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<td>CDFW</td>
<td>California Department of Fish and Wildlife</td>
</tr>
<tr>
<td>CNRA</td>
<td>California Natural Resources Agency</td>
</tr>
<tr>
<td>CVWD</td>
<td>Coachella Valley Water District</td>
</tr>
<tr>
<td>DWR</td>
<td>California Department of Water Resources</td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Assessment</td>
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<tr>
<td>IID</td>
<td>Imperial Irrigation District</td>
</tr>
<tr>
<td>LRP</td>
<td>Long-Range Plan</td>
</tr>
<tr>
<td>OMER</td>
<td>Operation, maintenance, energy and repair</td>
</tr>
<tr>
<td>PEIR</td>
<td>Programmatic Environmental Impact Report</td>
</tr>
<tr>
<td>SCH</td>
<td>Species Conservation Habitat (Project)</td>
</tr>
<tr>
<td>SHC</td>
<td>Saline Habitat Complex</td>
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<tr>
<td>SSMP</td>
<td>Salton Sea Management Program</td>
</tr>
<tr>
<td>SSRREI</td>
<td>Salton Sea Restoration and Renewable Energy Initiative</td>
</tr>
<tr>
<td>USBR</td>
<td>United States Bureau of Reclamation</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
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Appendix A: Summary of Reference Material Used to Develop Initial Concepts

This appendix provides a summary of reference material used to derive initial restoration concepts for the Long-Range Plan. The restoration concepts presented in the plan build upon current and past Federal, State and local investigations and the alternatives developed in those investigations. While the restoration concepts in the plan build on elements of the past alternatives, they have been updated to meet current habitat objectives, use the latest projections for future inflows, incorporate planned changes to the landscape, and use current-year cost estimates. The following four documents are the origin for the restoration concepts considered in the Long-Range Plan:

- Ecosystem Restoration Program Draft Programmatic Environmental Impact Report (PEIR), 2006
- Salton Sea Authority Funding and Feasibility Action Plan, 2016
- The SSMP 10-Year Plan as described in the Updated Draft Salton Sea Management Program, Phase 1: 10-Year Plan Project Description, 2021.

An overview of the alternatives presented in these four investigations is provided here in the chronological order mentioned above.

1.1. Ecosystem Restoration Program Draft PEIR, 2006

As described in the PEIR, State law required that “the Secretary for Resources undertake a study to determine a preferred alternative for the restoration of the Salton Sea ecosystem and the permanent protection of wildlife dependent on that ecosystem.” The PEIR focused on several key elements: protecting fish and wildlife, maintaining ecosystem benefits, minimizing air quality impacts, and improving water quality. The California Natural Resources Agency (CNRA) endeavored to bring together all contributing stakeholders involved in the project. After considering a set of eight alternatives, a Preferred Alternative was outlined in detail. The alternatives were published in the Draft PEIR in October 2006. The Final PEIR, published in 2007, provided a response to comments and errata, but no updates to the alternatives.
1.1.1. Range of Alternatives Considered

In addition to the Preferred Alternative, eight action alternatives were considered in the Draft PEIR:

- **Alternative 1.** Saline Habitat Complex I (38,000 acres of Saline Habitat Complex with minimum recirculation facilities and Air Quality Management);
- **Alternative 2.** Saline Habitat Complex II (75,000 acres of Saline Habitat Complex with brine recirculation and Air Quality Management);
- **Alternative 3.** Concentric Rings (61,000 acres of Marine Sea in two concentric rings, Air Quality Management, and no Saline Habitat Complex cells);
- **Alternative 4.** Concentric Lakes (88,000 acres of habitat similar to Saline Habitat Complex in four concentric water bodies as defined by the Imperial Group, with dedicated inflows for Air Quality Management but no long-term facilities);
- **Alternative 5.** North Sea (62,000 acres of Marine Sea in the northern seabed, 45,500 acres of Saline Habitat Complex in the southern seabed, and Air Quality Management);
- **Alternative 6.** North Sea Combined (74,000 acres of Marine Sea in the northern, western, and southern seabed; 29,000 acres of Saline Habitat Complex cells in the southern seabed; and Air Quality Management);
- **Alternative 7.** Combined North and South Lakes (104,000 acres of Marine Sea in the northern, western, and southern seabed; 12,000 acres of Saline Habitat Complex cells in the eastern seabed; water treatment of inflows and water withdrawn from the eastern portion of the northern Marine Sea; and use of Brine Stabilization for Air Quality Management at lower elevations); and
- **Alternative 8.** South Sea Combined (83,000 acres of Marine Sea primarily in the southern seabed with a smaller Marine Sea in the western and northern seabed, 18,000 acres of Saline Habitat Complex in the southern seabed, and Air Quality Management).

1.1.2. Methodology to Recommend the Preferred Alternative

In accordance with restoration legislation, the Secretary for Resources was to recommend a Preferred Alternative for restoration of the Salton Sea ecosystem to the California Legislature. The Preferred Alternative, shown in Figure 1, was developed based upon input from the Salton Sea Advisory Committee, broad public input, and the results of technical evaluations. The methodology and the results of each of these processes are described below.

1.1.3. Preferred Alternative

Eight alternatives were evaluated in the Draft PEIR. The Preferred Alternative (Figure 1) closely resembles Alternative 5 but takes aspects from many of the other alternatives evaluated. The Preferred Alternative, shown in Figure 1, includes Saline Habitat Complex in the northern and southern seabed, a Marine Sea that extends around the northern shoreline from San Felipe Creek to Bombay Beach in a “horseshoe” shape, Air Quality Management facilities to reduce particulate emissions from the exposed playa, brine sink for discharge of salts, Sedimentation/Distribution facilities, and Early Start Habitat to provide habitat prior to construction of the habitat components. The Preferred Alternative also could be configured to accommodate future geothermal development. These components are described below.
Saline Habitat Complex (SHC)

The Saline Habitat Complex (Figure 2) would border parts of the Marine Sea and the exposed playa to support indigenous food webs present in the area. Excavated areas of up to 15 feet in depth would be incorporated to increase habitat diversity and provide shelter for fish and invertebrates, as shown in Figure 2. To reduce vegetation growth, selenium ecorisk, and vector populations, the salinity in the complex will range from 20 PPT to 200 PPT. Supplied water would come from the New, Alamo and Whitewater rivers plus water recycled from the brine sink or upgradient Saline Habitat Complex cells to achieve a minimum salinity of 20 PPT. The first rows of the eastern and western southern Saline Habitat Complex would serve as a mixing zone for the inflows and saline water and would be maintained at a salinity of 20,000 to 30 PPT. Berms would
be constructed of suitable earthfill materials excavated from the seabed with 3:1 side slopes. A 20-foot wide gravel road on top of each Berm would allow access for maintenance. Rock slope protection would be placed on the water side of the Berm. Water depths would be less than 6 feet (2 meters). Berms could not be constructed until the brine sink (residual Salton Sea) recedes to an elevation below the Berm location.

**Marine Sea**

A Marine Sea would be formed through the construction of a Barrier. The Marine Sea would stabilize at a surface water elevation of -230 feet msl with salinity levels between 30 PPT and 40 PPT. Air quality Management Canals, Sedimentation/Distribution Basins, and Early Start Habitat would be constructed between the -228 and -230 foot msl contours and would avoid conflicts with existing land uses along the shoreline. Sources of inflows would include the Whitewater River, Coachella Valley drains, Salt Creek, San Felipe Creek, and local drainages. Flows from the New and Alamo rivers would be blended in a large Air Quality Management Canal and diverted into the Saline Habitat Complex and the southeastern and southwestern portions of Marine Sea. The portion of the Air Quality Management Canal located between the Sedimentation/Distribution Basins and Marine Sea would be located along the shoreline of the Saline Habitat Complex and would be siphoned under major drainages and agricultural drains. Air Quality Management Canals would continue on the interior side of the Barrier where the Marine Sea is located. Flows from the Marine Sea would be spilled to the brine sink to maintain salinity and elevation control.

The water depth would be less than 12 meters (39 feet), but additional data should be collected, and the maximum water depth should be re-evaluated prior to final design in project-level analysis. The barrier would be constructed of rock with a seepage barrier on the upstream base.
The Barrier would be up to 47 feet above the existing seabed and up to a half-mile wide at the base. The final slope of the Barrier would be 10:1 on the Marine side and 15:1 on the down gradient side, and it would need to comply with DWR, Division of Safety of Dams regulations. The barrier would be constructed using barges and would need to be constructed before the brine sink recedes. Efficient methods of construction are still in need of evaluation.

**Sedimentation/Distribution Basins**

Inflows from the New and Alamo rivers would be captured in two 200-acre Sedimentation/Distribution Basins to divert desilted river water into one of Several Air Quality Management Canals or bypass flows into the brine sink. The unlined Sedimentation/Distribution Basins would be excavated along the shoreline and would be located from -228 to -230 feet msl. Water depths would be about 6 feet. Sediment collected in the basins would be periodically dredged and flushed into the brine sink.

**Air Quality Management**

For the purposes of the PEIR and the Preferred Alternative, the following assumptions were used to define Air Quality Management components:

- 30 percent of the total exposed playa would be non-emissive and require no actions;
- 20 percent of the exposed playa would use management options that do not require freshwater supplies, such as Brine Stabilization, sand fences, or chemical stabilizers; and
- 50 percent of the exposed playa would use water efficient vegetation that is irrigated with a portion of the inflows to the Salton Sea.

To control dust emission, Air Quality Management Canals could be used to convey water from the Sedimentation/Distribution Basins to a series of 2-square mile units on the exposed playa that would include water filtration and chemical treatment units. The drip irrigators would be buried to reduce potential for selenium toxicity to wildlife from the ponded water, and facilities would be included in each unit to increase the salinity of the water to 10 PPT, if needed. Drains would be constructed under the irrigated area and drainage water would be conveyed to the brine sink. Construction of the irrigation system would require excavations up to 8 feet deep for trenches throughout the exposed playa. Salt bush, or similar vegetation, would be planted every 5 feet apart in rows that would be separated by 10 feet.

**Brine Sink**

The brine sink would provide the repository necessary to store excess salts, water discharged from the Saline Habitat Complex, Marine Sea, and Air Quality Management areas, and excess inflows. The elevation would fluctuate seasonally based upon the patterns of these tributary flows. During project-level analyses, partitioning of the brine sink could be considered to provide another area with salinities of less than 200 PPT that could support invertebrates and provide additional habitat on the seabed.
Early Start Habitat

The Early Start Habitat would include 2,000 acres of shallow saline habitat for birds. The habitat was assumed to be located at elevations between -228 and -232 feet msl and could either be a permanent or temporary feature to be eliminated or assimilated as other components are constructed. The Early Start Habitat area would be located along the southern shoreline because the flat slope of the seabed would provide a stable source of inflows into the habitat. Saline water from the Salton Sea would be pumped into the cells to be mixed with freshwater from the drains to provide salinity between 20 and 60 PPT.

The area would be divided into cells with Berms excavated from seabed materials. Average water depths within each cell would be less than four feet, although deep holes located away from the Berms may extend to 15-foot depths. Specific design and testing criteria would be developed in a project-level analysis.

Land Ownership Assumptions

The Preferred Alternative assumes that easements or deeds would be obtained for the entire seabed below elevation -228 feet msl to allow construction and operations and maintenance activities. If other land uses extend into the seabed, the Preferred Alternative would need to be modified in project-level analyses. For example, if exposed lands were to be converted to cultivated agriculture to an elevation of -235 feet msl, either the components would need to be constructed at lower elevations or displacement dikes would be required to protect the agricultural land.

Implementing Entities Assumptions

The Preferred Alternative was defined and evaluated as if one entity or group of entities implemented the program in a uniform manner. However, the State acknowledged that it would be possible for several entities to implement facilities under separate programs with some level of coordination. For example, facilities located in the northern and southern area of the seabed could be implemented by separate entities with coordinated operations for conveyance of inflows. As another example, separate entities could implement components with different functions, such as conveyance, Air Quality Management, Marine Seas, and/or Saline Habitat Complex.

Construction Materials Assumptions

For the purposes of the PEIR, development of new rock sources or transportation facilities are not considered part of the Preferred Alternative. For stabilizing components of the Barrier Design rocks or boulders between 1 to 5 feet in diameter are ideal. This rock size was not found to be available in large quantities at existing quarries during the preparation of this PEIR. However, the Preferred Alternative assumption is that this rock would be provided from a permitted quarry and transported to within 10 miles of the shoreline by methods other than trucks. Gravel would also be necessary for the road needed on top of the berms and barriers.
1.1.4. No Action Alternative

CEQA requires the evaluation of a “no project” alternative (Figure 3) to allow comparison of impacts of the restoration alternatives with those of not implementing any project. The No Action Alternative, which is the term used in this document for the no project alternative, reflects existing conditions plus changes that are reasonably expected to occur in the foreseeable future if the restoration is not implemented. The description of the No Action Alternative includes two different assumptions regarding inflow patterns over the 75-year study period and construction of QSA related facilities in the seabed.

Figure 3. No Action Alternative
Definition of Inflows for the No Action Alternative

It is difficult to predict changes in inflows over a 75-year period due to the influences of many future actions that cannot at present be accurately predicted. Therefore, two inflow scenarios were developed for the No Action Alternative in the PEIR.

One scenario is based upon future actions that have been previously defined in environmental documentation, including QSA implementation, reductions in flows from Mexico (due to new wastewater management facilities in Mexicali), and groundwater management in the Coachella Valley. This scenario, referred to as the No Action Alternative-CEQA Conditions, was developed in accordance with the CEQA Guidelines requirement for a no project alternative. The average inflows assumed for the No Action Alternative-CEQA Conditions from 2018 to 2078 would be 922,000 acre-feet/year (as compared to the existing conditions value of 1,300,000 acre-feet/year).

The second scenario is based upon implementation of actions under the No Action Alternative-CEQA Conditions and a conservative projection of changes in inflows due to potential changes in agricultural practices, further reductions in inflows from Mexico, and delayed implementation of groundwater management in the Coachella Valley. The No Action Alternative-CEQA Conditions may not accurately reflect future conditions over the 75-year study period. Therefore, this second scenario, referred to as the No Action Alternative-Variability Conditions, was developed to reflect these future uncertainties, and includes consideration of a wider range of projects and plans potentially developed by others that would affect inflows to the Salton Sea. Future variability is important to consider because it would be difficult to modify facilities should conditions change in the future. Under this scenario, the average inflows from 2018 to 2078 would be 717,000 acre-feet/year. For the purposes of comparison, this more conservative inflow scenario was used to develop Alternatives 1 through 8.

Facilities to be Constructed under the No Action Alternative

The No Action Alternative in the PEIR includes numerous actions and facilities to be constructed in accordance with implementation of the QSA. Most of these actions and facilities would not be located within the seabed and would be considered to occur in all alternatives. However, several of the QSA provisions require actions or construction of components within the seabed that could be modified substantially through implementation of the following PEIR alternatives:

- **Air Quality Management.** Mitigation of particulate emissions from the exposed playa between -235 and -248 feet msl; and
- **Pupfish Connectivity.** Construction of five pupfish channels on the seabed.

These measures would be part of the mitigation for the Imperial Irrigation District (IID) Water Conservation and Transfer Program, and costs would be jointly funded by IID, SDCWA, and CVWD up to a maximum amount of $133,000,000 (in 2003 dollars). Costs in excess of this amount would be the responsibility of the State, as determined in the QSA. These measures would be modified in each of the alternatives. Estimated costs for implementing these measures and impacts from construction and operations and maintenance are presented in the PEIR for comparative purposes. Facilities and costs would be identical for No Action Alternative-CEQA Conditions and No Action Alternative-Variability Conditions.
1.1.5. Alternative 1 Saline Habitat Complex

Alternative 1 (Figure 4) would provide Saline Habitat Complex in the southern seabed. Additional features include the brine sink, desert pupfish connectivity, and air quality management components.

Pupfish channels would be constructed along the shoreline. However, because these channels would not be connected to each other, five different populations of desert pupfish would be created. San Felipe and Salt creeks would not be connected to other areas and would flow into the brine sink.

Figure 4. Alternative 1, Saline Habitat Complex 1
Air quality management actions would include stabilization with brine and irrigation of water efficient vegetation in emissive areas.

The primary benefit of this alternative would be to provide habitat that would support tilapia, invertebrates, and a wide variety of birds. Water along the southern shoreline would minimize changes to the effects of the proximity of a large water body on the local climate (microclimate) and aesthetic values in the agricultural lands. Alternative 1 could also provide opportunities for fishing, use of non-motorized boats, bird watching, hiking, hunting, and day use activities.

1.1.6. Alternative 2 Saline Habitat Complex 2

Alternative 2 (Figure 5) would be similar to Alternative 1, but with more areas of Saline Habitat Complex. Alternative 2 would include Saline Habitat Complex in both the southern and northern portions of the seabed. This alternative would also include brine sink, desert pupfish connectivity, and air quality management components.

Desert pupfish connectivity would occur in the northern and southern shoreline waterways. However, five different populations of desert pupfish would be created since the shoreline waterways are divided by the Whitewater River in the north and the Alamo and New rivers in the south. San Felipe Creek would be connected to the shoreline waterway during low flow but would flow into the brine sink at high flows. Salt Creek would not be connected to other areas.

Air quality management actions would include stabilization with brine and irrigation of water efficient vegetation in emissive areas.

The primary benefit of this alternative would be to provide habitat that would support tilapia, invertebrates, and a wide variety of birds. Water along the southern, western, and northern shorelines would minimize changes to the microclimate and aesthetic values in these areas. Alternative 2 could also provide opportunities for fishing, use of non-motorized boats, bird watching, hiking, hunting, and day use activities.
1.1.7. **Alternative 3 Concentric Rings**

Alternative 3 (Figure 6) would include Concentric Rings that would provide moderately deep Marine Seas. The alternative also includes brine sink, desert pupfish connectivity, and air quality management components. All desert pupfish populations would be connected in the First Ring.

Air quality management actions would include stabilization with brine and irrigation of water efficient vegetation in emissive areas.

The primary benefit of this alternative would be to provide habitat that would support marine sport fish as well as tilapia, invertebrates, and a wide variety of birds. This alternative would also provide habitat and water along all of the shoreline and connect all desert pupfish populations.
Water along the shoreline would minimize changes to the microclimate and aesthetic values. Alternative 3 could also provide opportunities for fishing, use of motorized and non-motorized boats, water skiing, bird watching, hiking, hunting, swimming, camping, and day use activities.

![Figure 6. Alternative 3 Concentric Rings](image)

### 1.1.8. Alternative 4 Concentric Lakes

Alternative 4 (Figure 7) was defined by the Imperial Group, which is a coalition of Imperial Valley farmers. This alternative is comprised of four separate lakes that provide habitat like the Saline Habitat Complex without individual cells, with design salinity of 20 to 60 PPT. The alternative includes brine sink, desert pupfish connectivity, and air quality management components. The First Lake would provide desert pupfish connectivity for all of the direct drains, San Felipe Creek,
and other tributary waters along the southern shoreline. The Second Lake would connect all the northern drains and Salt Creek.

This alternative includes irrigation water supply. However, based upon the information provided by the Imperial Group, no long-term irrigation facilities were included. Therefore, long-term air quality management is not included in this alternative.

The lakes would be formed by berms using a different method than those employed in the other alternatives. Alternative 4 would use Geotube® berms which deploy geo-membrane tubes filled with dredged material from the seabed. The berms would primarily be constructed using barges.
The primary benefit of this alternative would be to provide habitat that would support tilapia, invertebrates, and a wide variety of birds. Water along the southern shoreline would minimize changes to the microclimate in the agricultural lands. Water would not be located, however, along the current western or northern shorelines. Alternative 4 could also provide opportunities for fishing, use of motorized and non-motorized boats, water skiing, bird watching, hiking, hunting, swimming, camping, and day use activities.

1.1.9. Alternative 5 North Sea

Alternative 5 (Figure 8) would include a deep Marine Sea at the north side of the seabed. Other features include Saline Habitat Complex in the south, brine sink, desert pupfish connectivity, and air quality management components.
Three separate areas containing desert pupfish would occur along the southern shoreline in the shoreline waterway, including one area that would connect San Felipe Creek, which would flow to the brine sink during high flows. The Marine Sea would connect all of the northern drains and Salt Creek.

Air quality management actions would include stabilization with brine and irrigation of water efficient vegetation in emissive areas.

The primary benefit of this alternative would be to provide habitat that would support marine sport fish as well as tilapia, invertebrates, and a wide variety of birds. Water along the southern shoreline would minimize changes to the microclimate in the agricultural lands. This alternative also would provide habitat and water along the northern shoreline. Alternative 5 could also provide opportunities for fishing, use of motorized and non-motorized boats, water skiing, bird watching, hiking, hunting, swimming, camping, and day use activities.

1.1.10. Alternative 6 North Sea Combined

Alternative 6 (Figure 9) would include a deep Marine Sea in the north combined with a moderately deep Marine Sea in the south, connected along the western shoreline. Saline Habitat Complex would be developed in the southern seabed. The alternative includes brine sink, desert pupfish connectivity, and air quality management components.

Desert pupfish in the drains along the southern shoreline and San Felipe Creek would be connected by the Marine Sea Mixing Zone. A pupfish channel would connect drains that are north of the Alamo River. All of the northern drains and Salt Creek would be connected by the Marine Sea.

1.1.11. Alternative 7 Combined North and South Lakes

Alternative 7 (Figure 10) was developed by the Salton Sea Authority and would include a deep Marine Sea (i.e., Recreational Saltwater Lake) in the north combined with a moderately deep Marine Sea (i.e., Recreational Estuary Lake) in the south. Saline Habitat Complex would be developed along the southeastern shoreline. Other features include brine sink, desert pupfish connectivity, air quality management components, and an 11,000-acre freshwater reservoir to be operated by IID.

Desert pupfish in drains along the northern and southern shorelines and San Felipe and Salt creeks would be connected by the Saltwater and Estuary lakes. The drains along the southeastern shoreline would not be connected.

Air quality management actions would include creation of a protective salt crust using salt crystallizer ponds.

The primary benefits of this alternative would be similar to those of Alternative 6. The main difference between Alternative 6 and 7 is the location of the barrier. Alternative 7 includes a barrier that would form a larger Marine Sea if average inflows from 2018 to 2078 were 800,000 acre-feet/year. However, to provide a uniform basis of comparison, this alternative also was evaluated assuming an average inflow of 717,000 acre-feet/year. Under the lower flows, the surface area would be smaller, and the salinity would be higher than projected in the definition of this alternative. Alternative 7 could also provide opportunities for fishing, use of motorized and non-motorized boats, water skiing, bird watching, hiking, hunting, swimming, camping, and day use activities.
Figure 9. Alternative 6 North Sea Combined
1.1.12. Alternative 8 South Sea Combined

Alternative 8 (Figure 11) would include a deep Marine Sea in the south combined with a moderately deep Marine Sea in the north, connected along the western shoreline. Saline Habitat Complex would be created along the southwestern and southeastern shorelines. The alternative includes brine sink, desert pupfish connectivity, and air quality management components.

Desert pupfish would be connected along the northern and southern shorelines which would include all of the drains and San Felipe Creek. Desert pupfish in Salt Creek would not be connected to other populations.
Air quality management actions would include stabilization with brine and irrigation of water efficient vegetation in emissive areas.

The primary benefit of this alternative would be to provide habitat that would support marine sport fish as well as tilapia, invertebrates, and a wide variety of birds. A large water body along the southern shoreline would maintain the microclimate in the agricultural lands. This alternative would also provide habitat and water along the western and northern shorelines. Alternative 8 could also provide opportunities for fishing, use of motorized and non-motorized boats, water skiing, bird watching, hiking, hunting, swimming, camping, and day use activities.

In September 2007, the US Bureau of Reclamation (Reclamation) proposed alternatives in their Summary Report: Restoration of the Salton Sea. The investigation was performed in fulfillment of the requirements of Public Law (P.L.) 108-361, the Water Supply Reliability and Environmental Improvement Act, November 2004 which states the following: “Not later than December 31, 2006, the Secretary of the Interior, in coordination with the State of California and the Salton Sea Authority, shall complete a feasibility study on a preferred alternative for Salton Sea restoration.”

The primary objective for Reclamation’s list of alternatives was to identify methods to restore the Sea’s ecosystem and provide permanent protection of the wildlife sustained by that ecosystem. Two secondary objectives of Reclamation’s study were to promote human activities supported by the Sea and to manage air quality. To accomplish their objectives, Reclamation lists six different alternatives: Alternative 1 Mid-Sea Dam with North Marine Lake, Alternative 2 Mid-Sea Barrier with South Marine Lake, Alternative 3 Concentric Lakes, Alternative 4 North-Sea Dam with Marine Lake, Alternative 5 Habitat Without Marine Lake, and Alternative 6 No Project.

During Reclamation’s evaluation of alternatives, a series of risks were considered: selenium risks to fish-eating birds, selenium risks to invertebrate-eating birds, hydrodynamic/stratification risks, eutrophication risks, fishery sustainability risks, and future inflow risks. Due to a “lack of data” and irresolvable issues of “hydrologic and biologic uncertainties” none of the alternative presented in the 2007 Executive Summary Report were recommended.

1.2.1. Mean Possible Future Inflows

The alternatives were assessed using computer modeling techniques. Each alternative was modeled using a statistics-based approach to inflows in which 10,000 different possible future Salton Sea inflows scenarios were simulated. The mean (or average) inflow computed from all of these possible future scenarios is described as the “Mean Possible Future Inflow Condition” and would have a value of 727,000 acre-feet per year.
1.2.2. Original Authority Alternative

The Authority’s original alternative incorporated a mid-Sea dam about 1.5 miles farther south than what is presented in Figure 12. This alternative also included a smaller SHC of 12,000 acres. Cost estimates were prepared for the Authority’s original alternative. These estimates provide a basis for making comparisons to cost estimates prepared by DWR and the Authority for this same original alternative. Attachment A of the Final Summary Report contains these cost estimates assuming that embankments would be built using rock fill embankments similar to those being proposed by the Authority (Alternative 1B). The estimate presented in Attachment A assumes the use of salt crusting (as originally proposed by the Authority) via construction of small earth embankments (2.5 feet tall) to impound brine released from the SHC. Reclamation evaluated the rockfill embankment concept and determined it would not meet Reclamation’s general design criteria.

Figure 12. Alternative No. 1: Mid-Sea Dam with North Marine Lake (The Authority’s Alternative)
1.2.3. Alternative No. 1: Mid-Sea Dam with North Marine Lake (The Authority’s Alternative)

Alternative No. 1 would provide both salinity and elevation control and up to 16,000 acres of SHC. Further details of this alternative are presented in Table 1. As shown in Figure 12, Alternative No. 1 includes a total of four embankments: (1) an impervious mid-Sea dam, (2) an east-side perimeter dike, (3) a west-side perimeter dike, and (4) a south-Sea dam. These structures would be built using the sand dam with stone columns concept (See Figure 13). The embankments would be constructed so the water north of the mid-Sea dam would be maintained at a higher elevation than the brine pool on the south side. The area south of the mid-Sea dam 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. In addition to the north marine lake, a smaller south marine lake would be created by the south-Sea dam. These two bodies of water would be connected along the western edge of the Sea by the west-side perimeter dike and along the eastern edge by the east-side perimeter dike and canal. The north marine lake would have a mean future water surface elevation of about -238 feet msl under mean possible future inflows. The estimated long-term elevation of the brine pool is about -272 feet msl. The alternative includes 16,000 acres of SHC and a dedicated habitat area on the north end of the Sea. It also includes a deep-water pipeline, an ozonation treatment plant, a water circulation system, and a phosphorous removal treatment plant. The conveyance features included in this alternative consist of a circulation canal, sludge conveyance pipeline, back-flush waste pipeline, three pumping plants, and two associated pipelines.

Table 1. Physical features of Alternative No. 1: Mid-Sea Dam with North Marine Lake

<table>
<thead>
<tr>
<th>Physical Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine lake surface area</td>
<td>98,900 acres</td>
</tr>
<tr>
<td>Marine lake maximum depth</td>
<td>43.5 feet</td>
</tr>
<tr>
<td>SHC surface area</td>
<td>16,000 acres</td>
</tr>
<tr>
<td>Total open water habitat surface area</td>
<td>106,900 acres</td>
</tr>
<tr>
<td>Total shoreline habitat surface area</td>
<td>26,600 acres</td>
</tr>
<tr>
<td>Brine pool surface area</td>
<td>17,600 acres</td>
</tr>
<tr>
<td>Exposed playa surface area</td>
<td>103,800 acres</td>
</tr>
</tbody>
</table>
Appendix A: Summary of Reference Material Used to Develop Initial Concepts

Working Draft

Figure 13. Typical cross-section of sand dam with stone columns
1.2.4. Alternative No. 2: Mid-Sea Barrier with South Marine Lake

Alternative No. 2 would provide salinity control but no elevation control and up to 21,700 acres of SHC (See Figure 14 and Table 2). The alternative includes a mid-Sea barrier designed to generally be operated with equal heads on both sides and to accommodate a differential head of up to 5 feet.

![Figure 14. Alternative No. 2: Mid-Sea Barrier with South Marine Lake Under Mean Possible Inflow Conditions.](image)

### Table 2. Physical features of Alternative No. 2 Under Mean Future Conditions: Mid-Sea Barrier with South Marine Lake.

<table>
<thead>
<tr>
<th>Physical Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine lake surface area</td>
<td>59,700 acres</td>
</tr>
<tr>
<td>Marine lake maximum depth</td>
<td>15.5 feet</td>
</tr>
<tr>
<td>SHC surface area</td>
<td>21,700 acres</td>
</tr>
<tr>
<td>Total open water habitat surface area</td>
<td>49,000 acres</td>
</tr>
<tr>
<td>Total shoreline habitat surface area</td>
<td>34,700 acres</td>
</tr>
<tr>
<td>Brine pool surface area</td>
<td>66,000 acres</td>
</tr>
<tr>
<td>Exposed playa surface area</td>
<td>73,600 acres</td>
</tr>
</tbody>
</table>
The water entering the Sea from the south into the south marine lake would support a large marine habitat. The estimated long-term elevation of the marine lake and brine pool under mean future conditions is -261 feet msl. Most inflows are expected to occur from the south end; therefore, the area north of the barrier embankment is expected to serve as an outlet for water and salt from the south side. The north side would quickly form a brine pool. As the main body of the Sea shrinks, embankments would be constructed to create SHC. The mid-Sea barrier would be constructed with a crest elevation of -245 feet and would accommodate the forecasted reductions in inflows. The 21,700 acres of SHC would be constructed on the southeast and north ends of the Salton Sea.

