Chapter 9

Analysis of Effectiveness

This chapter presents the results of the Salinity Model analysis and shows the effectiveness of representative alternatives considered.

The alternatives were evaluated for 1.346 million and 1.0 million acre-feet of drainage annually, with the associated salt loads. The model runs assume that design and construction would take 9 years to complete. Therefore, the conditions of year 9 no action alternative were used for each of the drainage inflow quantities. Baseline conditions are shown in figure 18 for the 1.346 million acre-feet of drainage annually at a salinity of 2.8 ppt. This baseline simulation shows that the target elevation is exceeded and that the Sea elevation would continue to rise above the goal of -232 m.s.l. The Sea salinity would also continue to increase above the goal of 40 ppt.

Each of the graphs plotted from the salinity model results (including 15 and 17 in chapter 6) can be understood by noting that all pump-in flow, pump-out flow, and drainage inflow numbers in 1,000 acre-feet per year are read from the left axis. The change in Salton Sea water surface elevation is read from the right axis, and the passage of time is shown along the bottom from 0 to 100 years. The changing salinity concentration line is plotted with a salinity concentration (printed number) in parts per thousand near the beginning and at the end of the line.

The salinity concentration can also be calculated from the flow scale on the left by dividing total flow in 1,000 acre-feet by 10,000. For instance, in figure 19, the salinity line begins at about 450,000 on the flow scale. The 450,000 divided by 10,000 = 45, which in this case is close to the number 44 provided. The concentration of ocean water salinity is also provided at 35 ppt for a reference point.

Pump-Out / Pump-In Alternatives—Salinity Model Results

The pump-out and pump-in alternatives were evaluated for the same two drainage conditions of 1.346 million acre-feet (current conditions) at 2.8 ppt and water conservation at 1.0 million acre-feet at 3.5 ppt. Under these alternatives, the pump-in was balanced with the pump-out to meet the elevation targets. The pump-out for the 1.346 million acre-feet of drainage needed to exceed the pump-in by approximately 100,000 acre-feet per year to meet the -232-foot target elevation. If the pump-out volume was increased, the pump-in needed to be increased by the same amount.

In the conservation scenario (figure 29) for baseline condition, drainage already reduced the inflow to the Sea by 346,000 acre-feet per year; therefore, the pump-in needed to be approximately 200,000 acre-feet per year more than the pump-out flow to meet a target elevation of -232.3 feet in 100 years (figure 30). This is just slightly below the -232-foot target elevation.

The pump-out and pump-in alternatives covered ocean water exchange, wastewater pump-in from Point Loma near San Diego, Hyperion WWTP near Los Angles, and Yuma, Arizona, which would be wastewater from Tucson. The current estimate of wastewater availability from the Hyperion, Point Loma, and Yuma plants are 470,000 acre-feet per year plus, 268,000 acre-feet per year, and 67,000 acre-feet per year (Tucson only), respectively. A discussion of nontributary groundwater availability is covered in chapter 5 under the heading "Groundwater for the Salton Sea Restoration." Colorado River surplus flows are discussed briefly in chapter 5 under "Pump-In Sources."

The results of each alternative are summarized in table 5. Each source had a different salinity, with the Point Loma water having a salinity of 1.75 ppt, Hyperion's salinity being 0.925 ppt, and the Yuma water being 4.0 ppt. It was found that the Sea salinity was not very sensitive to input water salinity because all three sources gave approximately the same results.

The three freshwater pump-in sources of Point Loma, Hyperion, and Yuma had slightly different salinities, which were found to be insignificant in the salinity model results. Graphs are provided in figures 21, 22, and 23 for each water source. The primary goal was to meet the Sea target of 40 ppt in 15 years after the alternative was activated. Each source would accomplish this with an annual pump-out flow rate of 250,000 acre-feet per year and a pump-in flow rate of 153,000 acre-feet per year. After the Sea reaches 35 ppt, the pumping can be reduced to pump-out only at 93,000 acre-feet per year. Both Point Loma and Hyperion pumping could be reduced in year 30, and Yuma pumping could be reduced in year 32.

The water exchanges were also evaluated for meeting the Sea target of 40 ppt in 30 years from implementation of the alternative. The ocean pump-in source required 400,000 acre-feet of annual pump-out and 303,000 acre-feet of annual pump-in, with results shown in figure 24.

Table 5.—Pump-out/pump-in alternatives simulation results

Alternative	Salton Sea water elevation (feet)			Salton Sea salinity (ppt)			Pumping rates (acre-feet per year)	
Water source	15 years[1]	30 years[2]	100 years[3]	15 years[1]	30 years[2]	100 years[3]	In	Out
1.346 million acre-feet of drainage to the Salton Sea at 2.8 ppt								
Baseline	-227	-226.9	-226.0	55,900	63,000	90,600	0	0
Ocean	-230.7	-231.9	-232.3	40,700	37,000	35,400	600,000	700,000
Hyperion	-230.6	-231.7	-232.1	38,900	35,200	37,600	153,000	250,000
Yuma	-230.6	-231.7	-232.1	39,700	36,200	38,000	153,000	250,000
Point Loma	-230.6	-231.7	-232.1	39,100	36,200	38,000	153,000	250,000
Ocean	-230.6	-231.7	-231.9	44,800	40,400	39,800	303,000	400,000
Hyperion	-230.6	-231.7	-231.9	45,000	39,300	38,000	73,000	170,000
Yuma	-230.6	-231.7	-231.9	45,800	40,000	38,400	73,000	170,000
Point Loma	-230.6	-231.7	-231.9	45,500	39,500	38,100	73,000	170,000
Pump-out	-230.7	-231.7	-232.2	52,000	50,700	43,100	0	100,000
1.0 million acre-feet of drainage to the Salton Sea at 3.5 ppt								
Baseline	-240.5	-242.9	-241.1	91,600	114,300	153,400	0	0
Yuma	-232.9	-234.2	-233.3	47,100	39,700	39,700	405,000	205,000

[1] The values are taken from the 24th year of the simulation to represent 15 years after implementation of the alternative.
[2] The values are taken from the 39th year of the simulation to represent 30 years after implementation of the alternative.
[3] The values represent the final year of the simulation. It was assumed that quantities of pump-out and pump-in using ocean water would not change, based on the ocean source. The ocean salinity used was 35 ppt. If an ocean source less than 35 ppt could be found and used as the pump-in source, the flows could be reduced slightly. This was not evaluated because no source had been identified. This alternative required 700,000 acre-feet per year of pump-out from the Sea and 600,000 acre-feet per year of pump-in ocean water. The results graph is shown at the end of this chapter. The graph covers the water source and discharge locations of Camp Pendleton, Hyperion, and the Gulf of California. Larger pump-out/pump-in quantities would be needed under the conservation alternative.

The sources were the same as described above. The fresh water sources from Point Loma, Hyperion, and Yuma required 170,000 acre-feet of annual pump-out and 73,000 acre-feet of annual pump-in to meet the 30-year goal of 40 ppt. Point Loma, Hyperion, and Yuma pump-out was reduced to 93,000 acre-feet, and the pump-in was stopped in year 50. Each alternative Sea salinity stayed below 38 ppt during the remaining 50 years of simulation, which is below the target of 40 ppt. The model output graphs are contained in figures 25, 26, and 27.

Alternative 21 (figure 28) represents a pump-out only alternative with 1.346 million acre-feet of drainage annually. The salinity initially increases to 52 and eventually reaches 43.1 ppt. But this does not meet the criteria of 40 ppt.

The water conservation alternative was also evaluated to meet the 40-ppt target in 30 years after implementation (figure 29). The required pump-out for the Yuma water source was 205,000 acre-feet, and the pump-in was

405,000 acre-feet annually. The pump-out and pump-in could be reduced to 120,000 acre-feet and 345,000 acre-feet in year 38 to maintain the Sea below the 40 ppt target, respectively. The Point Loma and Hyperion sources would meet the target at the same flows and are not shown in the table. The Yuma graph is in figure 30.

Designers studied several pump-out only alternatives. All of these alternatives pumped-out at particular flow rates for the first 30 years after construction and then continued pumping at 100,000 acre-feet per year. The alternative that was chosen for cost pumped-out at a steady rate of 100,000 acre-feet per year. The reader should note that some salinity values exceed 50 ppt. The model indicates that the target elevation would be met and that salinity would reach 43 ppt in 90 years, which is 3 ppt above the 40-ppt target (figure 28).

Diked Impoundment Alternatives—Salinity Model Results

The model had some restrictions regarding the diked alternatives due to the way the worksheets were developed. The impoundment surface areas did not fit the specific alternatives in the 1997 report. Approximations were made to demonstrate if the alternatives would meet the acceptance criteria.

