3.0 Restoration Alternatives

3.1 General

For purposes of preparing this report, the following is a summary list of alternatives being studied by the Reclamation.

Alternative No. 1 – Mid-Sea Dam/North Marine Lake
Alternative No. 2 – Mid-Sea Barrier/South Marine Lake
Alternative No. 3 – Concentric Lakes Dikes
Alternative No. 4 – North-Sea Dam/Marine Lake
Alternative No. 5 – Habitat Enhancement without Marine Lake

The general configurations of each of these alternatives are shown on Figures 3.1 through 3.5. Additional information on each alternative and the corresponding embankment characteristics and design requirements are provided in the sections that follow.

3.2 Alternative No. 1 — Mid-Sea Dam/North Marine Lake (Salton Sea Authority Alternative)

This alternative would provide both elevation and salinity control (Reclamation, 2005) and 16,000 acres of shallow habitat ponds. An impervious mid-Sea dam embankment would be constructed so the water north of the embankment would be maintained at a higher elevation than the brine pool on the south side. The area south of the embankment would serve as an outlet for water and salt from the north and would rapidly shrink in size and increase in salinity to form a brine pool. The North Marine Lake would have a water surface area of up to 140 square miles at elevation –230 feet mean sea level (msl). The estimated long-term elevation of the brine pool is –270 msl.

The general layout of this alternative is shown on Figure 3.1. The dam alignment shown on this figure is the most recent version of the restoration alternative that has been developed by the Salton Sea Authority. In addition to the north marine lake, a smaller south marine lake would be created by the construction of a south-Sea dam. These two bodies of water would be connected along the western edge of the Sea by the construction of a western perimeter dike. This alternative also includes a perimeter dike along a portion of the east side and a 6-mile-long canal.

The combination of the mid-Sea dam, south-Sea dam, and the perimeter dikes comprise the primary embankments needed for this alternative that must comply with Reclamation's Public Protection Guidelines (Reclamation, 2003). In general, each of these embankments would be constructed to meet Reclamation's design criteria for "high hazard" structures with an estimated annual probability of failure of less than or equal to 1×10^{-4} except for the perimeter dikes that are classified as "significant hazard" structures.

Other relevant details or requirements for each of these embankments are as follows:

North/South Sea design elevation:	-230 msl
Minimum embankment freeboard:	5 feet
Crest Elevation:	-225 msl
Minimum crest width:	30 feet

The planned Sea elevation and corresponding embankment crest elevation listed above have recently been decreased by two feet from the elevations reported in appraisal level study results. The elevations reported in the appraisal level study were used in seepage, stability, and deformation analyses. The decrease in the pool and dam crest elevations will improve the seepage and stability results as well as result in a small decrease in the deformations of the structure as reported in Appendices 2B and 2C.

Table 3.1 contains a summary of the anticipated maximum embankment section required for each of these embankment elements.

Table 3.1
Summary of Anticipated Maximum Section Attributes
Mid-Sea, South-Sea and Perimeter Dike Embankments

Item	Mid-Sea Dam	South-Sea Dam	Perimeter Dikes
Structural Height (feet) (1)	84	38.5	36.5
Hydraulic Height (feet) (2)	40	20	10
Length (miles)	8.1	14.1	17.5

Notes: a) Structural height estimated from the dam crest to the base of the soft lacustrine/alluvium excavation beneath the centerline axis of the dam

b) Hydraulic height estimated as the difference between the normal elevation of the marine lakes (-230 msl) to the normal elevation of the brine pool (-270 msl), or the normal elevation of the marine lake (-230 msl) and the downstream toe of the embankment, as appropriate

Additional details of the alternative embankment configurations considered for the mid-Sea dam are presented in Chapter 4.0. Descriptions of the optimized cross-sections for each of these embankments are presented in Chapter 5.0.

This alternative also includes the construction of 12,000 acres of habitat ponds adjacent to the canal along the southeast side of the exposed Sea bed/brine pool. The habitat ponds would be impounded by low earthfill embankments. Reclamation established a preliminary design for the habitat pond embankments during the appraisal level study that included the following features:

- ✓ Removal of Seafloor deposits
- ✓ Installation of geogrids/geotextile support in the excavation trench
- ✓ Placement of compacted clay and silt material backfill and embankment fill
- ✓ Exterior slopes of 3H:1V and embankment heights of up to 9 feet

The habitat pond embankments would be constructed in the dry. Because of their low-height and low-hazard classification, they would be constructed of homogenous soil fill with no filters or internal zoning. No erosion protection would be placed on the outer slopes of these embankments.

The mid-Sea dam, south-Sea dam, and perimeter dike embankments would be constructed in the wet using over-water, truck haul/conveyor, or a combination of these two placement methods.