The conveyance features included in this alternative consist of five diversion points and sediment detention basins, four pupfish/river water channels, five river water channels, and a pumping plant and two associated pipelines. These conveyance features would be used to provide water to AQM projects as well as to provide marine lake water to be mixed with river water delivered to the SHCs. A controlled outlet tower on the west end of the barrier would provide the ability to maintain up to a 5-foot head differential between the marine lake and brine pool.

The mid-Sea barrier embankment would be built using the fundamental concepts of the sand dam with stone columns (See Figure 13).

1.2.5. Alternative No. 3: Concentric Lakes (Imperial Group Alternative)

Alternative No. 3 was proposed by the Imperial Group. It provides both elevation and salinity control (See Table 3 and Figure 15).

**Table 3. Physical features of Alternative No. 3 Under Mean Future Conditions: Concentric Lakes**

<table>
<thead>
<tr>
<th>Physical Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine lakes surface area</td>
<td>47,600 acres(^1)</td>
</tr>
<tr>
<td>Marine lakes maximum depth</td>
<td>6 feet</td>
</tr>
<tr>
<td>SHC surface area</td>
<td>0 acres(^2)</td>
</tr>
<tr>
<td>Total open water habitat surface area</td>
<td>817 acres</td>
</tr>
<tr>
<td>Total shoreline habitat surface area</td>
<td>46,800 acres</td>
</tr>
<tr>
<td>Brine pool surface area</td>
<td>127,800 acres</td>
</tr>
<tr>
<td>Exposed playa surface area</td>
<td>65,000 acres</td>
</tr>
</tbody>
</table>

\(^1\) The 47,600 acres shown are for three concentric lakes. The fourth lake proposed by the Imperial Group is not necessary under the risk-based approach to future inflows described in Chapter 4. Including the fourth lake proposed by the Imperial Group would result in a total marine lakes surface area of 88,000 acres.

\(^2\) This alternative has habitat areas that are similar to SHC, which is reflected in the shoreline habitat surface area listed in this table.
The alternative consists of a series of three (or, as the Imperial Group proposed, four) independent lakes, with deep pools and habitat islands. Each lake would receive water directly from canals from the New and Alamo Rivers. Each lake would operate at increasingly higher salinities, with evaporation concentrating salinities from 20 to 60 PPT. The lakes would be formed by constructing dikes in a concentric ring pattern. The outermost lake would be formed by a partial ring dike located at the south end of the project. A brine pool would exist within the area of the innermost dike. Deep pool areas up to 20 feet in depth would be formed within the lakes with adjacent habitat islands. Outside of the deep areas, the maximum lake depth would be 6 feet.

The outer lake is shown with cell dividers that could allow different habitat types to be managed in a way similar to that under the SHC concept. The cell divider concept could be applied to any of the concentric lakes. Due to costs, it is assumed that cell dividers are only incorporated into the outer partial concentric lake.
This alternative would be constructed in stages with an estimated time frame of 40 years for completion. First, the outermost lake features would be constructed. The second, third, and fourth (if required) reservoir lakes would be constructed as the water surface of the residual Sea recedes to the target reservoir water surface elevation of the next lake to be constructed. The conveyance features included in this alternative consist of two river water channels to convey all flows from the Alamo and New rivers into the concentric lakes and brine pools area. Diversion structures would provide for control of flows into each lake to manage salinity levels.

The Imperial Group proposed using Geotube® technology to construct the concentric lake dikes as shown in Figure 16.

1.2.6. Alternative No. 4: North-Sea Dam with Marine Lake

Alternative No. 4 would provide both elevation and salinity control and up to 37,200 acres of SHC (See Table 4 and Figure 17).

Under Alternative No. 4, an impervious dam embankment would be constructed to impound Whitewater River inflows. The impervious dam would include an embankment built using the sand dam with stone columns concept as described later in this chapter. The embankment design would provide both static and seismic risk reduction. 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 shrink in size to achieve equilibrium with inflows from the south and discharges from the north marine lake. The salinity of the brine pool would increase over time. The north marine lake would have a water surface area of up to 19,500 acres at elevation -229 msl and would be operated to maintain a salinity of 35 PPT or less. SHC (37,200 acres) would be constructed on the south end of the Salton Sea.

As the main body of the Sea shrinks, these complexes would be constructed on the exposed seafloor to take advantage of the gently sloping seafloor. The conveyance features included in this alternative consist of three diversion points and sediment detention basins, three pupfish/river water channels, three river water channels, and two pumping plants and associated pipelines. These conveyance features would be used to provide water to AQM projects as well as to provide brine to be mixed with river water delivered to the SHCs. The brine and river water would be mixed in impoundments constructed in the seafloor. These mixing impoundments would need to be moved over time as the residual Sea recedes.
### Table 4. Physical features of Alternative No. 4 Under Mean Future Conditions: North-Sea Dam with Marine Lake

<table>
<thead>
<tr>
<th>Physical Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine lake surface area</td>
<td>19,500 acres</td>
</tr>
<tr>
<td>Marine lake maximum depth</td>
<td>33 feet</td>
</tr>
<tr>
<td>SHC surface area</td>
<td>37,200 acres</td>
</tr>
<tr>
<td>Total open water habitat surface area</td>
<td>23,800 acres</td>
</tr>
<tr>
<td>Total shoreline habitat surface area</td>
<td>32,900 acres</td>
</tr>
<tr>
<td>Brine pool surface area</td>
<td>91,300 acres</td>
</tr>
<tr>
<td>Exposed playa surface area</td>
<td>91,800 acres</td>
</tr>
</tbody>
</table>

![Figure 17. Alternative No. 4: North-Sea Dam with Marine Lake](image-url)
Appendix A: Summary of Reference Material Used to Develop Initial Concepts

Working Draft

The 19,500-acre lake was designed to reduce as much as possible the requirement to achieve acceptable salinity levels without dependence on long detention times in the marine lake. Smaller lakes would require evapoconcentration of salt without making releases from the lake for many years, which would result in the concentration of contaminants.

1.2.7. Alternative No. 5: Habitat Enhancement Without Marine Lake

Alternative No. 5 provides no structural solution for a marine lake. The alternative would rely entirely upon SHC to provide open water and shoreline habitat. Under this alternative, SHCs would be constructed at the south and north ends of the Sea (See Table 5 and Figure 18).

This alternative would not provide in-Sea marine habitat. About 20 percent of the SHC would be deep open water (up to 10 feet) for fisheries. These deep-water pond areas would be constructed through excavation; the excavated material would be used to create islands behind cell embankments. The remaining portion of the SHC would be divided into areas suitable for different species and their use; up to a quarter of these areas would be land. The majority of these shallow water pond habitats would be less than 3 feet deep.

Inflows to the SHCs would be managed to achieve an average starting cell salinity of more than 20 PPT through the mixing of waters from the rivers and residual Sea brine pool. The brine and river water would be mixed in impoundments constructed in the seabed. These mixing impoundments would have to be moved through time as the residual Sea recedes. Water would flow by gravity through each of the SHC cells. The salinity of each cell would increase until it reaches about 150 PPT, when discharges from the last cell would be made to the brine pool. The water is expected to have habitat value up to a salinity of about 150 PPT.

The conveyance features included in this alternative consist of five diversion points and sediment detention basins, three pupfish/river water channels, five river water channels, two mixing impoundments, three pipelines, and two pumping plants. These conveyance features would be used to provide water to AQM projects as well as to provide brine to be mixed with river water delivered to the SHCs.

Table 5. Physical features of Alternative No. 5 Under Mean Future Conditions: Habitat Enhancement without Marine Lake

<table>
<thead>
<tr>
<th>Physical Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine lake surface area</td>
<td>0 acres</td>
</tr>
<tr>
<td>Marine lake maximum depth</td>
<td>---</td>
</tr>
<tr>
<td>SHC surface area (Combined surface area of five complexes).</td>
<td>42,200 acres</td>
</tr>
<tr>
<td>Total open water habitat surface area</td>
<td>8,400 acres</td>
</tr>
<tr>
<td>Total shoreline habitat surface area</td>
<td>33,800 acres</td>
</tr>
<tr>
<td>Brine pool surface area</td>
<td>117,400 acres</td>
</tr>
<tr>
<td>Exposed playa surface area</td>
<td>81,200 acres</td>
</tr>
</tbody>
</table>
1.2.8. Embankment Design

The general design criteria determined for the mid-, south-, and north-Sea dams; the perimeter dikes; the concentric ring dikes; the mid-Sea barrier; and the habitat pond embankments would be as follows:

- Resist and control embankment seepage, foundation seepage, internal erosion, and static settlements.
- Resist large offsets, slope instability, and deformations due to seismic loading and flooding.
- Provide for constructability using proven methods and safe construction.

**Figure 18.** Alternative No. 5: Habitat Enhancement without Marine Lake (Note the SHC on both the north and south ends of the Sea)
Reclamation developed guidelines to assist in the management of risk associated with its existing dam inventory and in considering new structures. These guidelines for public protection are published in the document *Bureau of Reclamation, June 2003, Guidelines for Achieving Public Protection in Dam Safety Decision-Making*.

Reclamation’s guidelines focus on two assessment measures of risks related to Reclamation structures: (1) the estimated probability of a dam failure and (2) the potential life loss consequences resulting from the unintentional release in the event of failure. As a water resource provider, Reclamation must maintain and protect its dams and dikes that store water. The second measure addresses the potential life loss component of societal risk. Protection of human life is of primary importance to public agencies constructing, maintaining, and/or regulating civil works.

Within these guidelines, to ensure a responsible performance level across the inventory of Reclamation’s dams, it is specified that decision makers consider taking action to reduce risk if the estimated annual probability of failure exceeds 1 chance in 10,000. To achieve compliance with Reclamation guidelines, an annual probability of failure of any embankment (classified as significant or high hazard structures) at the Salton Sea must be below 1 in 10,000.

1.3. **Salton Sea Authority Funding and Feasibility Action Plan, 2016**

With a grant from CNRA, the Salton Sea Authority conducted a funding and feasibility investigation in 2015-2016. The most significant outcome from the investigation was the perimeter lake proposal in their Benchmark 4, Volume 2 Report. Benchmark 4, Volume 1 included concepts for exporting water via pipelines to provide an outlet for salts that enter the Sea each year in its inflows. Both concepts are discussed below.

1.3.1. **Perimeter Lake Proposal**

Following reviews of the features and benefits of past plans, a new smaller lake concept was proposed. The concept was referred to as the Perimeter Lake for the Salton Sea. It considered the immediate need for action, the limitations on water supply for the lake, and the possibility of constructing a project with incremental funding.

The perimeter lake approach would involve constructing a lake around the perimeter of the Sea along with a central saline pool within the current Sea footprint. This concept was planned to work with other projects being planned in the 2015-2016 timeframe by the State and the Imperial Irrigation District (IID) as part of an overall SSMP. A complete management plan for
the Salton Sea would include the Perimeter Lake concept combined with IID’s Salton Sea Restoration and Renewable Energy Initiative (SSRREI) Initiative, an air quality management plan, and other smaller projects around the Sea such as the Red Hill Bay and SCH projects, as illustrated Figure 19.

Benchmark 4 Volume 2 describes the Perimeter Lake in more detail. Important aspects of the concepts that are outlined in this document include the following:

- Project goals and Perimeter Lake concept overview;
- Conceptual construction details;
- Water inflow requirements and water quality improvement in inflow;
- Conceptual design of spillways and air quality mitigation (AQM);
- Geotechnical feasibility study; and
- Construction scenario, cost estimate, funding, and cost comparisons to past alternatives.

The Perimeter Lake would rely upon a system of low-profile levees to create a reasonably affordable and sustainable water body. This system would generally resemble an in-stream reservoir built along a slowly flowing river. It would include wider recreational areas in the north and south ends of the Sea, although boating would be accommodated along the entire 60+ miles of lake front property. The exposed playa on the southern end of the Sea near the Perimeter Lake project site was designated for IID’s SSRREI concept. Built incrementally, the water used in the
Perimeter Lake system would initially flow through a series of linked but separated elongated ponds.

Treatment wetlands, possibly those incorporated in the SCH project, were proposed near or upstream from the mouth of the New River to provide higher quality water entering the system, although no specific plans have been developed at this point. In sections ranging from 500 ft to over 2 miles in width, water entering the Perimeter Lake system would arrive in a wide area at the south end of the Sea, flow northward along the western shore, and arrive at another wide area in the north. Water would flow out of the northern area and move southward along the eastern shore to a terminus spillway. Here, at the terminus spillway, excess water would be channeled into a permanent saline pool in the center of the historic seabed.

Spillways at several locations within the system and the quantity and salinity of water diverted into the system would allow for management of salinity from near fresh to marine, with the expectation that the target salinity would be brackish (15-20 PPT). Excess salinity would concentrate in the saline pool located near the center of the Sea.

At full build out, the total length levee running parallel to the shore would be approximately 61 miles. Additionally, 13 perpendicular connector levees or dikes totaling 6 miles would connect to existing roads so that construction could proceed as individual cells. The total area of all 13 cells would be approximately 36 square miles, with 10 square miles in Riverside County and 26 square miles in Imperial County. The levees would be constructed by dredging a channel along the lake side of the levee which would create a deep-water habitat area of up to 25 ft in depth for the full length of the lake.

The annual inflow required to balance evaporative and seepage losses is estimated at 167,000 AFY (acre-ft per year). Initially, additional water could be run through the system to reduce salinity and nutrients in the water column and clean out detritus. Once in operation, the water body could be used to convey water to other habitat areas or for dust control.

Conceptual Construction Details

The Perimeter Lake concept has evolved over time and would work in concert with IID’s SSRREI Initiative Project, the State of California’s Species Conservation Habitat (SCH) project, Red Hill Bay Restoration Project, and Imperial County (AQM) objectives. The Benchmark 4, Volume 2 document describes concept development and conceptual construction details for the Perimeter Lake. Various depths, levee configurations and lake sizes for the Perimeter Lake were considered. Three embankment configurations were considered for use as levees on the seaside of the new lake configuration: Earthen Levees with broad 15:1 side slopes created from local dredging, Geotube® Levees, and Sheet Pile Levees. Each design was evaluated with respect to the following performance criteria: constructability, cost, maintenance, environmental considerations, permitting, footprint derived from angle of repose, and risk and uncertainty.

The earthen levee embankment was considered to have multiple advantages and was selected for further analysis in the Perimeter Lake concept. It was expected to be the lowest cost solution and rated best in constructability and related considerations. Furthermore, a significant allocation of the construction cost would be for dredging, which would have the advantage of creating deep water areas with ecological and recreational benefits. Figure 20 illustrates the earthen levee concept.
Two possible scenarios were considered for construction of the levees. The levee construction could be completed with one team in approximately ten years, or it could be completed with two teams working in parallel in approximately five years. The selected scenario would depend on the availability of funding.

**Water Inflow Requirements and Water Quality Improvement in Inflow**

Benchmark 4, Volume 2 includes a water budget analysis and a discussion of the residual saline pool. The water budget and salinity analysis for the Perimeter Lake is presented based on expected evaporation and seepage losses and other possible inflow considerations. Accounting for these variables, three scenarios were analyzed to estimate the water budget for the project: a base scenario that includes no releases for beneficial operations such as dust control, and two scenarios that would feature water releases for dust control or other beneficial uses.

Inflow water quality needs to be improved to achieve the full beneficial use potential of the Perimeter Lake. Treatment wetlands were proposed for this purpose and discussed in Section 4.0. These wetlands would be used to improve the water quality, particularly nutrients and suspended sediments, of the New River before they flow into the Perimeter Lake. Estimated area requirements were based on pilot wetland results from Brawley and Imperial. To meet project targets of 2-3 mg/l total nitrogen and 0.1-0.25 mg/l total phosphorus, the project would require surface areas from 590-1,150 acres under low infiltration conditions and 470-610 acres under mean infiltration conditions.

**Conceptual Design of Spillways**

Although the Salton Sea is set in an arid region, it is subject to occasional floods that must be considered in the Perimeter Lake design. Benchmark 4, Volume 2 includes conceptual designs of overflow spillways to address both the average annual inflow as well as the occasional flooding produced from the rare storm event. The intent of the structures is to allow the average inflow of water to circulate within the Perimeter Lake while maintaining a desired water level, provide emergency flood relief to prevent overtopping of the levee, and still maintain sufficient freeboard for safety purposes. The overflow structures include three 20-ft bellmouth spillways near the
North Shore Yacht Club, the Bombay Beach, and the old base; and a 1,000 ft wide broad crested weir near the North Shore Yacht Club. These structures would stimulate clockwise internal circulation and exchange water inside the Perimeter Lake up to a rate equal to the entire lake volume twice annually.

**Geotechnical Feasibility Study**

A feasibility-level geotechnical assessment was conducted to evaluate slope stability and seepage associated with the Perimeter Lake design. The evaluation did not identify any geotechnical factors that would preclude the successful design and construction of the project. However, several factors would require special consideration during the design, engineering and construction of the project. These factors would include dewatering of excavated materials and mechanical placement and compaction, mitigation of settlement and seepage, and soil liquefaction and seismic deformation mitigation, all of which were considered in developing the construction scenario and detailed cost estimates and schedules.

**Construction Scenario and Cost Estimate**

Construction would involve sheet pile installation, geotextile deployment, dredging and stockpiling of sediments, construction of spillway structures, grading and armoring of the levees, construction of roadways on top of the levees, and construction of causeways. Ferry barges or floating bridges would allow access to the levees for maintenance once causeways dividing the cells are breached.

A detailed feasibility-level cost estimate was prepared for two construction scenarios: construction of Phase 1 and 2 in series, and construction of Phase 1 and 2 in parallel. While funding sources were still being investigated, a review of funding sources was included. Details on the construction scenarios, the cost estimates, and the possible funding sources can be found in Benchmark 4, Volume 2. Alternative A was estimated at a total cost of $1.7 billion including contingencies with a 10-year construction period. Alternative B was estimated at a total cost of $1.8 billion including contingencies with a 5-year construction period. Cell and access levee locations are shown in Figure 21. Further details on funding sources and costs are presented in Benchmark 4 Volume 2.

**Benefits of the Perimeter Lake Concept**

According to the Salton Sea Authority documents, the Perimeter Lake concept would revitalize the Salton Sea and the surrounding area by providing the following benefits: stable shoreline with elevation control in a lake with an area of 36 square miles; improved water quality with reduced salinity; a source of water for AQM; compatibility with other Salton Sea management projects; and a deep-water habitat that would also be suitable for recreational uses. Spillways in the north and south would provide salinity control and allow management of water in the Perimeter Lake at brackish levels (15-20 PPT). Initial flushing would help remove detritus and nutrients that are already present in the lake at high levels, and proposed treatment wetlands would improve the quality of water flowing in from the New River.
Lake elevation with this plan would be slightly below historic shorelines from 1960-2010 period; however, these levels would reduce the water requirement for the Perimeter Lake component to only 167,000 AFY, and remaining inflow (522,000-689,000 AFY) could be used for other projects such as SCH, IID’s SSRREI, AQM, or other habitat projects. The Perimeter Lake was planned to be outside the boundaries of the KGRA and thus would not interfere with opportunities for development of geothermal or other renewable energy projects.

The deep-water areas of up to 25 ft have recreational value for boating and fishing, and they would also benefit habitat by providing a food source for resident and migratory piscivorous birds. Additionally, the Perimeter Lake plan would include 130 miles of shallow habitat along the existing shoreline and levees for wading birds. At 36 square miles, the Perimeter Lake would be significantly larger than all other lakes in southern California, including the 32-square mile Lake Havasu.

1.3.2. Pump Out Pipeline Options

Because the Salton Sea does not have an outlet, even low levels of salt in the inflow have no other place to go but to concentrate in the Sea. Therefore, the Salton Sea Authority investigated ways of creating an outlet by constructing a pipeline to various locations. The analysis considered four factors: water quantity removed, the conveyance system and hydraulics necessary for removal, capital and operational cost, and institutional considerations. An applicable screening level performance analysis using a salinity and elevation model was also conducted.

One of the largest challenges facing the Salton Sea is the lack of an outlet, as the salt content conveyed into the sea concentrates over time due to evaporation. Salt has historically been conveyed into the Sea with irrigation drainage and other flows with an average salinity of about...
2.5 PPT. If the salinity in the Sea could be reduced to concentrations similar to the ocean salinity of 35 PT, the outflow would need to be only 2.5/35 or 1/14 times the inflow.

The Salton Sea Authority investigated several possible discharge locations:

- Laguna Salada
- La Cienega de Santa Clara (Santa Clara Slough, Wetland)
- Gulf of California
- Land-based discharge areas

Export to the Gulf of California is probably the most feasible of these and, therefore, is discussed further below. Regardless of the discharge location, the concept of creating an outlet by pumping would have the same effect of controlling salinity in the Salton Sea.

**Pipeline to the Gulf of California**

As shown in Figure 22, the Gulf of California is approximately 120 miles from the Salton Sea and 30 miles away from La Cienega de Santa Clara. There is an existing and operational canal system which covers 80 percent of the distance from the Gulf of California to the US-Mexico border. Additionally, 95 percent of the distance from the Gulf to the border is below sea level, with an average elevation of -25 MSL. The general terrain in the area is loose, rocky to sandy soil. The Gulf of California has been losing coastal land at a very high rate over the last 50 years, and the environmental impact of discharging flows from the Salton Sea must be evaluated thoroughly. The flow paths to the Gulf of California could originate from either the southwest or southeast portions of the Salton Sea.

**Water Quantity**

The quantity of water that could be exported from the Salton Sea to the Gulf of California would depend on several factors. These factors include levels of salinity in the Salton Sea, environmental impacts of discharging the higher salinity water from the Salton Sea into the Gulf of California, and the associated costs and capabilities of the pumping systems and pipelines from the Salton Sea to the Gulf of California. Modeling was performed with an initial pump out rate of 150,000 AFY starting in 2025, which could be reduced to 100,000 AFY or less after 20 years. For this scenario, it would take about 25 years for the Sea to return to a salinity that could support fish populations and another 10 years to return to ocean-like salinity of 35 PPT. After that, the pump-out rate could be further reduced to 60,000 or 70,000 AFY for long-term salinity control. The effect of the outlet would be a reduction of the surface area of the Sea by about 7%.

**Conveyance System and Hydraulics**

Delivery of 150,000 AFY of water from the Salton Sea to the Gulf of California would require 120 miles of pipeline that is 86-inch diameter with two pump stations as shown in Figure 22. There is an elevation gain of approximately 530 feet from the Salton Sea to the Gulf of California with the high point located south of the international border near the Mexicali-Tecate Highway 2. Delivery of water to the Gulf of California would also require a minimum of two pump stations. The first pump station would be located near the Salton Sea to convey water into the pipeline. A second pump station would be necessary along the pipeline alignment to deliver water to the final
discharge point. Each pump station would be designed with a discharge head of 500 feet, and pipeline design would be based on internal pressure of 300 psi, accounting for surge.

Figure 22. Possible Pipeline Route from the Salton Sea to the Gulf of California

Institutional Considerations

The average salinity in the ocean is generally 35 PPT, whereas salinity values in the Salton Sea are currently around 70 PPT and projected to go substantially higher. Evaluation of discharge methods into the Gulf of California and significant consideration of environmental impacts to the coastal habitats would be necessary for determining whether this option is feasible. The cost-effectiveness of transporting a significant volume of water for 120 miles over significant elevation gains must also be evaluated. Again, this option requires a transfer of water across international borders, and the feasibility and validity of this option relies heavily on collaboration, permits, and approvals being resolved between the governments of the United States and Mexico.
Conceptual plans

Conceptual plans prepared for the Gulf of California Pipeline alternative can be found in Appendix 11.5 of the Salton Sea Authority’s Benchmark 4-1 Report. These plans were used to form the basic concept for the pipeline route and its key components. Conceptual level cost estimates were then developed from the layouts presented in these plans. Appendix 11.5 contains hydraulic profiles, pump station mechanical plans and sections, typical intake structures, and discharge headers.

Summary

Exportation of water from the Salton Sea to the Gulf of California would require significant infrastructure and operational costs for pumping the high salinity water for a distance over 120 miles. The environmental impact of importing higher salinity water to the already impacted coastline habitats must be considered. Should blending or treatment be required, the added costs in addition to the baseline conveyance costs may significantly impact the feasibility and cost-effectiveness of this option.

1.4. 10-Year Plan Environmental Assessment, 2022

An Environmental Assessment (EA) for the SSMP 10-Year Plan is being prepared in coordination with the US Army Corps of Engineers in compliance with the National Environmental Policy Act (NEPA). As part of the process, an Updated Draft Salton Sea Management Program, Phase 1: 10-Year Plan Project Description was released for public review in March 2021.

When completed, the EA is expected to include a Proposed Project plus five action alternatives and a No Action Alternative. All action alternatives are expected to include the SCH (which is currently under construction) plus a North Lake Project and an Alamo River Project. Acreage of various types of habitat and dust control measures are shown in Table 6.
Table 6. Areas in Acres of Habitat and Dust Control Expected to be Included in the 10-Year Plan EA

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Acronyms and Abbreviations

AF          Acre-feet
AFY         Acre-feet per year
CMIP        Coupled Model Intercomparison Project
CRMMS       Colorado River Mid-term Modeling System
CRSS        Colorado River Simulation System
CVSC        Coachella Valley Stormwater Channel
CVWD        Coachella Valley Water District
DCP         Drought Contingency Plan
DWR         California Department of Water Resources
ET          Evapotranspiration
GCM         Global Climate Model
ICS         Intentionally created surplus
IID         Imperial Irrigation District
kAF         Thousand acre-feet
LRP         Long-Range Plan
MAFY        Million acre-feet per year
MSL         Mean sea level
QSA         Quantification Settlement Agreement
RCP         Representative Concentration Pathway
Reclamation United States Bureau of Reclamation
SALSA2      Salton Sea Elevation Model version 2
SDCWA       San Diego County Water Authority
SSMP        Salton Sea Management Program
SSP         Shared Socioeconomic Pathway
TAFY        Thousand acre-feet per year
USGS        United States Geological Survey
WMP         Water Management Plan
1 Introduction

Long-term management of the Salton Sea requires an understanding of historical and future hydrology at the Salton Sea and the connected Imperial Valley and Coachella Valley watersheds. This report describes the historical hydrology, baseline assumptions for projected hydrology, and the resulting projected future conditions at the Salton Sea, which can be used to inform long-term management and planning.

The study area is described in Section 2. Sources of information used to build this memo are identified in Section 3. Such background information is offered by a combination of historical observations, management plans, and hydrological studies. Prior modeling work pertaining to Imperial Valley and Salton Sea hydrology can be found in Section 4. In Section 5, each source of inflow and outflow is individually discussed to provide the foundation for development of future scenarios. Annual and sub-annual flows are studied to provide a holistic understanding. This is followed by a final table of future water management scenarios and assumptions in Section 6. Concluding remarks are in Section 7, and references are in Section 8.
2 Description of the Study Area

Agriculture in the Imperial Irrigation District (IID) and the Coachella Valley Water District (CVWD) is sustained by Colorado River water diverted at the Imperial Dam and delivered via the All-American and Coachella Canals. Total diversions of approximately 2.8 million acre-feet (AF)/year at the Imperial Dam support irrigated agriculture in the Imperial and Coachella Valleys.\(^1\) Irrigated areas surrounding the Salton Sea are shown in relation to the entire Colorado River basin in Figure 1.

The Salton Basin is the northern arm of the former Colorado River delta system. Agricultural return flows and drainage from these valleys and parts of the Mexicali Valley, in addition to municipal and industrial discharges in the watershed, feed the major rivers flowing to the Salton Sea. The Salton Sea watershed encompasses an area of approximately 8,000 square miles from San Bernardino County in the north to the Mexicali Valley (Republic of Mexico) to the south.

The principal sources of inflow to the Salton Sea are the Whitewater River to the north (also know as the Coachella Valley Stormwater Channel [CVSC]), the Alamo and New Rivers to the south, and direct return flows from agricultural drains in the Imperial Valley and Coachella Valley. The riverine sources of inflow are recorded by United States Geological Survey (USGS) gage stations situated at the river mouths, with observations dating back to at least 1988 (Figure 2).

The Whitewater River (CVSC) is the primary river drainage channel of CVWD. It brings stormwater runoff, agricultural return flows, and municipal and fish farm discharges from the Coachella Valley to the Salton Sea. In the last few years, flows recorded by the Whitewater River USGS gage (USGS Station ID: 10259540) have been less than 50,000 AF/year.\(^2\)

The Alamo River originates approximately two miles south of the International Border with Mexico and flows north and into the Salton Sea. The USGS station that records Alamo River inflows into the Salton Sea is located near this point of discharge into the Sea (USGS Station ID: 10254730). The Alamo River is dominated by agricultural return flows from IID. In recent years, this flow has averaged 560,000 AF/year.\(^2\)

The New River also originates in Mexico. It travels through the Mexicali Valley, crosses the International Border, and flows into the Salton Sea. The New River carries urban runoff, industrial and municipal flows, and agricultural runoff from the Mexicali Valley. There are two USGS gages along the New River. One is in the Imperial Valley, near the mouth of the river at the Salton Sea (USGS Station ID: 10255550). The other is at the International Border (USGS Station ID: 10254970). Since 2018, flows at the New River (Imperial Valley) station have been consistently less than 350,000 AF/year.\(^2\) Flows at the New River (International Border) station have remained stable between 60,000 AF/year and 64,000 AF/year in the same time frame.\(^2\)

Other outflows to the Salton Sea include a system of agricultural drains in the Imperial Valley, which discharge surface runoff into the Alamo and New Rivers, and agricultural drains in the Coachella Valley.

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\(^1\) This value is computed by averaging total consumptive use for Imperial Irrigation District (IID) and Coachella Valley Water District (CVWD) for the period of 2015 – 2020. Total consumptive use of (i.e., Colorado River inflows to) IID and CWVD are detailed in the Colorado River Accounting and Water Use Reports.

\(^2\) This estimate is based on the most recent USGS gage flows.
Figure 1. The Colorado River Basin. (SOURCE: U.S. Bureau of Reclamation)
Figure 2. USGS sampling locations for river flows and for Salton Sea elevation. The Whitewater River is also known as the CVSC.