The specific evaporation pond simulation results are shown in table 6. The 30-square-mile evaporation pond with pump-out to Palen Dry Lake or some other evaporation pond had to be estimated, since the model was not set up for pump-out conditions with evaporation ponds. Without the pump-out, this alternative would exceed the elevation criteria, and the salinity would not be reduced to the selected targets (figure 31). The model had the capability to accept pump-in water but did not provide for pumping out. About 65,000 acre-feet were input and had significant improvements in the Sea salinity of 3 ppt in 30 years; however, the Sea elevation was raised 3 feet in the same 30 years. Estimates for the 100-year results were based on the pump-out information. The estimated results are shown for 50,000 and 100,000 acre-feet of pumping out to an external evaporation pond. It is estimated that the 100,000 acre-feet of water pumped out would meet or be very close to the elevation and salinity goals in 30 years. Table 6 shows that it would in the 100-year timeframe.

Table 6.—Diked impoundment alternatives simulation results

Alternative	Salton Sea water elevation (feet)			Salton Sea salinity (ppt)			Pumping rates (acre-feet per year)	
Surface area	15 years	30 years	100 years	15 years	30 years	100 years	In	Out
1.346 million acre-feet of drainage								
30	-226.9	-226.5	-226.3	46.2	44.7	42.8	0	0
30	-224.6	-223.5	-222.9	43.3	41.7	41.9	65,000	0
[1]30			-229			39.3	0	50,000
[1]30			-232			35.8	0	100,000
48.3	-226.3	-225.9	-225.8	41.1	36.6	27.9	0	0
142.2	-226.7	-226.0	-223.5	16.1	9.5	8.7	0	0
[6]142.2	-226.9	-226.8	-224.9	35.0	35.0	35.0	0	0
1.0 million acre-feet of drainage								
30	-239.6	-242.8	244.3	79.1	82.6	[5]61.5	0	0
30	-231.9	-233.1	-233.6	60.4	61.2	56.2	200,000	0
48.3	-239.3	-241.2	-238.8	72.4	80.2	110.9	0	0
48.3	-225.6	-225.2	-229.3	45.0	41.2	38.0	[2]360,000	0
142.2	-239.0	-240.9	-241.5	22.5	10.6	8.8	0	0
[3]142.2	-239.1	-240.9	-241.5	35.0	35.0	35.0	0	0
142.2	-232.7	-233.6	-232.1	35.0	35.0	35.0	[4]175,000	0

[1] Estimates of the final 100-year salinity based on data from other spreadsheet output.
[2] Pump-in cut back to 280,000 acre-feet per year in year 41.
[3] The model feature for pumping from the evaporation pond to the Salton Sea was activated. The pumping started in year 9 and averaged about 63,000 acre-feet per year to maintain the salinity at 35 ppt.
[4] This pump-in is required to meet the elevation target. It increases the volume of pump-back water to maintain the Sea at 35 ppt.
[5] This value is incorrect due to a model instability that occurs when the impoundment volume is calculated as zero.
[6] The salinity was held at 35 ppt using the model option for pump-back from the evaporation pond. The quantity ranged from 464,000 acre-feet to 84,000 acre-feet.

The evaporation pond containing 48.3-square-mile surface area was used to simulate the 40- and 50-square-mile alternatives. The elevation target was exceeded and would be expected to be exceeded in both the 40- and 50-square-mile evaporation ponds under these drainage conditions. The 40-square-mile pond would be expected to meet the salinity target in 30 years but not in 15 years (figure 32). The 50-square-mile pond alternative may meet the salinity target in 15 years and more than meet the 30-year target. The model simulated the Sea salinity at 27.9 ppt in 100 years after construction of the dikes for the impoundments. The model has a pump-back feature that allowed evaporation pond water to be pumped back to the Sea to prevent the Sea salinity from going below 35 ppt. The Sea elevation may be increased due to sightly lower evaporation from the higher salinity Sea. This is shown in the 142.2-square-mile evaporation pond simulation results.

The 142.2-square-mile evaporation pond model setup was used to simulate the 127-square-mile alternative. The simulations again show (figure 33) that the elevation targets would not be met; however, the salinity target was easily met. The salinity level could be as low as 16 ppt in 15 years. The second line in the table for this size area shows that the salinity could be controlled at 35 ppt with the pump-back option or some other means of reducing flow to the evaporation pond.

It is expected that water conservation activities in the Salton Sea drainage area will take place and reduce the flow to the Sea by 346,000 acre-feet per year or reduce it to 1.0 million acre-feet per year from 1,346,000 acre-feet. The inflow is expected to be reduced by at least 20,000 acre-feet annually. This accounts for 200,000 acre-feet of the 346,000 acre-feet; the remaining 146,000 acre-feet were removed in the 10th year. This causes the drop in Sea water surface elevation shown in the conservation plots (figures 29 and 30). The salt load to the Sea would also be reduced. The inflow salinity was reduced in the simulation runs for the conservation alternatives was 300,000 tons per year. The salinity was reduced by the same percentage as the drainage during the same time period. The resulting salinity of the drainage was 3.5 ppt. The no action simulation for the Sea resulted in the salinity increasing at a much faster rate and the elevation dropping well below the target elevation. None of the in-Sea evaporation ponds under conservation will meet the elevation target without approximately 200,000 acre-feet of replacement water being input to the Salton Sea.

Under water conservation, the 30-square-mile evaporation pond could not be evaluated fully because the model did not have pump-out capability. The target elevation and salinity were not met as shown in table 6. With 200,000 acre-feet of pump-in, the elevation target was met, and the salinity improved by 20 ppt at 30 years (figure 34). Any water pumped to an external evaporation pond to meet the salinity target would have to be replaced to meet the elevation goals. This alternative could be made to meet the targets with proper pump-out and pump-in quantities.

The 48.3-square-mile evaporation pond which represents the 40- and 50-square-mile alternatives became unstable in the 21st year of the simulation and overestimated the Sea's salinity for the remaining simulation period (figure 35). This is due to the evaporation pond becoming dry, since it was located in a shallow part of the Sea. Adding 360,000 acre-feet per year of pump-in water improved conditions and raised the Sea elevation to 229.3 feet and lowered the Sea salinity to 41.2 ppt in year 30 (simulation year 39). The pump in was cut back to 280,000 acre-feet per year in simulation year 41. A small amount of pump-out would reduce the Sea salinity and probably meet the targets.

Conservation and the 142.2-square-mile evaporation pond (north end of Sea) went well below the target salinity and elevations. The pump-back was activated, and the Sea salinity was held at 35 ppt; however, the elevations were not improved. A pump-in volume of 175,000 acre-feet per year raised the Sea elevation to the target level and the pump-back was increased to maintain the Sea at 35 ppt.

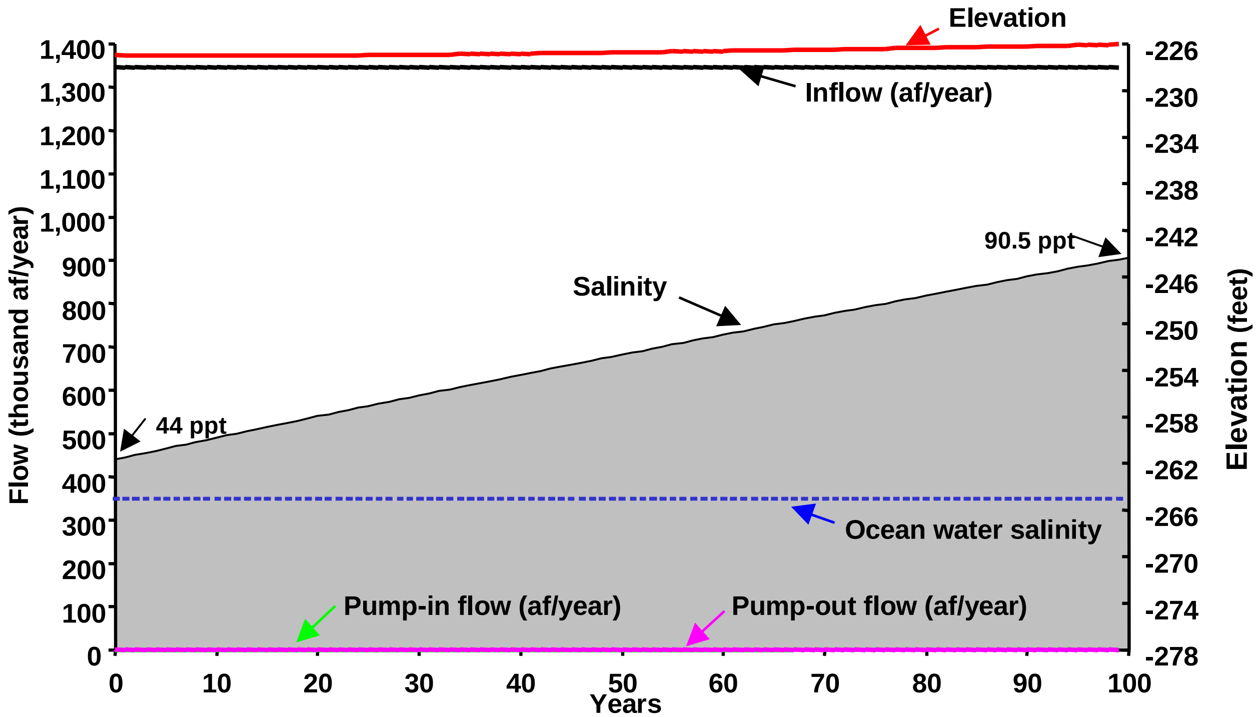

Figure 19.—Baseline conditions, no pump-out or pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

