea. Therefore, biology is outside the scope of this report.

Additional geologic work is beyond the scope of this report but was considered in these designs based upon the information in the 1974 report. The 1974 report does contain much geologic information, including field investigations, sampling, and laboratory testing data. Seismic activity in the Salton Sea area is very high and is an important consideration in final designs.

Salinity, as used in this report, is a measure of the concentration of total dissolved solids (TDS) in water. Salts are inorganic compounds of metals, such as sodium, calcium, magnesium, and potassium and bases such as carbonates, sulfate, and chloride. Soluble salts will dissolve into metallic and basic ions when exposed to water. Salinity values are commonly given in parts per million (ppm), parts per thousand (ppt), and milligrams per liter (mg/L). The values of ppm and mg/L are essentially equal. There are a thousand more ions in 1 ppt than in 1 ppm. This report uses mostly parts per thousand because of the large quantities of ions in the waters discussed.

The reader should keep in mind that ocean water has a salinity concentration of 35 ppt, and the Salton Sea currently has a salinity concentration of 44 ppt. However, at this time, the overall effects of salinity on the fishery are not known. The questions of what effect salinity has on the aquatic habitat has been given to the Science Sub-Committee for analysis and recommendations.

Public Involvement

While a number of alternatives were identified during previous studies, it was important that any new ideas be included in the alternatives being evaluated. Opportunity was given to companies, universities, individuals, and the general public to suggest alternatives for solving challenges of the Sea.

A public discussion was opened on ideas and suggestions for management of the Sea in the form of two public workshops hosted by the Salton Sea Authority Board's TAC in August and September 1995. The public was again invited to propose solutions during summer 1998 at three public meetings. The TAC, along with *ex officio* members, was there to listen, discuss, and record alternatives proposed by the public. Notice of these meetings was given in Imperial and Coachella Valley newspapers and posted in local libraries in accordance with the California Government Code Section 54950 (Ralph M. Brown Act), governing open meetings. (All meetings of the Authority and TAC also fall under the Act.) In addition to ideas and suggestions presented in the workshops, written submissions were accepted with the understanding that all the alternatives submitted to the TAC would be considered on their technical and economic merit.

Development Process

One consideration in selecting a management alternative is that a drop in elevation could also cause developments to be left at a considerable distance from a receding shoreline. There is also a correlation between salinity and elevation such that any increase in the Sea’s volume is accomplished by inflow from a less saline water source which dilutes the existing salt concentration. Also, any decrease in volume is by evaporation, which raises the salinity by concentrating the salt in the remaining water.

Rising water surface elevations also can disrupt historic flow patterns and contribute to access problems at marinas. Deposition of sediment and barnacles in channels that provide access to boat slips and docking facilities can require increased maintenance to keep those channels open. In some cases, these problems have resulted in denied access altogether.

The development process, therefore, involved designing alternatives that meet the three criteria. These criteria were applied to all submitted alternatives. An alternative must have the ability to:

- Reduce salinity to not more than 40 ppt
- Control water surface elevation to -232 m.s.l.
- Use proven technology

Alternatives that did not meet all criteria may be dropped from further consideration and are described later in this report.

Target Salinity: 40 ppt

Salinity management targets have been established at levels that protect the existing fishery in the Salton Sea. The Sea currently supports a fishery of marine species (that is, corvina, sargo, and bairdiella) transplanted to the Sea when the salinity concentrations rose too high to support freshwater species. The Sea's fishery is important to the region from both environmental and economic viewpoints. For example, fish are important biologically to fish-eating birds and other animals found around the shore of the Salton Sea, and the wildlife in the region attracts fisherman, hunters, and naturalists, providing economic growth to the area. Furthermore, the Water Quality Control Plan for the Colorado River Basin (California Regional Water Quality Control Board, 1994) designates warm-water aquatic habitat as a beneficial use, and its water quality objective for salinity relates to sustenance of aquatic life.