The agricultural drains in the Imperial Valley introduce approximately 830,000 AF/year of surface runoff to the Alamo and New Rivers.\(^3\)

The relationship between these flows, the Salton Sea, and the IID and CVWD watersheds are illustrated in **Figure 3**. Other losses are from IID and CVWD watershed evapotranspiration (ET) and evaporation out of the Salton Sea. Other inflows include precipitation, local watershed, and groundwater inflows into the

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\(^3\) This estimate is provided by California Water Boards ([Salton Sea | Colorado River Basin Regional Water Quality Control Board (ca.gov)](ca.gov)).
Sea. The ungaged flows (italicized in Figure 3) can be estimated by using the reported irrigated acreage and ET rates in the valleys and local weather data that are available for Imperial County, California.

The background information presented in Section 3 is used to quantify the flows in Figure 3 based on historical observations and guidelines for water management in the IID and CVWD watersheds and in the Colorado River Lower Basin.

Figure 3. Flows into and out of the Imperial Irrigation District (IID), the Coachella Valley Water District (CVWD), and the Salton Sea. Flows that are italicized are ungaged but can be estimated.
3 Background Information

Background information sources are divided into observational data sets and management plans/hydrological studies. Observational data sets include historical readings and guidelines for hydrological management and planning in the Lower Basin of the Colorado River, in the Imperial and Coachella Valleys, and in the Salton Sea. Additional studies and plans provide context for developing future hydrological scenarios. Studies about the future management of Colorado River allocations and future climate scenarios for Imperial County, which provide insight into some aspects of the future water budget, are also included.

3.1 Observational Data Sets Relating to Irrigation Water Use

Data related to water use by the agricultural sector include Colorado River water use reports, satellite-based estimates of ET, and inventory and reports compiled by IID and CVWD. These data sources are described in the following sections.


Reclamation provides records of diversions, measured and unmeasured returns, and consumptive use of the Colorado River Lower Basin in a series of annual reports. These values are individually reported for the users of the basin, including IID and CVWD, from 1964 – 2020.

The term “diversions” refers to the routing of water from the Colorado River mainstream, through regulatory structures, to entitled users of the Basin and includes each user’s proportionate share of the total canal losses during diversion. “Measured and unmeasured returns” of such diverted water is subtracted from the diversion number to provide an estimate of the “consumptive use” of such water.4 “Consumptive use,” which diminishes the available supply of water, is defined as the depletion of water for domestic and agricultural beneficial uses, as outlined in the 1922 Colorado River Compact. For this reason, “consumptive use” values estimate the Colorado River inflows into the IID and CVWD water systems. These values were also used to inform future inflow scenarios based on averages over various time periods.

IID and CVWD consumptive use of Colorado River water is provided in Table 1. Data is collected by Reclamation’s Boulder Canyon Operations Office, USGS, the International Boundary and Water Commission, water users, and other agencies. In general, the diversions of Colorado River water include reported diversions from the surface channel of the river and any reported volumes of water pumped by wells.

Table 1. Consumptive use of Colorado River water by the Imperial Irrigation District (IID) and Coachella Valley Water District (CVWD) (units: AF). (SOURCE: Reclamation, 1964 – 2020)

<table>
<thead>
<tr>
<th>CONSUMPTIVE USE</th>
<th>IMPERIAL IRRIGATION DISTRICT (IID)</th>
<th>COACHELLA VALLEY WATER DISTRICT (CVWD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>3,054,188</td>
<td>369,685</td>
</tr>
<tr>
<td>1991</td>
<td>2,898,963</td>
<td>317,563</td>
</tr>
</tbody>
</table>

4 For IID, total consumptive use was computed by summing diversions at Imperial Dam and deliveries from Warren H. Brock Reservoir and then subtracting the measured and unmeasured returns.
<table>
<thead>
<tr>
<th>CONSUMPTIVE USE</th>
<th>IMPERIAL IRRIGATION DISTRICT (IID)</th>
<th>COACHELLA VALLEY WATER DISTRICT (CVWD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>2,572,659</td>
<td>309,367</td>
</tr>
<tr>
<td>1993</td>
<td>2,772,148</td>
<td>318,990</td>
</tr>
<tr>
<td>1994</td>
<td>3,048,076</td>
<td>326,102</td>
</tr>
<tr>
<td>1995</td>
<td>3,070,582</td>
<td>326,697</td>
</tr>
<tr>
<td>1996</td>
<td>3,159,609</td>
<td>331,473</td>
</tr>
<tr>
<td>1997</td>
<td>3,158,486</td>
<td>338,028</td>
</tr>
<tr>
<td>1998</td>
<td>3,101,548</td>
<td>337,466</td>
</tr>
<tr>
<td>1999</td>
<td>3,088,980</td>
<td>333,810</td>
</tr>
<tr>
<td>2000</td>
<td>2,931,251</td>
<td>329,367</td>
</tr>
<tr>
<td>2001</td>
<td>3,089,911</td>
<td>325,096</td>
</tr>
<tr>
<td>2002</td>
<td>3,152,984</td>
<td>331,107</td>
</tr>
<tr>
<td>2003</td>
<td>2,978,223</td>
<td>296,808</td>
</tr>
<tr>
<td>2004</td>
<td>2,743,909</td>
<td>318,616</td>
</tr>
<tr>
<td>2005</td>
<td>2,756,846</td>
<td>304,768</td>
</tr>
<tr>
<td>2006</td>
<td>2,909,680</td>
<td>329,322</td>
</tr>
<tr>
<td>2007</td>
<td>2,872,754</td>
<td>311,971</td>
</tr>
<tr>
<td>2008</td>
<td>2,825,116</td>
<td>299,064</td>
</tr>
<tr>
<td>2009</td>
<td>2,566,713</td>
<td>308,560</td>
</tr>
<tr>
<td>2010</td>
<td>2,545,593</td>
<td>306,141</td>
</tr>
<tr>
<td>2011</td>
<td>2,915,784</td>
<td>309,348</td>
</tr>
<tr>
<td>2012</td>
<td>2,903,216</td>
<td>329,576</td>
</tr>
<tr>
<td>2013</td>
<td>2,554,854</td>
<td>331,137</td>
</tr>
<tr>
<td>2014</td>
<td>2,533,414</td>
<td>349,372</td>
</tr>
<tr>
<td>2015</td>
<td>2,480,933</td>
<td>342,068</td>
</tr>
<tr>
<td>2016</td>
<td>2,504,258</td>
<td>356,358</td>
</tr>
<tr>
<td>2017</td>
<td>2,548,171</td>
<td>335,321</td>
</tr>
<tr>
<td>2018</td>
<td>2,625,422</td>
<td>338,035</td>
</tr>
<tr>
<td>2019</td>
<td>2,335,136</td>
<td>343,971</td>
</tr>
</tbody>
</table>

In general, IID’s consumptive use of Colorado River water was largely steady at an average of 3,003,800 AF/year from 1991 to 2002 but has since been decreasing. The last time inflows exceeded 3,000,000 AF/year was in 2002, after which the implementation of water transfers via the Quantification Settlement Agreement (QSA) (discussed below) have decreased agricultural consumptive use over time.

CVWD’s consumptive use of Colorado River water has increased most noticeably from less than 300,000 AF/year in 2008 to 350,618 AF in 2020. Before 2008, consumptive use was relatively stable at an average of 306,600 AF/year (average excludes 1990).
3.1.2  

**Estimates of Evapotranspiration and Evaporation Along the Lower Colorado River.**


Reclamation uses satellite and aerial imagery and field-based inspections to map irrigated agricultural fields, riparian vegetation, and open water in the Lower Colorado River Basin to estimate ET and evaporation rates (Figure 4). This is done by classifying various crop types, estimating total acres of each type, and computing ET coefficients, which can be used to estimate total ET from each crop within the area in AF/year. Total acres of open water are also estimated, and a separate evaporation coefficient is computed. From 1995 – 2014, these evaporation and ET estimates have been recomputed every year with change detection analyses of the satellite and aerial imagery. Since 2004, the study area has been expanded to include IID and CVWD. In 2014, 173,273 AF of ET was attributed to irrigated agriculture and 5,760 AF of evaporation was attributed to open water in CVWD. In the same year, 1,515,621 AF of ET was attributed to irrigated agriculture and 12,939 AF of evaporation was attributed to open water in IID. Both IID and CVWD are considered devoid of riparian vegetation.

As part of this estimation effort, Reclamation develops area-specific reference ET rates for the Imperial and Coachella Valleys and for other areas served by the Lower Colorado River. These reference ET and average precipitation rates are provided in Table 2.

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**Table 2. Reference ET and average precipitation rates used to estimate ET in the Imperial/Coachella Valleys (units: inches). (SOURCE: Reclamation, 1995 – 2014)**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>REFERENCE EVAPOTRANSPIRATION</th>
<th>AVERAGE PRECIPITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>72.85</td>
<td>3.97</td>
</tr>
<tr>
<td>2005</td>
<td>73.31</td>
<td>4.15</td>
</tr>
<tr>
<td>2006</td>
<td>77.84</td>
<td>0.38</td>
</tr>
<tr>
<td>2007</td>
<td>71.04</td>
<td>1.26</td>
</tr>
<tr>
<td>2008</td>
<td>68.63</td>
<td>1.74</td>
</tr>
<tr>
<td>2009</td>
<td>70.69</td>
<td>0.78</td>
</tr>
<tr>
<td>2010</td>
<td>71.40</td>
<td>3.45</td>
</tr>
<tr>
<td>2011</td>
<td>73.09</td>
<td>3.73</td>
</tr>
<tr>
<td>2012</td>
<td>72.60</td>
<td>2.30</td>
</tr>
<tr>
<td>2013</td>
<td>69.60</td>
<td>2.80</td>
</tr>
<tr>
<td>2014</td>
<td>72.10</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Large fluctuations in average precipitation have been observed over the years from over 4 inches/year to less than 1 inch/year. Reference ET values were the greatest in 2006. Consequently, estimated agricultural ET in IID and in CVWD was greatest in 2006 (Table 3).

Table 3. Annual agricultural ET and open water evaporation estimated for the Imperial Irrigation District (IID) and the Coachella Valley Water District (CVWD) (units: AF). (SOURCE: Reclamation, 1995 – 2014)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>IMPERIAL IRRIGATION DISTRICT (IID)</th>
<th>COACHELLA VALLEY WATER DISTRICT (CVWD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AGRICULTURAL EVAPOTRANSPIRATION</td>
<td>OPEN WATER EVAPORATION</td>
</tr>
<tr>
<td></td>
<td>AGRICULTURAL EVAPOTRANSPIRATION</td>
<td>OPEN WATER EVAPORATION</td>
</tr>
<tr>
<td>2004</td>
<td>1,711,737</td>
<td>1,690</td>
</tr>
<tr>
<td>2005</td>
<td>1,707,998</td>
<td>6,080</td>
</tr>
<tr>
<td>2006</td>
<td>1,889,373</td>
<td>6,916</td>
</tr>
<tr>
<td>2007</td>
<td>1,730,300</td>
<td>9,168</td>
</tr>
<tr>
<td>2008</td>
<td>1,563,637 (+ 1,454)</td>
<td>11,199</td>
</tr>
<tr>
<td>2009</td>
<td>1,514,046</td>
<td>10,415</td>
</tr>
<tr>
<td>2010</td>
<td>1,448,441</td>
<td>14,057</td>
</tr>
<tr>
<td>2011</td>
<td>1,528,247</td>
<td>13,302</td>
</tr>
<tr>
<td>2012</td>
<td>1,618,502</td>
<td>13,179</td>
</tr>
<tr>
<td>2013</td>
<td>1,468,642</td>
<td>12,761</td>
</tr>
<tr>
<td>2014</td>
<td>1,515,621</td>
<td>12,939</td>
</tr>
</tbody>
</table>

In 2008, riparian vegetation growth was observed in the Colorado River floodplain within IID (noted in parentheses). On average, open water evaporation increased greatly in IID from around 6,000 AF/year in 2005 to nearly 13,000 AF/year in 2014. On the other hand, agricultural ET consistently fluctuated around an average of 1,610,000 AF/year.

Open water evaporation at CVWD drastically decreased in 2009, likely due to the completion of the All-American Canal lining project. The lining prevents seepage and flooding which otherwise inflate estimates of evaporation from the canal. From 2004 – 2008, agricultural ET in CVWD averaged over 212,000 AF/year. From 2009 – 2014, agricultural ET in CVWD fluctuated around 161,000 AF/year.


IID maintains an annual inventory of areas receiving water. This dataset was used to corroborate Reclamation’s estimates of ET described above. The archived data spans 2002 – 2021. This data includes annual crop surveys (including garden, field, and permanent crops), accounting of farms and their acreages, and a summary of the total area served. Within these annual inventories, the reported “Net Area Irrigated” was used to estimate the rate of ET at IID. Total ET from agriculture and evaporation from open water was reported in AF/year.

In general, the recorded net irrigated acreage fluctuated between 405,000 and 453,500 acres over the last two decades with a net decrease over the first five years (Table 4). “Net Area Irrigated” includes areas

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5 According to IID’s website at https://www.iid.com/water/library/all-american-canal-lining-project
with one or many crops (including field, garden, and permanent crops), and areas being reclaimed by leaching.

Table 4. Net area irrigable in the Imperial Irrigation District (IID) from 2002 – 2021 (units: acres).
(SOURCE: IID, 2002 – 2021)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>IMPERIAL IRRIGATION DISTRICT (IID) NET AREA IRRIGATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>453,409</td>
</tr>
<tr>
<td>2003</td>
<td>450,571</td>
</tr>
<tr>
<td>2004</td>
<td>435,866</td>
</tr>
<tr>
<td>2005</td>
<td>433,321</td>
</tr>
<tr>
<td>2006</td>
<td>426,244</td>
</tr>
<tr>
<td>2007</td>
<td>423,617</td>
</tr>
<tr>
<td>2008</td>
<td>429,717</td>
</tr>
<tr>
<td>2009</td>
<td>432,158</td>
</tr>
<tr>
<td>2010</td>
<td>431,823</td>
</tr>
<tr>
<td>2011</td>
<td>440,650</td>
</tr>
<tr>
<td>2012</td>
<td>432,555</td>
</tr>
<tr>
<td>2013</td>
<td>411,195</td>
</tr>
<tr>
<td>2014</td>
<td>405,246</td>
</tr>
<tr>
<td>2015</td>
<td>426,607</td>
</tr>
<tr>
<td>2016</td>
<td>432,797</td>
</tr>
<tr>
<td>2017</td>
<td>425,006</td>
</tr>
<tr>
<td>2018</td>
<td>444,098</td>
</tr>
<tr>
<td>2019</td>
<td>443,226</td>
</tr>
<tr>
<td>2020</td>
<td>446,049</td>
</tr>
<tr>
<td>2021</td>
<td>446,670</td>
</tr>
</tbody>
</table>


From 2013 – 2019, CVWD summarized crop types, acreage, irrigation methods, and estimated gross value of agricultural production within CVWD. Within these annual reports, reported “Irrigable Acres” was used to estimate the rate of ET at CVWD. Total ET from agriculture and evaporation from open water was reported in AF/year. This dataset was used to corroborate Reclamation’s estimates of ET described above.

In general, the recorded number of acres of irrigated lands was consistently between 75,000 and 77,200 acres across the years (Table 5). “Irrigable Acres” is the sum of commercial acres, non-commercial acres, acres irrigated but not harvested, and acres not irrigated that were fallow and idle.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>COACHELLA VALLEY WATER DISTRICT (CVWD) IRRIGABLE ACRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>75,144</td>
</tr>
<tr>
<td>2014</td>
<td>76,354</td>
</tr>
<tr>
<td>2015</td>
<td>76,465</td>
</tr>
<tr>
<td>2016</td>
<td>76,411</td>
</tr>
<tr>
<td>2017</td>
<td>77,101</td>
</tr>
<tr>
<td>2018</td>
<td>76,364</td>
</tr>
<tr>
<td>2019</td>
<td>77,103</td>
</tr>
</tbody>
</table>

3.2 Management Plans and Hydrological Studies

Management plans and forecasts of the Colorado River water supply and demand are provided in several data sources and reports described in the following sections.


The Colorado River Basin Water Supply and Demand Study was conducted by Reclamation’s Upper and Lower Colorado regions and other agencies. The study defined current and future imbalances in water supply and demand in the Basin and in the adjacent areas of the Basin states, which will receive Colorado River water over the next 50 years (i.e., through 2060). The study was motivated by the worst 11-year drought in the 20th century, which required tapping into the Colorado River system’s 60 million AF stores to meet the Lower Basin states’ requested deliveries. Additionally, periodic shortages in the Upper Basin introduced variability that required a reassessment of future supply of and demand for water from the over-allocated Colorado River system. The study also provided a technical foundation for understanding the likelihood of increased demand for water and projections of reduced supply due to climate change.

Four scenarios for future water supply and six scenarios for future water demand were developed in this study. Water supply scenarios were assumed to fall under four categories:

1. Observed resampled: Future hydrologic trends and variability were assumed to be similar to the past 100 years of observations.
2. Paleo resampled: Future hydrologic trends and variability were assumed to be similar to the past 1,250 years, so reconstruction of streamflow over this longer period was used to account for enhanced variability.
3. Paleo conditioned: Future hydrologic trends and variability were represented by a blend of wet-dry states of the past 1,250 years but with magnitudes that were more similar to the last 100 years of observations. This scenario provided greater weight to the most recent period within the expanded, paleo-scaled variability.
4. Downscaled global climate models (GCMs) projected: Future climate was predicted to warm, and regional precipitation and temperature trends were represented by an ensemble of 112 GCMs with projected outputs downscaled to the Colorado River Basin study area. In general, this would result in a trend towards drying with increased ET and decreased snowpack, which would
culminate in a 9% decrease in mean natural flow and a 50% increase in droughts lasting longer than 5 years over the total simulation period of 50 years.

Prior to this study, Reclamation used a single projection of future demands in Colorado River Basin planning studies. This supply and demand study implemented scenario planning with information and data provided by the Basin states, tribes, federal agencies, and other users. Scenarios were described by demographic and economic storylines and were denoted as:

2. Slow growth (B): where population growth slows with an emphasis on economic efficiency.
3. Rapid growth (C1 and C2): where there is an economic resurgence in population and energy, and current preferences towards environmental conservation values are preserved.
4. Enhanced environment (D1 and D2): where the economy grows but with expanded environmental awareness and stewardship.

These scenarios were then quantified by associated changes in agricultural, municipal, and industrial; energy; fish and wildlife; and tribal demand for total Colorado River water, which could then be divided by states and study areas. California’s demand for Colorado River water, for example, was projected to grow by about 0.2 - 0.35 million AF/year, primarily due to population growth.\(^6\) The resultant changes in Lake Mead pool elevation due to specific supply and demand scenario combinations are presented in Figure 5.


The 2007 Interim Guidelines were a collaborative approach to establishing Colorado River operations during drought and low reservoir conditions. They provided a degree of certainty to the volume of future annual water deliveries to the Lower Basin water users until 2026. Four key components of the guidelines include:

1. An intentionally created surplus (ICS) mechanism for shortage and delivery of conserved water in Lake Mead, which provides credits for the delivery of conserved system water, thereby promoting water conservation in the Lower Basin.
2. Modification and extension of elements in the 2001 Interim Surplus Guidelines, including a determination of conditions under which surplus water is available for use by Lower Basin states and an elimination of liberal surplus conditions to ensure that more water is stored in reservoirs in preparation for longer drought periods.

\(^6\) The reduction in fish and wildlife demand for Colorado River water in the Lower Basin is noted to be caused by the cessation of mitigation water provided to the Salton Sea, in accordance with the Colorado River Water Delivery Agreement which was approved in 2003. There is also projected to be a small reduction in demand for Colorado River water for agriculture in California across scenarios, as suggested by the California Department of Water Resources 20 x 2020 Water Conservation Plan. Additionally, almost all of the growth in water demand for energy in the Lower Basin occurs in California due to the projected expansion of geothermal and solar projects.
Figure 5. 10th, 50th, 90th percentiles for Lake Mead pool elevation by demand and supply scenario combinations. Scenarios assume that the 2007 Interim Guidelines for Lower Basin Shortage (see below) are extended beyond 2026, when they are currently due to expire.⁷ (SOURCE: Reclamation, 2012a)

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⁷ Other operational assumptions, aside from the extension of the 2007 Interim Guidelines past 2026, are explored in the demand and supply study; however, the 2007 Interim Guidelines (see below for more details) are the operational guidelines that are currently in practice.
3. Coordinated operations of Lake Powell and Lake Mead, to minimize overall shortages in the Lower Basin and to reduce the risk of water-use curtailments in the Upper Basin by re-balancing reservoir supplies.

4. A shortage strategy for Lake Mead, wherein Lake Mead elevations on January 1 of each year determine how much water deliveries are to be reduced during low reservoir conditions. Curtailments for each of the Lower Basin States are defined individually with Minute 323 separately delineating curtailments for Mexico.

The Lower Basin Drought Contingency Plan (DCP) authorizes additional ICS contributions (i.e., water conservation) by the Lower Basin water users when Lake Mead elevations fall below 1,090 ft above mean sea level (MSL). The DCP introduces formal requirements for California’s allocations, which were otherwise absent from the 2007 Interim Guidelines. The Metropolitan Water District (MWD) is responsible for 85% of California’s DCP contribution (up to 297,500 AF/year). The maximum curtailment to California’s allocations is 350,000 AF/year, which is equivalent to 7.95% of the allocations for the state.

The combined total volumes of curtailments outlined in these documents is presented in Table 6. Total volumes are in units of 1,000 AF (kAF). The highlighted row defines the shortage operating parameters for 2022, given that Lake Mead elevations were between 1,050 and 1,075 ft above MSL on January 1, 2022.

Table 6. Sources of total Colorado River water allocation curtailments to the Lower Basin, including the 2007 Interim Guidelines Shortages, Minute 323 Delivery Reductions, DCP Water Savings Contributions, and Binational Water Scarcity Contingency Plan Savings. Of these, only DCP outlines curtailments for California (units: thousand AF). (SOURCE: Reclamation, 2020)

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8 As stated in IID’s 2021 Colorado River Update: Operating Criteria, Current Hydrology, and 2022 Shortage Determination.
These operational guidelines do not detail formal requirements for IID delivery curtailments under the Lower Basin DCP. However, while IID can utilize its full consumptive use of entitlements of 3.1 million AF, IID is not authorized to take delivery of its Lake Mead ICS (i.e., water conservation credits). 8

On August 16, 2022, Reclamation released the Colorado River Basin August 2022 24-Month Study, which sets the annual operations for Lake Powell and Lake Mead in 2023 in light of critically low reservoir conditions. The August 2022 24-Month Study projects Lake Mead’s Jan. 1, 2023 operating determination elevation to be 1,047.61 feet. 9 This projected elevation reflects a Level 2a Shortage Condition, within the DCP elevation band of 1,045 and 1,050 feet, with required shortage reductions and water savings contribution for the Lower Basin States and Mexico, pursuant to Minute 323, as shown in Table 6.


Reclamation also projects Colorado River Basin system-wide conditions up to five years in the future for determining reservoir operations and planning scenarios. Projections are probabilistic and generated using Colorado River Mid-term Modeling System (CRMMS) implemented in RiverWare, a river modeling platform (Figure 6). The model is maintained and updated continually by Reclamation’s Upper and Lower Colorado regions. Output variables include the volume of water in shortage, reservoir elevations, releases from the dams, energy generation, streamflow, and diversions to and return flows from water users throughout the system. Simulations use a mass balance calculation which accounts for all water entering, stored in, and leaving the system. The model uses a set of rules to inform how water is released and delivered under various hydrologic conditions.

For the 5-year time-period probabilistic projections, CRMMS was initialized using current basin soil moisture and snowpack and was forced with a 1991 to 2020 calibration period time series of precipitation and temperature. The result was a 30-member ensemble of streamflow forecasts which provided more information about risk and uncertainty for operations. The most recent 5-year projections of future Colorado River system conditions were produced in May 2022 with reservoir elevations initialized based on previous end-of-the-month values, historical intervening flows from 1991 to 2020 in the Lower Basin, and reflecting 2007 Interim Guidelines, Lower Basin DCP, and Minute 323 policies (Table 7).

Uncertainties aim to consider variability in future climate scenarios, hydrology, and water demands. Reclamation works with stakeholders and scientists to develop the best modeling practices and to calibrate using the most appropriate assumptions. For projections beyond 2026, when the 2007 Interim Guidelines, the Colorado River Basin DCP, and the Minute 323 to the 1944 Treaty with Mexico expire, models are generated for specific study purposes designed by Reclamation and other agencies.


This document summarizes the Law of the River, a commonly used shorthand to refer to the multiple laws, court decisions, and other documents that govern Colorado River operations. Where possible, each operational guideline within the Law of the River is an individual input for the modeling exercises described above. The combination of this document and the model outputs are referred to as the Annual Operating Plan, which uses projected water conditions on January 1 to establish a baseline for future annual operations.

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8 https://doi.gov/pressreleases/interior-department-announces-actions-protect-colorado-river-system-sets-2023
Figure 6. Projected Lake Mead elevations based on the latest model run from May 2022 using CRMMS. The colored region associated with the model run represents the minimum and maximum of the projected reservoir elevations. Solid lines represent historical elevations (black) and median projected elevations for the May 2022 CRMMS model run (yellow). Dashed and dot-dashed lines represent the 10th and 90th percentiles, respectively. Horizontally labeled conditions are important elevations for operations, including surplus condition (> 1,145 ft above MSL), normal condition (> 1,075 ft above MSL), and Level 1-3 shortage conditions (> 1,050, > 1,025, and < 1,025 ft above MSL, respectively). (SOURCE: Reclamation, 2022a)

Table 7. Results of the most recent CRMMS run (from May 2022), showing the probability of falling below critically low Lake Mead pool elevations in any month in the calendar year. Results are visually depicted in the yellow-colored region of the accompanying figure. (SOURCE: Reclamation, 2022)

<table>
<thead>
<tr>
<th></th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
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<tr>
<td>Lake Mead elevation &lt; 1,020 ft above MSL</td>
<td>0%</td>
<td>40%</td>
<td>50%</td>
<td>47%</td>
<td>50%</td>
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<tr>
<td>Lake Mead elevation &lt; 1,000 ft above MSL</td>
<td>0%</td>
<td>0%</td>
<td>13%</td>
<td>20%</td>
<td>20%</td>
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<td>Lake Mead elevation &lt; 950 ft above MSL</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>Lake Mead elevation &lt; 900 ft above MSL</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

In December 2021, the *Annual Operating Plan* for calendar year 2022 was drafted. It indicated that Lake Mead elevation was 1,067.68 ft above MSL on October 1, 2021, with 9,020,000 AF in storage (i.e., the reservoir was at 35% capacity). Under the most probable inflow scenario, Lake Mead was projected to end water year 2022 at elevation 1,051.90 ft above MSL. Lake Mead was projected to decline to elevation 1,050.42 feet with 7.71 million acre-feet (MAF) in storage (30 percent of capacity) at the end of 2022. Flows arriving at Imperial Dam for 2022 were projected to be 5,300,000 AF. Diversions from Imperial Dam provide water to IID and CVWD, among other regions.

3.2.6 **Water & Quantification Settlement Agreement Implementation Annual Report.** Imperial Irrigation District. 2020.

Prior to 2002, California had been using approximately 5.2 million AF/year of Colorado River water. Under the QSA, an agreement between several California water districts and the Department of the Interior, California agreed to reduce its use to 4.4 million AF/year under the *Law of the River*. This was achieved through conservation efforts (e.g., lining the All-American Canal to reduce seepage and increase usable supplies) and providing for several large-scale long-term agriculture-to-urban water transfers. As specified in the QSA, IID will transfer nearly 415,000 AF annually over a 35-year or longer period. The QSA also committed the state of California to a path for the ecological restoration of the Salton Sea. QSA transfers from IID to San Diego, Los Angeles, and Coachella Valley began in 2003. Since the signing of the QSA, approximately 777,000 AF of conserved water has also been used to mitigate salinity at the Salton Sea, and over 159,000 AF of ICS has been generated, often by fallowing (*Figure 7*).

For IID, ICS is surplus water created through extraordinary conservation, including but not limited to the lining of canals or land fallowing. ICS water is available for use under the terms and conditions of water delivery agreements under the 2007 Interim Guidelines for Lower Basin Shortages and the Coordinated Operations of Lake Powell and Lake Mead. Under the current guidelines, the total amount of ICS that IID may store in any year is limited to a 25,000 AF annual cap and a cumulative 50,000 AF total.

An annual water accounting summary from the *Water & QSA Implementation Annual Report* (IID, 2020) tabulates the sources of water conservation (fallowing and efficiency) in addition to transfer obligations of the counties participating in the QSA, including San Diego County Water Authority (SDCWA) and CVWD (
For the Salton Sea, the effects of the QSA transfers include an increasing rate of water elevation decline. Improved efficiency of irrigation has reduced rates of agricultural runoff that feed into the Sea and help maintain its size and water levels. Shrinking of the Salton Sea has negative impacts on public health as the exposed lakebed worsens dust-driven air pollution. Since 2018, total deliveries to the Salton Sea have been negligible as the transferring parties (SDCWA and CVWD) are no longer required to provide inflows to mitigate the reduced agricultural runoff into the Salton Sea.

**Figure 7.** Imperial Irrigation District’s (IID’s) QSA transfer schedule showing sources of water conservation and ICS generation from 2003 – 2026. (SOURCE: IID, 2020)
Table 8. San Diego County Water Authority (SDCWA) and Coachella Valley Water District (CVWD) water conservation obligation and achievements (via fallowing and efficiency), and total delivery of water to the Salton Sea under QSA from implementation in 2003 to present (2020) and future obligations (units: AF). (SOURCE: IID, 2020). SDCWA under-obligations are denoted by a downward red triangle and over-obligations are denoted by an upward green triangle.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SDCWA</th>
<th>CVWD</th>
<th>QSA MITIGATION WATER DELIVERED BY IID</th>
</tr>
</thead>
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<tr>
<td></td>
<td>OBLIGATION</td>
<td>FALLowing</td>
<td>EFFICIENCY</td>
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<tr>
<td>2003</td>
<td>10,000 ▼</td>
<td>3,445</td>
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</tr>
<tr>
<td>2047</td>
<td>200,000</td>
<td>103,000</td>
<td>0</td>
</tr>
</tbody>
</table>
4 Previous Modeling of Inflows to the Salton Sea with SALSA2

This section summarizes prior work performed by IID using the Salton Sea Elevation Model version 2 (SALSA2) to characterize inflows to the Salton Sea. This prior work is described because some of the methodologies and inflows became the basis for the inflow terms used for the purposes of the Long-Range Plan (LRP).