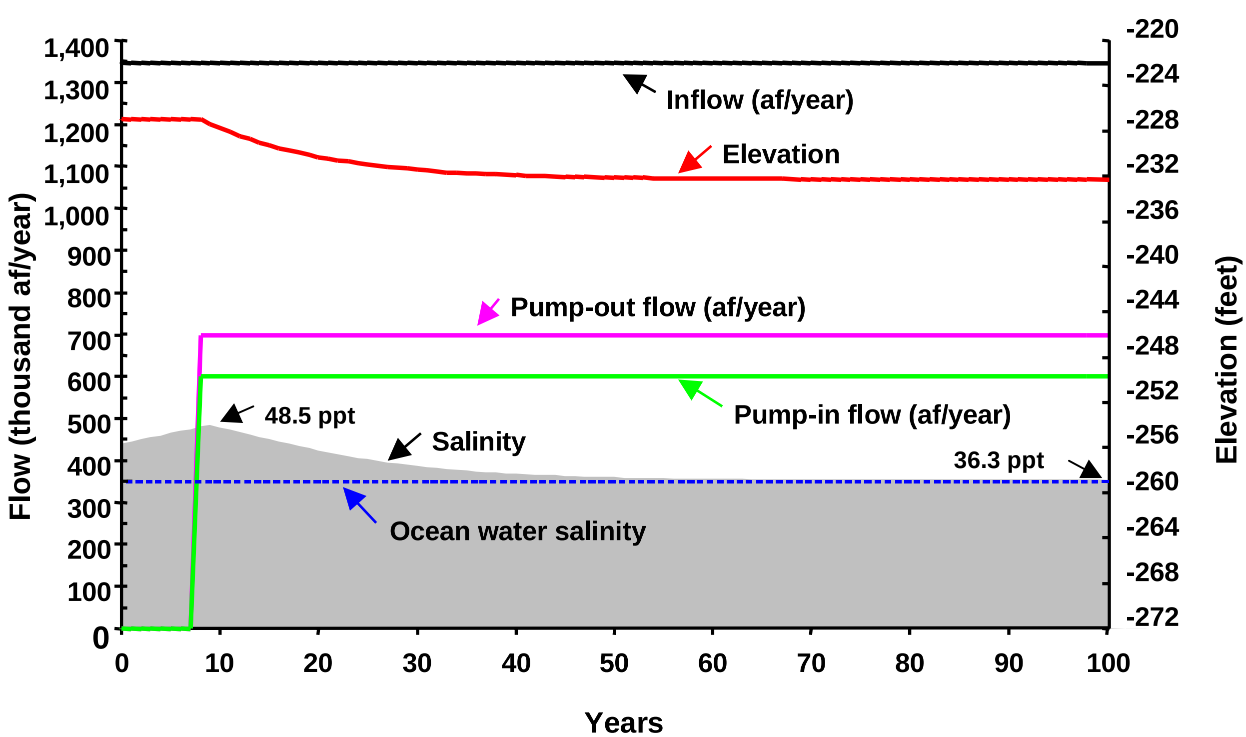

Figure 20.—Alternative 1 water exchange from Camp Pendleton—700,000-acre-foot pump-out with 600,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

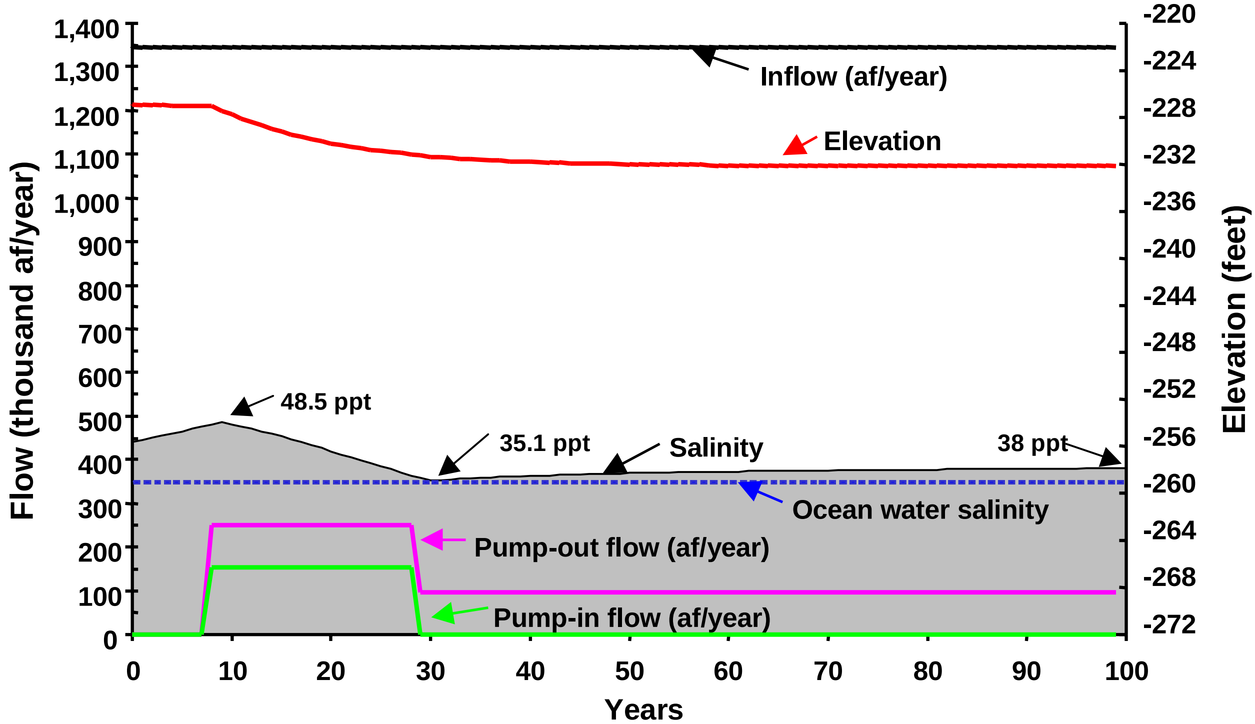

Figure 21.—Alternative 4 water exchange from Point Loma at 1.75 ppt—250,000-acre-foot pump-out with 153,000-acre-foot replacement with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

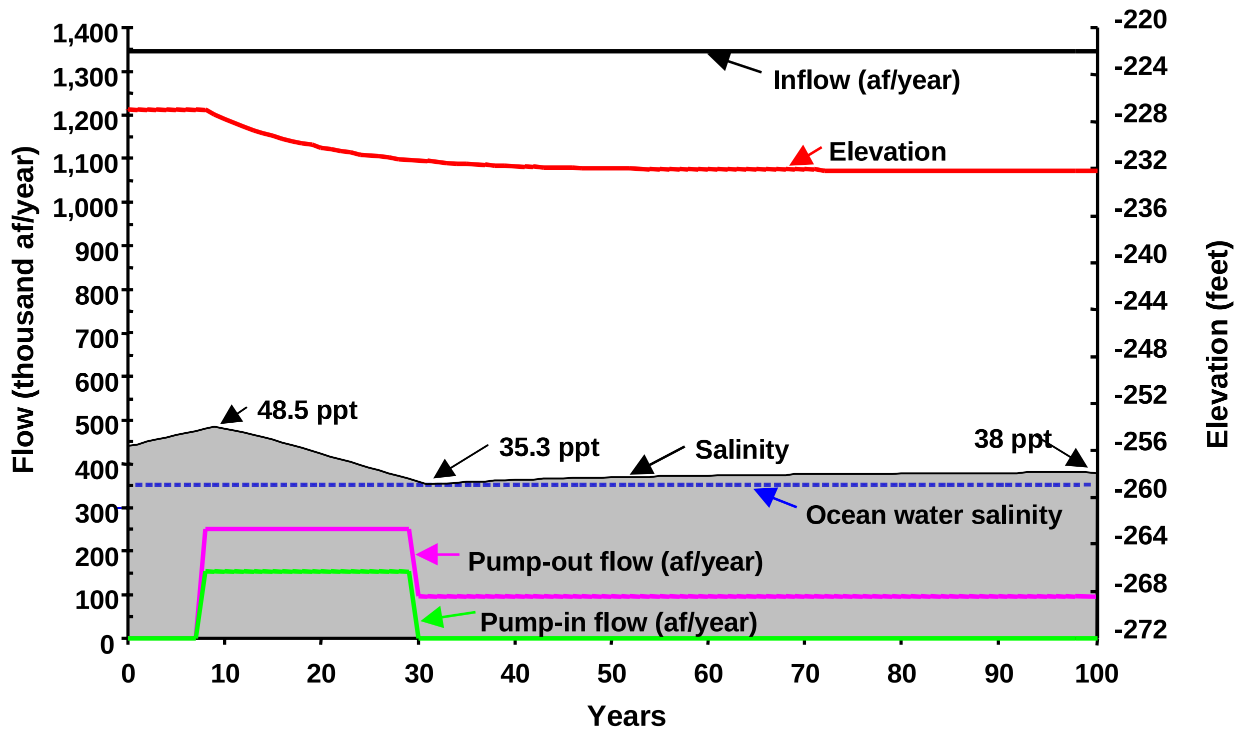

Figure 22.—Alternative 5 water exchange from Hyperion at 0.925 ppt—250,000-acre-foot pump-out with 153,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