3.3 Alternative No. 2 — Mid-Sea Barrier/South Marine Lake

This alternative would provide salinity control but no elevation control, and up to 21,700 acres of shallow habitat ponds (Reclamation, 2005). The water entering the Sea from the south into the south marine lake would support marine habitat. The estimated long-term elevation of the marine lake is –258 msl. The area north of the barrier embankment would serve as an outlet for water and salt from the south side to form a brine pool. As the main body of the Sea shrinks, dikes would be constructed to create impoundments to provide freshwater marsh and shallow water shoreline. As the main body of the Sea shrinks, the 21,700 acres of habitat ponds would be constructed on the exposed seabed at the locations shown on Figure 3.2 to take advantage of the shallow and gently sloping Seafloor for different habitat.

Unlike the mid-Sea dam, which can support differing water elevations on each side, the barrier would not experience a differential head of more than 5 feet. At the initiation of these studies, Reclamation designs called for the barrier to have a semi-pervious core to allow seepage flows to safely pass through the structure. Similarly, Reclamation is considering the possibility of accepting the risk of barrier failure during a seismic event, thus not requiring designs to consider foundation liquefaction. The structure would likely be classified as a “significant hazard” structure based on consideration of the loss of significant wildlife benefits and the significant costs associated with repair/replacement of the barrier should failure occur. Two optimized sections have been developed for the mid-Sea barrier. The first (2A) provides both seismic and static risk reduction and the second (2B) provides only static risk reduction. The designs were developed for the purposes comparing the costs of constructing a structure that reduces the seismic risks with the risk-based replacement costs for a structure that does not.

Other relevant details or requirements for the barrier embankment are as follows:

Marine Lake/Brine Pool design elevation:	-258 msl
Maximum embankment freeboard:	13 feet
Crest Elevation:	-245 msl
Minimum crest width:	30 feet

The anticipated maximum embankment section for the barrier would have a structural height of up to 60 feet. The estimated length of the barrier would be 7.3 miles.

The Sea elevation and corresponding barrier crest elevation listed above have recently been increased by two feet from the elevations reported in the appraisal level study results. The elevations reported in the appraisal level study results were used in our seepage and stability analyses. The increase in the pool and barrier crest elevations will cause a small the change to seepage and stability results reported in Appendix 2B. This change will not impact the findings and recommendations of this report.

Additional details on the mid-Sea barrier are presented in Chapter 4.0. Descriptions of the optimized cross-section are presented in Chapter 5.0.

As described above this alternative also includes the construction of habitat ponds that would be impounded by low earthfill embankments as described under Alternative No. 1 in Sub-section 3.2.

The mid-Sea barrier embankment could be constructed in the wet using over-water placement methods, or by a combination of over-water and truck haul/conveyor placement equipment once the Sea level has dropped below the planned crest elevation of –245 msl. The habitat pond embankments would be constructed in the dry.

3.4 Alternative No. 3 – Concentric Lakes Dikes

This alternative provides both elevation and salinity control and involves forming four concentric annular 5- to 6-foot-deep lakes/pools within the Sea. Inside these pools, a brine pool would develop as shown on Figure 3.3.

Several alternative design approaches are being considered for the concentric lakes dikes based upon consideration of hazard, and loss of potential benefits should one of the outer-most lakes fail, and replacement costs. Two optimized concepts for embankments have been developed for the concentric lakes alternative. One is similar to the sand dam with stone columns cross-section that would reduce seismic and static risks (3A). The second is a Sand Dam without stone columns concept that is designed to only reduce static risks (3B). The concentric lakes dikes would likely be classified as “significant hazard” structures. The two designs were developed for the purpose of comparing the costs of constructing structures that reduce seismic and static risks with the risk based replacement costs for structures that do not. Additional details of the alternative embankment configurations are presented in Chapter 4.0. Descriptions of the optimized cross-sections for each of these embankments are presented in Chapter 5.0.

Other relevant details or requirements for each of these embankments are as follows:

Marine Lake/Brine Pool design elevations:	-230, -240, -255, and -265 msl
Minimum embankment freeboard:	4 feet
Crest Elevations:	-226, -236, -251, and -261 msl
Minimum crest width:	20 feet
Total length of embankments:	252 miles

For the outer two lakes dike structures that reduce seismic and static risk, the maximum embankment sections would have a structural height of up to 20 to 40 feet depending on the thickness of the soft seafloor, soft lacustrine, and upper alluvium materials. The other two lakes dike embankments would have a structural height of 10 to 20 feet depending on the thickness of the Seafloor deposits that would be removed for embankment construction.

Embankments for the concentric lakes would be constructed in the wet using over-water or truck haul/conveyor placement methods following dredging to establish the required foundation-bearing surface. Each of the inner concentric lakes would be constructed once the water surface of the inner Sea had dropped to approximately the planned level of the pool behind the embankment. A system of outlet works and emergency spillways would be strategically placed to provide for the operation of system and overflow necessary to protect the embankments from floods or other large inflow events.