4.1 Modeling Set-up

SALSA2, a computer program developed by IID, estimates future changes in Salton Sea elevation. SALSA2 follows certain assumptions regarding projected future inflows to calculate the elevation and salinity of the Salton Sea. The report *Salton Sea Hydrological Modeling and Results* (IID 2018a) describes the model, SALSA2, which simulates the overall water and salt balance for the Salton Sea under prescribed future conditions. SALSA2 is a stochastic simulation model that allows for analysis of uncertainty in the input flow assumptions.

The report *Salton Sea Hydrology Development* (IID 2018b) describes the development of input probability distributions for each of the inflow inputs. Inflows to the Salton Sea were categorized by the following geographical source area contributions: Mexico, Imperial Valley, Coachella Valley, and local watershed. Each of these inflow components, their historical (pre-2015) description, and assumptions for the future no-action condition are summarized in Table 9.

An annual water accounting summary from the *Water & QSA Implementation Annual Report* (IID, 2020) tabulates the sources of water conservation (fallowing and efficiency) in addition to transfer obligations of the counties participating in the QSA, including San Diego County Water Authority (SDCWA) and CVWD.
Table 8).

For the Salton Sea, the effects of the QSA transfers include an increasing rate of water elevation decline. Improved efficiency of irrigation has reduced rates of agricultural runoff that feed into the Sea and help maintain its size and water levels. Shrinking of the Salton Sea has negative impacts on public health as the exposed lakebed worsens dust-driven air pollution. Since 2018, total deliveries to the Salton Sea have been negligible as the transferring parties (SDCWA and CVWD) are no longer required to provide inflows to mitigate the reduced agricultural runoff into the Salton Sea.

4.2 Detailed Inflow Assumptions

The uncertainty in future inflows from Mexico is represented by a triangular probability distribution of future inflow reductions as shown in Figure 8. The probability distribution is described as a percent reduction and ranges from a 0% to a 100% reduction in inflows, with a future reduction in inflows from Mexico of 75% considered the most likely. Under the Future No Action condition, the mean of all traces sampled for Salton Sea inflows from Mexico averaged approximately 48,600 AF/year for the 2016 – 2077 period. The resulting inflow distribution over time is shown in Figure 9.

Table 9. Summary of SALSA2 model inflow assumptions. (SOURCE: IID, 2018a)

<table>
<thead>
<tr>
<th>INFLOW COMPONENT</th>
<th>HISTORICAL DESCRIPTION</th>
<th>FUTURE NO ACTION</th>
</tr>
</thead>
</table>
| MEXICO           | Updated historical measured inflows from Mexico in New and Alamo Rivers (1950 – 2015) adjusted for Colorado River deliveries to Mexico variability. | Initial model conditions plus reduced New River flows for:  
• Mexicali Wastewater Improvements  
• Mexicali Power Plants  
Further reductions based on recent water management trends |
| IMPERIAL VALLEY  | Estimated flows for 1980 – 1999 cropping patterns under 1925 – 1999 climate conditions; IID Salton Sea simulations provided by IID.  
Changes for projects in-place since 2002:  
• QSA  
• IID Water Conservation and Transfer Project  
• Inadvertent Overrun and Payback Policy  
• All-American Canal Lining Project | Initial model conditions plus changes for:  
• QSA  
• IID Water Conservation and Transfer Project  
• Entitlement Enforcement  
• Inadvertent Overrun and Payback Policy  
• All-American Canal Lining Project  
Further reductions based on water management trends, urban growth, and Colorado River drought |
### Appendix B: Hydrology and Climate Change

#### Working Draft

<table>
<thead>
<tr>
<th>INFLOW COMPONENT</th>
<th>HISTORICAL DESCRIPTION</th>
<th>FUTURE NO ACTION</th>
</tr>
</thead>
</table>
| **COACHELLA VALLEY** | Updated historical inflows from Coachella Valley from Whitewater River (Coachella Valley Storm Channel), direct drains, and groundwater; includes Coachella Canal Lining Project. | Initial model conditions plus changes for:  
• IID-CVWD Transfer  
Coachella Valley WMP Update (2012) (uncertainty added to reflect current conditions and CVWD projected conditions) |
| **LOCAL WATERSHED** | Derived surface water and flow estimates from rainfall-runoff regressions and previous studies. | Initial model conditions plus reduced flows from Salt Creek due Coachella Canal Lining Project. |

As a surrogate for the uncertainty associated with the water and land use changes within the Imperial Valley and management of the Colorado River (see Table 9), inflows from the Imperial Valley were reduced as a fraction of the estimated tailwater flows to the Salton Sea. Tailwater, representing the water that drains from the surface of a field during an irrigation event, was selected as a reasonable substitute for the future maximum change in Imperial Valley contributions to the Salton Sea inflow. The probability distribution of possible future reductions in tailwater was described as a percent reduction from 5% to 95% percent. A triangular distribution (Figure 10) was used to reflect the fact that greater reductions in tailwater will generally require more complex methods of water conservation at greater costs and are thus less likely than smaller reductions. Under the Future No Action condition, the mean of all traces sampled for Salton Sea inflows from Imperial Valley was approximately 586,000 AF/year for the 2016–2077 period. The resulting inflow distribution over time is shown in **Figure 11**.

![Figure 8](image-url)  
**Figure 8.** Probability distribution applied to reflect reductions in inflows from Mexico under the Future No Action condition, expressed as a percentage reduction from No Action Alternative-CEQA Conditions inflows. A 75% reduction in inflows from Mexico is considered most likely. (SOURCE: IID, 2018b)
Figure 9. Possible future inflows from Mexico under the Future No Action condition. The dark red region denotes the range of uncertainty captured between the 25th and 75th percentiles. The light red region denotes the range of uncertainty captured between the 5th and 95th percentiles. After 2026, the 50th percentile of future inflows declines to an average below 40,000 AF/year. (SOURCE: IID, 2018b)

Figure 10. Probability distribution to describe the range of uncertainty in future Imperial Valley inflows to the Salton Sea under the Future No Action condition, as expressed by percentage reduction in tailwater. (SOURCE: IID, 2018b)
Figure 11. Possible future inflows from the Imperial Valley under the Future No Action condition. The dark red region denotes the range of uncertainty captured between the 25th and 75th percentiles. The light red region denotes the range of uncertainty captured between the 5th and 95th percentiles. After 2035, the 50th percentile of future inflows plateaus to an average just above 500,000 AF/year. After 2048, the 50th percentile of future inflows is projected to increase slightly but stabilize at an average just under 600,000 AF/year. (SOURCE: IID, 2018b)

Agricultural and storm water runoff in the Coachella Valley is conveyed to the Salton Sea in the Whitewater River/Coachella Valley Stormwater Channel (CVSC) and through drains that discharge directly to the Salton Sea. Projected future flows from the Coachella Valley to the Salton Sea are consistent with those included in the CVWD’s Water Management Plan (WMP). Through implementation of the WMP, flows from the Coachella Valley to the Salton Sea are projected to increase, although there is uncertainty in the magnitude and timing of these changes. Annual inflows to the Salton Sea from the Coachella Valley are projected to grow from about 56,000 AF in 2015 to over 130,000 AF/year by 2060 without desalination of drain flows (Figure 12). The WMP includes several scenarios of varying quantities of desalinization of drain flows. The range of potential drain flow desalination included in the WMP by 2045 is between 55,000 AF/year and 85,000 AF/year. Under the Future No Action condition, the range of future flows coming from the Coachella Valley has been estimated as the range reflecting minimum and maximum desalination as indicated in the WMP.
Figure 12. Possible future inflows from the Coachella Valley to the Salton Sea under the Future No Action condition. With desalination, flows are projected to peak in 2028. Without desalination, flows are projected to increase continuously but at a slower rate after 2028. (SOURCE: IID, 2018b)

The document Salton Sea Hydrology Development (IID, 2018b) reports that groundwater inflow to the Salton Sea from areas outside of Imperial and Coachella Valleys is estimated to be approximately 10,000 AF/year. The groundwater underflow entering the Salton Sea at the perimeter comes primarily from the alluvium underlying San Felipe Creek. Groundwater inflow from the Imperial and Coachella Valleys is accounted for in the values discussed above under their respective geographical source areas.

4.3 Future Climate Scenarios

The SALSAT2 modeling assessment relies on projected temperature and precipitation changes using median values computed from 112 future climate projections, representing 16 different climate models under three emission scenarios. Figure 13 shows the range of simulated annual average temperature and precipitation derived from the 112 climate projections over the Salton Sea. As shown, annual temperatures are projected to continuously increase throughout the century. Conversely, projections of annual precipitation exhibit greater variability with some projections showing future decreases and some showing future increases.
In SALSA2, the net evaporation rate was adjusted for increasing temperature (approximately 2°C by 2050 and up to 3°C by 2075) and a negligible change in precipitation. The effect on future evaporation was evaluated through an analysis of reference ET rates, temperature, wind, net radiation, and other meteorological data.

4.4 Model Inflow Summary

Figure 14 presents graphical representation of the projected Salton Sea inflows for the Future No Action condition over the period 2015 to 2077.
Figure 14. Projected future total inflows into the Salton Sea under the Future No Action condition. The dark red region denotes the range of uncertainty captured between the 25th and 75th percentiles. The light red region denotes the range of uncertainty captured between the 5th and 95th percentiles. In 2035, the 50th percentile of future inflows is at its minimum but increases slightly. After 2048, the 50th percentile of future inflows is projected to plateau at an average just under 750,000 AF/year. (SOURCE: IID, 2018b)
5 Data and Methodology

This section provides a detailed discussion of the data sources and methodology used to develop the inflow scenarios discussed in Section 6. Discussed below are Colorado River allocation trends and observations, followed by a discussion of how climate change is considered, and an accounting of inflow terms to the Salton Sea. Additionally, outflow terms from the Salton Sea watershed, including ET losses from agriculture and evaporation from the Salton Sea itself are characterized.

5.1 Colorado River Allocations

California is allocated 4.4 million AF of the Colorado River’s total 16.5 million AF of allocations that are made available to the Basin states and to Mexico (Reclamation, 2020). Canals and aqueducts deliver most of California’s allocation to agricultural and urban export areas outside the river basin. Due to the Lower Basin states’ higher consumption and reduced runoff, there exists an imbalance between water supplies and demands. Laws and policies require Upper Basin states to allow an average of 8.25 million AF/year to reach the Lower Basin. However, shortages will trigger usage cuts for Arizona, Nevada, and Mexico. Even though California has senior and relatively more secure water rights, any negotiations in voluntary use-reduction agreements to slow the decline of Lake Mead elevations will ultimately benefit California and minimize mandatory usage cuts (PPIC Water Policy Center, 2018).

Additionally, trading water and carrying over supplies for use in later years can alleviate the cost of expected shortages. However, such practices are stringently governed. Some workarounds include the storage of water, that is to be directed to California and Nevada, in Arizona’s groundwater basins (PPIC Water Policy Center, 2018).

Within California, irrigators have the first right to use 3.85 million AF of the total allocated 4.4 million AF/year. Recent adaptations to reduced Colorado River supplies include regional collaboration and more flexible management, as exemplified by the QSA. The two major changes that have been implemented include the establishment of state funding for lining of canals and the establishment of long-term trades between urban agencies and irrigators. Lining the All-American Canal, for example, reduced seepage and increased usable supplies. Alternatively, trade agreements for over 500,000 AF/year make water available from land fallowing and encourage investment in more efficient irrigation practices. In particular, the acquiring of water for the Metropolitan Water District of Southern California from Palo Verde Irrigation District, the Bard Water District, and IID is one such agreement. SDCWA’s purchase agreement with IID is another. These responses are quantified below.

Figure 15 shows the Colorado River inflows into IID and CVWD as reported over the last two decades by Reclamation in the Colorado River Accounting and Water Use Reports. Also shown is the 1995 – 2002 average inflow, which was historically much higher in Imperial Valley but slightly lower in Coachella Valley than the reported inflows in the latest 2015 – 2020 period. Colorado River allocations for IID have decreased in the last two decades but allocations for CVWD have been steady and have even increased on average in the last seven years.
Figure 15. Annual Colorado River inflows into IID and CVWD from 2000 to 2020. From 1995 – 2002, Colorado River allocations for IID averaged 3.09 million AF. During the same period, Colorado River allocations for CVWD averaged 331,600 AF. (SOURCE: Reclamation, 1964 – 2020)

Sub-annual Colorado River allocations for IID show that allocations are the lowest in December and January and that they increase sharply each month until May through July (Figure 16). In recent years, allocations have fallen below 300,000 AF/month on average from May through July, but historically exceeded 350,000 AF/month. From the summer peak onwards, allocations slowly decrease for the remaining months to a similar minimum in December of around 131,000 AF/month. This overall sub-annual flow has been consistent over the last two decades.

For CVWD, allocations are also lowest in January and peak from May to July as well (Figure 17). Between 2002 and 2016, flows increased most substantially during and directly following peak irrigation in May. Overall, the difference in sub-annual flows is not as pronounced as at IID.
Figure 16. Sub-annual Colorado River inflows (top) and variability (bottom) at IID in 2002, pre-QSA, and in 2020, most recently. Trends show that the peak inflows occur during the summer for both time periods but that the magnitude of these flows has decreased. (SOURCE: Reclamation, 1964 – 2020)
Figure 17. Sub-annual Colorado River inflows (top) and variability (bottom) at CVWD in 2002, pre-QSA, in 2020, most recently, and in 2016, when Colorado River allocations were their highest in the last 20 years. Trends show that the peak inflows occur during the summer for each time period. (SOURCE: Reclamation, 1964 – 2020)
In developing future scenarios, Colorado River allocation curtailments for California can be generalized to extend to IID. Curtailments for California will be introduced when Lake Mead elevation is less than 1,045 ft above MSL on January 1 (see Table 6). The maximum curtailment for California is 350,000 AF or 7.9% of California’s total allocation and is reached when Lake Mead elevations fall below 1,030 ft above MSL on January 1.

As stated in the 2007 Interim Guidelines, there are no formal requirements for IID delivery curtailments under the Lower Basin DCPs. However, future scenarios can be built based on the assumption that curtailments for IID are proportional to curtailments for California, as a percentage of allocation. That is, if California is to be allocated 4.5% less water than the California allocation in any given year, IID will also be allocated 4.5% less water than the IID allocation in that same year. By extension, such future allocations for IID also inform allocations for the management of the Salton Sea.

Stream flow observations provide insight into the changes in the hydrology of the Salton Sea basin. Recent changes include reductions in flows from Mexico, and with long-term QSA water transfer commitments, stream flows are expected to decrease further. To provide a general understanding of the flow contributions in the basin, and to provide a baseline for this work, historical flow from the Alamo and New River Basins, focusing on the last two decades, are summarized in Section 5.3 below.

5.2 Climate Change Effects on Hydrology

Climate change effects on the hydrology of the Salton Sea were examined using three methodologies. The first assessed the climate change effects on the climate and hydrology of Upper Colorado River Basin. The second analyzed the climate change impacts on inflow to the Imperial Valley. The third examined climate change impacts on ET.

5.2.1 Climate Change Effects on Upper Basin Climate and Hydrology

Historical and Future climate and hydrology of Upper Colorado River Basin are discussed in this section to provide background information on historical and future projected natural flows of Colorado River Basin, with an emphasis on the effect from climate variability and climate change. As Upper Colorado River Basin contributes to 92% of basin-wide total natural flow (Lukas and Payton, 2020), the analyses presented in this work focus on the upper basin. Three types of climate hydrology information are discussed: the historical observations; the reconstruction of historical hydrology from tree ring datasets; and the climate model projections of future conditions.

5.2.1.1 Historical Climate and Hydrology

Historical natural flows and temperature and precipitation records were obtained from Bureau of Reclamation (Reclamation, 2022c) and a NOAA database (NOAA, 2022). Specifically, annual natural flows of water years at the Lees Ferry, Arizona for the Colorado River were obtained, whereas the annual temperature and precipitation records of water years were aggregated for Upper Colorado River Basin by NOAA (NOAA, 2022) and were calculated as changes from the means of the first 30-year period (1895–1924) in this section. The time series of annual natural flows, temperature changes, and precipitation changes are presented in Figure 18.
Figure 18. Historical annual natural flows, temperature changes, and precipitation changes of water years for Upper Colorado River Basin.

As presented in Figure 18, although some year-to-year and decadal variability can be observed, natural flow decreases and temperature increases over the periods of records. The natural flow level during the 1906–1930 period, for example, has an average value of around 18 maf/year, whereas the recent 2000–2022 period has an average of around 13 maf/year. Using the 1895–1924 period as a reference period, annual average temperature increased slightly less than 2°C for the upper basin. Long-term precipitation changes are not observable, with the recent precipitation level slightly lower than the 1895–1924 reference period. In addition to the year-to-year variability (as presented in all three time series), some decadal variations can be identified in Figure 18. For example, the temperature level during 1930s exhibit a sudden increase, whereas the natural flows and precipitation during 1930s are generally lower than the previous and subsequent years.

As the increase of temperature and decrease of precipitation resulted in the deduction of natural flows as presented in Figure 18, the effect of annual temperature and precipitation on natural flows were further assessed. The relationships between annual natural flows and temperature (or precipitation) were plotted in Figure 19. Each point in Figure 19 represents the natural flow and temperature (or precipitation) from one water year (same data records presented in Figure 18).
Figure 19. Scatter plots of annual natural flows vs. (left) annual temperature changes and (right) precipitation changes of water years for Upper Colorado River Basin. The blue lines present the linear regression lines with the slopes (values inside parentheses: 95% confidence intervals) and R squared values presented at the top left of the graphs.

As suggested in right graph of Figure 19, annual natural flows are largely affected by annual precipitation. The annual natural flows and precipitation are consistent with dry and wet years (as also indicated by the time series plots of Figure 18), i.e., for a high-precipitation water year, the natural flow is likely high for the upper basin and a lower precipitation value generally corresponds to a year with a lower natural flow. Additionally, the slope of the linear regression line suggests that 1% of increase of precipitation in average leads to an additional 0.206 maf of natural flow.

The temperature effect on natural flows exhibits greater noise, while a greater temperature value generally corresponds to a deduction of natural flows. As suggested by the R squared values, temperature effect on natural flows is subject to greater uncertainty compared to the precipitation effect. The annual natural flows are negatively correlated with annual temperature, with 1 °C increase of temperature corresponding to an estimated 2.77 maf decrease of natural flow. Previous studies such as Lukas and Payton (2020) have suggested a similar negative correlation between temperature and natural flow and a positive correlation between precipitation and natural flow, although the quantitative estimates of the temperature and precipitation effects vary. This deduction of natural flows as a result of temperature increase is critical for understanding and assessing the implication of climate change on water availability of Colorado River Basin.

5.2.1.2 Paleohydrology

Long-term historical natural flows reconstructed from tree ring data are available for Upper Colorado River Basin (Lukas and Payton, 2020), offering important insight on variability of climate and natural flows. The time series of reconstructed natural flow were assessed in this section.

The reconstructed water year natural flow series completed in 2017 by Meko et al. (2017) were obtained and assessed in this work (several other reconstructed series in earlier studies are also available). The reconstructed natural flow series consists of one with a shorter period but will a higher accuracy and one series with the longest period of reconstruction (Meko et al., 2017).
A comparison of natural flows from historical observed natural flows and the two reconstructed time series is presented in Figure 20.

![Figure 20](image_url)

**Figure 20.** Moving 20-year averages of historical observed and reconstructed water year natural flows for Upper Colorado River Basin.

As presented in Figure 20, the two reconstructed series are generally comparable to historical records of natural flows and notably, low natural flow levels (similar to the recent 20-year level) can be found in the reconstructed series during historical periods. For example, the natural flows during 1460s and 1600s (note that the 20-year moving averages were calculated and were assigned to the last years) from the most skillful reconstructed series are generally below 12 maf/year, lower than the average of recent 20 years. Such results suggest that the large variability of natural flows in the upper basin. Together with future climate change effects, the natural flows can be lower than the flow level of the recent 20 years given with this large variability of natural flows.

### 5.2.1.3 Climate Model Projected Future Climate and Hydrology

Water supply for Colorado River Basin will experience further challenges from climate change and it is therefore crucial to assess how future climate change conditions can affect regional water supply and in this case, the annual natural flows in the upper basin. As presented previously, the annual natural flows are correlated to both temperature and precipitation changes, and consequently future climate change (such as increase of temperature and reduction of precipitation) can result in deduction of natural flows and subsequently stresses the already challenging regional water supply.

GCMs serve as an important tool to provide projections of future climate conditions and were subsequently used in this section to assess the projected future changes in Upper Colorado River Basin. Bureau of Reclamation, for example, has conducted a comprehensive study in 2012 (Reclamation, 2012a) on the water supply and demand of Colorado River Basin including the use of GCM projections from the Coupled Model Intercomparison Project phase 3 (CMIP3). Progress has been made to improve the GCMs, with the release of CMIP phase 5 (CMIP5; Taylor et al., 2012) and CMIP phase 6 (CMIP6; Eyring et al., 2016) results. Comparisons of the Upper Colorado River Basin projections from these different CMIP phases were consequently performed in this section to assess the evolution of the future projections from the different CMIP phases and to offer some insight on interpreting the previous results such as from Reclamation, (2012a).
Two similar future scenarios of GCM projections from the three phases were obtained and assessed for the upper basin. Specifically, shared socioeconomic pathways (SSP) 2-4.5 and SSP5-8.5 of CMIP6 (Eyring et al., 2016) were assessed, along with the equivalent representative concentration pathway (RCP) 4.5 and RCP8.5 scenarios (Taylor et al., 2012) from CMIP5 and similar B1 and A2 scenarios from CMIP3 (USGCRP, 2014). Additionally, as GCM projections were provided in relatively coarse resolution, fine-resolution projections from using a same statistical downscaling method (the bias-correction spatial disaggregation method) were obtained and assessed for the results of the three CMIP phases. Downscaled CMIP3 and CMIP5 projections were obtained from LLNL (2022), whereas the CMIP6 projections were obtained from NASA (2022). The obtained downscaled projections were aggregated for the upper basin and were calculated as the temperature and precipitation changes from the historical 1895–1924 average. Note that as the downscaled projections are available starting from 1951 water year, a change factor method was used (Lai et al., 2022), i.e., calculating the future changes from downscaled projections for each year and adding to the 1951–1980 historical observed level.

Comparison results of annual average temperature and total precipitation changes from historical observations and the three CMIP phases for Upper Colorado River Basin are presented in Figure 21.

**Figure 21.** Comparisons of historical observed and GCM-projected (left: from CMIP3; middle: CMIP5; right: CMIP6) annual temperature and precipitation changes from the 1895–1924 average for Upper Colorado River Basin.

As presented in Figure 21, the obtained GCM projections are generally comparable to historical observations during historical period, while some differences among the three CMIP phases are
noticeable including the projected greater increasing trends for both temperature and precipitation in CMIP6.

Further analyses on temperature and precipitation projections were carried out to assess their effects on natural flows. Specifically, the annual temperature and precipitation changes are plotted in scatter plots with x-axes presenting annual temperature changes and y-axes presenting the annual precipitation changes, commonly used in “bottom-up” (Brown et al., 2012) engineering studies. The results are presented in Figure 22, with historical observations and estimated confidence levels from CMIP projections presented as well.

**Figure 22.** The estimated GCM mid-century downscaled projections (left: CMIP3; middle: CMIP5; right: CMIP6) of annual average temperature and precipitation changes from the 1895–1924 average for Upper Colorado River Basin and compared with historical observations. Each colored point represents a one-year result during the 2035–2064 period from one GCM and for one future scenario. The contour lines represent confidence levels and were estimated based on all colored points and are based on the Kernel density estimation.

As presented in Figure 22, the GCM projections from the three phases are generally similar, with the most recent CMIP6 results providing slightly higher temperature and precipitation projections but also greater uncertainty. Additionally, while the CMIP3 results suggest moderately negative correlation between temperature and precipitation changes (e.g., warm and dry years), such a negative correlation is not observable in CMIP5 and CMIP6 results.

Given with the previous estimated temperature and precipitation effects, the results of Figure 22 serve as a basis to assess projected future natural flows. A preliminary approach of utilizing a linear regression model was applied and assessed in this section, i.e., using annual temperature and precipitation changes (such as presented in Figure 22) to predict annual natural flows. This linear regression model was then used to provide results of natural flows with different incremental changes of temperature and precipitation, which were subsequently superimposed to the results of temperature and precipitation projections. The results of the linear regression model and the combination of climate projections and natural flow estimates are presented in Figure 23.
Figure 23. (Left) the performance of the linear regression model for predicting annual natural flows (produced from a 5-fold cross validation) and (right two graphs) the climate projections from CMIP5 and CMIP6 superimposed with natural flow estimates from the linear regression model. Historical observations and GCM projections (including CMIP6 scenarios SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 and equivalent RCP scenarios) of annual temperature and precipitation changes from the 1895–1924 average for Upper Colorado River Basin. GCM projections are presented as contour lines as confidence levels.

As presented in Figure 23, the GCM projections suggest a deduction of natural flows in average, although such projections are subject to great uncertainty. For example, the projected mid-century natural flow in average is 8–12 maf/year, with a possible variation from above 4 maf/year to slight less than 20 maf/year. However, it should be noted that such estimates are preliminary, given with the limitation from the linear regression model (the extrapolations were made in right two graphs of Figure 23 for the ranges of temperature and precipitation changes greater than the available observed ranges) and the uncertainty with respect to the temperature and precipitation effects [the estimated quantitative temperature and precipitation effects on natural flows can be different in previous studies (Lukas and Payton, 2020)].

5.2.2 Climate Change Effects on Inflow

Projections of future IID water delivery were produced using the Colorado River Simulation System (CRSS) model (Reclamation, 2022b). The input of hydrological conditions for the CRSS model, the results of projected Lake Mead elevation, and the results of IID water delivery and corresponding probabilities are discussed below.

The CRSS model was developed and is used by Reclamation to provide long-term projections at the Colorado River Basin (Reclamation, 2012b). The June 2021 version of the CRSS model was obtained from Wheeler et al. (2022) and was provided with the initial conditions in June 2021. Future water demands as the “2016 demands” (2016 Upper Colorado River Commission Schedule for the Upper Division States; and 2007 Final Environmental Impact Statement for the Colorado River Interim Guidelines with the update on Nevada demand in 2019 for the Lower Division States) provided in CRSS June 2021 version (Wheeler et al. 2022) were used. The projections of water delivery and other conditions at the Colorado River Basin were obtained from the CRSS model during the period 2022–2060.
5.2.2.1 Using CMIP3 projections and resampled 2000–2018 hydrology as the CRSS input

Two hydrological conditions were used as the input for the CRSS model: from the global climate model projections of Coupled Model Intercomparison Project Phase 3 (CMIP3; Meehl et al. 2007) and from the resampled 2000–2018 historical hydrology. For the CMIP3 projections, 112 traces of the Colorado River Basin hydrology were available and were produced by Reclamation (2012b) using CMIP3-GCM downscaled projections and the Variable Infiltration Capacity model with different future emission scenarios. Alternatively, the obtained June 2021 version of the CRSS model included the resampled 2000–2018 historical hydrology with 100 traces utilized in Wheeler et al. (2022). The 100 traces of resampled 2000–2018 historical hydrology along with the 112 traces from the CMIP3-projected hydrology were used as the input for the CRSS model and were assessed.

Figure 24 presents the time series of the 112 (CMIP3) and 100 (resampled 2000–2018) traces of annual natural flow from the Upper Basin and their comparisons with the historical period (historical estimates provided by Reclamation, 2022c).

As presented in Figure 24, the CMIP3-projected hydrology generally exhibits a greater range of annual flow conditions across different traces, whereas the resampled 2000–2018 hydrology exhibits drier flow conditions which are consistent with the post-2000 historical flows. Some traces from the CMIP3 hydrology have lower flows than those of the resampled 2000–2018 hydrology, and some CMIP3 traces in some years have substantially greater flow conditions (e.g., more than 25 MAF/year) than historical estimates and the resampled 2000–2018 hydrology. The average flows from both CMIP3 and resampled 2000–2018 hydrology do not exhibit a substantial future trend.
5.2.2.2 Results of Lake Mead elevation

Based on the input of CMIP3 and resampled 2000–2018 hydrology, the future simulations of operation and water delivery were produced from the CRSS model. The results of Lake Mead December elevation are presented in Figure 25 for the two hydrological conditions.

![Exceedance probabilities of Lake Mead December elevation from using the CMIP3-projected (left) and resampled 2000–2018 hydrology (right).](image)

Figure 25. Exceedance probabilities of Lake Mead December elevation from using the CMIP3-projected (left) and resampled 2000–2018 hydrology (right).

Consistent to the input hydrology presented in Figure 24, the results of Figure 25 suggest that the CMIP3-projected Lake Mead elevation exhibit a greater range than the elevation results from using the resampled 2000–2018 hydrology. The elevations from using the resampled 2000–2018 hydrology generally exhibit a lower level than the elevations from using the CMIP3 projections, although some traces from the CMIP3 (i.e., with drier conditions than the resampled 2000–2018 conditions) lead to greater probabilities with low Lake Mead elevations.

5.2.2.3 Results of IID water delivery

The results of annual water delivery to IID were produced from the CRSS model with the 112 (CMIP3) and 100 traces (resampled 2000–2018) and the results are presented in Figure 26.
Figure 26. Exceedance probabilities of IID annual water delivery from using CMIP3-projected hydrology (left) and resampled 2000–2018 hydrology (right).

As presented in Figure 26, the results from using the CMIP3 and resampled 2000–2018 hydrology on average do not result in decreases in IID water delivery. Given a relatively higher exceedance probability (e.g., 90% probability), the resampled 2000–2018 hydrology can have a greater decrease in IID water delivery than the results produced from the CMIP3 hydrology. Consistent with previous results in Figure 24 and Figure 25, traces from the CMIP3 exhibit a greater variation, and some traces can result in substantially lower IID water delivery.

Probabilities and thresholds are summarized in Table 10 and Table 11 for IID water delivery using the CMIP3 and the resampled 2000–2018 hydrology. Because the resampled 2000-2018 hydrology represents more stress on future hydrology of the Salton Sea, the delivery thresholds from this scenario are utilized for future inflow scenarios as further described below.