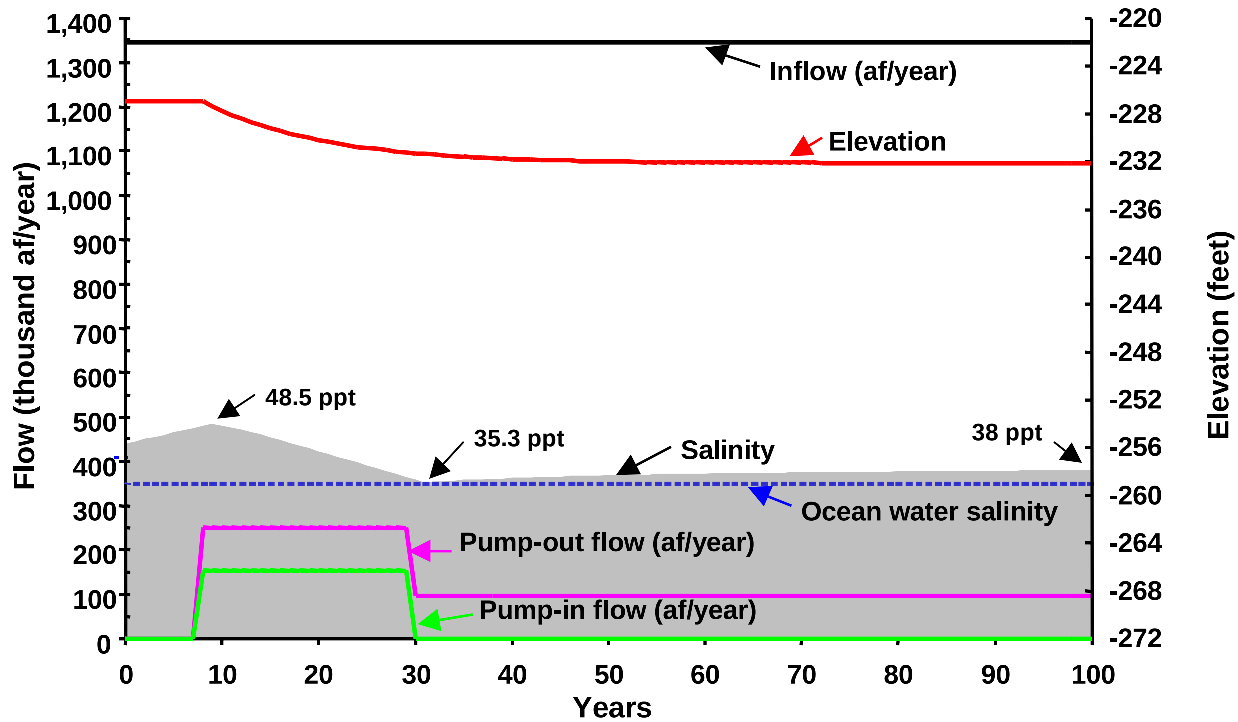

Figure 23.—Alternative 6 water exchange from Yuma at 4 ppt—250,000-acre-foot pump-out with 153,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

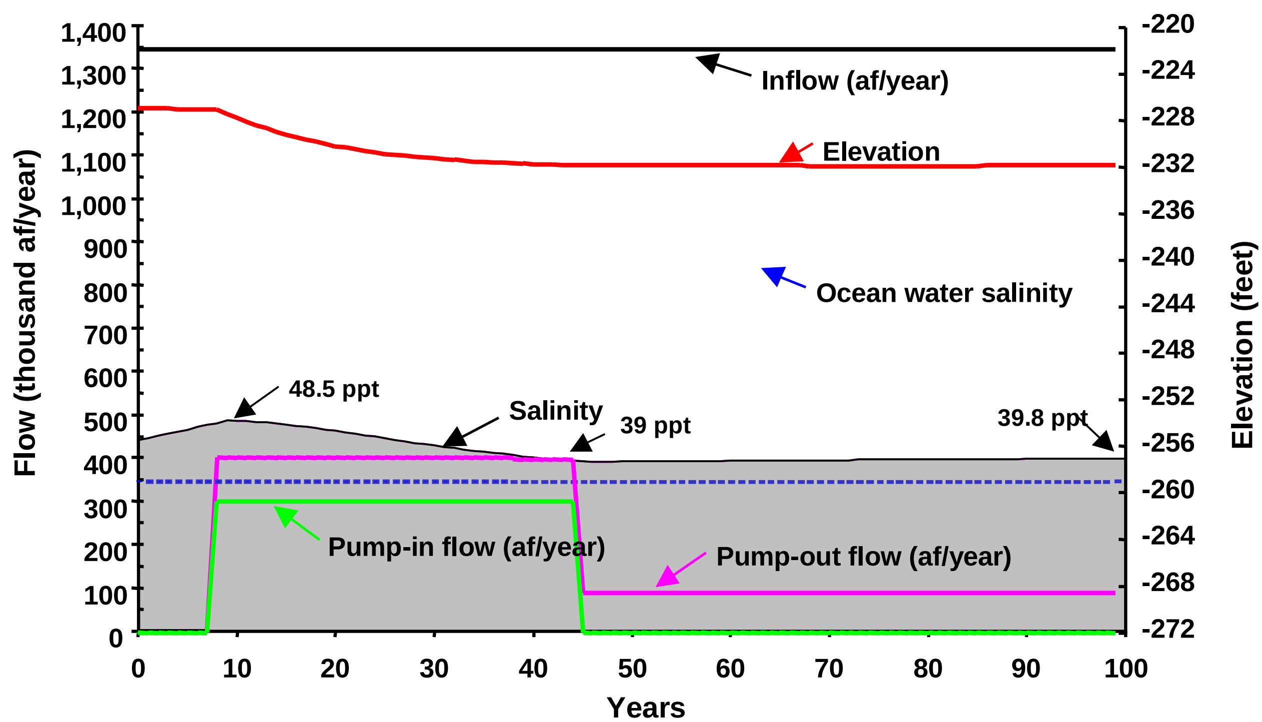

Figure 24.—Alternative 11 water exchange at Camp Pendleton at 35 ppt—400,000-acre-foot pump-out with 303,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