For the existing fishery to be maintained, a salinity range of 35 to 40 ppt has been determined acceptable. The criteria identified for these alternatives was selected to meet a salinity concentration of no more than 40 ppt. This salinity concentration would stabilize the fishery at the existing conditions of the Sea. As a comparison, ocean water is approximately 35 ppt; Salton Sea water, at the time of this report, is approximately 44 ppt. This salinity would allow fish species currently found in the Sea to spawn, thereby complying with Water Quality Control Plan for the Colorado River Basin requirements for protecting beneficial uses of the Sea.

Target Water Surface Elevation: -232 feet m.s.l.

Many considerations determine a target water surface elevation of the Salton Sea. Private and commercial property owners are concerned with the Sea's elevation because of its direct effect on property values and on future construction projects along the shore. Because the Sea is a repository for agricultural drainage, the Sea's elevation is important to agricultural interests. The Sea's elevation is also important to the biota of the area. Birds, such as the endangered Yuma clapper rail, depend on wetland habitat around the margins of the Sea for breeding, and many hundreds of acres of wildlife refuge have been inundated by rising Sea levels. State and Federal agencies must also plan for potential flood conditions. History has shown that rapid flooding occurs regularly in the area, and the Sea is a repository for storm runoff. Finally, the Sea's target water surface elevation is closely connected to its target salinity concentration. The removal of water from the Sea as a means of removing salt can result in dramatic changes in water surface elevation. The elevation management target and ability to regulate water surface elevation may ultimately determine the salinity management option selected for implementation.

The water surface elevation of the Sea is currently about -227 feet m.s.l. The Sea's elevation fluctuates about 1 foot per year based on Imperial Irrigation District elevation data for the past 9 years. In 1994, for example, the Sea's elevation ranged from between -227.75 to -226.75 feet m.s.l. and from -227.8 to -227.2 m.s.l. from November 1994 to February 1995.

While current shoreline damage resulted from high water surface elevations, much lower levels could also cause damage. A large drop in Sea elevation could adversely affect shoreline development, including marinas, the Salton Sea State Recreation Area, commercial enterprise, and residential developments. Large drops in elevation would also expose large areas of land that were Sea bottom and degraded biomatter. Some people feel that this would become a health hazard when made airborne by wind. As a method of balancing between excessively high and low levels, a target elevation range of -232 feet m.s.l. was established.

Maintaining the water surface elevation of the Sea within the target range is certainly of interest, but uncertainties of future flows into the Sea make it difficult to determine an alternative’s effect on the Sea’s elevation. As a result, the elimination of an alternative due to its inability to achieve and maintain the target elevation is used only on those alternatives that have no ability to control the water surface elevation of the Sea.

Proven Technology

Because of the short timeframe allowed for applying the alternative, the technology employed in the alternative must be currently available and proven in similar situations. The goal of the development process was to design alternatives with the best chance of success. To further the design process, only alternatives that could present data demonstrating the involved technology's effectiveness were considered. An alternative's technology could be demonstrated by data gathered in a full-scale application, prototype, or lab results, but all data necessary for evaluation had to be available. By definition, this eliminated all research proposals.

Salinity Model

An operational model was developed for the Salton Sea by Richard Thiery for use by the Salton Sea Authority (Thiery, 1998). The model is a workbook or spreadsheet model created using the Microsoft Excel spreadsheet program. For the most part, the model uses simple mass balance arithmetic to calculate changes in elevation and salinity in response to annual estimates of inflow and evaporation with pump-in and pump-out alternatives. Work-sheets were developed to evaluate water exchange (pump-out/pump-in) alternatives with the Sea and several in-Sea evaporation pond configurations containing 48, 85, and 143 square mile surface areas based on total Sea area at -227-foot elevation.

Elevation-area and elevation-capacity relationships were developed for each of the alternative configurations. New area and capacity relationships would need to be developed for any new in-Sea evaporation pond configuration. One worksheet was developed to evaluate variable areas as desired by the model operator; however, the area and capacity relationships are general and do not represent actual conditions. The original model was provided to Reclamation and was evaluated by the Technical Service Center (TSC) for applicability to this preappraisal study. It was concluded that the original model could be used in alternative evaluations.

