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Integrated Systems Analysis Applied to Environmental Remediation.

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Abstract

At the request of the Congressional Task Force on the Salton Sea and the Salton Sea Authority, we provided technical assistance on examining options to reverse the decline of the Salton Sea. The options fell into four categories: do nothing, diking, pump-in/pump-out, and desalination. We found that diking and pump-in/pump-out could meet the criteria set by the Salton Sea Authority and depending on the particulars would reduce the salt level in the Sea. Implementing only pump-out could meet some of the criteria, while desalination was deemed as too expensive to be practical. We also did a preliminary examination of the feasibility of disposing of Salton Sea water by pumping the water into an existing geothermal aquifer.

Background and Research Objectives

The Salton Sea is a isolated inland lake created in 1905 from an accidental diversion of the Colorado River. The lake has no outlet and has been maintained since its creation by run-off water from irrigation in the Imperial Valley. Over the years the Salton Sea has supported a large fish population which, in turn, has supported recreational fishing and large bird populations. The Salton Sea has replaced the Los Angeles area as a stopping point for migrating birds in the Pacific Flyway and now boasts one of the largest concentrations of migrating sea birds in the west.

Since 1905 the salinity of the Salton Sea has gradually increased as the incoming irrigation water is evaporated until today the salinity 20 to 25% greater than that of the ocean and is approaching levels that will be unable to support fish life. In the past few years there have been large bird die offs in the Salton Sea caused by birds eating diseased fish and possibly due to the accumulation of hazardous materials in sediments.

A Congressional Task Force and an organization (The Salton Sea Authority) have been created to examine methods to reverse the decline of the Salton Sea. Los Alamos has been

requested by the Congressional Task force to provide technical assistance to the Task Force and the Salton Sea Authority in examining possible solutions to the problems existing at the Salton Sea. This LDRD supported the analyses requested by those organizations.

Importance to LANL's Science and Technology Base and National R&D Needs

The project was in response to a request to provide technical assistance on an environmental problem that was facing the Salton Sea. Because of the large bird die-offs and increasing environmental problems at the Salton Sea, Congressional and national attention has focused on ways to alleviate the problems. Because of this attention, studies on the Salton Sea in its environment are being undertaken. This project allows the Integrated Systems Analysis approach to provide the information decision makers require. The analysis of this problem requires a Systems and Integrated Environmental Science approach. The Laboratory's core competencies in Earth and Environmental Systems and Analysis and Assessments, especially in Systems Analysis and Cost/Benefit Tradeoff Analysis, are required to address the problems.

Scientific Approach and Accomplishments

The primary activities that were supported by this LDRD were to analyze the implications and costs of the proposed methods for remediating the Salton Sea. The results of these analyses were reported in two congressional hearings held by the Congressional Task Force on the Salton Sea^{1,2}.

A systems approach was used to analyze the various options. This approach examined the non-biological effects of implementing the various options and also provided rough cost estimates. The resulting summaries provided decision makers with information they required to better understand the implications of the various remediation proposals.

The options proposed for the Salton Sea generally fall into 1 of 4 categories:

1. Do Nothing
2. Desalination
3. Pump In/Pump-Out
4. Diking

The results of the analysis of these categories are presented below.

1. Do Nothing

If no action is taken to remediate the Salton Sea the salinity will increase as shown in Figure 1 and would reach level of 60 ppt in about 15 years. Most fish will not be able to survive at this salinity and therefore once this salinity is reached the Sea will change into a body of water similar to the Dead Sea or the Great Salt Lake. This would severely reduce the food supply for the fish eating birds that frequent the Sea and will impact the plants, algae, and other organisms that may be contributing to the reduction of pollution and mineral buildup in the Sea.

2. Desalination

Desalination has the advantage of providing a reduction in the salinity level of the Salton Sea with the lowest loss of usable water to the Sea. The disadvantages are: there is still a high salinity waste stream that requires disposal, and the initial and operating cost of a facility with enough capacity to have an effect is very large. Proposed facilities to treat the incoming water to the Salton Sea have estimates of initial costs of \$750 million to \$1.1 billion, with operating costs of \$50 to \$60 million per year. Desalination facilities that could treat the much more saline water of the Salton Sea would be more costly. Most of the proposals for desalination are to treat the incoming water to produce potable water for use elsewhere. They would not contribute to the remediation of the Salton Sea and in fact would increase the rate at which the salinity in the Sea is increasing.