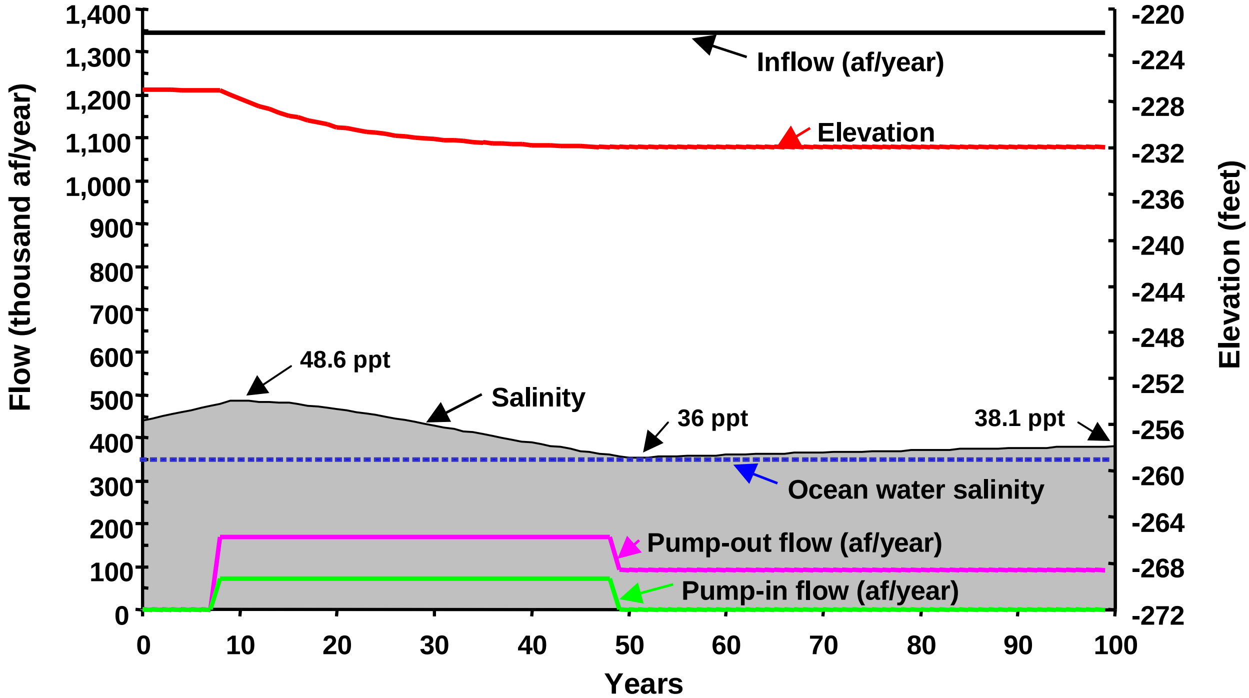

Figure 25.—Alternative 14 water exchange at Point Loma at 1.75 ppt—170,000-acre-foot pump-out with 73,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

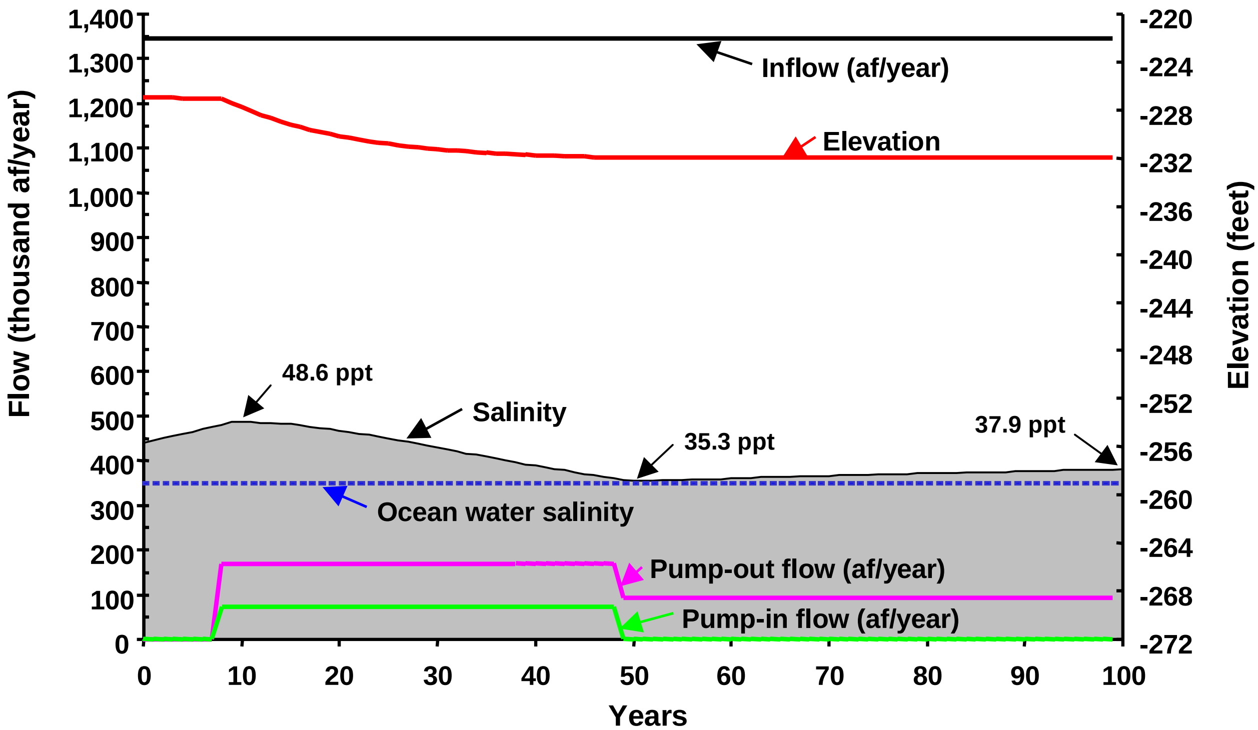

Figure 26.—Alternative 15 water exchange at Hyperion at 0.925 ppt—170,000-acre-foot pump-out with 73,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

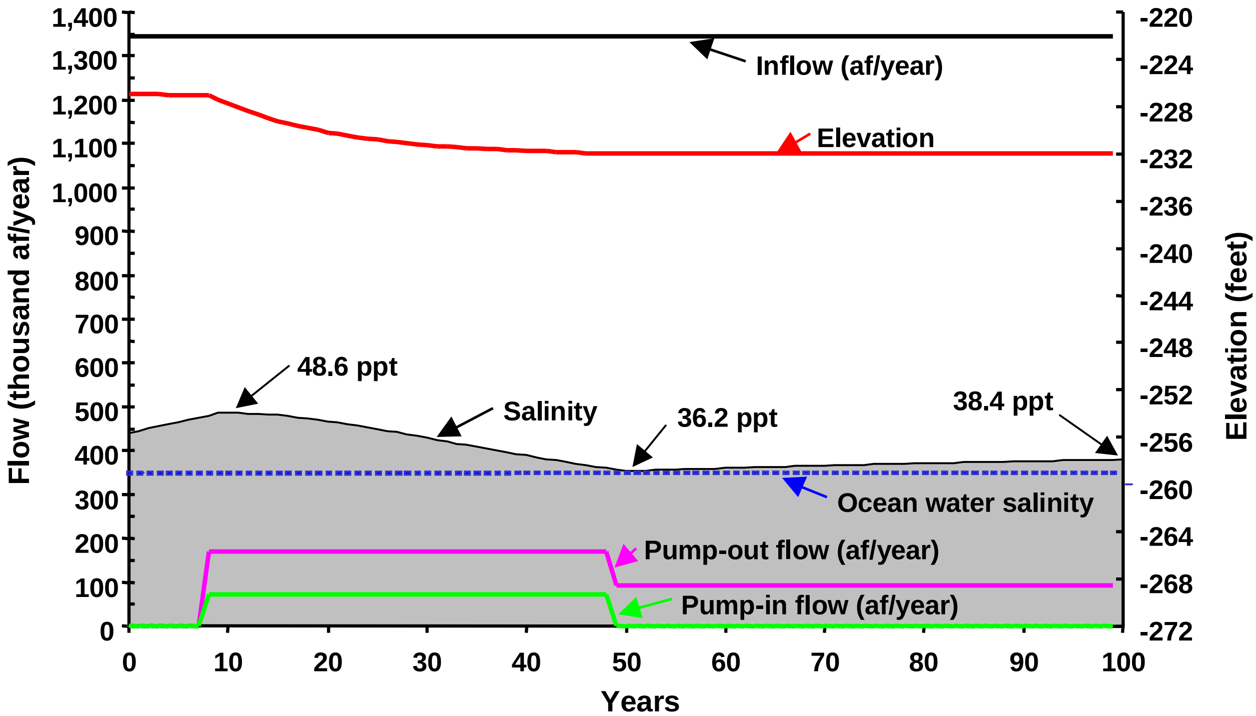

Figure 27.—Alternative 16 water exchange at Yuma at 4 ppt—170,000-acre-foot pump-out with 73,000-acre-foot pump-in with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