3.5 Alternative No. 4 — North-Sea Dam/Marine Lake

This alternative would provide both elevation and salinity control and up to 37,200 acres of shallow habitat ponds. An impervious dam embankment would be constructed so the water north of the embankment would be maintained at a higher elevation than the brine pool on the south side as shown in Figure 3.4. The area south of the embankment would serve as an outlet for water and salt from the north and would shrink in size to achieve equilibrium with inflows from the south and discharges from the north marine lake. The brine pool would increase in salinity through time. The north marine lake would have a water surface area of up to 17,000 acres at elevation -228 msl. An emergency spillway on the dam crest would be required to regulate pool level and to pass design flood discharges from the Whitewater River basin

In addition to the north marine lake, 37,200 acres of habitat ponds would be created in the southern end of the Sea. As the main body of the Sea shrinks, these habitat ponds would be constructed on the exposed seabed to take advantage of the shallow and gently sloping Seafloor for different habitat.

The combination of north-Sea dam and the habitat pond dikes comprise the primary embankments needed for this alternative. The north-Sea dam embankment must comply with Reclamation's Public Protection Guidelines (Reclamation, 2003). These guidelines require that the north-Sea dam embankment be constructed to meet Reclamation's design criteria for "high hazard" structures with an estimated annual probability of failure of less than or equal to 1×10^{-4}.

Other relevant details or requirements for the north-Sea dam embankment are as follows:

North Sea design elevation:	-228 msl
Minimum embankment freeboard:	5 feet
Crest Elevation:	-223 msl
Minimum crest width:	30 feet

The anticipated maximum embankment section for the north-Sea dam would have a structural height of between 55 and 65 feet. The estimated length of the dam would be 23.2 miles. The north-Sea dam embankment would be constructed in the wet using over-water, truck haul/conveyor, or a combination of these two placement methods. Additional details of the alternative embankment configurations considered for the north-Sea dam are presented in Chapter 4.0. Descriptions of the optimized cross-sections for this embankment are presented in Chapter 5.0.

As described above, this alternative also includes the construction of habitat ponds that would be impounded by low earthfill embankments as described under

Alternative No. 1 in Sub-section 3.2. The habitat pond embankments would be constructed in the dry. Because of their low-height and low-hazard classification, they would be constructed of homogenous soil fill with no filters or internal zoning. No erosion protection would be placed on the outer slopes of these embankments.

3.6 Alternative No. 5 — Habitat Enhancement Without Marine Lake

Saline habitat pond complexes would be constructed at the south and north ends of the Sea. Five separate complexes would be constructed with a combined surface area of 42,200 acres as shown on Figure 3.5. As a whole, the complexes would average about 60 percent land (levees, berms, islands, etc.) and 40 percent water. About 25 percent of the habitat would be open water with little land development and deep water (up to 10 feet) for fisheries. These deep-water pond areas would be constructed through excavation, with the excavated material used to create islands behind non-deep water cell embankments. The remaining 75 percent of the habitat would be divided into areas suitable for different species and their use, with the ratio of land to water varying from 70:30 to 30:70. The majority of these shallow water pond habitats would be less than 3 feet deep.

The habitat pond dikes comprise the primary embankments needed for this alternative. These ponds would be impounded by low earthfill embankments as described under Alternative No. 1 in section 3.2. The habitat pond embankments would be constructed in the dry. These structures would likely be classified as “low hazard” structures. Because of their low-height they would be constructed of homogenous soil fill with minimal or no filters or internal zoning as appropriate to meet hazard classification and stability criteria. No erosion protection would be placed on the outer slopes of these embankments.

3.7 Risk Reductions Summary

The five alternatives and options described in the preceding sections each require different embankments to achieve the desired water storage and management objectives. A summary of the required embankments and appropriate risk reduction design criteria for embankments is presented in Table 3.2.

Table 3.2
Summary of Project Alternatives

Component	Mid-Sea Dam/North Marine Lake (1)	Mid-Sea Barrier/South Marine Lake (2)	Concentric Lakes Dikes (3)	North-Sea Dam/Marine Lake (4)	Habitat Enhancement Without Marine Lake (5)
Mid-sea dam	X				
Mid-sea barrier		X			
Perimeter dikes	X				
South-sea dam	X				
North-sea dam				X	
Concentric lakes dikes			X		
Habitat pond embankments	X	X		X	X
Annual Probability of Failure (APF – max)	$\leq 1x10^{-4}$	Non – Risk Reduction Design $\geq 1x10^{-4}$, Risk Reduction Design $\leq 1x10^{-4}$	Non-Risk Reduction Design $>1x10^{-4}$, Risk Reduction Design $\leq 1x10^{-4}$	$\leq 1x10^{-4}$	Non-Risk Reduction Design $>1x10^{-4}$