3. Pump-In/Pump-Out

Pump-In/Pump-Out options are capable of providing the salinity and elevation control desired by the Salton Sea Authority. However, two problems are encountered with the Pump-in/Pump-Out options: where to obtain the water that is pumped into the Salton Sea and where to dispose of the saline water that is pumped out of the Salton Sea. Ocean water can be used for the input water but a large amount of water will need to be pumped to meet the Salton Sea Authority's goal of maintaining the salinity of the Salton Sea around that of the ocean.

To approach ocean water salinity in the Salton Sea by pumping in ocean water, approximately 400 thousand acre feet of water would need to be pumped in and 550 thousand acre feet of water would need to be pumped out (Figure 2). This would result in lowering the level of the Sea by about 23 ft. (Figure 3) and would have an initial cost in the range of \$1.7 billion and an annual operating cost of \$30 million per year.

Salinity and elevation control could be achieved with less water being pumped if the input water is less saline than ocean water. Numerous sources of fresh or agricultural runoff water have been suggested, but there are political and cost issues associated with each one. If

an alternative source of non-saline water is found, the ability to utilize it in remediating the Salton Sea will depend more on politics than on the cost and infrastructure requirements.

The other problem with the Pump-In/Pump-Out option is where to dispose of the saline water that is pumped out of the Salton Sea. Disposal in solar ponds, in the Gulf of Mexico, and in the Pacific Ocean off of San Diego have been proposed. Each of these has its own political problem.

As part of the study we examined injecting the water from the Salton Sea into the Geothermal reservoirs near the Salton Sea. A preliminary study concluded that the annual loss of water for power production from the reservoirs was about one-third of the minimum annual pump-out rate required to maintain the desired salinity level of the Salton Sea. Because the geothermal fields have been in use for a number of years additional water could be injected into the reservoirs for a short period of time. The preliminary conclusion was that this could be a possible environmentally attractive, short term solution to disposing pumped-out Salton Sea water that could be implemented rapidly.

One variation on the Pump-In/Pump-Out scheme is to only pump water out of the Salton Sea. This will reduce salinity of the Sea along with reducing the size of the Salton Sea (Figure 4). About 150 thousand acre feet per year would need to be pumped out of the Sea to maintain the salinity at ocean levels. This option would have a much lower initial cost of about \$300 million and an annual operating cost of \$5 million per year. If this were combined with injection of the pumped out water into the geothermal reservoirs, it could be implemented rapidly. One problem that does exist with the Pump-Out only option is that there would be an initial increase in the salinity of the water in the Salton Sea (Figure 5) that could reach a level that would kill off the fish in the Sea.

4. Diking

Diking involves isolating a part of the Salton Sea with a dike with a small inlet from the remainder of the Sea. The isolated portion of the Sea becomes more saline while the rest of the Sea becomes less saline because of the flow through to the isolated part of the Sea. This is a relatively inexpensive option with initial costs of about \$300 million and annual costs of \$2 million per year. The dikes could be implemented rapidly and would result in immediate lowering of the salinity in the main part of the Sea. A minimum area of about 10% of the Sea would be required to be isolated in order for the rest of the Sea to reach ocean salinity levels (Figure 6). However, the consensus is, that in the future, water conservation measures in the

Imperial Valley will reduce the inflow into the Salton Sea by 25%. Meeting the Salton Sea Authority's criteria for the elevation level of the Sea with this reduced flow requires an impoundment area equal to approximately 30% of the area of the Salton Sea (Figure 7).

The primary opposition to diking is that it creates a very saline pond next to the Salton Sea and a possible concentrator of toxic material that enters the Salton Sea. Also there is considerable controversy over where the diked area should be placed. Eventually the water in the diked area will reach saturation and the salt will precipitate out filling the diked area. Thus plans for removing the salt from the diked area are required, although depending on the size of the diked area salt removal may not be necessary for 50 to 100 years.

Another concern with diking is that if water conservation is implemented in the Imperial Valley, the existing level of the Salton Sea can only be maintained by having an elevation difference between the main part of the Sea and the isolated portion. This would require a dam to be constructed to isolate the saline portion of the Sea rather than a simple dike. This would increase costs and because of the soil conditions of the floor of the Salton Sea and the proximity of the San Andreas fault there are concerns about failure of the dam (or dike) during an earthquake.