Evaporation Rates

The evaporation rate from water surfaces is a function of energy exchange at the water surface and the salinity concentration of the water body. The energy relationship was handled by using average annual energy conditions for the Sea area and developing a relationship for the Sea based on salt concentration in ppt. This resulted in an annual Sea evaporation rate of 66 inches of water at a salinity concentration of 44 ppt. It was reduced to 56.1 inches at a salinity of 200 ppt. This evaporation relationship was programmed into the model. As salinity in the Sea or salt concentrations varied, the appropriate evaporation rate was calculated and used in evaporation calculations.

Precipitation Rate

The original version of the model did not account for direct precipitation to the Sea water surface and was not available for use in evaluating the pump-in and pump-out alternatives. Mr. Thiery added precipitation as a model input in version 1.1 of the model, which also contained a worksheet that would hold the Sea elevation constant and let the in-Sea evaporation pond elevation vary independent of the Sea for one impoundment configuration (143-square-mile surface area). The average annual precipitation rate used in version 1.1 of the model was 2.80 inches per year. To be consistent in all model calculations, precipitation to the Sea was not used. However, it was determined that if precipitation was input to the worksheets, the Sea water surface elevation in the model would increase approximately 3 feet in 100 years. The total increase depends on the Sea and evaporation pond salinity concentrations.

Drainage to the Sea

The current drainage to the Sea is estimated to be 1,346,000 acre-feet annually from all sources, including the Alamo, New, and Whitewater Rivers and other drainages discharging directly to the Sea. The estimated salinity concentration of this drainage is 2.8 ppt and was used in all alternative evaluations using current conditions. The maximum Sea salinity concentration rose to 91 ppt at the end of 100 years under these baseline conditions.

Water conservation activities are planned in the Sea drainage area and are expected to reduce the drainage inflow from 1,346,000 acre-feet annually to 1,000,000 acre-feet annually over the next 10 years. For evaluation of the water conservation alternatives, an additional 20,000 acre-feet were removed from the inputs for each of the first 9 years. The remaining 166,000 acre-feet were removed in year 10 to reach a total inflow of 1,000,000 acre-feet per year, a reduction of 346,000 acre-feet. It was assumed that an associated 300,000 tons of salt also would not drain into the Sea. This reduction was prorated as the drainage was prorated with 12,000 tons being removed each year for 9 years and the remaining 192,000 tons removed in the tenth year. The rest of the time, the drainage inflow to the Sea was 1.0 million acre-feet at a salinity concentration of 3.5 ppt. These changes were programmed into the water exchange worksheet to determine required pumpage.

The in-Sea evaporation impoundment worksheets were programmed with the salinity concentration and water surface elevation at the end of year 9 as initial conditions for each of the drainage quantities. This was done because it was assumed that it would take at least 9 years to design and construct effective salinity control measures. Under this assumption, the Sea would increase in salinity for the first 9 years in the water exchange scenarios before pumping started.

Salinity and Sea Elevation Goals

The salinity goals for the alternatives in the model were to keep the salinity concentration from exceeding 50 ppt and to reduce the Sea's salinity concentration to 40 ppt in 15 or 30 years after the control measure was initiated. The salinity target would be accomplished by pumping quantities of Sea water out and disposing of it in evaporation ponds or the ocean. Water with lower salinity concentrations could also be pumped into the Sea to help meet the salinity target. Usually, both pump-out and pump-in were required to meet the target of maintaining the Sea at -232 feet m.s.l.

All pump-in/pump-out alternatives could be made to meet the targets by balancing the pump-out and pump-in volumes of water. The ocean water pump-in alternative required large volumes of water to meet the target salinity. For example, 700,000 acre-feet of pump-out and 600,000 acre-feet of pump-in were required to meet the target salinity concentration of 40 ppt in 15 years. Under this scenario, the elevation target was met in simulation year 42.

The 30-year salinity target was met with 400,000 acre-feet of pump-out and 303,000 acre-feet of pump-in of ocean water. The ocean water used had a salinity concentration of 35 ppt. The target water surface elevation of -232 m.s.l. was met in simulation year 47. With ocean pump-in water, the Salton Sea salinity could not be lowered to 35 ppt. The minimum salinities (100 year) were 35.4 ppt and 36 ppt, respectively, for the two ocean water examples above. Other pump-in/pump-out alternatives could have the Sea salinity go below 35 ppt and the target elevation if pumping was not properly balanced.