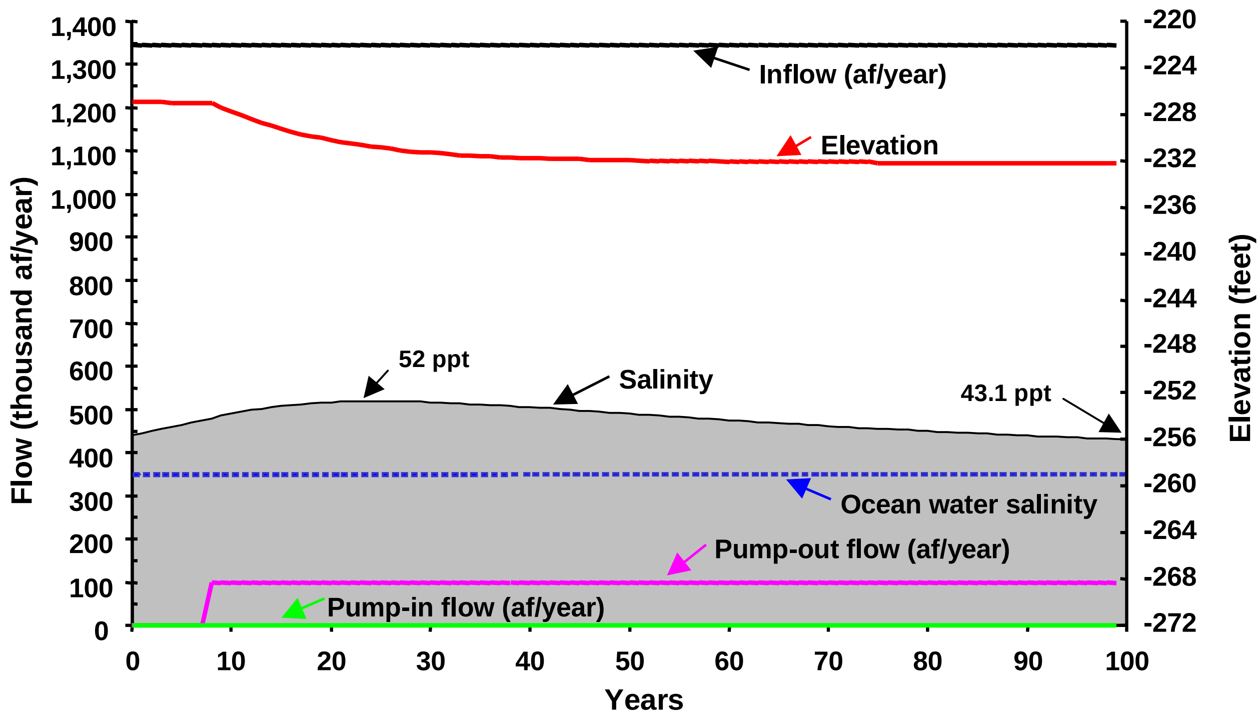

Figure 28.—Alternative 21 water exchange with pump-out only—100,000-acre-foot pump-out with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

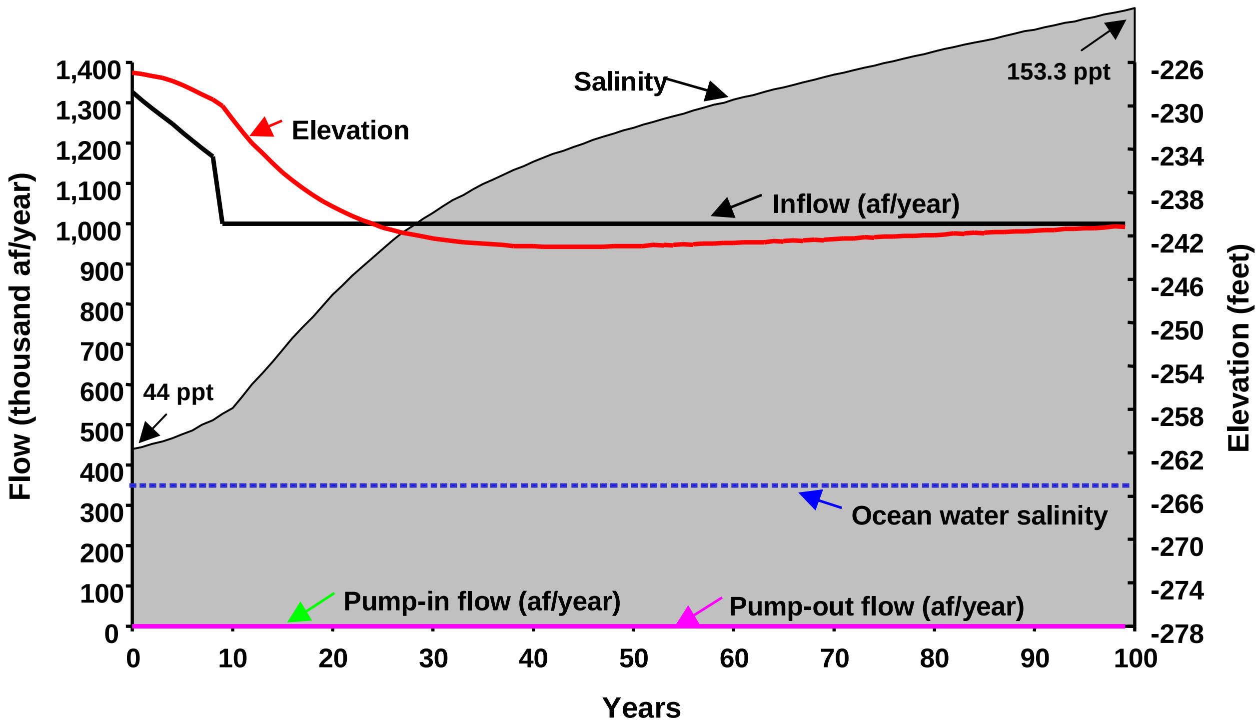

Figure 29.—Conservation baseline 1.0-million-acre-foot drainage inflow at 3.5 ppt.

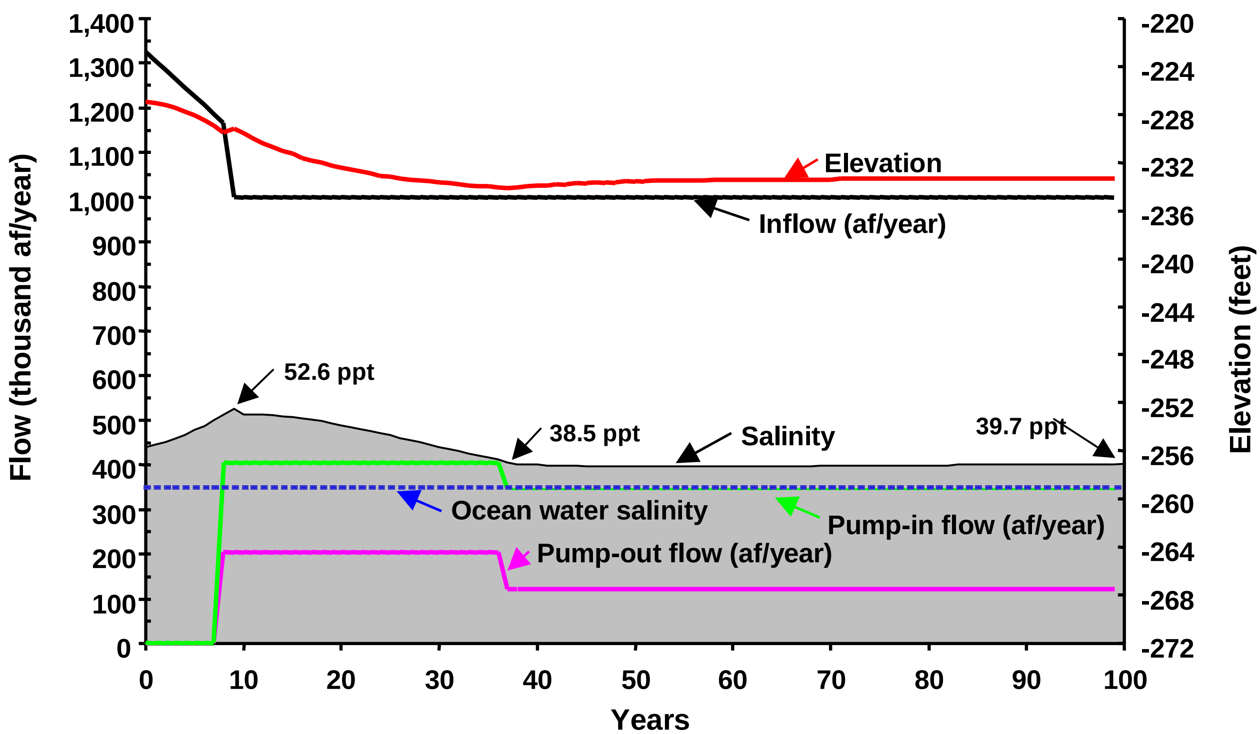

Figure 30.—Alternative 23 water exchange with conservation—205,000-acre-foot pump-out with 405,000-acre-foot pump-in at 4 ppt with 1.0-million-acre-foot drainage inflow at 3.5 ppt.