Conclusions

As part of the work we did for the Congressional Task Force and the Salton Sea Authority we did not recommend any one solution to the remediation of the Salton Sea. We did not examine the political implications and the environmental and biological effects which will have a considerable weight in choosing an option for remediation. However, we did conclude that both Diking and Pump-In/Pump-Out options could provide the required control in salinity and elevation if solutions could be found for the problems with earthquake potential, sources of fresh water, and disposal of saline water. Injection of the Salton Sea water into the local geothermal reservoirs may provide a short-term, environmentally attractive solution to disposal of the saline water from the Salton Sea but would require more investigation before a definite conclusion could be reached. Desalination would probably be too expensive and in most of the proposals for desalination would not contribute to the remediation of the Salton Sea.

Publications

1. Hardie, R., "Evaluation of Options for Remediation of the Salton Sea" Testimony given before the Subcommittee on Water and Power, US House of Representatives Committee on Resources October 3, 1997, LAUR 97-3999, Los Alamos National Laboratory, Los Alamos, NM (Oct. 1977)
2. Thayer, G., Catherwood, R., Gould, T., and Hardie, R., "Analysis of a Pump-In, Pump-Out Option for Controlling Salton Sea Salinity and Level" LAUR-97-2028, Los Alamos National Laboratory, Los Alamos, NM (June 1977)
3. Hardie, R., and Thayer, G., "Evaluation of Options for Remediation of the Salton Sea", Salton Sea Symposium, Rancho Mirage, CA, LAUR-98-0003, Los Alamos National Laboratory, Los Alamos, NM (Jan. 1998)
4. Hardie, R., "Evaluation of Options for Reclamation of the Salton Sea" Testimony given before the Subcommittee on Water and Power, U.S. House of Representatives Committee on Resources, March 12, 1998, LAUR-98-1408 Los Alamos National Laboratory, Los Alamos, NM (March 1998)

References

[1] See Publication #1

[2] See Publication #4

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Figure 1: Changes in Salton Sea elevation and salinity where no action is taken. Water conservation of ~25% of the present flow into the Salton Sea is assumed to begin in 10 years.

Figure 2: Salinity level of the Salton Sea for various Pump-In and Pump-Out rates after 50 years of pumping. Water conservation of ~25% of the present flow into the Salton Sea is assumed.

Figure 3: Salton Sea surface elevation for various Pump-In and Pump-Out rates after 50 years of pumping. Water conservation of ~25% of the present flow into the Salton Sea is assumed.

Figure 4: Salton Sea surface elevation and salinity changes as a function of the pumping rate for the Pump-Out only option. Pumping for 50 years is assumed. Water conservation of ~25% of the present flow into the Salton Sea is assumed.

Figure 5: Salinity level of the Salton Sea over time with a 150 thousand acre feet per year pump out rate. Water conservation of ~25% of the present flow into the Salton Sea is assumed to begin at year 10.

Figure 6: Variability of equilibrium Salton Sea salinity levels with the size of the impoundment area. Estimates of time to precipitation of salt (200ppt) and the filling of the impoundment area with salt are provided. Water conservation of ~25% of the present flow into the Salton Sea is assumed.

Figure 7. Minimum impoundment area required to meet the salinity and surface elevation criteria set the Salton Sea Authority. The consensus estimate of long-term annual flow into the Salton Sea is 1 million acre-feet per year.