Model Behavior

The model has some unique behavior characteristics that occur, such as the case described above for ocean water pump-in conditions. The Sea salinity will approach the pump-in water salinity asymptotically if large enough quantities are pumped for a long enough period of time. Pump-in water with low salinities (4 ppt), such as from Yuma (Tucson, Arizona), discussed later, had to have both the pump-out and pump-in quantities reduced to prevent the Sea salinity from going below this 35-ppt target, the salinity of the ocean.

The difference between the final pump-in and pump-out quantities needs to be balanced with the evaporation rate and the drainage volume to the Sea after the target salinity is reached to maintain the Sea at the target elevation. The ocean example given above, with 1,346,000 acre-feet of annual drainage, required between 97,000 and 100,000 acre-feet less water pumped in than pumped out to meet the -232-foot target elevation. The two examples had final elevations of -232.3 and -232.1 m.s.l., respectively.

The model operation results showed that the most effective way to reach the target salinity was to pump as much water as possible from the Sea as quickly as possible. This should be started as soon as the pump-out system can be designed and constructed. The maximum pump-out design capacity needs to be balanced with the later steady pumping rate to minimize infrastructure and pumping costs. Also, the pump-in flow can be delayed from start of pump-out. This may be delayed until the most appropriate source is determined. It should start at the appropriate time to balance the evaporation, pump-in, and pump-out to the Sea target water surface elevation and prevent significant drops in elevation prior to reaching the target salinity. Once the target salinity is reached, then the inputs and outputs need to be set at reduced pumping rates to maintain both the target elevation and salinity.

The results of the model analysis—the success of the alternatives to meet the salinity and water surface elevation goals—are discussed in chapter 9.

Cross-Reference Table to 1997 Report

All alternatives presented in the 1997 report have been reconsidered using the three criteria stated above. Some are discussed in detail in later chapters, and others have been considered for elimination from further consideration because they could not lower salinity concentrations, could not maintain the water surface elevation at the desired levels, or did not use a proven technology.

Table 1 lists the alternatives considered in the 1997 report and provides a cross-reference location to that alternative's discussion in this document.

Table 1.—List of alternatives and cross-reference location

54 original alternatives		Location in this report
Diked Impoundments		Page
1.	50 square miles, south end	27
2.	40 square miles, south end	27
3.	127 square miles, north end	27
4.	47 square miles, in-Sea evaporation basin	30
5.	Phased impoundment	30
6.	30 square miles with pumping to Palen Lake	30
7.	30 square miles with maximum pumping	30
13.	190 square miles, plastic curtain	74
14.	Various sized impoundments—plastic curtain	74
Pump-Out		
8.	Onshore evaporation ponds	71
9.	Enhanced evaporation/solar pond/power	72
10.	Dry lakebed (Palen, Clark, or Ford)	48,51
11.	Pipe to Pacific Ocean/Camp Pendleton	48-51
12.	Navigable waterway/Mexicali seaport	73
15.	Canal/dam to base of Chocolate Mountains	74
16.	Diked impoundment to Gulf of California	74
17.	Frontier Aquadyne enhanced evaporation	75
18.	Solar still desalt/Colorado River replenish	75
19.	SNAP technology	76
20.	Aquaculture/evaporation ponds	76
21.	Pump to Gulf of California (415K acre-feet)	56
22.	Pump to Laguna Salada/Gulf of California (415K acre-feet)	56
23.	Pumped storage canal to Gulf of California	76
24.	Solar membrane distillation	77
25.	Disposal of reject stream to Yuma	77
Combination		
26.	Impound/evaporation pond/pipe to Gulf of California/Yuma Desalting Plant	77
27.	Impound/power generation/wetlands	78
28.	Freshwater shore/pumped storage/wetlands	78
29.	Solar power/pumped storage/wetlands with Laguna Salada disposal	79
30.	Move Yuma Desalting Plant to Sea	79
31.	Poplar tree constructed wetlands	80
32.	Special pretreatment reservoirs	80
33.	U.S. Filter-New River desalting	80
34.	Groundwater pump for selenium management	81
Water Imports		
35.	Freshwater blending—Calexico	81
36.	Replenish—Colorado River surplus	81