Table 10. Probabilities of IID water delivery below different thresholds, and delivery thresholds given with different probabilities during the projected 2022–2060 period based on the CMIP3 hydrology.

<table>
<thead>
<tr>
<th>Delivery thresholds (MAF/year)</th>
<th>2.5</th>
<th>2</th>
<th>1.5</th>
<th>1</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probabilities below thresholds</td>
<td>11.0%</td>
<td>5.8%</td>
<td>3.3%</td>
<td>1.7%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Probabilities of delivery below thresholds</td>
<td>50%</td>
<td>25%</td>
<td>10%</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Delivery thresholds (MAF/year)²</td>
<td>2.61</td>
<td>2.61</td>
<td>2.41</td>
<td>1.88</td>
<td>0.64</td>
</tr>
</tbody>
</table>

¹For example, the probability of delivery below 2.0 MAF/year is 5.8%.
²For example, with a threshold of 2.41 MAF/year, the probability of delivery below 2.41 MAF/year is 10%.
5.2.3 Climate Change Effects on ET

Cal-Adapt is a peer-reviewed data tool that presents local, county, or state-level historical meteorological variables and their projected changes under future climate scenarios. In Cal-Adapt, global climate projection methodologies are downscaled to provide a relatively higher resolution of 7 km x 7 km that represent California’s regional variability. Future climates are simulated based on two emission scenarios:

- Representative Concentration Pathway (RCP) 8.5, a high-emissions (business-as-usual) case where greenhouse gas emissions continue to rise during the 21st century, and
- RCP 4.5, a medium-emissions case where greenhouse gas emissions plateau in the mid-21st century.

For most climate variables, projections presented in Cal-Adapt are from three priority global climate models: a warmer/drier simulation (HadGEM2-ES), a cooler/wetter simulation (CNRM-CM5), and an average simulation (CanESM2). Historically, these models have been able to simulate California’s climate well.

For Imperial County, the downscaled projections in temperature until 2100 show that annual average minimum temperatures are likely to increase to 62.2 – 67.5°F, depending on the emissions scenario (Figure 27). Alternatively, annual average maximum temperatures are likely to increase to 92.5 – 98.5°F, depending on the emissions scenario and climate model. Average wind speed is projected to decrease very slightly to 2.78 m/s – 3.12 m/s by the end of the century, depending on the emission scenario and climate model.

The projected temperature and windspeed changes from Cal-Adapt RCP8.5 scenarios were incorporated into Penman-Monteith estimates of ET. For both maximum/minimum temperature and windspeed, the projected change between 1991-2020 and 2035-2064 was added to a set of baseline numbers. For temperature, the baseline numbers were a seasonal pattern (monthly) of maximum/minimum temperature observations from 2004-2021. For wind speed, the baseline number was based on an average of four windspeed stations near the Salton Sea from 2015-2021. The percentage change in the Penman-Monteith estimates for the baseline numbers vs. the baseline numbers plus the climate adjustments were used to estimate changes in ET. The range of temperature and wind speed changes described above correspond to ET increases of 3.56% to 5.02% (}
Table 12).

**Figure 27.** Annual average minimum (top) and maximum (bottom) temperatures projected for Imperial County, CA, under the RCP 4.5 and RCP 8.5 emissions scenarios until 2100. (SOURCE: Cal-Adapt)
Table 12. Penman-Monteith estimates of ET.

<table>
<thead>
<tr>
<th>Trace</th>
<th>Annual average maximum temperature increase (°C)</th>
<th>Annual average minimum temperature increase (°C)</th>
<th>Average wind speed change (m/s)</th>
<th>Estimated % increase in ET (1971-2000 to 2035-2064) via Penman-Monteith Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1.69</td>
<td>1.66</td>
<td>0.987</td>
<td>3.56%</td>
</tr>
<tr>
<td>Average</td>
<td>2.01</td>
<td>1.96</td>
<td>0.988</td>
<td>4.46%</td>
</tr>
<tr>
<td>High</td>
<td>2.20</td>
<td>2.22</td>
<td>0.990</td>
<td>5.02%</td>
</tr>
</tbody>
</table>

5.3 Inflows to the Salton Sea

The inflow categories discussed in this section include inflow from Mexico, inflow from the IID watershed, inflow from the CVWD watershed, groundwater inflow, and inflow from local watersheds not tributary to the IID or CVWD watersheds.

5.3.1 Inflows from Mexico

The New River originates in northern Mexico and terminates at the southern end of the Salton Sea. It receives runoff from agricultural drainage conveyed by a network of surface and subsurface tile drains, wastewater treatment effluent, industrial effluent, and stormwater runoff. The New River watershed is at or below sea level and receives up to 10 inches of precipitation from northern Mexico. Since 2005, IID and USGS have cooperatively measured streamflow data for the river; however, USGS observations are available from 1980 onward.

Inflows from New River International Border have dwindled in the last two decades independently of the QSA implementation timeline. From 1980 to 1990, inflows from Mexico consistently exceeded 150,000 AF/year and sometimes exceeded 250,000 AF/year (Figure 28). However, from 1990 to 2006, flows decreased to an average of 142,000 AF/year and from 2007 onwards, flows have averaged 75,000 AF/year.

Historically, inflows were quite consistently near 20,000 AF/month year-round (Figure 29). In 2000, flows showed a decreasing trend over the course of the year but remained above 10,000 AF/month. By 2010, January through April was a clear peak in the sub-annual time series and inflows quickly tapered down to near 5,000 AF/month thereafter. Between 2010 and 2020, annual flows have continued to decrease. Most recently, peak inflows are measured in March and April, with the baseline flow remaining at approximately 5,000 AF/month.

5.3.2 Inflows from IID Watershed

Major inflows from the IID watershed are recorded at the USGS gages at the mouth of the Alamo and New Rivers in Imperial Valley. At the New River Imperial Valley station, while flows were abnormally low in 1989 – 1992, the future high average inflow years never reached the high flows achieved in 1983 – 1988 (Figure 30 top panel). The decreasing trend has since become more prominent.
Figure 28. Average annual inflows recorded at the New River International Border USGS station from 1980 to 2021. (SOURCE: USGS)

Monthly trends over three time periods (1980 – 2002, 2003 – 2014, and 2015 – 2021, Figure 30 bottom panel) showed similar sub-annual behavior, with monthly peak flows occurring in March – April and a secondary peak in October. This figure illustrates the same decreasing annual flow trend as shown in the top panel.

The Alamo River originates at the south side of the All-American Canal on the eastern boundary of Calexico and terminates at the Salton Sea. Source waters include seepage from the All-American Canal, runoff from the Chocolate Mountains, agricultural drain flows, and stormwater runoff. In general, flows from Alamo River are greater in magnitude than flows from New River and demonstrate less inter-annual variability, as shown in Figure 31 (top panel). The record annual maximum occurred in 2012.

Monthly trends over three time periods (1980–2002, 2003–2014, and 2015–2021) are presented in Figure 31 (bottom panel). As at the New River, monthly flows showed similar sub-annual behavior for the three time periods. Lowest flows were recorded in December – January, monthly flows sharply increased with a peak in April – May during the irrigation season, with a more gradual decrease in flows in the latter half of the year.

Figure 32 shows a different view of sub-annual variability for New River and Alamo River. Taking 2002 as a representative year for the historical sub-annual flows and 2020 as the most recent flows, the figure shows a similar sub-annual pattern throughout the last two decades for both New River and Alamo River. The total volume of these flows is smaller at the New River, which also has less sub-annual variability, as shown by the smaller differential between January and May recorded flows as compared to the Alamo River flows.

In addition to these two gaged flows, there are ungaged inflows into the Salton Sea from the Imperial Valley. IID (2018b) calculated the ungaged inflows into the Salton Sea from the Imperial Valley as equal to approximately 9% of the total volume of the gaged flows.
Figure 29. Sub-annual New River International Boundary inflows in 1985, 2000, 2010, and 2020 (top) and variability in the 2003–2014 and 2015–2021 periods (bottom). Historically, there was no strong sub-annual pattern. Most
recently, inflows dominate in March and April and are near 5,000 AF/month in the remaining months. (SOURCE: USGS)

Figure 31. Average annual inflows (top) and average monthly inflows in the 1980 to 2002, 2003 – 2014, and the 2015 – 2021 periods (bottom) recorded at the Alamo River USGS station from 1980 to 2021. (SOURCE: USGS)
5.3.3 Inflows from CVWD Watershed

The Whitewater River, also referred to as the CVSC, originates in the San Bernardino Mountains and collects stormwater runoff, wastewater flows, and agricultural drainage flows in the Coachella Valley, and terminates at the Salton Sea. The Upper Whitewater River is considered fully appropriated by the State Water Resources Control Board (California Department of Water Resources [DWR] and DFW 2013). The upper reaches convey natural runoff and State Water Project exchange water to agricultural fields and to the Whitewater Spreading Facility for groundwater recharge (CVWD 2002). Lower reaches of the CVSC consist of unlined conveyance of stormwater, agricultural return flows, and wastewater discharge (CVWD 2012).

Inflows from the CVSC show a strong decreasing trend from 1980 to 2010 (Figure 33, top panel). The surface water supply has decreased since historical levels due to increased water use efficiency, drought, and decreased supply reliability. Since 2010, there has been an equally apparent increasing trend. Within the last two decades, flows decreased most significantly from 2008 to 2010 but have since been increasing.

Monthly trends over three time periods (1980 – 2002, 2003 – 2014, and 2015 – 2021) are presented in Figure 33 (bottom panel). During the earliest period (1980 – 2002), the maximum monthly flow peaked in February, but there was no evident pattern for monthly flows in the 2003 – 2014 and 2015 – 2021
periods. Figure 34 shows the sub-annual patterns at the end of the historical period (in 2002), in the year of lowest annual average flows (2010), and most recently (in 2020). Over these years, there was no uniform seasonality of relatively higher or lower flows.

Direct to sea agricultural drains collect subsurface drainage and provide inflow to the Salton Sea. Flows in drains other than the CVSC are measured by CVWD. Figure 35 presents the measured drain flows over the period 2000 – 2021. These drain flows varied from a high of 43,000 AFY in 2013 to a low of 27,000 AFY in 2019.

5.3.4 Local Watershed Inflows

Several smaller creeks flow into the Salton Sea. The San Felipe Creek watershed drains about 1,693 square miles in the southwest Salton Sea watershed. Flows generally consist of desert summer storms and heavy winter storms (IID, 2018b). San Felipe Creek was measured by the USGS (station no. 10255885) from 1961 to 1991, located approximately four miles upstream of the Sea. Average flow to the Salton Sea from 1961 to 1991 was 4,532 AF/year with a minimum of 60 AF in 1973 and a maximum flow of 40,638 AF in 1976. IID (2018b) analyzed rainfall at Brawley and measured flow to develop a relationship between rainfall and runoff. For the period 2000 to 2021, annual flow varied from 2,834 AFY to 15,542 AFY and averaged 3,605 AFY.

Salt Creek is located in the northern portion of the Salton Sea watershed and drains about 269 square miles. The USGS monitors flow at Salt Creek at USGS Gage 10254050 (Salt Creek Near Mecca). From 2000 to 2021, annual flow varied from 295 AFY (2009) to 2,860 AFY (2006) and averaged 840 AFY.

IID (2018b) utilized an area-weighting methodology to estimate runoff from the remaining 330 square miles not flowing to Salt or San Felipe Creeks. However, instead of using the entire 1693 square miles of the San Felipe runoff area, only the lower hydrologic unit of the San Felipe Creek drainage (504 square miles) was assumed to contribute to discharge at the Salton Sea as most of the upper drainage runoff flows to sinks, groundwater recharge, or is consumed by phreatophyte vegetation. Table 13 presents the total inflow to the Sea from the smaller creeks, including San Felipe Creek, Salt Creek, and ungaged areas.

5.3.5 Groundwater Inflows

The SALSA2 modeling performed by IID (IID, 2018b) used a constant annual groundwater inflow from the Imperial Valley of 1,000 AFY, citing IID (2002). Updated groundwater modeling was performed for the Indio Subbasin WMP Update (Indio Subbasin GSAs, 2021). The simulated groundwater flow between the Sea and the groundwater system is presented in Figure 36 below. The net flow, shown as the black line, was to groundwater from the Sea prior to 2015, and after 2015 was from groundwater to the Sea.

The SALSA2 modeling performed by IID used a constant annual groundwater inflow of 10,000 AFY from areas not tributary to the Imperial and Coachella valleys. This value is from Hely et al. (1966), which states that the groundwater underflow entering the Salton Sea at the perimeter comes primarily from the alluvium underlying San Felipe Creek.

Therefore, total groundwater inflow to the Salton Sea was computed by using annual values from the black line, combined with a constant value of 10,000 AFY from San Felipe alluvium and a constant value of 1,000 AFY from Imperial Valley. The total net inflow to the Sea from groundwater varied from 8,500 AFY in 2000 to 12,300 AFY in 2019. Constant values of 12,300 AFY were also assumed in 2020 and 2021.
Figure 33. Average annual inflows (top) and average monthly inflows in the 1980 – 2002, 2003 – 2014, and 2015 – 2021 periods (bottom) recorded at the Whitewater River USGS station from 1980 to 2021. (SOURCE: USGS)
Figure 34. Sub-annual Whitewater River inflows in 2002, 2010, and 2020. There has been no consistent sub-annual pattern observed across the years. Inflows in 2020 have on average exceeded 2002 historical levels. (SOURCE: USGS)

Figure 35. Inflow to the Salton Sea from Coachella Valley agricultural drains other than the CVSC. The period 2000-2016 is calendar year data and the period 2017-2021 is water year data. (SOURCE: CVWD personal communication)
Table 13. Inflows to the Salton Sea from local creeks outside of the Imperial and Coachella Valleys.

<table>
<thead>
<tr>
<th>Year</th>
<th>San Felipe Creek (AFY)</th>
<th>Salt Creek (AFY)</th>
<th>Ungaged Areas (AFY)</th>
<th>Sum of local watershed inflows (AFY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2834</td>
<td>542</td>
<td>1013</td>
<td>4388</td>
</tr>
<tr>
<td>2001</td>
<td>2834</td>
<td>562</td>
<td>1019</td>
<td>4415</td>
</tr>
<tr>
<td>2002</td>
<td>2834</td>
<td>485</td>
<td>996</td>
<td>4315</td>
</tr>
<tr>
<td>2003</td>
<td>2834</td>
<td>631</td>
<td>1039</td>
<td>4504</td>
</tr>
<tr>
<td>2004</td>
<td>7090</td>
<td>898</td>
<td>2396</td>
<td>10384</td>
</tr>
<tr>
<td>2005</td>
<td>2834</td>
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<td>2006</td>
<td>2834</td>
<td>2860</td>
<td>1708</td>
<td>7402</td>
</tr>
<tr>
<td>2007</td>
<td>2835</td>
<td>1216</td>
<td>1215</td>
<td>5267</td>
</tr>
<tr>
<td>2008</td>
<td>2834</td>
<td>570</td>
<td>1021</td>
<td>4425</td>
</tr>
<tr>
<td>2009</td>
<td>2836</td>
<td>295</td>
<td>939</td>
<td>4071</td>
</tr>
<tr>
<td>2010</td>
<td>15542</td>
<td>464</td>
<td>4802</td>
<td>20808</td>
</tr>
<tr>
<td>2011</td>
<td>2834</td>
<td>633</td>
<td>1040</td>
<td>4508</td>
</tr>
<tr>
<td>2012</td>
<td>2834</td>
<td>525</td>
<td>1008</td>
<td>4367</td>
</tr>
<tr>
<td>2013</td>
<td>2834</td>
<td>724</td>
<td>1067</td>
<td>4625</td>
</tr>
<tr>
<td>2014</td>
<td>2834</td>
<td>473</td>
<td>992</td>
<td>4299</td>
</tr>
<tr>
<td>2015</td>
<td>2834</td>
<td>458</td>
<td>987</td>
<td>4279</td>
</tr>
<tr>
<td>2016</td>
<td>2834</td>
<td>570</td>
<td>1021</td>
<td>4425</td>
</tr>
<tr>
<td>2017</td>
<td>2834</td>
<td>804</td>
<td>1091</td>
<td>4729</td>
</tr>
<tr>
<td>2018</td>
<td>2834</td>
<td>818</td>
<td>1096</td>
<td>4748</td>
</tr>
<tr>
<td>2019</td>
<td>2834</td>
<td>985</td>
<td>1146</td>
<td>4964</td>
</tr>
<tr>
<td>2020</td>
<td>2834</td>
<td>956</td>
<td>1137</td>
<td>4927</td>
</tr>
<tr>
<td>2021</td>
<td>2834</td>
<td>789</td>
<td>1087</td>
<td>4710</td>
</tr>
<tr>
<td>AVG 2000-2021</td>
<td>3605</td>
<td>840</td>
<td>1333</td>
<td>5778</td>
</tr>
<tr>
<td>AVG 2015-2021</td>
<td>2834</td>
<td>768</td>
<td>1081</td>
<td>4683</td>
</tr>
</tbody>
</table>
5.3.6 Summary of Recent Historical Inflows Compared to Modeled Inflows

Table 14 provides a summary of recent inflows to the Sea, as discussed in the previous sections. Over the recent period (2015 to 2020), inflow has remained stable. In 2021, total inflow was 40,000 AF higher than the inflow in 2020. SALSA2-predicted inflows are also presented in the table, as summarized in Section 4. Notably, recent inflows (column 8) are consistently higher than the SALSA2-predicted inflows.

5.4 Outflows from the Salton Sea Watershed

Outflows from the Salton Sea watershed discussed in this section include ET from the Imperial Valley and Coachella Valley watersheds and evaporation from the Salton Sea.

5.4.1 Evapotranspiration from Agricultural Land

From 2004 – 2014, evaporation and ET have been estimated computed by Reclamation using satellite and aerial imagery and field-based inspections to map irrigated agricultural fields, riparian vegetation, and open water in the Lower Basin study area that includes IID and CVWD. These Reclamation estimations are reported each year; however, they are only available in the form of a spreadsheet from 2010 to 2014. Thus, the following ET plots are only available for 2010 to 2014.
Table 14. Recent historical inflows, compared to the SALSA2-predicted inflows (units: AF).

<table>
<thead>
<tr>
<th>Year</th>
<th>Imperial Valley Flow Gaged (1)</th>
<th>Imperial Valley Estimated Ungaged (2)</th>
<th>Mexico Flows (3)</th>
<th>CVSC Gaged (4)</th>
<th>Coachella Valley Drain Flow (5)</th>
<th>Local Watershed (6)</th>
<th>Groundwater (7)</th>
<th>Total Inflow to Sea (8)</th>
<th>Mean SALSA2 Inflow, Low Uncertainty</th>
<th>Mean SALSA2 Inflow, Moderate Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>885,643</td>
<td>79,708</td>
<td>75,252</td>
<td>42,980</td>
<td>27,779</td>
<td>4,279</td>
<td>11,000</td>
<td>1,127,000</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2016</td>
<td>902,053</td>
<td>81,185</td>
<td>69,562</td>
<td>46,643</td>
<td>33,325</td>
<td>4,425</td>
<td>11,500</td>
<td>1,149,000</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2017</td>
<td>864,193</td>
<td>77,777</td>
<td>68,548</td>
<td>45,730</td>
<td>31,528</td>
<td>4,729</td>
<td>11,800</td>
<td>1,104,000</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2018</td>
<td>837,531</td>
<td>75,378</td>
<td>60,509</td>
<td>44,971</td>
<td>29,779</td>
<td>4,748</td>
<td>12,200</td>
<td>1,065,000</td>
<td>934,000</td>
<td>907,000</td>
</tr>
<tr>
<td>2019</td>
<td>810,277</td>
<td>72,925</td>
<td>63,926</td>
<td>52,324</td>
<td>27,359</td>
<td>4,964</td>
<td>12,300</td>
<td>1,044,000</td>
<td>917,000</td>
<td>871,000</td>
</tr>
<tr>
<td>2020</td>
<td>817,934</td>
<td>73,614</td>
<td>63,332</td>
<td>51,154</td>
<td>30,350</td>
<td>4,927</td>
<td>12,300</td>
<td>1,054,000</td>
<td>906,000</td>
<td>834,000</td>
</tr>
<tr>
<td>2021</td>
<td>856,862</td>
<td>77,118</td>
<td>61,866</td>
<td>46,548</td>
<td>34,172</td>
<td>4,710</td>
<td>12,300</td>
<td>1,094,000</td>
<td>905,000</td>
<td>808,000</td>
</tr>
<tr>
<td>AVG</td>
<td>853,000</td>
<td>76,800</td>
<td>66,100</td>
<td>47,200</td>
<td>30,600</td>
<td>4,680</td>
<td>11,900</td>
<td>1,090,000</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes:
1. New River near Westmorland (USGS Station ID: 10255550) + Alamo River near Niland (USGS Station ID: 10254730) – New River at International Boundary (USGS Station ID: 10254970); see Section 5.3.2
2. 9% of Column 1; see Section 5.3.2
3. New River at International Boundary (USGS Station ID: 10254970); See Section 5.3.1
4. Whitewater River near Mecca (USGS Station ID: 10259540); See Section 5.3.3
5. Drain flow other than the gaged CVSC. See Section 5.3.3.
6. See Section 5.3.4
7. See Section 5.3.5
8. Sum of columns 1 to 7

5.4.1.1 Imperial Valley Watershed

Figure 37 shows that, over the five-year period of available data, ET from agriculture in IID is consistently lowest in December, increases rapidly to an annual maximum in May, and decreases gradually thereafter. There is no clear increasing or decreasing trend across the five years.

Evaporation from open water sources, as shown in Figure 38, peaks in June instead with more symmetrical rates of increase and decrease throughout the year. Evaporation stays constant from 2011 to 2014 but is substantially lower in 2010. This is due to total acres of open water being recorded as 1,230 in 2010 but averaging over 2,200 acres from 2011 to 2014.
Reported total ET estimates (in AF) are divided by IID’s reported net irrigated area to compute a net ET rate of 3.60 AF/acre of irrigated lands. Since net irrigated land has been relatively stable at around 433,540 acres from 2002 to 2021, ET since 2003 is assumed to average 1,561,000 AF/year.

Figure 37. Sub-annual ET from agriculture in the Imperial Irrigation District (IID) from 2010 – 2014. (SOURCE: Reclamation, 1995 – 2014)

Figure 38. Sub-annual evaporation from open water in the Imperial Irrigation District (IID) from 2010 – 2014. (SOURCE: Reclamation, 1995 – 2014)
5.4.1.2 Coachella Valley Watershed

Figure 39 shows that, over the five-year period of available data, ET from agriculture in CVWD is consistently lowest in December, increases rapidly to an annual maximum in May, and decreases gradually thereafter. There is no clear increasing or decreasing trend across the five years.

Evaporation from open water sources, as shown in Figure 40, peaks in June instead with more symmetrical rates of increase and decrease throughout the year. The monthly trend in evaporation is consistent from 2010 to 2014.

![Figure 39](image-url)

Figure 39. Sub-annual ET from agriculture in the Coachella Valley Water District (CVWD) from 2010 – 2014. (SOURCE: Reclamation, 1995 – 2014)

![Figure 40](image-url)

Figure 40. Sub-annual evaporation from open water in the Coachella Valley Water District (CVWD) from 2010 – 2014. (SOURCE: Reclamation, 1995 – 2014)
Reported total ET estimates (in AF) are divided by CVWD reported net irrigated area to compute a net ET rate of 2.23 AF/acre of irrigated lands. Net irrigated land has been relatively stable between 75,000 and 77,000 acres from 2013 to 2019 (average 76,420 acres). Therefore, ET since 2013 is assumed to average 170,650 AF/year.

Note that the ET rate computed for CVWD agricultural lands are not used in the development of future inflow scenarios, but instead are provided here for completeness.

5.4.1.3 Climate Change Effects on Evapotranspiration

Table 15 presents the percent increase in ET rates presented in
Table 12 applied to the net ET rates determined above for the Imperial Valley, to provide the resulting ET rates for the different climate conditions (low, average, and high traces).

Table 15. Climate change effects on ET in the Imperial Valley

<table>
<thead>
<tr>
<th>Condition</th>
<th>Estimated percent increase in ET</th>
<th>ET, Imperial Valley (AF/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-</td>
<td>3.60</td>
</tr>
<tr>
<td>Low Trace</td>
<td>3.56%</td>
<td>3.73</td>
</tr>
<tr>
<td>Average Trace</td>
<td>4.46%</td>
<td>3.76</td>
</tr>
<tr>
<td>High Trace</td>
<td>5.02%</td>
<td>3.78</td>
</tr>
</tbody>
</table>

5.4.2 Evaporation from the Salton Sea

Evaporation is the most significant outflow component of the Salton Sea water balance. Evaporation studies in the Salton Sea performed by USGS since the early 1960s used water and energy budgets to compute annual evaporative losses. With this method, annual evaporation was computed as the difference between the sum of all inflows, including precipitation, and the storage volume change in the Salton Sea over the year. Inflow sources included those outlined above while storage volume was computed using water surface elevation measurements and Salton Sea bathymetry. Based on this method, total annual evaporation from the Salton Sea was estimated to be 1.3 million AF/year in the historical period.

While recent inflows (2015–2021) have remained relatively stable, they are nonetheless much lower than the rate of evaporative loss from the surface of the Sea. For this reason, the Sea continues to decline in elevation.
6 Future Water Inflow Scenarios and Assumptions

To inform long-term management of the Salton Sea, different future water management scenarios have been created to account for short-term drought reductions and long-term impacts from climate and policy changes.

6.1 Short-term Drought Reductions (2023 - 2026)

On October 5, 2022, California users of Colorado River water released a statement proposing to conserve 400,000 AF of water each year from 2023 to 2026 to contribute towards stabilizing elevations in Lake Mead. IID pledged to cut 250,000 AFY, an amount contingent on federal funding and voluntary participation of water users. Other California users of Colorado River Water that signed the statement were the Metropolitan Water District, CVWD, and the Palo Verde Irrigation District.

6.2 Inflow Scenarios Considered for the Long-Range Plan

The data and methodologies presented in Section 5 were used to prepare a summary of inflow scenarios considered for use in the LRP, as presented in Table 16. Scenario 1 (Continued Baseline) is the average of the inflows over the recent period (2015-2021), as derived in Section 5.3. The total inflow is the same as presented in Table 14, and is repeated here for comparison. Scenarios 2, 3, and 4 are developed using the frequency modeling and climate change assumptions presented in Section 5.2. Scenarios 5 and 6, derived from SALSA2 modeling performed by IID and previously described in Section 4, are presented here for comparison. Each scenario is discussed in more detail below.

Table 16. Summary of inflow scenarios to the Salton Sea (units: AFY).

<table>
<thead>
<tr>
<th>Number</th>
<th>Summary</th>
<th>Imperial Valley Flow Gaged</th>
<th>Imperial Valley Estimated Ungaged</th>
<th>Mexico Flows</th>
<th>Coachella Valley Gaged</th>
<th>Coachella Valley Drain Flow</th>
<th>Local Watershed</th>
<th>Ground-water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>Continued Baseline</td>
<td>853,000</td>
<td>76,800</td>
<td>66,100</td>
<td>47,200</td>
<td>30,600</td>
<td>4,680</td>
<td>11,900</td>
<td>1,090,000</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>High Probability Inflow Scenario</td>
<td>852,900</td>
<td>0</td>
<td>70,000</td>
<td>4,680</td>
<td>11,900</td>
<td>889,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Low Probability Inflow Scenario</td>
<td>647,900</td>
<td>0</td>
<td>70,000</td>
<td>4,680</td>
<td>11,900</td>
<td>684,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 4</td>
<td>Very Low Probability Inflow Scenario</td>
<td>407,900</td>
<td>0</td>
<td>70,000</td>
<td>4,680</td>
<td>11,900</td>
<td>444,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 5</td>
<td>IID Low Uncertainty (2025-2077 average)</td>
<td>694,000</td>
<td>48,640</td>
<td>72,870</td>
<td>29,150</td>
<td>10,000</td>
<td>10,000</td>
<td>864,700</td>
<td></td>
</tr>
</tbody>
</table>

10 http://crb.ca.gov/2022/10/california-water-agencies-pledge-to-conserve-additional-water-to-stabilize-the-colorado-river-basin/
11 https://calmatters.org/environment/2022/10/california-colorado-river-water/
### Scenario 1: Continued Baseline

Under this scenario, net inflows and outflows are assumed to remain similar to the most recent period represented by 2015 – 2021. That is, inflows from the Salton Sea are dominated by Imperial Valley contributions via the New and Alamo River. An additional 9% of these flows was added to represent ungaged flows. Coachella Valley inflows were gaged at the USGS Whitewater River gage. Coachella Valley drain flow, as measured by CVWD, was averaged over 2015 – 2021. Local watershed flow was discussed in Section 5.3.4 and was averaged over 2015 – 2021. Groundwater inflow was discussed in Section 5.3.5 and contributes 11,900 AF/year. The inflows for Scenario 1 are itemized below.

<table>
<thead>
<tr>
<th>INFLOW TERM</th>
<th>VALUE (AF/year)</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Valley gaged</td>
<td>853,000</td>
<td>2015-2021 AVG New River (USGS 10255550) plus Alamo River (USGS 10254730) minus Mexico flows (USGS 10254970)</td>
</tr>
<tr>
<td>Imperial Valley ungaged</td>
<td>76,800</td>
<td>9% of gaged flow (see Section 5.3.2)</td>
</tr>
<tr>
<td>Mexico</td>
<td>66,100</td>
<td>2015-2021 AVG New River Int’l Border (USGS 10254970)</td>
</tr>
<tr>
<td>Coachella Valley gaged</td>
<td>47,200</td>
<td>2015-2021 AVG Whitewater River (USGS 10259540)</td>
</tr>
<tr>
<td>Coachella Valley drain</td>
<td>30,600</td>
<td>Refers to drain flow other than the CVSC, see Section 5.3.3; average 2105-2021 from Table 14</td>
</tr>
<tr>
<td>Local watershed</td>
<td>4,680</td>
<td>See Section 5.3.4; average 2015-2021 from Table 14</td>
</tr>
<tr>
<td>Groundwater</td>
<td>11,900</td>
<td>See Section 5.3.5; average 2015-2021 from Table 14</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,090,000 AF/year</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Scenario 2: High Probability Inflow

For the high probability inflow scenario, water deliveries to Imperial Valley were based on the CRSS model and resampling hydrology from 2000-2018 (information from Wheeler et al. 2022), as described in Section 5.2.1. For the high probability inflow scenario, the 50th percentile flow (2.535 MAF) is assumed (Table 11). In other words, the model predicts that 2.535 MAF of inflow to Imperial Valley will be exceeded 50 percent of the time. This represents full delivery of water to Imperial Valley.
Based on climate change effects discussed in Section 5.2.2, ET is expected to increase by 3.5 to 5.0% by the end of the century based on application of the Penman Monteith Method (see
Table 12). As a conservative estimate for the future inflow scenarios, an increase of 5% is assumed. Therefore, the climate-adjusted ET rate is 3.78 AF/acre of irrigated land (or 5.0% increase from the current estimate of 3.60 AF/acre, see Table 15). The volume of water lost assumes an acreage value of 445,011 acres, which is the average over 2018 to 2021 for the Imperial Valley.