Elevation and Salinity for No Action

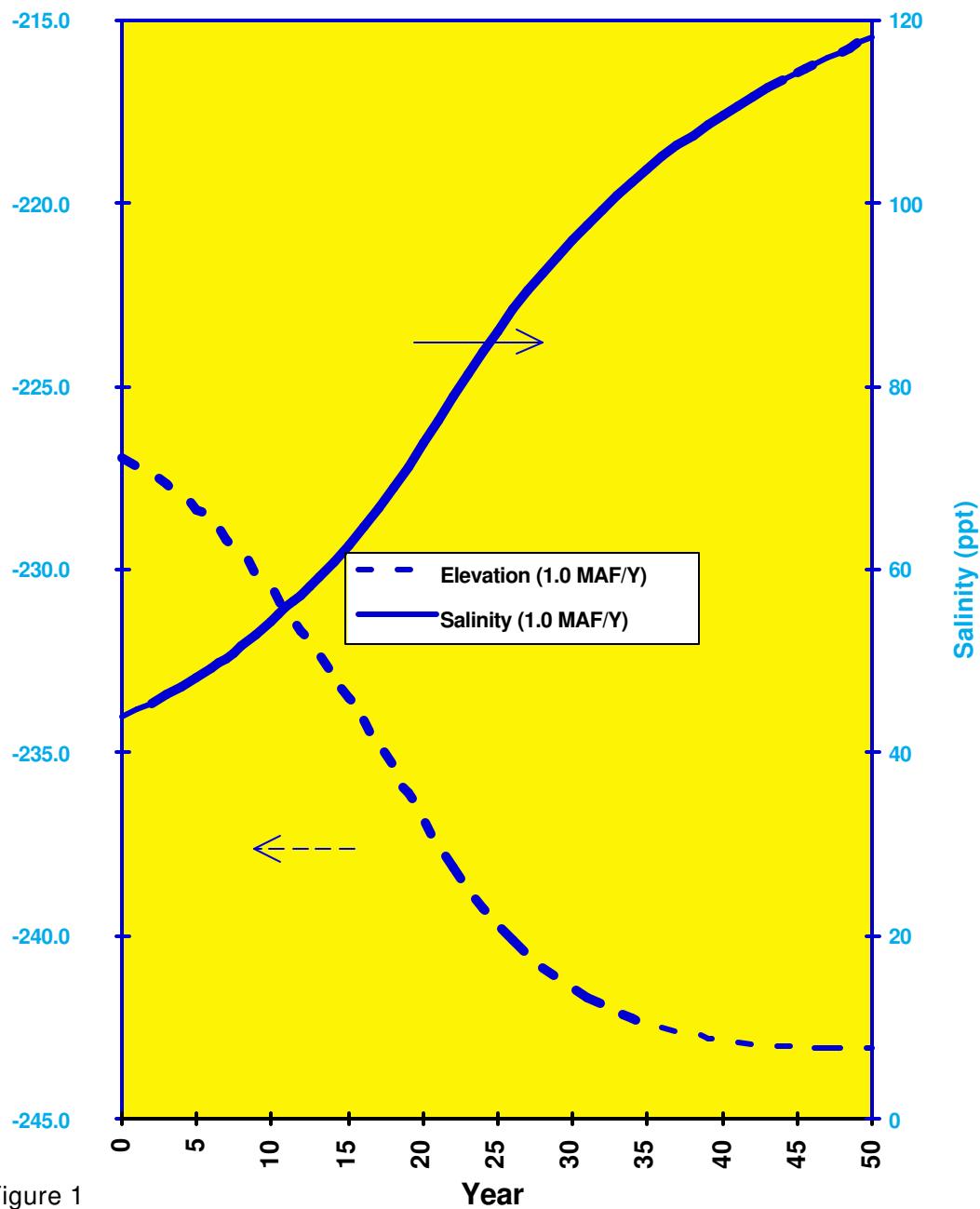


Figure 1

**Pump-In, Pump-Out
Salinity Level After 50 Years
(1.0 MAF/Y)**