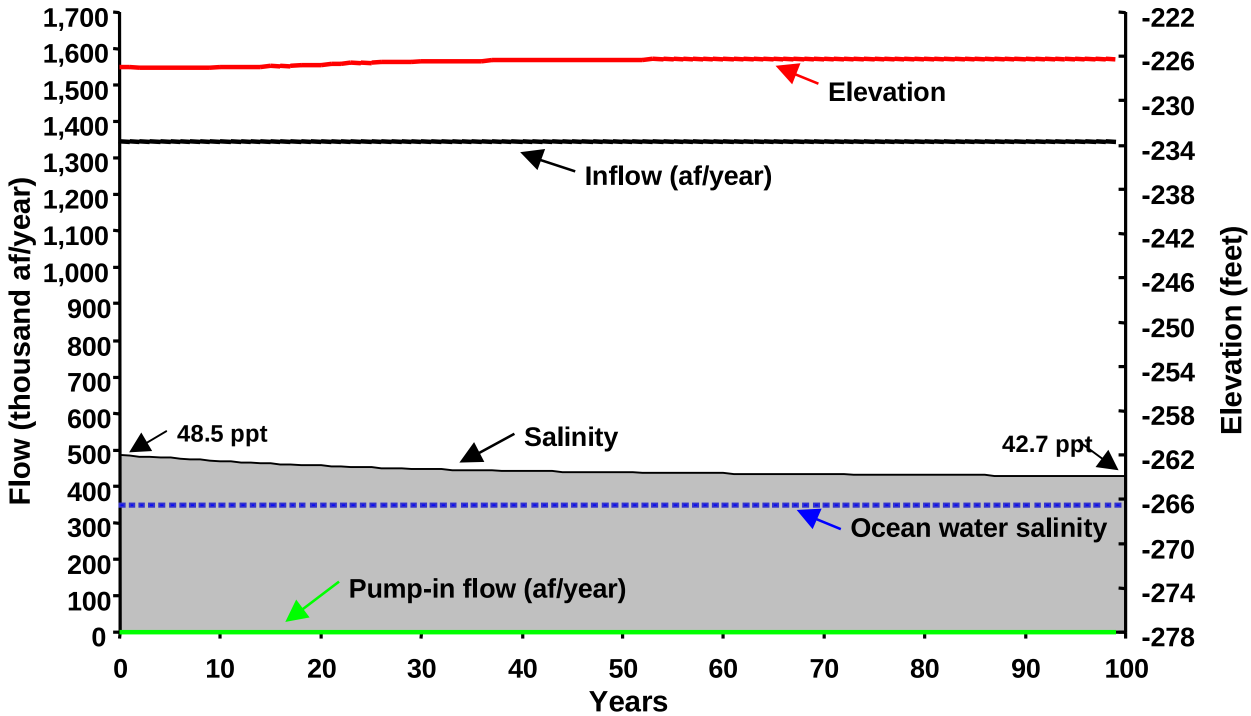

Figure 31.—Variable impoundment at 7.83-percent surface area or 30 square miles with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

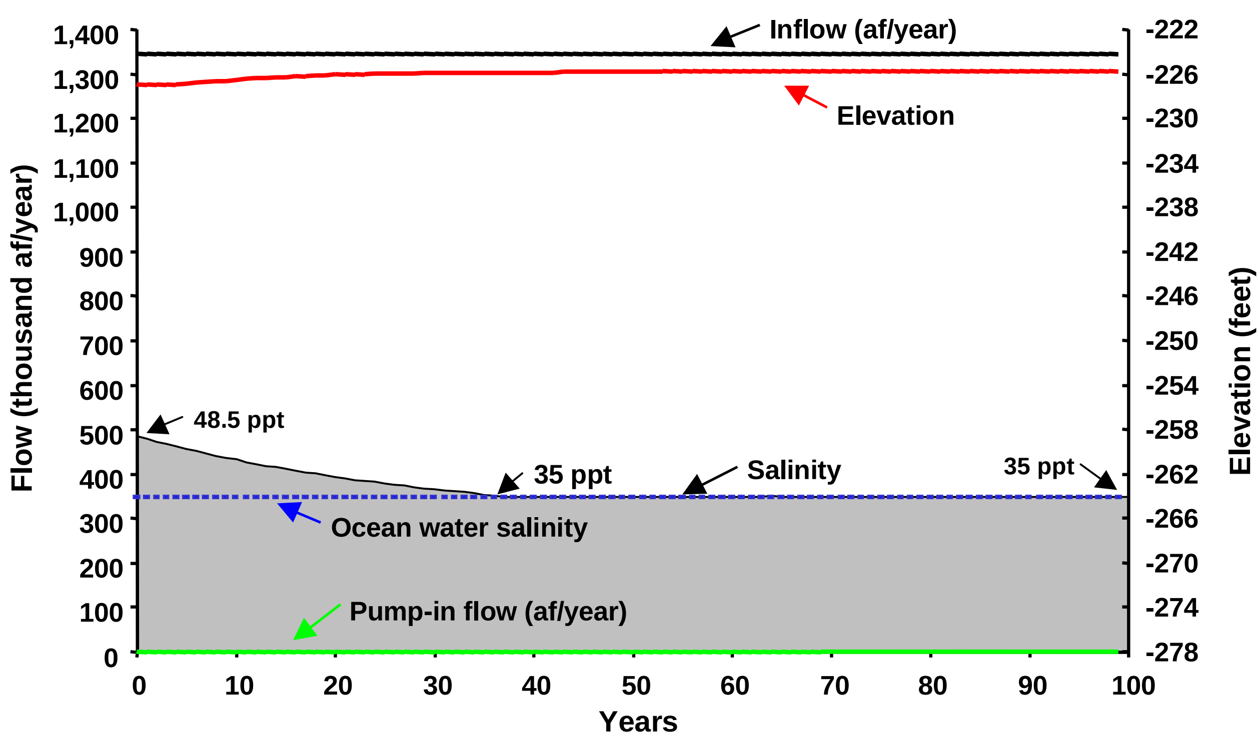

Figure 32.—48-square-mile impoundment; pump-back activated to maintain Sea at 35 ppt with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

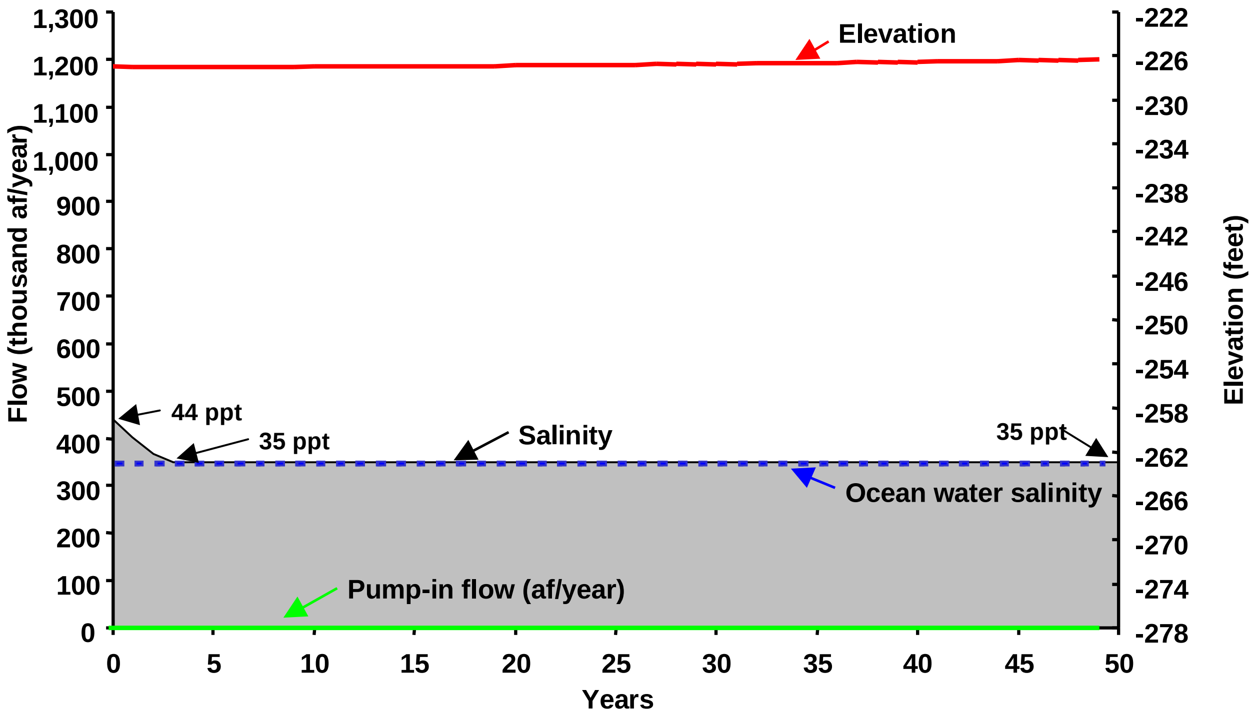

Figure 33.—142-square-mile impoundment; pump-back activated to maintain Sea at 35 ppt with 1.346-million-acre-foot drainage inflow at 2.8 ppt.