In the Coachella Valley, the Indio Subbasin Water Management Plan Update (Indio Subbasin GSAs, 2021) was utilized as the source for future inflow to the Sea (Figure 41). The scenario representing future projects with climate change was selected as the most appropriate scenario with 70,000 AFY as the flow representing future conditions at the Sea. This represents the total inflow to the Sea from the Coachella Valley, including the gaged CVSC.

![Figure 41](image-url)

**Figure 41.** Simulated Drain Flow for Future Scenarios, Representing Total Inflow to the Salton Sea from the Coachella Valley. (SOURCE: Indio Subbasin GSAs, 2021)
For Scenario 2, the local watershed and groundwater terms remain the same as the baseline values. The inflows for Scenario 2 are itemized below.

<table>
<thead>
<tr>
<th>INFLOW TERM</th>
<th>VALUE (AF/year)</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Valley</td>
<td>852,900</td>
<td>Inflow to Imperial Valley (2,535,000 AFY) minus ET at 3.78 AF/acre of irrigated land</td>
</tr>
<tr>
<td>Mexico</td>
<td>0</td>
<td>Mexico flows gradually decrease to zero from the Scenario #1 value of 66,100 AFY</td>
</tr>
<tr>
<td>Coachella Valley</td>
<td>70,000</td>
<td>Simulated drain flow for future projects with climate change scenario (Indio Subbasin GSAs, 2021)</td>
</tr>
<tr>
<td>Local watershed</td>
<td>4,680</td>
<td>See Section 5.3.4</td>
</tr>
<tr>
<td>Groundwater</td>
<td>11,900</td>
<td>See Section 5.3.5</td>
</tr>
<tr>
<td>Lithium Allocation</td>
<td>-50,000</td>
<td>Lithium is a new and growing water use in the basin.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>889,000 AF/year</strong></td>
<td></td>
</tr>
</tbody>
</table>

### 6.2.3 Scenario 3: Low Probability Inflow

For the low probability inflow scenario, the 90th percentile flow (2.33 MAF) from the CRSS model resampling hydrology from 2000-2018 is assumed (Table 11). In other words, the model predicts that 2.33 MAF of inflow to Imperial Valley will be exceeded 90 percent of the time. Evapotranspiration in the Imperial Valley is estimated as for Scenario 2, assuming an increase of 5 percent over baseline ET values.

For Scenario 3, Coachella Valley inflows are the same as for Scenario 2. The local watershed and groundwater terms remain the same as the baseline values. The inflows for Scenario #3 are itemized below.

<table>
<thead>
<tr>
<th>INFLOW TERM</th>
<th>VALUE (AF/year)</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Valley</td>
<td>647,900</td>
<td>Inflow to Imperial Valley (2,330,000 AFY) minus ET at 3.78 AF/acre of irrigated land</td>
</tr>
<tr>
<td>Mexico</td>
<td>0</td>
<td>Mexico flows gradually decrease to zero from the Scenario #1 value of 66,100 AFY</td>
</tr>
<tr>
<td>Coachella Valley</td>
<td>70,000</td>
<td>Simulated drain flow for future projects with climate change scenario (Indio Subbasin GSAs, 2021)</td>
</tr>
<tr>
<td>Local watershed</td>
<td>4,680</td>
<td>See Section 5.3.4</td>
</tr>
<tr>
<td>Groundwater</td>
<td>11,900</td>
<td>See Section 5.3.5</td>
</tr>
<tr>
<td>Lithium Allocation</td>
<td>-50,000</td>
<td>Lithium is a new and growing water use in the basin.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>684,000 AF/year</strong></td>
<td></td>
</tr>
</tbody>
</table>
6.2.4 Scenario 4: Very Low Probability Inflow

For the very low probability inflow scenario, the 95th percentile flow (2.09 MAF) from the CRSS model resampling hydrology from 2000-2018 is assumed (Table 11). In other words, the model predicts that 2.09 MAF of inflow to Imperial Valley will be exceeded 95 percent of the time. Evapotranspiration in the Imperial Valley is estimated as for Scenario 2 and 3, assuming an increase of 5 percent over baseline ET values.

For Scenario 4, Coachella Valley inflows are the same as for Scenario 2 and 3. The local watershed and groundwater terms remain the same as the baseline values. The inflows for Scenario 4 are itemized below.

<table>
<thead>
<tr>
<th>INFLOW TERM</th>
<th>VALUE (AF/year)</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Valley</td>
<td>407,900</td>
<td>Inflow to Imperial Valley (2,090,000 AFY) minus ET at 3.78 AF/acre of irrigated land</td>
</tr>
<tr>
<td>Mexico</td>
<td>0</td>
<td>Mexico flows gradually decrease to zero from the Scenario #1 value of 66,100 AFY</td>
</tr>
<tr>
<td>Coachella Valley</td>
<td>70,000</td>
<td>Simulated drain flow for future projects with climate change scenario (Indio Subbasin GSAs, 2021)</td>
</tr>
<tr>
<td>Local watershed</td>
<td>4,680</td>
<td>See Section 5.3.4</td>
</tr>
<tr>
<td>Groundwater</td>
<td>11,900</td>
<td>See Section 5.3.5</td>
</tr>
<tr>
<td>Lithium Allocation</td>
<td>-50,000</td>
<td>Lithium is a new and growing water use in the basin.</td>
</tr>
<tr>
<td>TOTAL</td>
<td>444,000 AF/year</td>
<td></td>
</tr>
</tbody>
</table>

6.2.5 Scenario 5: IID Low Uncertainty

This scenario uses the low uncertainty results of the Salton Sea modeling efforts performed by IID, which are summarized in Section 4. The low uncertainty scenario is intended to represent flows and assumptions that are similar to current conditions. Modeled flows from 2025-2077 were averaged to determine the values in the table below.

<table>
<thead>
<tr>
<th>INFLOW TERM</th>
<th>VALUE (AF/year)</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Valley</td>
<td>694,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Mexico</td>
<td>48,640</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Coachella Valley gaged</td>
<td>72,870</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Coachella Valley drain</td>
<td>29,150</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Local watershed</td>
<td>10,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>10,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>TOTAL</td>
<td>864,700 AF/year</td>
<td></td>
</tr>
</tbody>
</table>
6.2.6 Scenario 6: IID Moderate Uncertainty

This scenario uses the moderate uncertainty results of the Salton Sea modeling efforts performed by IID, which are summarized in Section 4. The moderate uncertainty scenario is intended to represent flows and assumptions that represent more extreme or uncertain conditions. Therefore, under moderate uncertainty, inflows will be lower than the IID low uncertainty case. Modeled flows from 2025-2077 were averaged to determine the values in the table below.

<table>
<thead>
<tr>
<th>INFLOW TERM</th>
<th>VALUE (AF/year)</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial Valley</td>
<td>576,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Mexico flows</td>
<td>38,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Coachella Valley gaged</td>
<td>48,400</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Coachella Valley drain</td>
<td>19,360</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Local watershed</td>
<td>10,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>10,000</td>
<td>Average predicted flows from 2025-2077; also see Section 4.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>701,800 AF/year</strong></td>
<td></td>
</tr>
</tbody>
</table>

6.3 Inflow Scenarios Modeled for the Long-Range Plan

Three inflow scenarios were modeled for the LRP, the high probability inflow scenario, the low probability inflow scenario, and the very low probability inflow scenario (Scenarios 2, 3, and 4 from Table 16). Figure 42 presents the graphical representation of annual inflows to the Salton Sea for the three inflow scenarios over the period of 2010 to 2060. Key assumptions for the inflow scenarios are described above and are summarized as follows:

- Water deliveries to IID are based on CRSS model and resampling hydrology from 2000-2018 (information from Wheeler et al. 2022). The assumption that the current dry conditions in the 21st century will continue over the following four decades is a relatively stressful scenario from the hydrologic perspective. The three scenarios use the 50th percentile exceedance flow (high probability inflow scenario, 2.535 MAF), 90th percentile exceedance flow (low probability inflow scenario, 2.33 MAF), and 95th percentile exceedance flow (very low probability inflow scenario, 2.09 MAF).
- Mexico inflows are assumed to decline from current levels to zero by 2035, and those flows are assumed to be recycled south of the border.
- Water used for lithium production is assumed to reduce inflows to the Sea by 50,000 AFY by 2035 and remain constant thereafter. This is a new and growing water use in the basin.
- Climate change is estimated to increase ET in the Imperial Valley, based on average temperature from 2035-2064 (30-year window). It reaches this value by 2035 and remains at this level for the rest of the simulation period.
- The current drought results in a decrease of 250,000 AF of water allocation to IID from 2023 to 2026 (4 years), based on published reports. This is to be met by land fallowing, so the net decrease of flow to the Salton Sea is 89,000 AF. For the low probability inflow and very low probability inflow assumptions, the reduction continues and fallowing is replaced by efficiencies which are implemented over 5 years.
With the above assumptions, the high probability inflow scenario stabilizes at 889,000 AFY, the low probability inflow scenario stabilizes at 684,000 AFY, and the very low probability inflow scenario stabilizes at 444,000 AFY, with a transition from current conditions as shown in Figure 42.

Figure 42. Graphical representation of the annual inflows to the Salton Sea for the high probability, low probability, and very low probability inflow scenarios over the period 2010 to 2060.
7 Conclusions

As depicted and discussed in Section 5, the key drivers of change in future inflow scenarios to the Salton Sea are projected to be Imperial Valley flows to the Salton Sea and climate change impacts to ET. New water demands related to geothermal and lithium development are expected to be an additional draw on inflows into the Salton Sea.

Inflow scenarios discussed in Section 6 represent the range of possible inflows to the Salton Sea, which account for variability in future climate conditions and policy changes surrounding Colorado water deliveries. These future hydrology scenarios do not account for fluctuations in flow during shorter, sub-annual time periods. During drought conditions, these short time-scale lowflow periods may be of greater concern than long-term average flows. More extreme climate impacts to Lake Mead elevations are possible in the 21st century, which could have significant impacts on Imperial Valley deliveries.
8 References


Imperial Irrigation District, 2002. IID Water Conservation and Transfer Project EIR/EIS.


https://www.usbr.gov/lc/region/g4000/riverops/coriver-projections.html

Reclamation. 2022b. General Modeling Information. 
https://www.usbr.gov/lc/region/g4000/riverops/model-info.html

https://www.usbr.gov/lc/region/g4000/NaturalFlow/current.html


https://www.waterboards.ca.gov/coloradoriver/water_issues/programs/salton_sea/?msclkid=4760b0ff bce911ec8927dab235d103e9

Salton Sea Long-Range Plan

Appendix C: Water Use and Availability for Lithium Extraction
Public Draft – December 2022

SALTON SEA MANAGEMENT PROGRAM
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Acronyms

CEC California Energy Commission
DLE direct extraction of lithium
GHG greenhouse gas
Li lithium
MW megawatts
SSGF Salton Sea Geothermal Field
SSMP Salton Sea Management Program
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Appendix C: Water Use and Availability for Lithium Extraction

1.1. Introduction

The United States has a large, domestic source of lithium (Li) in geothermal brines at the Salton Sea Geothermal Field (SSGF) of southern California, where estimates of Li pass-through at existing geothermal plants exceed 24,000 metric tons per year, based on 2019 geothermal plant operations (~350 MW [megawatts] capacity) (Warren, 2021).

According to a recently updated geothermal conceptual model of the SSGF (Kaspereit et al., 2016), it has been estimated that the SSGF has a total reserve of 2,950 MW electricity generating capacity, a potential reserve of 2,000 metric kilotons of Li, with a potential annual production rate of ~600,000 tons per year of lithium carbonate equivalent (McKibben et al., 2020; Ventura et al., 2020). This is equivalent to ~7.2 billion US dollars in annual revenue based on a $12,000/ton price of Li carbonate.

The State of California has some of the most aggressive greenhouse gas (GHG) mitigation and renewable energy generation targets globally. Geothermal electric power production from the SSGF is one renewable energy source that will help California meet its legislated targets. Unlike wind or solar power, geothermal power has no intermittency issues and provides stable baseload capacity with minimum GHG emission. However, the upfront costs of developing geothermal power plants are very high, with much longer construction cycles when compared with wind and solar. These costs could partly be addressed through the production of Li from geothermal plants. The relatively high Li concentration in Salton Sea geothermal brines provides an opportunity for providing a secure, stable domestic supply of Li that could meet all US potential needs. Economically sustainable development of renewable geothermal energy can be performed by integrating geothermal development and Li production from geothermal brines together in the SSGF.

Extensive research and development over several decades have demonstrated the feasibility of extracting Li from geothermal brines in the SSGF (see Warren 2021 and references therein). Many techniques and process strategies have been proposed for the direct extraction of Li (DLE) from geothermal brines. These can be generally categorized into adsorption, ion exchange, and solvent extraction techniques. Of these technologies, the ones currently advancing to pilot- and near-commercial-scale demonstration involve adsorption/desorption and ion exchange techniques. Three planned and ongoing field projects for integrating geothermal and Li extraction are currently under development in the SSGF (BHER Minerals, 2020, Energy Source Minerals, 2021, Controlled Thermal Resources, 2020a, b). DLE technologies also present the opportunity to increase sustainability and reduce overall environmental impacts when compared to traditional evaporative pond and hardrock mining methods for producing Li.

This memo provides a brief overview of the potential environmental impacts of integrated geothermal development and Li production in the Salton Sea region, in the context of restoration efforts that are being implemented as part of the Salton Sea Management Program (SSMP).
1.2. Potential Environmental Impacts

In general, the integrated geothermal development and Li production in the SSGF are expected to have low GHG emissions, and potential water quality impacts will be managed by reinjection of effluent brines and process wastewater into the source reservoir. Two key known environmental concerns are (1) induced seismicity due to continuous pumping and injection of a large amount of brine from/into the reservoir and (2) consumptive freshwater use associated with Li production processes in the arid Salton Sea area.

INDUCED SEISMICITY An environmental impact concern of future integrated geothermal development and Li production at the SSGF is the potential for induced seismicity due to the increased pumping and re-injection of geothermal brines, a well-known phenomenon associated with large-scale subsurface fluid extraction and injection operations. This concern is of particular interest at the SSGF since it is located within a tectonically active region of many active regional faults, including the San Andreas Fault nearby. According to the seismic monitoring data (Brodsky and Lajoie, 2013; Trugman et al, 2016), the seismic rate in the area was initially low during the period of low-level geothermal operations before 1986. As the operations expanded, so did the seismicity. The seismic rate increased during the mid-1980s to early 1990s, during which most geothermal development activities occurred in the SSGF. After that, the rate of seismicity remained relatively stable despite continuous (however, at a lower rate) geothermal development in the area.

Based on the mapped seismicity events from 1981 to 2012, Brodsky and Lajoie (2013) concluded that the SSGF seismicity is dominated by small earthquakes, and the magnitude distribution follows the Gutenberg-Richter relationship: the number of earthquakes of magnitude greater or equal to M is proportional to $\sim 10^{-0.99M}$. The largest recorded magnitude earthquake in the SSGF is 5.1, which occurred in August 2005. According to Brodsky and Lajoie’s (2013) analysis, the risk of triggering a damaging earthquake due to geothermal development in the Salton Sea is relatively low.

Historically, the geothermal brines have been produced from the reservoir at a temperature of $\sim 450 - 480 ^\circ F$, and the effluent brines were re-injected back into the reservoir at a temperature of 205-230 ^\circ F. When coupled with Li extraction from brines, the injected brines might be cooler than the current normal power plant reinjection temperature. It is unclear from publicly available data what the temperature range of injectate would likely be after the removal of Li. The cooler injectate might promote seismic activities within the reservoir. Reservoir modeling considering the thermoelastic effects could clarify the importance of the impacts on reservoir stress state and fault slip potential due to the injection of cooler brines.

CONSUMPTIVE FRESHWATER USE Operations of geothermal power plants in the SSGF require limited freshwater use. Most of the freshwater is obtained from Imperial Irrigation District (IID) canal water and used primarily for preparing diluted acidic solutions for controlling silica scale buildups, supplemental cooling tower makeup water, conditioning/treating brines during power generation cycles, and diluting brines prior to re-injection and portable usage (CEC, 2003; CEQA Report-Hell’s Kitchen PowerCo 1 and LithiumCo 1 Project, 2022; CEQA Report- Energy Source Mineral ATLIS Project, 2021). While the exact amount of freshwater used for normal geothermal power plant operations in the SSGF is not available from public sources, based on very limited information in permit applications and environmental documents (CEC, 2003; CEQA Report-Hell’s Kitchen PowerCo 1 and LithiumCo 1 Project, 2022), the estimated freshwater use is in the range
of ~1.58 to 4 acre-feet per year per MW generating capacity. Under the current geothermal generating capacity of ~350MW, the annual freshwater use for Salton Sea geothermal power plant operations is approximately in the range of 550 to 1,400 acre-feet per year. At roughly double the generation capacity (700 MW), the freshwater use would be ~1,110 to 2,800 acre-feet per year.

Despite the extensive literature on various direct Li extraction technologies, there is limited information available in the public domain on freshwater use associated with the various sorbent and ion-exchanger-based Li extraction processes that have been proposed in the SSGF (Harrison, 2014; Ventura et al., 2018; Ventura et al., 2020), largely due to the proprietary nature of these various extraction technologies. Freshwater is primarily used for cooling water makeup to cool down brines to desired optimal temperatures, makeup solutions for pre-treating/conditioning brines for controlling mineral precipitation (e.g., silica, iron, etc.), to prepare various process waters, including acidic and alkaline solutions of desired chemical compositions and pH values for use at all stages of Li extraction, purification, concentration, and conversion processes, and to make up solutions for regenerating sorbents or ion-exchangers and solutions to extract sorbed Li and other metals (e.g., zinc, manganese, etc.) wash water. For example, Harrison (2014) noted that about 6 to 9 L of wash water per kg Li₂CO₃ is required to wash Li₂CO₃ precipitates prior to downstream concentration and purification stages. Ventura et al. (2020) reported using CO₂-loaded, deionized water for extracting sorbed Li and regenerating their proprietary sorbents/ion exchangers, without any information on how much deionized water was required for their process.

A few permit applications and environmental documents filed for developing integrated geothermal power and Li extraction field projects in the SSGF listed freshwater use for plant operations and targeted Li production (CEC, 2003; CEQA Report-Hell’s Kitchen PowerCo 1 and LithiumCo 1 Project, 2022; CEQA Report-Energy Source Mineral ATLiS Project, 2021). Water use for Li extraction associated with these projects, per unit of Li production, is summarized below:

- **BHER Minerals Demonstration Project**, funded by the California Energy Commission (CEC)
  - Technology: Ion exchanger
  - Targeted water use: 0.154 acre-feet/ton Li₂CO₃
- **Energy Source Minerals** (project ATLiS)
  - Technology: Adsorption-desorption
  - ~20,000 tons/year LiOH equivalent
  - ~0.18 acre-feet/ton Li₂CO₃
  - ~3,400 acre-feet annual water use
- **Control Thermal Resources: Hell’s Kitchen Project**
  - Technology: Ion-exchanger
  - ~17,000 tons/year Li₂CO₃ equivalent
  - ~0.382 acre-feet /ton Li₂CO₃
The environmental documents cited above provide reasonable estimates of overall water use associated with Li production, as shown in Table 1 (using upper and lower bounds of unit water use rates from the above numbers). If Li extraction were coupled with current levels of geothermal generation (350 MW), the water use would be in the range of 13,938 – 34,574 acre-feet per year. The numbers would increase proportionally at higher levels of geothermal generation and Li production, as shown in Table 1.

<table>
<thead>
<tr>
<th>Generating Capacity (MW)</th>
<th>Projected Li Annual Production Potential (metric tons)</th>
<th>Projected annual freshwater use on full scale of Li production (acre-feet per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>350*</td>
<td>17,000</td>
<td>13,938 – 34,574</td>
</tr>
<tr>
<td>700</td>
<td>40,000</td>
<td>32,796 – 81,351</td>
</tr>
<tr>
<td>1,000</td>
<td>93,000</td>
<td>48,960 – 121,445</td>
</tr>
</tbody>
</table>

* 350MW is the current geothermal power generation in Salton Sea Geothermal Field

### 1.3. Conclusions

In general, the integrated geothermal development and Li production in the SSGF will pose very few adverse impacts on the environment. All effluent brines and wastewater from production cycles will be reinjected back into the deep reservoir, therefore the risk of water pollution is low. The plant operations emit very little GHG and pose a negligible impact on air quality. After the construction of the plants, the increased land coverage by buildings and paved ground surface could help reduce dust emissions.

Based on the past nearly four-decade history of geothermal power plant development and seismicity mapping records in the area, the risk of damaging earthquakes triggered by the continuous development of geothermal power in the Salton Sea Reservoir Field is likely to be low. However, the additional cooling of geothermal brines during Li production processes prior to reinjection will induce additional changes in the stress state to the deep reservoir around injection wells. The temperature of the injectate after the removal of Li from brines is unclear. The largest earthquake observed in the SSGF was M5.1, which occurred in August 2005. Therefore, precautions need to be taken in designing and constructing buildings and berms in the area to avoid potential liquefaction events associated with earthquakes triggered by pumping and injection operations.

At the current geothermal power generating capacity of 350MW in the SSGF, annual production of 17,000 metric tons of Li could be reached by processing effluent geothermal brines after power generation. At this annual Li production rate, about 13,938 to 34,574 acre-feet of fresh water per year are required during various stages of Li extraction, purification, concentration, and conversion processes. All currently proposed field Li production projects in the Salton Sea are planning to purchase fresh water from IID canal water for irrigation. The water is expected to be used entirely consumptively in that it is either evaporated or injected into deep formations and is not returned to the near-surface environment. The amount of water needed for Li extraction, over and above that needed for geothermal production, is not insignificant, particularly within
the arid Salton Sea area, and needs to be considered in the overall water balance for restoration project planning.

1.4. References


CEC, 2003. Salton Sea Geothermal Unit #6 Power Project Application For Certification (02-AFC-2), P800.03.021.


CEQA Report, 2022. Initial Study & Environmental Analysis for Hell’s Kitchen PowerCo 1 and LithiumCo 1 Project, prepared by the County of Imperial Planning & Development Services Department.


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Appendix D: Salton Sea Salinity and Elevation Modeling

This appendix lays out the details of the Salton Sea Accounting Model (SSAM) used to produce estimates of future Salton Sea salinity and elevation. Each combination of Long-Range Plan (LRP) restoration concept and estimated future hydrology is represented in a separate Microsoft Excel workbook. There are 57 such combinations—19 concept variants and subvariants with 3 hydrology scenarios each. Automated scripts were used to operate on template files that contain the union of all the features needed to express the LRP concepts. These scripts were then used to enable only the relevant features, set up the relevant project areas, populate the relevant elevation-area-capacity relationship, and set the estimated hydrology for each individual model run. There are two separate templates: one for the divided sea concepts (Concepts 2a-2d) and one for all other concepts. Once the script populates the template, however, each workbook is a self-contained simulation of the model runs described in this report.

1.1. Primary Model Calculations

The model operates by water and salt mass conservation of the main, dynamically sized portion of the Sea. At each annual timestep, the following quantities of water volume are added (+) or subtracted (-) from the volume that was present at the beginning of the year:

- (+) Freshwater Inflows, a time series input from the relevant estimated hydrology scenario.
- (-) Total Water Volume needed to satisfy evaporation demands of fixed-size conservation projects, including the marine sea of Concept 1, the perimeter lake cells of Concepts 2 and 3, and all planned shallow-water habitat areas.
- (-) Total Water Volume needed to meet dust suppression obligations, defined as 1 acre-ft of water annually per acre of area within the 2003 shoreline not covered by the remaining Sea or any planned habitat projects in a given year.
- (-) Direct evaporation volume from the dynamically sized Sea, dependent on the area and salinity of the Sea in a given year, using the same quadratic polynomial regression in USGS’s original SSAM model, which takes a baseline evaporation rate (calibrated to be 69.9 inches annual, see Section 1.2 and 1.4 below) and returns a smaller evaporation rate with increasing salinity.
- (+) Direct precipitation volume on the Sea, set at a constant value of 2.5 inches per year, approximately equal to a historical average of the rain gauge of Imperial, CA.
- (+/-) Any direct imports or exports, such as out-of-basin exports (Concept 4) or imports (Concept 11-13), or remediation desalination (Concepts 7, 11-13).
Similarly, salt mass has the following additions (+) and subtractions (-) at each timestep, assuming direct evaporation and precipitation to have minimal effect on salt balance:

- (+) Salt coming in with freshwater inflows, using the inflow-dependent regression present in USGS’s original SSAM model, which has higher salt concentrations with lower inflow volumes.
- (-) One-time salt withdrawal corresponding to the initial construction of saline habitat/water optimization areas in Concepts 1, 3, and 5.
- (+/-) Any direct imports or exports, such as out-of-basin exports (Concept 4) or imports (Concept 11-13), or remediation desalination (Concepts 7, 11-13).
- (-) Annual salt precipitation of 0.15% of the current salt mass in the Sea.
- (-) Any salt above saturation salinity of 280 ppt.

At any state of the Sea, there is a 1-1-1 relationship between its elevation, area, and capacity (volume), also known as the EAC relationship or EAC curve. This relationship was estimated from the latest available bathymetry data and may vary slightly from scenario to scenario. For each model run, this EAC curve is used to get the initial Sea volume (as the initial conditions are specified as an elevation) and to convert the Sea volume at each timestep to a Sea area and Sea elevation.

For every concept except Concept 2, there is only the one central, dynamically sized water body. This may represent a marine sea type area when certain remediation areas are in place (e.g., Concepts 4 or 7) or it may represent a higher-salinity residual sea area when the primary marine sea instead is a smaller fixed footprint (e.g., Concepts 1 or 3). In Concept 2, both portions of the divided sea are dynamically sized with their own precipitation and evaporation processes, but the whole freshwater inflow process is assumed to be first routed to the southern marine sea. After, there is a transfer process of water at the current salinity to the northern residual sea to approximately equalize both elevations at the end of each timestep.

1.2. Model Inputs

The main inputs that the template scripts are setting to estimate the specifics of any particular scenario are the following:

- The initial Sea state. All model runs are currently set to begin in 2020 at an elevation of -235.5 ft NAVD88 with an initial salinity of 74,250 ppm.
- Freshwater inflow at each year, specified as a time series from 2020 to 2100. The derivation of the time series for each of the three hydrology scenarios is described in Section 3.1 of the LRP (with more detail provided in Appendix B).
- The baseline evaporation for each year. This was derived as a calibrated average value from historical data from 2004 to 2020. The current value has been set at 69.9 inches per year.
- The schedule for fixed-area projects with an evaporative loss, including Phase 1 habitat projects as well as concept-specific Sea areas that have a fixed footprint. This is specified as an area for each year and a per-area water use rate. Most projects have a single starting year (based on an estimated time to design, permit, and construct). Before that time, they occupy zero area and after that they occupy one repeating fixed value;
however, large habitat projects like the water optimization area in Concepts 1 and 5 have a staggered construction schedule. Open water habitat is currently set to use 6 feet of water per acre annually, wetland areas use 5 feet annually, and vegetation areas use 0.5 feet annually.

- The schedule for any imports and exports:
  - Pumpout-type transfers (e.g., Concept 4) that permanently remove water from the Sea do so at the current timestep’s salinity. There is a threshold parameter that stops pumping once a target salinity has been met.
  - Import-type transfers (e.g., Concepts 11-13) do so at a fixed volume and salinity.

- Any local remediation desalination (e.g., Concept 7, Concepts 11-13) has six relevant parameters:
  - Starting year, based on estimated time to design, permit, and construct.
  - Salinity threshold, which determines whether desalination should be active in a given year (40 ppt).
  - Desalination volume: the amount of water withdrawn from the Sea at current salinity.
  - Desalinated water salinity (0.2 ppt).
  - Desalination water percent, the percent of the water withdrawn from the Sea to be returned (can be up to 100% if supplemental water use, e.g., from groundwater, is part of the concept design)
  - Damping factor: strong oscillations in Sea salinity can arise if the Sea volume gets sufficiently low (on the order of the desalination volume). This factor decreases the amount of water withdrawn for desalination in these very low volume situations to dampen the oscillatory behavior.

- For concepts in which major construction changes the EAC relationship, the year in which this happens is based on estimated time to design, permit, and construct. Water volume is preserved when the EAC curve is changed.

### 1.3. Model Outputs

The primary outputs of interest are Sea area, elevation, and salinity, which are all straightforward extractions of data columns from the model calculation sheet of the individual scenario workbooks. The maps in the main report involve post-processing these data with GIS tools to obtain breakdown of habitat areas by depth, estimated salt crust sizes, and GHG emissions.

### 1.4. Calibration of Model Evaporation

No sufficiently robust sources of direct Salton Sea evaporation data exist, so the baseline evaporation rate was treated as a calibration parameter. Daily Sea elevation data from 2004-2021 and periodic salinity data (approximately every three months) from 2004-2020 were available for use in calibration.
The model was initialized to January 2004 based on the average data of the first month of each of the above series. Then, historical inflow from 2004-2020 (see Section 5.3 of the Hydrology Appendix B) was input into the model.

First, evaporation was initialized to 68 inches for all years. Then an iterative calibration process was then applied to each year from 2004 to 2020 to better match observed salinity and elevation data as follows:

- Evaluate the effect of setting the evaporation of the year in question to each value in the set of candidates: {66, 67, 68, ..., 74}. This range was deemed to be consistent with previously used estimates of annual evaporation in other analyses.
- Linearly interpolate the model output within the calendar year since the observed data are daily while the model output is annual.
- Note the rank for each candidate according to best sum of squared error performance on each for salinity and elevation only within the year being evaluated.
- Choose the candidate salinity with the best performance according to the weighted average of three times the elevation rank and one times the salinity rank. The elevation data were given more weight because there is less noise in that dataset.
- Proceed to the next year and repeat the process.