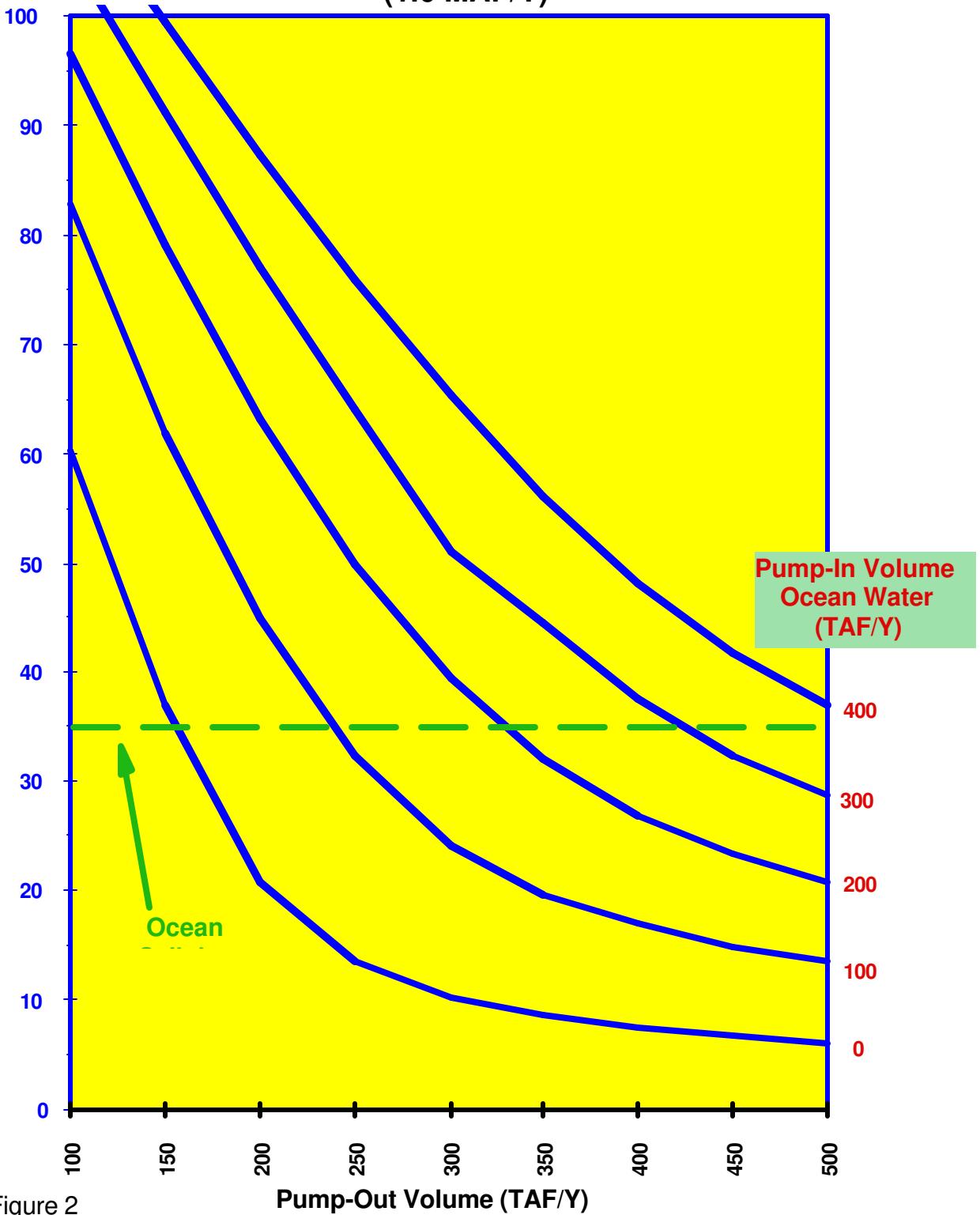


Figure 2

**Pump-In, Pump-Out
Elevations After 50 Years
(1.0 MAF/Y)**

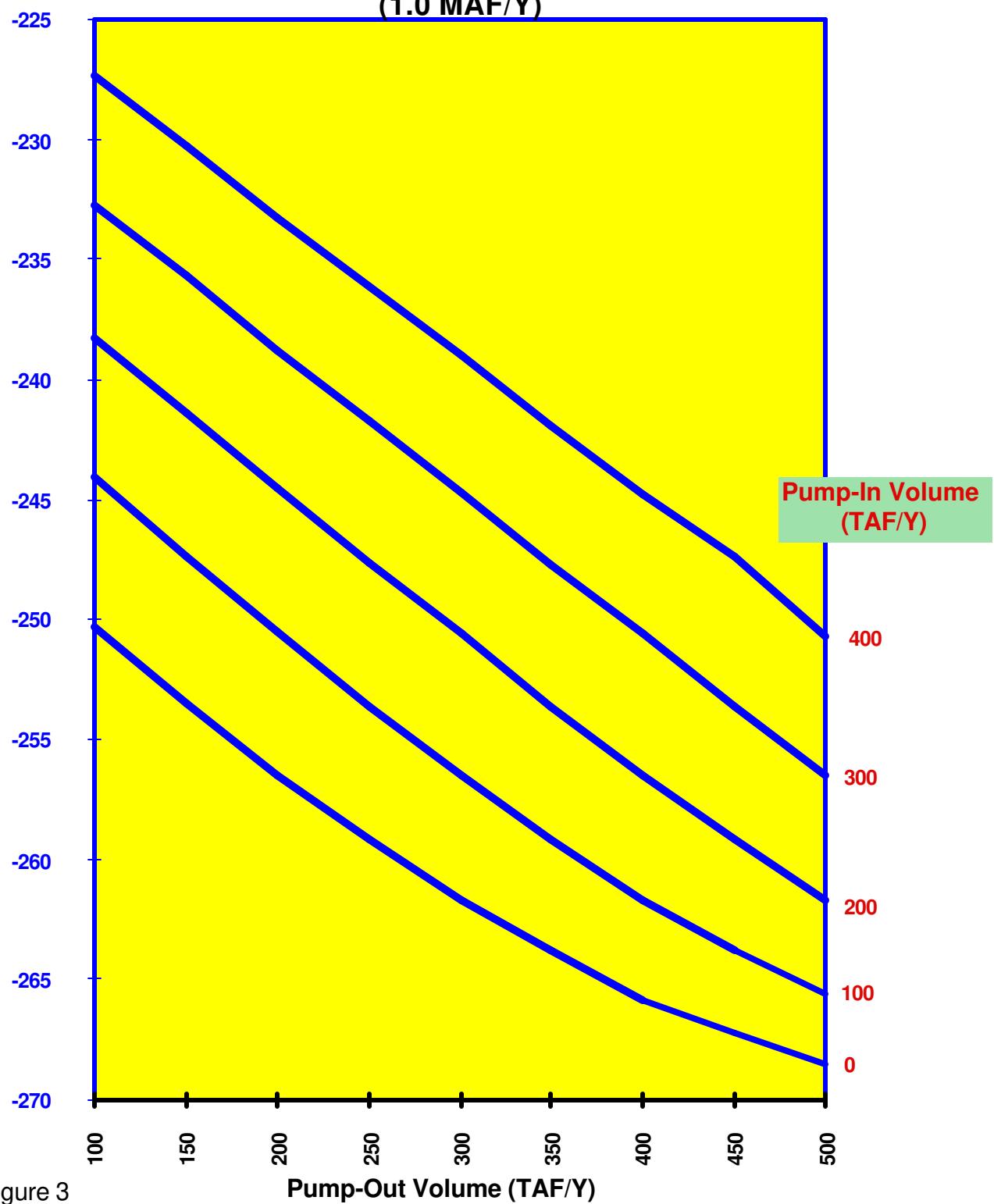