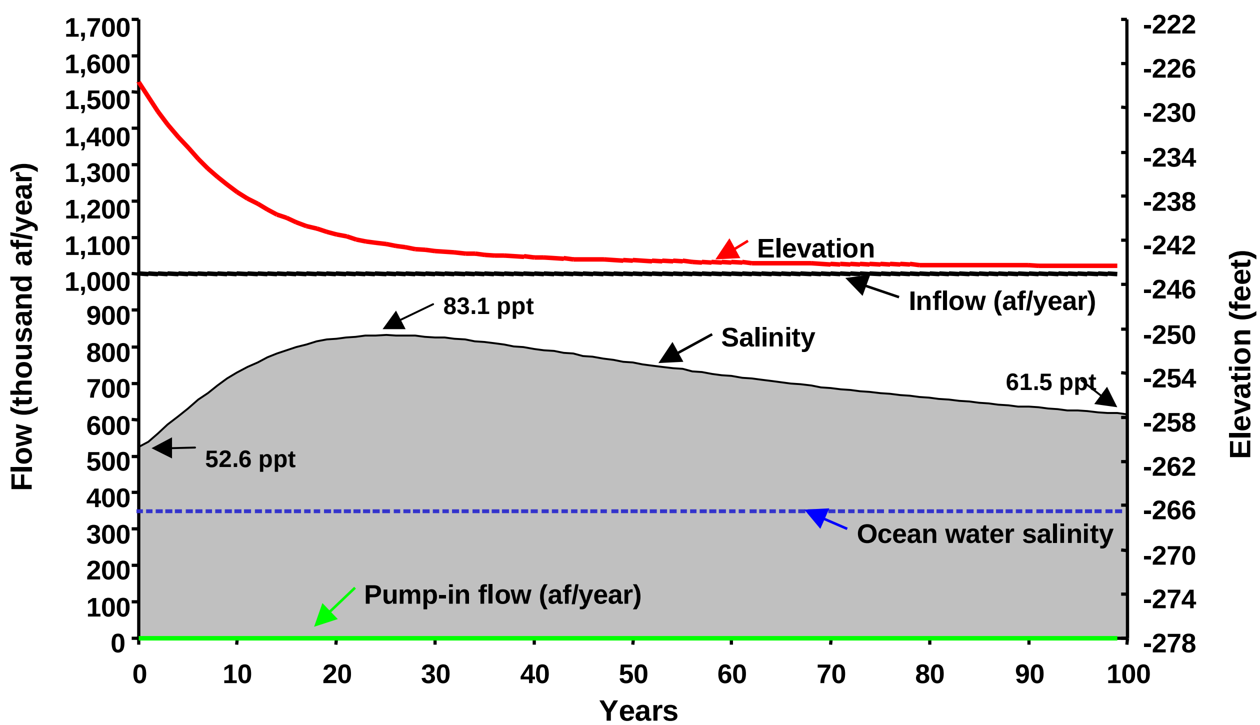

Figure 34.—Variable impoundment at 7.83-percent surface area or 30 square miles with 1.0-million-acre-foot drainage inflow at 3.5 ppt.

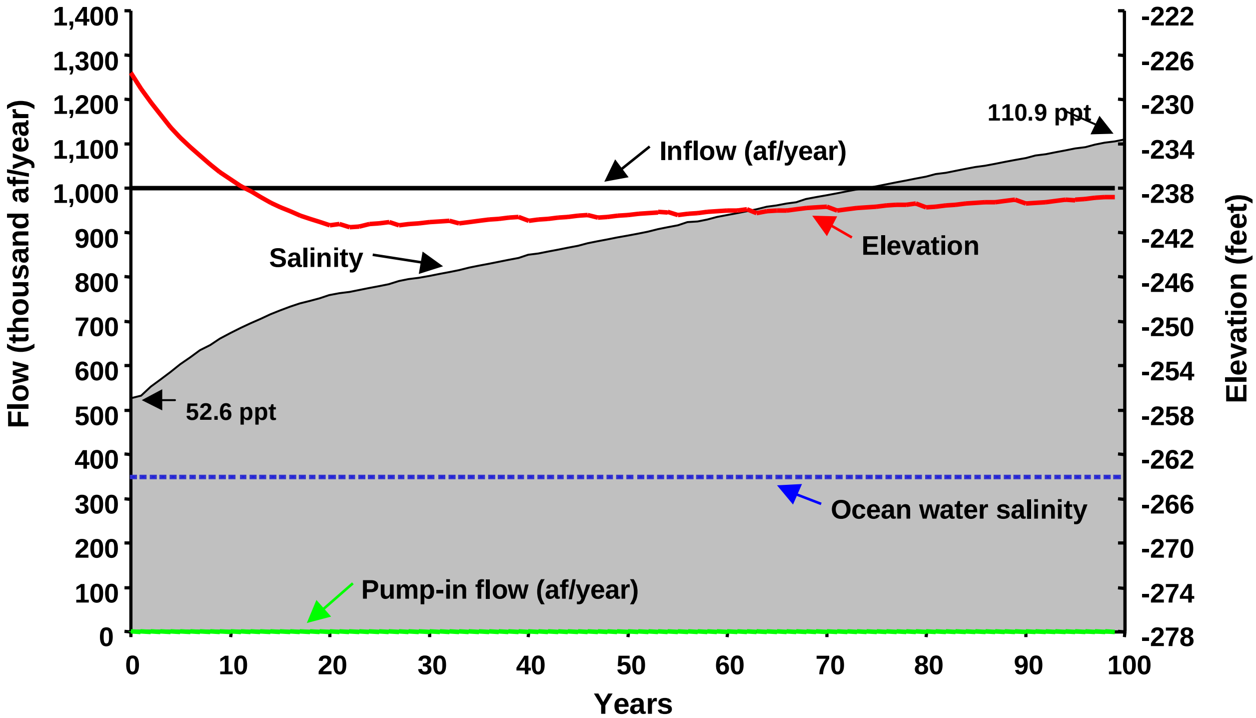

Figure 35.—48-square-mile impoundment with water conservation with 1.0-million-acre-foot drainage inflow at 3.5 ppt.

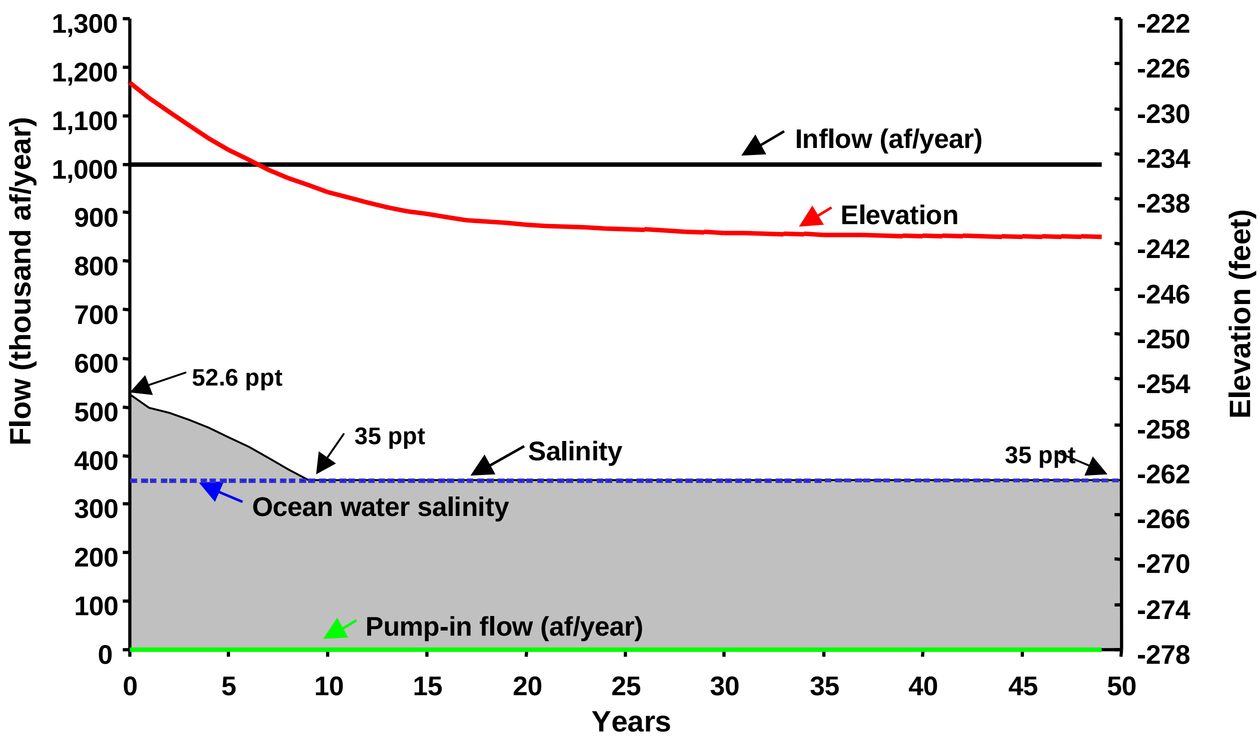

Figure 36.—142-square-mile impoundment; pump-back to maintain Sea at 35 ppt with 1.0-million-acre-foot drainage inflow at 3.5 ppt.