The model was able to match the observed elevation and salinity data well after calibration (see Figures 1 and 2). The resulting average annual evaporation used for all future years was 69.9 inches.

![Figure 1. Calibrated Salton Sea Elevation (ft NAVD88)](image-url)
As a sensitivity analysis, we also repeated the entire calibration with best-estimate historical inflows perturbed by +/- 5%. The case with 5% less inflow decreased the calibrated average evaporation to 68.0 inches, whereas the case with 5% more inflow increased it to 71.0 inches.
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Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>km</td>
<td>kilometer</td>
</tr>
<tr>
<td>LCC</td>
<td>Lambert Conformal Conic</td>
</tr>
<tr>
<td>LRP</td>
<td>Long-Range Plan</td>
</tr>
<tr>
<td>MMIF</td>
<td>Mesoscale Model Interface</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>Concentration of particulate matter with diameter less than 10 micrometers</td>
</tr>
<tr>
<td>SSMP</td>
<td>Salton Sea Management Program</td>
</tr>
<tr>
<td>WRF</td>
<td>Weather Research and Forecasting</td>
</tr>
</tbody>
</table>
Appendix E: Air Quality Evaluation

1.1. Introduction

The Salton Sea Management Program (SSMP) prepared a draft Long-Range Plan (Plan) to comply with the State of California Water Board Revised Order WR 2002-0013 (Order). The Plan must be consistent with the requirements of the Order and the Salton Sea Restoration Act (Act) (Fish and Game Code § 2930, et seq.), including the statutory restoration objectives set forth in Fish and Game Code Section 2931, subdivision (c).

The Plan is being developed as a second phase to the Phase 1: 10-year Plan projects, which will establish at least 14,900 acres of aquatic habitat and up to 14,900 acres of vegetated habitat by the year 2028, with the purpose of suppressing dust emissions and improving ecological conditions at the Salton Sea. One of the goals of the Plan is to protect or improve air quality to prevent or reduce health and environmental consequences anticipated from the long-term recession of the Salton Sea.

This air quality analysis establishes a baseline of air emission estimates from the existing exposed lakebed and predicted ambient air concentrations of particulate matter in the vicinity of the Salton Sea. The CALPUFF dispersion model was used to perform the analysis. The focus of this baseline analysis is to demonstrate that dispersion modeling can be a useful tool in understanding the meteorological conditions that can lead to elevated predicted concentrations and the potential transport of emissions to communities in the region. This modeling indicates that exposed lakebed emissions alone can produce the level of elevated concentrations being measured in the basin, and consequently fugitive dust control efforts can have meaningful benefit. Further modeling will be performed to address future recession of the Salton Sea and the resulting increased exposure of exposed lakebed to wind erosion as well as address mitigation strategies proposed in the Plan.

The emission estimation procedures are detailed in Section 2.0. The modeling methodology is described in detail in Section 3.0 and a discussion of the baseline predicted impacts is presented in Section 4.0 of this memo.

1.2. Dispersion Modeling Methodology

1.2.1. Model Selection

CALPUFF is a Lagrangian modeling system that can address complex wind situations over a large domain. The model is useful as a screening technique for long-range transport of air emissions and for addressing dispersion of air emissions in complex non-steady state meteorological conditions. In rugged hilly or mountainous terrain, along coastlines, or near large variations in land use, the characterization of the winds is a balance of various forces, such that the assumption of steady-state straight-line transport both in time and space used by other dispersion models (such as AERMOD) are inappropriate.
Appendix E: Air Quality Evaluation

CALPUFF is a multi-layer, multi-species non-steady-state puff model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation, dispersion, and removal through the treatment of air pollutant emissions from sources released as a series of discrete puffs. Each puff is tracked individually by the model until it leaves the modeling domain, and the contribution of each puff to receptor concentrations (or deposition fluxes) is calculated separately and can be used to create individual source impacts or summed to create total impacts over source groups based on the user’s selections. CALPUFF uses three-dimensional meteorological fields developed by the CALMET model based on prognostic meteorological model output (e.g., Weather Research and Forecasting model, or WRF), station meteorological data (surface observations and upper air soundings), or a combination of both (hybrid mode). CALPUFF can be applied on scales of tens to hundreds of kilometers. It includes algorithms for subgrid scale effects (such as terrain impingement), as well as longer range effects (such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, and visibility effects of particulate matter concentrations). CALPUFF is well suited for situations involving complex flows including spatial changes in meteorological fields due to factors such as the presence of complex terrain or the influence of water bodies. CALPUFF can assess plume fumigation (coastal fumigation or inversion break-up conditions), light wind speed or calm wind impacts, or other factors for which a steady-state-straight-line modeling approach is not appropriate. CALPUFF can account for the cumulative impact of multiple spatially distributed sources with temporally varying emissions within a large region.

CALPUFF View is a CALPUFF model graphical user interface (GUI) developed and maintained by Lakes Environmental (Ontario, Canada). The software combines the various CALPUFF pre- and post-processing programs, providing a user-friendly model setup wizard interface and other tools and creates a graphical display of the various model inputs and outputs for visualization and QA/QC. CALPUFF View allows for visualization of plume predicted concentrations and wind fields, thereby enabling conclusions to be drawn regarding the meteorological conditions that lead to plume formation, transport, and elevated ambient air concentrations.

Wind fields in the Salton Sea basin are influenced by non-uniform land cover (i.e., desert, exposed lakebed, sea surface) and mountainous terrain to the west and northeast. These geographical variations tend to modify the prevailing winds, generating local winds and circulations that influence the transport of fugitive dust emissions. The CALPUFF model can simulate the dispersion from many spatially distributed sources with hourly varying emissions (as described in Section 2.0). For these reasons the CALPUFF modeling system is appropriate for use in this assessment.

1.2.2. Meteorology

The modeling used prognostic data derived from the Weather Research and Forecasting (WRF) model and processed with EPA’s Mesoscale Model Interface (MMIF) program to generate CALPUFF model-ready meteorological parameters. The gridded WRF-derived multi-level meteorological data for the one-year period of 2020 was purchased from Lakes Environmental. Lakes Environmental ran the WRF model for the 100 kilometer (km) by 100 km domain with 1 km horizontal resolution. Lakes Environmental prepared the files using MMIF to convert the prognostic meteorological model output fields to the parameters and formats required for direct input into CALPUFF. To account for the curvature of the earth, Lambert Conformal Conic (LCC) projection coordinates were used for the MMIF extractions. The meteorological grid was defined...
with ten vertical layers, as consistent with the default layers specified by EPA/Federal Land Manager (FLM) guidance (cell face heights of 20, 40, 80, 160, 320, 640, 1200, 2000, 3000 and 4000 meters). Table 1 summarizes the input parameters for the MMIF extraction. Due to the size of the meteorological data files, the one-year period is comprised of 12 monthly files.

<table>
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<th>Setting</th>
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</thead>
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<td>Projection</td>
<td>Lambert Conformal Conic</td>
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<td>-8</td>
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<tr>
<td>Projection origin (RLAT0, RLON0)</td>
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<td>False Easting, Northing at Projection Origin</td>
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<tr>
<td>Datum</td>
<td>NWS-84 (NWS 6370 km radius, sphere)</td>
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<tr>
<td>Number of Grid Cells</td>
<td>nx = 100, ny = 100</td>
</tr>
<tr>
<td>Grid Spacing</td>
<td>1.0 km</td>
</tr>
<tr>
<td>Number of Vertical Levels</td>
<td>10</td>
</tr>
<tr>
<td>Cell Face Heights (ZFACE)</td>
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</tr>
<tr>
<td>Southwest Corner of Grid Origin (1,1)</td>
<td>-50.0 km, -50.0 km</td>
</tr>
</tbody>
</table>

1.2.3. Model Domain

The CALPUFF modeling domain was inherently defined by the domain of the meteorological data extraction (100 km by 100 km, centered at approximately 33.308416°N, 115.836615°W) which encompasses the Salton Sea and sufficient surrounding topography. The CALPUFF domain is shown in Figure 1. The LCC projection coordinates are used to define source and receptor locations in CALPUFF.

1.2.4. Receptors

Receptors are geographic locations at which the model predicts ambient air concentrations. For this modeling analysis, receptors were located in the following communities: Bombay Beach, Brawley, Calipatria, Desert Camp, Desert Shores, Mecca, Mortmar, Niland, North Shore, Salton City, Salton Sea Beach, Torres Martinez, and Westmorland. Grids of receptors were developed to cover each community with uniform spacing ranging from 150 meters to 400 meters depending on the size of the area covered by the community. Salton City covers a large area, therefore three receptor grids of 400 m spacing each were developed to provide adequate coverage. In addition to the community receptors, a grid of receptors extending throughout the modeling domain with 2 km spacing was modeled. A total of 3,185 receptors were included in the modeling analysis. The CALPUFF receptor locations are shown in Figure 2. The blue symbols in the figure are community receptors and the green symbols are gridded receptors.
CALPUFF’s terrain preprocessor program, TERREL, was used to calculate terrain elevations and critical hill heights for each model receptor using National Elevation Data (NED). The 1/3 arc-second (~10-meter resolution) NED dataset was downloaded from the United States Geological Service (USGS) website using the CALPUFF View GUI.
1.2.5. CALPUFF Model Options

CALPUFF was run with the default technical options selected that conform to the EPA guidance (MREG = 1), except that chemical transformation was not incorporated for modeling particulate matter with aerodynamic diameter less than or equal to 10 microns (PM$_{10}$). Hourly emissions of PM$_{10}$ were calculated and input to CALPUFF (see Section 3) and both dry and wet deposition were considered by applying CALPUFF’s default depositional parameters.

1.3. Emission Rate Estimation Procedures

Using ArcGIS, each of the 1 km by 1 km grid cells in the modeling domain were intersected with a layer defining the geographic extent of the current exposed lakebed, thereby assigning the proportion of exposed lakebed within each grid cell. Emission rates assigned to each grid cell were then calculated based on the land cover represented within the boundary of the grid cell. Much of the basis for the emissions calculations were obtained from the Salton Sea Emissions Monitoring Program, 2020/2021 Annual Report (Formation Environmental, 2022). Land cover factors for consideration included the surface type (dry exposed lakebed, moist [wet] exposed lakebed, and desert), sand presence, exposed lakebed crust types, and surface roughness. Threshold friction velocity, which is a measure of the wind speed above which fugitive dust is generated, is a function of these land cover factors and was identified from rulesets available in the annual report. Fugitive dust emission rates were then calculated for each hour of 2020 for each grid cell based on exposed lakebed crust type and on the hourly wind speed data extracted from the meteorological data described above.

The annual report presents ruleset charts that provide relationships between PM$_{10}$ fluxes and surface friction velocity for exposed lakebed surface types. The ruleset charts are reproduced and presented here as Figure 3. The curves presented in these charts were used to establish the threshold friction velocity for each land cover combination and to derive PM$_{10}$ emission rate equations for each land cover combination. Three different curves are presented on each chart, each representing the 25$^{th}$, 50$^{th}$, and 75$^{th}$ percentiles of each underlying data set. For the purposes of this evaluation, the 50$^{th}$ percentile curves were used to establish the threshold friction velocity and to calculate the PM$_{10}$ emission rate.

The following attributes of land cover factors were selected to establish friction velocities for each of the exposed lakebed surface types:

- A surface roughness of 0.0001 meter was assigned to all exposed lakebed coverage;
- Dry exposed lakebed was assumed for all exposed lakebed coverage as the proportion of dry exposed lakebed over time as the sea recedes will increase;
- Two surficial sand presence coverages of the exposed lakebed, 80 percent and 20 percent, were considered to perform a sensitivity analysis; and
- Using ArcGIS, detailed crust type coverages (i.e., barnacle bed, botryoidal, weak botryoidal, smooth crust, and no crust) were intersected with the grid cells to assign the proportion of crust type within each grid cell.

The PM$_{10}$ emission rate was calculated from linear relationships established over discrete ranges of surface friction velocity. These linear relationships have the form:

$$\log(Q) = m \times u^* + b$$
Appendix E: Air Quality Evaluation Working Draft

Where $Q$ is the PM$_{10}$ emission rate, $u^*$ is the surface friction velocity, $m$ is the slope of the line, and $b$ is the intercept of the line. These discrete linear relationships were derived by digitizing each of the ruleset charts. The surface friction velocity was computed for each hour of wind speed data in each grid cell over the 1-year period of the meteorological record. For hours when the wind speed was less than the threshold wind velocity, a zero emission rate was assigned to the crust type coverage of the grid cell.

**Figure 3. PM$_{10}$ Emissions Ruleset for Exposed Lakebed (from Formation Environmental, 2022)**

The surface friction velocity was calculated for each hour and each grid cell from the above-described wind speed data and surface roughness as follows:

$$u^* = \frac{(0.4 \times u)}{\ln(10/z_o)}$$

where $u^*$ is the friction velocity, $u$ is the wind speed, and $z_o$ is the surface roughness.

Finally, the PM$_{10}$ emission rate assigned to each grid cell was based on the proportion of surface type present within the boundary of the grid cell. For grid cells comprised entirely of a single
surface type, the assigned emission rate is based solely on the calculation parameters for that surface type. For grid cells containing multiple surface types, the assigned emission rate is based on the weighted fraction of the surface type present within the grid cell as determined by GIS analysis. The resulting surface friction velocities were used to perform the emission rate calculation.

The emission source locations and the calculated annual emissions for each grid cell are shown in Figures 4a and 4b for the 80 percent and 20 percent sand presence cases, respectively. The figures show that emissivity is greatest in the southeastern, southwestern, and western areas of exposed lakebed, and lowest in the northern and eastern areas of exposed lakebed. These results are consistent with information presented in the 2020/2021 Annual Report.

**Figure 4a. CALPUFF Emissions Source Locations Showing Calculated 2020 Total Emissions, 80% Sand Presence**
1.4. Evaluation of Model Predictions

CALPUFF modeling was conducted for a full year (2020) of meteorological data with emission rates based on 80% sand presence on the exposed lakebed surface. The results for the annual run were evaluated to identify discrete episodes when elevated 1-hour average ambient PM$_{10}$ concentrations (i.e., greater than 200 μg/m$^3$) were predicted. These predicted episodes were compared to ambient monitoring measurements to assess whether elevated 1-hour average ambient PM$_{10}$ concentrations were measured during the same time periods.

Selecting discrete episodes for further evaluation is consistent with the strategy of performing modeling for ozone and PM$_{2.5}$ attainment demonstrations by state and local air quality management agencies. The strategy is to identify episodes with high predicted ambient concentrations, compare those to actual observations to have assurance that the modeled episode is representative of the actual observed episode, and then apply mitigation measures to the modeled emissions inputs to identify the effectiveness of the mitigation measure in reducing ambient air impacts. Because the magnitude of fugitive dust emissions in the Salton Sea Basin are a product of elevated wind speeds, the emissions are highly variable over time and do not occur on days when the wind speed is insufficient to erode the exposed lakebed surface.
Evaluation of the effectiveness of mitigation measures cannot be performed on days when emissions do not occur, and therefore episode selection is the most efficient means of focusing the labor and computational resources to perform the evaluation.

Episodes of elevated predicted 1-hour average ambient air concentrations corresponding to days were identified and then re-run with a second set of emission rates developed assuming 20% sand presence on the exposed lakebed surface. The following episodes were modeled:

- January 27 through January 30, with January 29 being the particular day of interest;
- February 28 through March 4, with March 1 being the particular day of interest;
- June 3 through June 8, with June 5 being the particular day of interest;
- June 28 through July 1, with June 30 being the particular day of interest;
- October 24 through October 27, with October 26 being the particular day of interest; and
- November 5 through November 9, with November 7 being the particular day of interest.

It is notable that elevated 1-hour average ambient PM$_{10}$ concentrations were measured during these days at one or more of the six monitoring sites located around the Salton Sea. Thus, the methodology described above predicted elevated 1-hour average ambient PM$_{10}$ concentrations to occur on days when elevated 1-hour average ambient PM$_{10}$ concentrations were actually observed. This result is one indicator that the modeling approach is a useful tool for evaluating ambient air quality impacts associated with future exposed lakebed conditions and mitigation strategies.

Isopleths of predicted 1-hour average ambient PM$_{10}$ concentration were plotted with corresponding wind field vectors for each hour of the episodes identified above. These isopleths were examined to determine if predicted elevated 1-hour average ambient PM$_{10}$ concentration could be consistently attributed to specific wind field characteristics. The isopleths consistently show that predicted elevated 1-hour average ambient PM$_{10}$ concentration are associated with localized areas of stagnating winds that are in turn located adjacent to areas of stronger winds capable of producing fugitive dust emissions and with the wind direction oriented in a way that can transport the fugitive dust into the area of stagnating wind. Preceding hours also consistently show stronger winds capable of producing fugitive dust emissions in these areas.

As described above, CALPUFF treats air emissions from sources as a series of discrete puffs released on a nearly continuous basis. Each puff is individually transported and dispersed through the modeling domain and the predicted concentration of each puff at each receptor is calculated separately. Those individual puff results are then summed for all puffs to produce the total predicted concentration at each receptor. This treatment provides a representative simulation of actual plume transport and dispersion in a way that is not provided by steady-state straight-line dispersion models such as AERMOD. In the meteorological case described above that leads to predicted elevated 1-hour average ambient PM$_{10}$ concentration, the transport of the simulated puffs is slowed due to the reduced wind speed and the dispersion of the simulated puffs is reduced due to the reduced turbulence in the areas where light or calm winds occur. Thus, CALPUFF allows puffs to accumulate in these localized areas of stagnant winds and as such the model provides a meteorological explanation for elevated ambient air concentrations that goes beyond a simplistic attribution of to elevated wind speeds. Such meteorological explanations are not readily identified by the ambient monitoring data alone, which generally show that elevated
ambient air concentrations can occur across the spectrum of concurrent high and low wind speeds. This finding is another indicator that the modeling approach is a useful tool for evaluating ambient air quality impacts associated with future exposed lakebed conditions and mitigation strategies. The attachment presents selected isopleth plots with corresponding wind field vectors for several of the above-listed episodes and provides examples of the above-described meteorological conditions.

Review of the isopleths for the full-year CALPUFF run indicate that persistent durations of predicted elevated 1-hour average ambient PM$_{10}$ concentration are associated with winds blowing from the northwest to the southeast along the axis of orientation of the Salton Sea and with winds blowing from west to east across the Salton Sea. The modeling indicates that episodes are infrequently occurring where fugitive dust emissions from exposed lakebed are being transported to communities north of the Salton Sea. Rather, transport of fugitive dust emissions from exposed lakebed toward the communities south of the Salton Sea are much more likely. This observation is not only associated with the wind vectors occurring on episode days, but also with the relatively high emissivity of the exposed lakebed in the southern and western regions of the Salton Sea. It is notable, however, that the predicted concentrations in the communities south and north of the Salton Sea are considerably lower than those predicted along the seashore itself and no exceedances of ambient air quality standards in these communities is predicted by CALPUFF for the communities.

As described above, two sets of emissions were developed to assess the sensitivity of the modeling results to the amount of sand present on the exposed lakebed surface. A comparison of the CALPUFF-predicted maximum 1-hour average PM$_{10}$ concentrations for each set shows that the results are sensitive to the assumption of how much sand is present on the exposed lakebed surface. In general, predicted ambient air concentrations based on 80% sand presence were a multiplication factor of 3 to 4 greater than predicted ambient air concentrations based on 20% sand presence. The ratio of these results is consistent with the emissions ratio described above and provides context for the uncertainty of the numeric value of the results. Nevertheless, the order of magnitude of the values of the maximum predicted 1-hour average concentrations are consistent with those measured at the six monitoring sites located around the Salton Sea (i.e., greater than 1,000 $\mu g/m^3$). This order-of-magnitude result is another indicator that the modeling approach is a useful tool for evaluating ambient air quality impacts associated with future exposed lakebed conditions and mitigation strategies, while the uncertainty assessment informs the treatment of surficial exposed lakebed sand in future modeling assessments.

As noted in the description of the methodology for developing the emissions inputs to CALPUFF, fugitive dust contributions from the desert are not included in the modeling assessment. Thus, the results presented in this report should not be construed to mean that elevated 1-hour average ambient PM$_{10}$ concentrations are attributable solely to exposed lakebed sources. Work performed by others demonstrates the contribution of desert sources are significant to elevated ambient PM$_{10}$ concentrations. Nevertheless, the predicted concentrations presented in this report are representative of ambient measurements in the domain, and therefore the modeling indicates that exposed lakebed emissions alone can sometimes lead to the level of elevated concentrations being measured in the basin and even to a level where ambient air quality standards can be exceeded. This indicates that fugitive dust control efforts in the areas of exposed lakebed can have meaningful benefit and further indicates that the modeling approach
is a useful tool for evaluating ambient air quality impacts associated with future exposed lakebed conditions and mitigation strategies.

In summary, the following findings resulted from the assessment of baseline exposed lakebed conditions:

- For the selected episodes, predicted elevated 1-hour average ambient PM$_{10}$ concentrations occurred on days when measured elevated 1-hour average ambient PM$_{10}$ concentrations were observed.

- Isopleths of predicted elevated 1-hour average ambient PM$_{10}$ concentration are consistently associated with localized areas of stagnating winds that are in turn located adjacent to areas of stronger winds capable of producing fugitive dust emissions and with the wind direction oriented in a way that can transport the fugitive dust into the area of stagnating wind; further, preceding hours also consistently show stronger winds capable of producing fugitive dust emissions in these areas which can become entrained in areas of stagnating winds that forming in subsequent hours.

- Acquisition of the WRF meteorological data set for 2020 was instrumental in understanding meteorological conditions under which elevated PM$_{10}$ concentrations can occur. The monitoring data alone from the six monitoring stations shows that elevated PM$_{10}$ concentrations do frequently occur during light winds, but the monitoring data do not provide insight into how elevated PM$_{10}$ concentrations can occur during light winds. The WRF meteorological data input to the CALPUFF model provided a means for obtaining the insight.

- The order of magnitude of the values of the maximum predicted 1-hour average concentrations are consistent with those measured at the six monitoring sites located around the Salton Sea (i.e., greater than 1,000 $\mu$g/m$^3$) and therefore the modeling indicates that exposed lakebed emissions alone can sometimes lead to the level of elevated concentrations being measured in the basin. The predicted concentrations are consequential and indicate exceedances of ambient air quality standards can be due solely to exposed lakebed fugitive dust emissions.

- Elevated predicted 1-hour average concentrations are generally transported toward the east and southeast from areas of emissivity. Communities north of the Salton Sea are generally not impacted by elevated PM$_{10}$ concentrations that are associated with fugitive dust from exposed lakebed. While transport in the direction of communities south of the Salton Sea does occur, the CALPUFF-predicted concentrations in the community areas are not sufficient to exceed ambient air quality standards. These results are consistent with the wind directions associated with episodes of elevated ambient concentrations and with the locations of elevated exposed lakebed emissivity.
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Attachment

CALPUFF Predicted PM10 Concentration Contours of Baseline Fugitive Dust Emissions from Salton Sea Exposed Lakebed
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12:00, January 29, 2020; Sand Presence = 80%

Max. Predicted PM$_{10}$ Conc. = 15,000 μg/m$^3$
12:00, January 29, 2020; Sand Presence = 20%

Max. Predicted PM$_{10}$ Conc. = 3,800 μg/m$^3$
02:00, November 7, 2020; Sand Presence = 80%

Max. Predicted PM$_{10}$ Conc. = 860 µg/m$^3$
04:00, November 7, 2020; Sand Presence = 20%

Max. Predicted PM$_{10}$ Conc. = 1,100 $\mu$g/m$^3$
14:00, March 1, 2020; Sand Presence = 80%

Max. Predicted PM$_{10}$ Conc. = 3,900 $\mu$g/m$^3$
14:00, March 1, 2020; Sand Presence = 20%

Max. Predicted PM$_{10}$ Conc. = 870 $\mu$g/m$^3$
20:00, March 1, 2020; Sand Presence = 80%

Max. Predicted PM$_{10}$ Conc. = 3,100 µg/m$^3$
20:00, March 1, 2020; Sand Presence = 20%

Max. Predicted PM$_{10}$ Conc. = 840 μg/m$^3$
Max. Predicted PM$_{10}$ Conc. = 80 μg/m$^3$
Salton Sea Long-Range Plan

Appendix F: Greenhouse Gas Emissions
Public Draft – December 2022

SALTON SEA MANAGEMENT PROGRAM

C A L I F O R N I A
N A T U R A L
R E S O U R C E S
A G E N C Y

CALIFORNIA DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE
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Table 2. The same information as in Table 1 but with the values from the sources converted into different units and filled out in COLUMN 5, 6, 7. NOTE: for CO₂ emissions from open water diffusive flux, a range of values suggested by McDonald et al., 2013 is provided along with a mean value that is suitable for California. This is to illustrate the relatively high uncertainty in emission rates associated with this process. ................................................................. 16

Table 3. For the Phase 1: 10-Yr Plan concept, annual estimates of OC burial, CO₂ emissions from the oxidation of the exposed lakebed, CH₄ emissions, and diffusive flux of CO₂ and N₂O from the lake water surface in 2000, 2030, 2050, and 2100. Units are in metric tons of CO₂-equity per year unless otherwise stated. ................................................................. 18

Table 4. For the Phase 1: 10-Yr Plan concept, cumulative estimates of OC burial, CO₂ emissions from the oxidation of the exposed lakebed, CH₄ emissions, and diffusive flux of CO₂ and N₂O from the lake water surface by 2000, 2010, 2020, 2030, 2050, and 2100. Units are in metric tons of CO₂-equity to date (i.e., since 1905). ................................................................. 18
1.1 Introduction

This memo describes a methodology that can be used to estimate the greenhouse gas (GHG) budget of the Salton Sea. GHG emission estimates are needed to compare current and future emissions for different proposed approaches for restoration of the Salton Sea. This work uses published literature sources and field observations to draw conclusions about carbon burial, cycling, and emissions while also factoring in expected changes in such processes in future years due to enhanced eutrophication, salinity increases, and general warming and drying of the lakebed and surface waters.

The memo is organized as follows:
Section 2: Description of Study Area
Section 3: Background Information and Assumptions
Section 4: Summary of Reference Values
Section 5: GHG Budget of the Salton Sea Per Year (until 2100) and To Date (from 1905)
Section 6: Conclusion

1.2 Description of Study Area

1.2.1 Inflows

The Salton Sea is located in the Sonoran Desert of southeastern California. The Sea itself was formed during a 17-month period from October 1905 to February 1907 by the breaching of a temporary diversion of the Colorado River. Since then, the Salton Sea has been sustained by agricultural discharge, municipal and industrial effluent, and stormwater runoff from the Imperial, Coachella, and Mexicali Valleys. These flows are delivered to the Salton Sea via the New, Alamo, and Whitewater Rivers in addition to some ungauged local watershed discharge. Over time, evaporation and reduced inflows have caused the Salton Sea’s elevation to gradually recede. Climate change-exacerbated increases in temperature and evaporation as well as decreases in water allocation and subsequent inflow are projected to further shrink the size of the Salton Sea and significantly warm the waters of the Sea.

For characterizing future volume, area, and salinity of the Salton Sea, we used a simple water and salt balance model termed the Salton Sea Accounting Model (SSAM). This is a spreadsheet model originally developed by the US Bureau of Reclamation (Reclamation) in the 1990s. Starting in 2014 Tetra Tech updated this model with the latest available data for sea inflows, elevations, and bathymetry data; recalibrated the model to be consistent with the latest elevation and salinity observations; and used the model to assist various Salton Sea conservation studies. SSAM is a conceptually simple “bucket”-type model guided by water and salt mass balance on an annual timestep. The recent historical elevation of the sea compared to the SSAM calculation is shown in Figure 1.
Appendix F: Greenhouse Gas Emissions

SSM
SSMP
Long-Range Plan

Figure 1. Plot of observed elevation (feet below mean sea level with a NAVD88 datum) and modeled elevation at the Salton Sea. Observed data are from the US Geological Survey and modeled elevations are calculated using the SSAM, given measured inflows over this period.

SSAM was used to establish the future state of the Salton Sea and exposed lakebed. The projected area of the Sea and the exposed lakebed over the 21st century were calculated using the SSAM and are shown in Figure 2. The discontinuity in modeled exposed lakebed area, particularly between 2020 to 2030, reflects the effective reduction in exposed lakebed area following the completion of habitat projects as part of the Phase 1: 10-yr plan. The ensuing GHG estimates are made based on the contributions of the modeled lake and exposed lakebed areas to carbon burial, cycling, and emissions.

Figure 2. Results of a hydrologic model of the Salton Sea (SSAM) showing the decline in lake area during the first half of the 21st century and a corresponding increase in the exposed lakebed area. These model results will be used to scale estimates of carbon burial, cycling, and emissions over time. Note that the discontinuity in modeled exposed lakebed area, particularly between 2020 to 2030, reflects the expected completion of restoration projects.
that will effectively reduce exposed lakebed area. The sum of the exposed playa area and the lake area are constant (953.7 million m² or about 235,000 acres).

1.2.2 Salinity

The Salton Sea is a terminal water body. As there is no outflow, salts and nutrients from continual agricultural and municipal discharge have accumulated and substantially increased the salinity of the Sea. Currently, the Salton Sea is more saline than ocean water (IID, 2022), and the concentration of salt in the Salton Sea increases by a rate of approximately 1% annually (UCANR, 2022). Pronounced evaporation and subsequent shrinking of the water volume will further increase the salinity over time. A plot of salinity over the recent historical period, and the modeled values using SSAM, is shown in Figure 3.

![Figure 3](image-url)  
**Figure 3.** Plot of observed salinity and modeled salinity at the Salton Sea. Observed salinity data are from the US Bureau of Reclamation and modeled salinity were calculated using the SSAM, given measured inflows over this period.