Figure 3

Pump-Out Only Elevation and Salinity

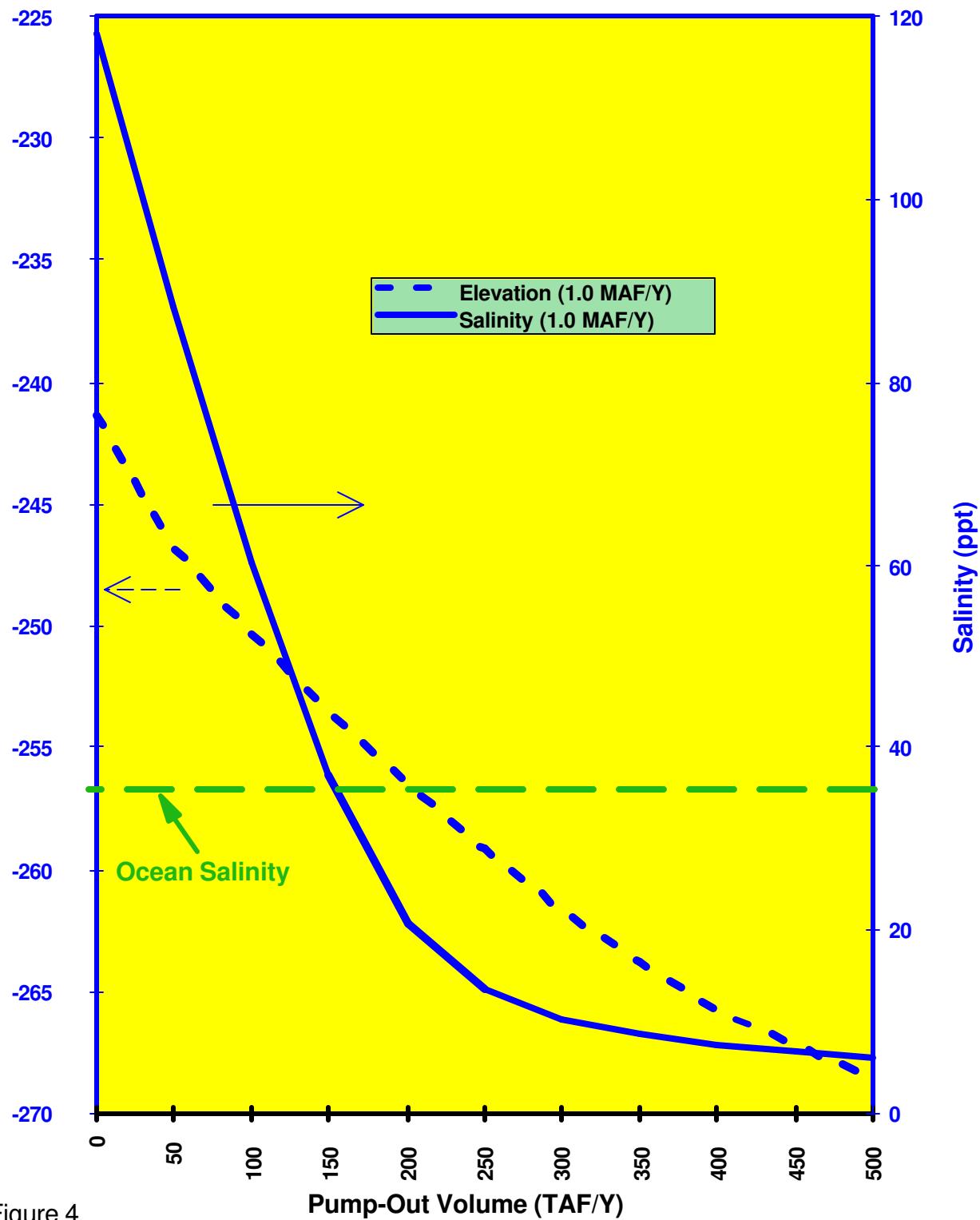


Figure 4

Salinity Vs Time (With Diversion & 150 TAF/Y Pump-out)

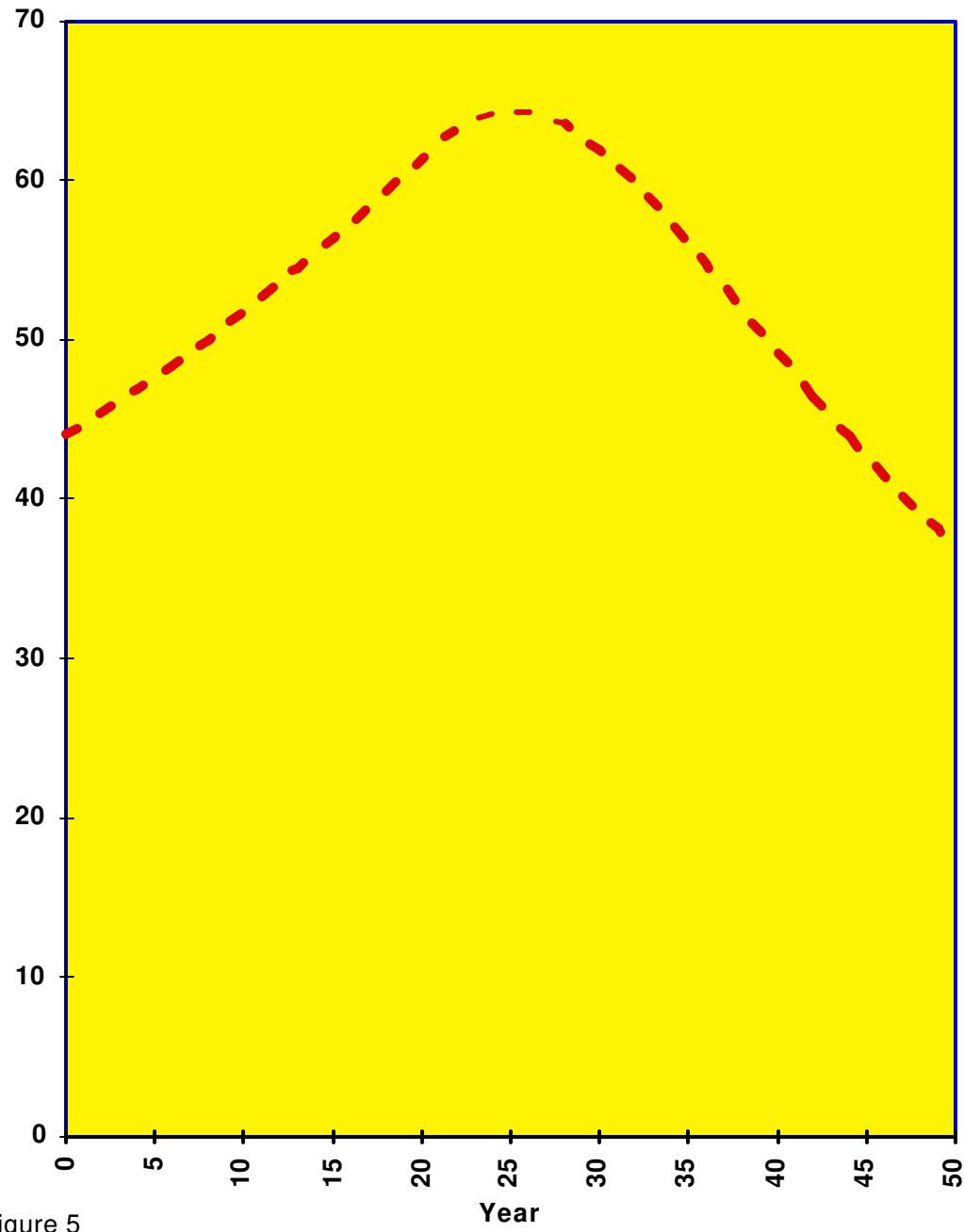


Figure 5

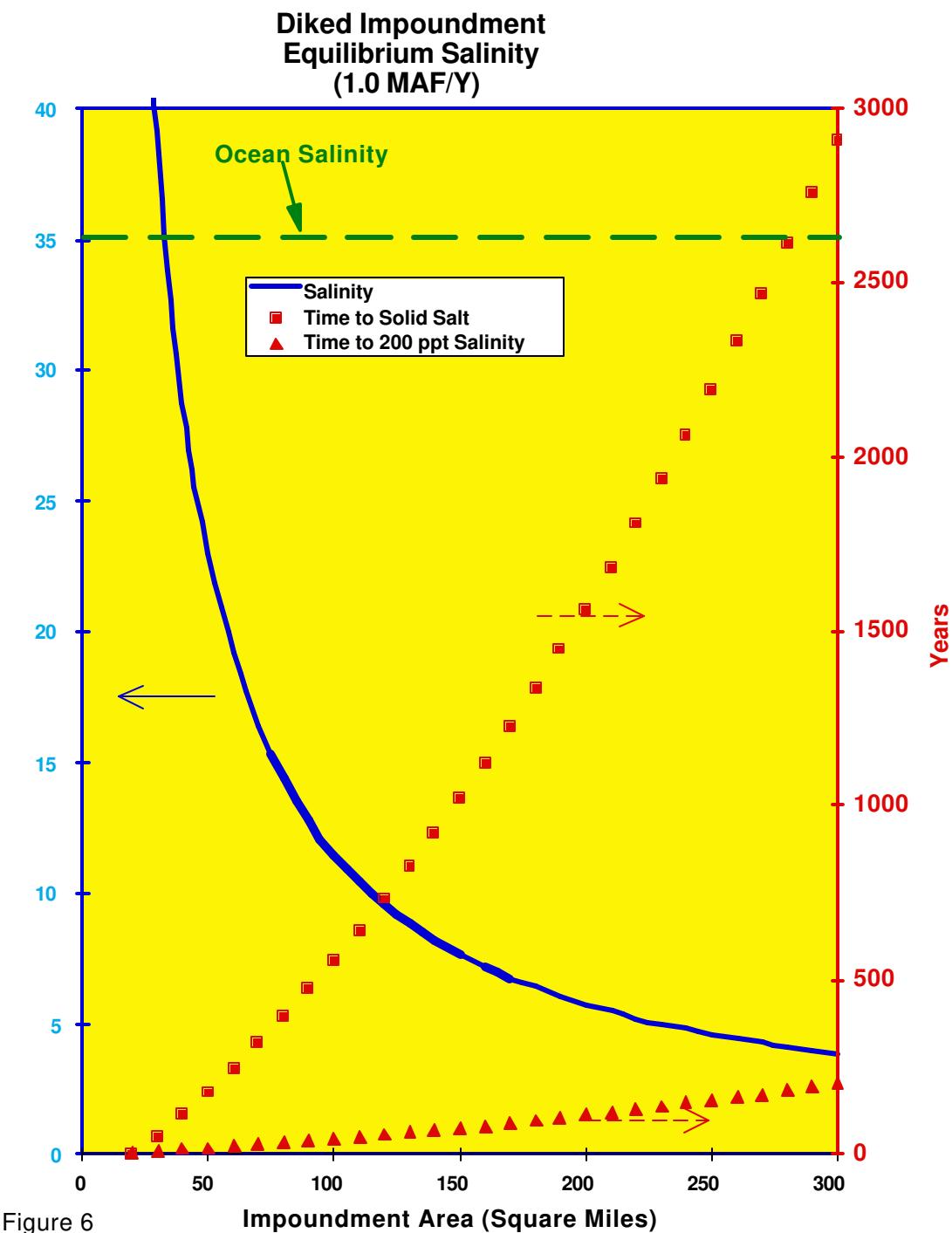


Figure 6

**Minimum Impoundment Area to Meet Salton
Sea Authority Criteria
(35 ppt Salinity & Existing Shore Line)**