1.2.3 Eutrophication

The continual loading of nutrients from agricultural drainage has also made the Salton Sea a productive saltwater ecosystem that is classified as a “eutrophic to hypereutrophic water body characterized by high nutrient concentrations, high algal biomass as demonstrated by high chlorophyll a concentration, high fish productivity, low clarity, frequent very low dissolved oxygen concentrations, massive fish kills, and noxious odors” (Setmire et al., 2000). Extensive oxygen depletion and the resultant creation of anoxic zones indicate that the biological productivity of the Salton Sea exceeds the capacity of the system to support it (Setmire et al., 2000). Representative data for phosphorus and nitrogen from 2002-2015 are shown in Figure 4 and Figure 5 (Tetra Tech, 2016).
The combination of warming, drying, salinity increases, and eutrophication is expected to influence biological, chemical, and physical processes that take place within the water column and in the lakebed. In turn, these conditions and processes will impact the GHG budget of the Salton Sea.
1.3 Background Information and Assumptions

Inland water bodies are an important component of the global carbon cycle. The quantification of net carbon emissions from lentic (still water bodies including lakes, ponds, and reservoirs), and lotic (flowing water bodies such as rivers and streams) has important implications for regional and global carbon budgets (Clow et al., 2015; Raymond et al., 2013).

Within a lacustrine environment, numerous processes involving carbon take place. Carbon enters lakes from upstream flow, groundwater inputs, atmospheric deposition, or fixation of atmospheric CO₂ by emergent macrophytes (Travnik et al., 2009). Primary production in the surface waters of lakes also sequesters CO₂ in the form of organic carbon. Carbon is lost through inorganic and organic carbon sedimentation, CO₂ efflux to the atmosphere, and downstream flows via streams and groundwater (Travnik et al., 2009). Within the water column, aquatic organisms perform aerobic and anaerobic respiration/oxidation, which release CO₂ and CH₄, respectively, and may even facilitate carbonate formation. At the water-sediment interface, burial of organic and inorganic carbon formed by these organisms occurs. Additionally, microbial decomposition and methanogenesis may occur, thereby releasing some of this sequestered carbon as CO₂ and CH₄. Thus, carbon is continually absorbed, cycled, buried, and emitted. The many carbon processes within a lacustrine environment are represented by input and output arrows shown in Figure 6. Lakes may also act as sources or sinks of nitrous oxide (N₂O), which is produced by nitrification and denitrification (Travnik et al., 2009).

![Figure 6](image-url)  
**Figure 6.** A flow diagram showing the major carbon-involving processes in the Salton Sea ecosystem. The goal of this memo is to estimate the magnitudes of each of these arrows.
To study net GHG emissions from lentic water bodies such as the Salton Sea, background information in this section was used to understand the consumption and production of carbon (in the form of CO₂ and CH₄) and N₂O by microorganisms in the lake system. All processes are mediated by geology, biology, and/or chemistry, and are affected by climate change and human activities in settlements surrounding the Sea, as discussed below.

### 1.3.1 Carbon Inputs

Terrestrial carbon inputs into lake systems vary depending on climate, soil texture, geochemistry, and land use (Travnik et al., 2009). Carbon is transported from the water column to the sediments via flocculation of organic carbon, incorporation into biological material, and sedimentation of particulate organic matter (Travnik et al., 2009). Together, these processes represent a lake’s potential for carbon burial. Presently, lakes are rarely considered in regional terrestrial carbon budget calculations/estimations; however, carbon burial in lacustrine sediments is a significant global long-term carbon sink (Travnik et al., 2009). A national-level analysis of the organic carbon (OC) burial rates shows that water bodies of the conterminous U.S. (CONUS) sequester 20.8 trillion grams of C per year (Tg C/year) and that spatial patterns in OC burial are influenced by factors including water body type, size, and abundance, land use, and soil and vegetation characteristics (Clow et al., 2015).

Estimates of OC burial were developed from literature estimates. Although there are limited sediment data from the Salton Sea, these have not been previously evaluated for OC burial rates. Burial rates of organic and inorganic carbon are usually highest in small, eutrophic lakes where sediment collected from the watershed is retained for extended periods of time and can be mineralized or buried (von Wachenfeldt et al., 2008). OC burial in inland lentic water bodies is studied through field experiments that involve collecting sediment cores and calculating the proportion of organic carbon within the sample while also factoring in estimates of mass accumulation rates, burial efficiency, and other responses to geomorphic, climatic, and land-use/land-cover variables. OC concentrations in such sediment cores have shown high dependence on mean annual air temperature, due to its impact on ecosystem productivity, and on the k-factor of the soil (a measure of soil erodibility), due to how erosion introduces mineral matter to sediments (Clow et al., 2015). The eutrophic state of the Salton Sea system suggests that it has a high potential to bury OC, which will increase with projected increases in mean annual air temperatures. Additionally, reduced inflows over time have created a crusted, low-moisture layer, over 70% composed of sand and silt (Gao et al., 2021). This means that the soil has relatively moderate to high k-factor indicating higher erodibility than fine textured soils composed primarily of clay, for instance (USDA, 2022). However, soil composition is heterogenous around the Salton Sea and may include more clay in some areas (Setmire et al., 1993).

OC burial in lakes/ponds in CONUS has been shown to follow a log-normal distribution with median 31 g C/m²/year and mean 46 g C/m²/year (Clow et al., 2015). Recent increases in carbon sequestration by lakes have been driven by land-cover change, which has in general increased nutrient availability, aquatic productivity, and therefore OC burial in lakes (Anderson et al., 2013). Based on agricultural expansion in California and trends in nutrient loads in the Salton Sea, it is reasonable to conclude that the Salton Sea ecosystem has and will continue to experience similar productivity-boosted OC burial rates. Modern OC burial rates in lakes in the western U.S. are
estimated at 72 g C/m²/year, with lake sediments containing approximately 6.2% carbon (Clow et al., 2015).

Based on these estimates and changes in lake and exposed lakebed area as suggested in Figure 2, OC burial at the Sea was estimated at 0.25 million (M) metric tons of CO₂-eq/year from 1905 to 2004. Following 2004, decreases in lake area were assumed to have decreased OC burial but it was assumed that the burial rate of 72 g C/m²/year remained constant. After 2050, the lake area was modeled to have reached a steady size which will be able to bury approximately 0.17 M metric tons of CO₂-eq/year. Single-year and cumulative estimates of CO₂-eq burial are shown in Figure 7.

Figure 7. Top: Estimated cumulative metric tons of CO₂-eq of OC buried in lacustrine sediments of the Salton Sea. Bottom: Estimated metric tons of CO₂-eq of OC buried per year in lacustrine sediments of the Salton Sea. Both the top and bottom figures were computed using an estimated burial rate of 72 g C/m²/year for lakes in western U.S. (Clow et al., 2015) and based on lake area assumptions and hydrology models used to support the development of Figure 2.
The estimated 72 g C/m²/year burial rate is consistent with OC burial rate observations in eutrophic lakes in Europe, which themselves exhibit burial rates ranging from 60 to 100 g C/m²/year (Anderson et al., 2014). However, a study of OC burial in eutrophic farm ponds in Iowa reveals much greater and highly variable OC burial rates ranging from 148 to 17,000 g C/m²/year (Downing et al., 2008). This latter study includes a multiple regression analysis that considers watershed to lake area ratio and sediment bulk density to estimate OC burial which could be used to refine the OC burial rate estimates for the Salton Sea. However, based on these additional studies, 72 g C/m²/year is a conservative burial rate that can be used to estimate carbon sequestration by the Salton Sea ecosystem. As noted earlier, this estimate is based on a literature evaluation and future fieldwork in the Salton Sea may help develop refined estimates that capture its unique characteristics.

1.3.2 Carbon Outputs

1.3.2.1 Water-Atmosphere Interface

CH₄ is the most important GHG emitted from aquatic systems in terms of climate impacts because CH₄ is about 25 times more potent as a GHG than CO₂ on a 100-year time scale (DelSontro et al., 2018; IPCC, 2013). Total CH₄ flux from a lake includes diffusive and ebullitive flux from the water column. Diffusive flux is the flux rate from water to the atmosphere and is driven by supersaturation in the water column. Ebullitive flux is the flux rate from the formation of bubbles that are transported to the surface. Ebullitive flux is directly related to biological activity in the water column while diffusive flux is mainly mediated by water temperature.

CH₄ emission rates are mostly influenced by the biological productivity of the surface water layer of lakes and reservoirs (ebullitive flux). It is estimated that a three-fold increase in phosphorus loading can cause a two-fold increase in CH₄ emissions rates (Beaulieu et al., 2019). Overall, two mechanisms are expected to increase aquatic productivity of lakes over the 21st Century:

1. Increases in fertilizer use and nutrient runoff from expanding crop-livestock ecosystems, which support increasing populations, and
2. Climate-driven increases in water temperature, which will enhance bacterial decomposition of algae and resultant emission of CH₄.

DelSontro et al. (2018) studied 8,233 aquatic systems (including lakes and impoundments) from 54 different countries to develop a global model to estimate total CH₄ emissions. Variables that were considered include lake size, chlorophyll a concentration (a proxy for biological productivity), and total concentrations of nitrogen and phosphorus (nutrients); however, it was found that the following relationship sufficiently predicted total CH₄ emissions rates from chlorophyll a concentration alone:

\[
\log_{10}(\text{total CH}_4 \text{ emission rate} + 1) = 0.778 \times \log_{10}(\text{chlorophyll } a) + 0.940,
\]

where emissions are in mg C/m²/day and chlorophyll a is in µg/L.

A conservative estimate of total CH₄ emissions assumes that chlorophyll a concentration has and will continue to remain steady at 33.4 µg/L, which was measured in 1999 at the Salton Sea (Robertson et al., 2008). Thus, \( \log_{10} \left(33.4\right) = 1.52 \) and total CH₄ emission rate = -1 + 10 \( 0.778 \times 1.52 + 0.940 \) = 131.61 mg C/m²/day.
Using this estimate and changes in lake and exposed lakebed area as suggested in Figure 2, CH₄ emissions from the Salton Sea were estimated at 0.17 M metric tons of CO₂-eq/year from 1905 to 2004. Following 2004, decreases in lake area were assumed to have decreased CH₄ emissions but it was assumed that the burial rate of 131 mg C/m²/year remained constant. After 2050, lake area was modeled to have reached a new equilibrium which will emit approximately 0.11 M metric tons of CO₂-eq/year (Figure 8).

A more refined approach for computing CH₄ emissions from the Salton Sea since its formation in 1905 would consider the extent to which the Sea’s eutrophic status, biological productivity, and temperature-driven microbial degradation have evolved over time. Estimates of CH₄ emission rates at other lakes can be applied to the Salton Sea by comparing key ecosystem indicators such as change in % agriculture in catchment (indicating land-use change), total phosphorous and nitrogen (indicating runoff), and chlorophyll a concentration (indicating biological productivity). Furthermore, predictions of global land-use change, disruptions of nutrient cycles, and warming climate scenarios can affect burial rate assumptions for future planning.
Chlorophyll a data, indicative of planktonic algae and algal blooms, can be variable over time. Data collected by Reclamation from 2004 to 2015 shows that the chlorophyll a concentration often exceeded 150 µg/L from 2005 to 2007; however, from 2009 to 2015, it was generally around 30 µg/L, suggesting that a concentration of 33.4 µg/L is a valid assumption for at least the last decade (Reclamation, 2007). The cause of this decline is not known, because the overall nutrient status of the Sea still indicates an excess of nutrients.

The diffusive flux of CO₂ from the lake surface can also be estimated. Solubility of GHGs in water changes with temperature. Additionally, surface water turbidity (represented by wind fetch) may stimulate more rapid influx or efflux. In saline lakes, chemical processes, such as carbonate precipitation/dissolution reactions and the chemical enhancement of CO₂ exchange rates due to hydration of atmospheric CO₂ directly to bicarbonates, are more prevalent (Duarte et al., 2008). Thus, saline lakes support higher CO₂ exchange rates with the atmosphere due to the chemistry of the environment. Flux of CO₂ is dependent on surface water pCO₂ (partial pressure of CO₂), surface water temperature, and chemical enhancement of the rate of gas exchange (detailed above). Chemical enhancement alone was shown to increase average CO₂ fluxes by a factor of 2.3 (Duarte et al., 2008). Furthermore, eutrophication may amplify or reverse some of these chemical enhancements due to its effect on the cycling of carbon (Morales-Williams et al., 2021).

The previously established OC burial rate was estimated at 72 g C/m²/year or 16.4 mmol C/m²/day (Clow et al., 2015). Clow et al. (2015) also states that 72% of the estimate for total OC burial in CONUS water bodies (including lakes and reservoirs), is emitted as CO₂ (Clow et al., 2015). 72% of 16.4 mmol C/m²/day is approximately 11.8 mmol C/m²/day.

CO₂ flux computed for 15 shallow, eutrophic lakes in Iowa ranged from −0.01 to 0.05 mol C/m²/day (-10 to 50 mmol C/m²/day) (Morales-Williams et al., 2021), while a study of 196 globally distributed saline lakes shows that CO₂ flux averaged 81 mmol C/m²/day (Duarte et al., 2008). McDonald et al. (2013) specifically studies mean CO₂ flux in the Mediterranean California ecoregion and suggests an estimate of 0.29 g C/m²/day or 24.2 mmol C/m²/day with a 95% confidence interval of 5.8 to 58 mmol C/m²/day, which is largely encompassed by the ranges established by Morales-Williams et al., 2021. These studies show that the Salton Sea, a eutrophic and saline inland water body in Mediterranean California, is most likely a CO₂ net emitter. A flux rate of 58 mmol C/m²/day is used, which is the upper rate of the study by McDonald et al. (2013). Note that this is much higher than the 11.8 mmol C/m²/day suggested by Clow et al. (2015); however, we assume that the effect of eutrophication and salinity on the diffusive flux of CO₂ are masked in such a global study and would most likely be represented by the upper bound for a California-specific study.

Using this estimate and changes in lake and exposed lakebed area as suggested in Figure 2, CO₂ flux from the Salton Sea was estimated at 888,000 metric tons of CO₂/year from 1905 to 2004. Following 2004, decreases in lake area are assumed to have decreased CO₂ flux but it was assumed that the flux rate of 58 mmol C/m²/day remains constant. After 2050, lake area was modeled to have reached a new equilibrium which will emit approximately 610,000 metric tons of CO₂/year (Figure 9).
Figure 9. Top: Estimated cumulative metric tons of CO$_2$ emissions from the lake area of the Salton Sea. Bottom: Estimated metric tons of CO$_2$ emissions per year from the lake area of the Salton Sea. Both the top and bottom figures are computed using an estimated emission rate of 58 mmol C/m$^2$/day (McDonald et al., 2013) and based on lake area assumptions and hydrology models used to support the development of Figure 2.

1.3.2.2 Sediment-Atmosphere Interface

The intermittent or permanent, partial or complete desiccation of inland waters due to climate change, diversion and/or consumptive use of water resources, and other modifications of the water bodies and hydrologic cycle expose previously submerged sediments to the atmosphere (Keller et al., 2020; Marce et al., 2019). Such drying of inland waters allows the oxidation of organic carbon in sediments, thereby releasing carbon into the atmosphere. This carbon flux is largely due to enzymatic activity and microbial growth, which results in the CO$_2$ emissions from dry sediments (Keller et al., 2020; Fromin et al., 2010). The onset of drying stimulates the breakdown of OC and release of CO$_2$ by sediment-dwelling microbes while short re-wetting episodes can trigger microbial respiration and remobilization of OC and nutrients, which releases more CO$_2$ (Marce et al., 2019). Thus, some variables that impact CO$_2$ emissions from dry sediments include moisture, organic matter, and air temperature (Keller et al., 2020).

A global estimate of 320 mmol C/m$^2$/day (minimum of 216 to maximum of 515 mmol/m$^2$/day) can be used for CO$_2$ emissions from the dry sediments of lakes with a permanent or seasonally dry area that exceeds 900 m$^2$ (Marce et al., 2019). This estimate is based on gas chamber sampling of desiccated sediments of lakes and reservoirs in Germany and Spain, representing a
total of 187,542 km² of permanently and seasonally dry area. Alternatively, Keller et al. (2020) studies the CO₂ emissions from dry sediments of lakes based on Köppen-Geiger climate zone – tropical, arid, temperate, continental, and polar. The Salton Sea is in an arid climate zone. Based on the 196 inland water ecosystems studied in Keller et al. (2020), CO₂ flux from dry sediment in arid lakes averaged 623 mmol C/m²/day (minimum of 187 to maximum of 1907 mmol C/m²/day). This contrasts with the global estimate of 320 mmol C/m²/day cited above.

The lake associated with the maximum flux in the arid zone is located at 5 m elevation and experiences annual mean air temperatures of 42°C and 37.7% moisture content. As the Salton Sea is located at low elevation and experiences peak summer air temperatures that are similarly high, we can use 1907 mmol C/m²/day as a worst-case scenario for CO₂ flux from dry sediment.

Based on this estimate and changes in lake and exposed lakebed area as suggested in Figure 2, CO₂ emissions from the exposed lakebed surrounding the Salton Sea can be estimated from 2006 onwards, when exposed lakebed area was non-zero. We also assume that sediment oxidation can take place over a 5 to 20-year time period and that, once oxidized, sediment will not contribute to CO₂ flux.

CO₂ emissions from the exposed lakebed surrounding the Salton Sea under a 5-year oxidation period assumption and under a 20-year oxidation period assumption are shown in Figure 10 and Figure 11, respectively.

![Figure 10](image-url) **Figure 10.** Top: Estimated cumulative metric tons of CO₂-eq of CO₂ emissions from dried lacustrine sediments surrounding the Salton Sea under an assumed 5-year oxidation period. Bottom: Estimated metric tons of CO₂-eq of CO₂ emissions from dried lacustrine sediments surrounding the Salton Sea. Both the top and bottom figures were computed using an estimated emission rate of 1907 mmol C/m²/day (Keller et al., 2020) and based on lake area assumptions and hydrology models used to support the development of Figure 2.
The CO₂ flux estimates for the drying lakebed surrounding the Salton Sea can be refined by using a model based on a global study of lakes. A closed chamber gas analysis of samples of desiccated sediment from 196 drying water bodies shows that CO₂ emissions rates from dry inland lakes or reservoirs is around 207 mmol/m²/day with a global standard deviation of 405 mmol/m²/day (Keller et al., 2020). This means that while most dry sediments are net emitters of CO₂, some sediments may still be net absorbers of CO₂ from the atmosphere. Supporting in situ measurements of moisture, conductivity, and air temperature, local elevation and latitude can be used to refine the CO₂ flux estimate for the Salton Sea using the following linear mixed effects model developed by Keller et al., 2020:

\[
F(\text{CO}_2) = -0.22 \times \text{Elevation} + 0.25 \times \text{Latitude} - 0.14 \times \text{Conductivity} + 0.3 \times \text{Temperature} + 0.4 \times \text{Moisture} + 0.3 \times \text{Organic Matter} + 0.23 \times (\text{Moisture} \cdot \text{Organic Matter}) + 0.12 \times (\text{Moisture} \cdot \text{Temperature}) + 0.04,
\]

where variables are log₁₀- and z-transformed.
Not considered in this analysis are CH$_4$ emissions from shallow, oxygenated sediments due to methanogenic bacterial respiration. This is because we assume that the Salton Sea is largely anoxic owing to its eutrophic to hypereutrophic status. However, some findings indicate that surficial sediments are key to understanding CH$_4$ dynamics and fluxes of whole lake CH$_4$ budgets (Bastviken et al., 2008). At the same time, algal productivity provides a source of labile carbon to stimulate CH$_4$ emission under anoxic conditions via methanogenesis (Beaulieu et al., 2018). Thus, an assessment of such CH$_4$ emissions could further affect the future GHG budget of the shrinking and drying Salton Sea, especially since CH$_4$ has a higher global warming potential than CO$_2$ and since methane production rates are enhanced by temperature, which itself is projected to increase due to climate change. The data to do this evaluation at present are not available at the Sea, but future study is recommended if a more refined GHG estimate is desired.

### 1.3.3 Nitrous Oxide Emissions

N$_2$O is an immediate product of denitrification (reduction of NO$_3^-$ to N$_2$) and by-product of nitrification (oxidation of NH$_4^+$ to NO$_3^-$) (Woszczyk and Schubert, 2021). Thus, flux of N$_2$O is correlated with availability of oxygen and nitrates, and with temperature of the water column. N$_2$O flux from lakes is not well studied. A study of lakes in the Colorado Rocky Mountains shows that N$_2$O flux from high-deposition lakes (i.e. receiving 5 – 8 kg N/ha/year) varied from 0.8 to 6.4 µmol N/m$^2$/hour (0.308 to 2.47 g N$_2$O/m$^2$/year) (McCrackin and Elser, 2011). Therefore for a eutrophic lake such as the Salton Sea that is influenced by agricultural drainage, the upper limit of 2.47 g N$_2$O/m$^2$/year can be used. For comparison, in the south Baltic coastal lakes, N$_2$O flux is estimated at 0.269 g N$_2$O/m$^2$/year (Woszczyk and Schubert, 2021). This is lower than the lower limit cited above. There is little data on N$_2$O flux from warmer lakes, so we use 2.47 g N$_2$O/m$^2$/year as a conservative estimate for the Salton Sea. Figure 12 shows the cumulative and annual emission of N$_2$O from the lake surface.
Figure 12. Top: Estimated cumulative metric tons of CO₂-eq of N₂O flux from the lake area of the Salton Sea. Bottom: Estimated metric tons N₂O flux per year from the lake area of the Salton Sea. Both the top and bottom figures were computed using an estimated emission rate of 2.47 g N₂O/m²/year (McCrackin and Elser, 2011) and based on lake area assumptions and hydrology models used to support the development of Figure 2.

1.4 Summary of Reference Values

Tables 1 and 2 summarize the sources of reference values that were used to understand the GHG budget of the Salton Sea.
**Table 1.** COLUMN 1: Sources of background information that were used to compute the GHG budget of the Salton Sea; COLUMN 2, 3, 4: The GHG process that can be estimated based on information gathered from the source and its contribution (either + or -) to the GHG budget; COLUMN 5, 6, 7: Estimated rates of input or output from the system based on the information gathered, converted to a variety of units to allow for comparison across studies.

<table>
<thead>
<tr>
<th>Sources</th>
<th>GHG Process</th>
<th>mmol C/m²/day</th>
<th>g C/m²/year</th>
<th>g CO₂-eq/m²/year</th>
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<tbody>
<tr>
<td>Clow, et al. (2015)</td>
<td>Carbon Burial (+)</td>
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<td>Eutrophication</td>
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<tr>
<td>Keller, et al. (2020)</td>
<td>CO₂ Emissions (-)</td>
<td>Drying</td>
<td></td>
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<tr>
<td>McDonald, et al. (2013)</td>
<td>CO₂ Emissions (-)</td>
<td>Open Water Diffusive Flux</td>
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<td>McCrackin and Elser (2011)</td>
<td>N₂O Emissions (-)</td>
<td>mmol N₂O/m²/day</td>
<td>g N₂O/m²/year</td>
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</tbody>
</table>

**Table 2.** The same information as in Table 1 but with the values from the sources converted into different units and filled out in COLUMN 5, 6, 7. NOTE: for CO₂ emissions from open water diffusive flux, a range of values suggested by McDonald et al., 2013 is provided along with a mean value that is suitable for California. This is to illustrate the relatively high uncertainty in emission rates associated with this process.

<table>
<thead>
<tr>
<th>Sources</th>
<th>GHG Process</th>
<th>mmol C/m²/day</th>
<th>g C/m²/year</th>
<th>g CO₂-eq/m²/year</th>
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<td>N₂O Emissions (-)</td>
<td>mmol N₂O/m²/day</td>
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<td>2.47</td>
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*factor for global warming potential*
1.5 GHG Budget of the Salton Sea Per Year (until 2100) and To Date (from 1905)

Plotting cumulative emissions for the Phase 1: 10-Yr Plan concept in CO$_2$-eq from CO$_2$, N$_2$O, and CH$_4$ open water flux shows that CO$_2$ and N$_2$O are similarly important contributors to the Salton Sea’s GHG budget (Figure 13). GHG emissions from open water are calculated from the sum of the wetted surface of the Sea and 10-year plan projects.

![Graph showing cumulative emissions of CO$_2$, CH$_4$, and N$_2$O for the Phase 1: 10-Yr Plan concept.](image)

**Figure 13.** Cumulative emissions of CO$_2$, CH$_4$, and N$_2$O for the Phase 1: 10-Yr Plan concept in units of metric tons of CO$_2$-eq. Note that CH$_4$ has a global warming potential that is 25x that of CO$_2$, and N$_2$O has a global warming potential that is 298x that of CO$_2$ on a 100-year time scale (IPCC, 2013). For comparison across global warming potentials, y-axis units are in metric tons of CO$_2$-eq.

For a per annum understanding of the Salton Sea GHG for the Phase 1: 10-Yr Plan concept, see Table 3 to compare estimates of OC burial, CO$_2$ emissions from the oxidation of the exposed lakebed, CH$_4$ emissions, and diffusive flux of CO$_2$ and N$_2$O from the lake water surface. For cumulative estimates since the formation of the Salton Sea since 1905, see Table 4.
Table 3. For the Phase 1: 10-Yr Plan concept, annual estimates of OC burial, CO<sub>2</sub> emissions from the oxidation of the exposed lakebed, CH<sub>4</sub> emissions, and diffusive flux of CO<sub>2</sub> and N<sub>2</sub>O from the lake water surface in 2000, 2030, 2050, and 2100. Units are in metric tons of CO<sub>2</sub>-eq per year unless otherwise stated.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Carbon Burial</th>
<th>Drying from Exposed Lakebed</th>
<th>Eutrophication (diffusive + ebullitive)</th>
<th>Diffusive Flux from Lake Water Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (assuming 5-year Oxidation)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (assuming 20-year Oxidation)</td>
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<tr>
<td>2000</td>
<td>0.25 M</td>
<td>0</td>
<td>0</td>
<td>0.17 M</td>
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<td>2030</td>
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</tr>
<tr>
<td>2050</td>
<td>0.18 M</td>
<td>0.12 M</td>
<td>0.21 M</td>
<td>0.12 M</td>
</tr>
<tr>
<td>2100</td>
<td>0.18 M</td>
<td>0</td>
<td>0</td>
<td>0.12 M</td>
</tr>
</tbody>
</table>

Table 4. For the Phase 1: 10-Yr Plan concept, cumulative estimates of OC burial, CO<sub>2</sub> emissions from the oxidation of the exposed lakebed, CH<sub>4</sub> emissions, and diffusive flux of CO<sub>2</sub> and N<sub>2</sub>O from the lake water surface by 2000, 2010, 2020, 2030, 2050, and 2100. Units are in metric tons of CO<sub>2</sub>-eq to date (i.e., since 1905).

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Carbon Burial</th>
<th>Drying</th>
<th>Eutrophication (diffusive + ebullitive)</th>
<th>Diffusive Flux from Lake Water Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (assuming 5-year Oxidation)</td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (assuming 20-year Oxidation)</td>
</tr>
<tr>
<td>2000</td>
<td>24.2 M</td>
<td>0</td>
<td>0</td>
<td>16.2 M</td>
</tr>
<tr>
<td>2010</td>
<td>26.7 M</td>
<td>0.29 M</td>
<td>0.073 M</td>
<td>17.9 M</td>
</tr>
<tr>
<td>2020</td>
<td>29.0 M</td>
<td>2.2 M</td>
<td>0.89 M</td>
<td>19.5 M</td>
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<tr>
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<td>2050</td>
<td>35.2 M</td>
<td>8.1 M</td>
<td>6.1 M</td>
<td>23.6 M</td>
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<tr>
<td>2100</td>
<td>44.1 M</td>
<td>9.2 M</td>
<td>8.4 M</td>
<td>29.6 M</td>
</tr>
</tbody>
</table>
1.6 Conclusion

Based on the assumptions made and references consulted in Sections 3 and 4, we can estimate that by 2000, the Salton Sea sequestered 24.2 M metric tons of CO$_2$-eq of carbon, while emitting 85.3 M metric tons as CO$_2$, 16.2 M metric tons as CH$_4$, and an additional 67.4 M metric tons CO$_2$-eq of N$_2$O from open water flux. This means that the Salton Sea increased the global warming potential of the atmosphere, when measured in terms of CO$_2$-eq. This is consistent with global findings as an estimated 90% of aquatic ecosystems studied emit CO$_2$ to the atmosphere, showing that lakes are significant global and regional CO$_2$ emitters (Kling et al., 1992; Cole et al., 1994; Cole et al., 2007). Warmer lakes also emit more CO$_2$ than comparable cooler lakes (Kosten et al., 2010).

Furthermore, estimated CH$_4$ emissions from the Salton Sea are amplified due to eutrophication. Methane is a major product of carbon metabolism in lakes (Bastviken et al., 2008). Studies show that CH$_4$ emissions from lakes account for 6-16% of global non-anthropogenic emissions and that reservoirs account for 18% of global anthropogenic emissions (Bastviken et al., 2004; St. Louis et al., 2000). Currently, GHG emissions from lakes are equivalent to ~20% of global fossil fuel emissions, and even moderate levels of enhanced eutrophication could increase the atmospheric effect of GHG emitted from lakes (measured as CO$_2$-eq) by 5, 26, or 42% based on increases in chlorophyll $a$ concentration by 1, 5, or 10 µg/L (DelSontro et al., 2019). Due to the magnitude of such changes, a refined estimate of CH$_4$ emissions to date and in the future would benefit from higher resolution observations of chlorophyll $a$ concentration at the Salton Sea.

We estimate that by 2020, an additional 0.89 to 2.2 M metric tons CO$_2$-eq of CO$_2$ had been emitted following the slow oxidation of an increasing exposed lakebed area, depending on the oxidation timeline (i.e., a 20- to 5-year process timeline). From 2050 to 2100 for the Phase 1: 10-Yr Plan concept, assuming that the Salton Sea’s lake and exposed lakebed areas stabilize, carbon burial rates will plateau at 0.18 M metric tons of CO$_2$-eq/year while emissions of N$_2$O and CO$_2$ will be at least 0.50 and 0.64 M metric tons of CO$_2$-eq/year, respectively. CH$_4$ emissions from the lake are less significant than emissions of N$_2$O and CO$_2$ but would equal at least 0.12 M metric tons of CO$_2$-eq/year.

Total emissions from the lake surface would therefore be at least 1.28 M metric tons of CO$_2$-eq/year by 2050, by which time oxidation of the exposed sediment would have contributed an additional 6.1 to 8.1 M metric tons CO$_2$-eq of CO$_2$. 
1.7 References


Imperial Irrigation District 2022. https://www.iid.com/water/salton-sea#:~:text=As%20a%20terminal%20waterbody%2C%20the%20Salton%20Sea%20has,salinity%20concentrations%20are%20significantly%20higher%20than%20ocean%20water.

University of California Agriculture and Natural Resources 2022. Salton Sea and Salinity. https://ceimperial.ucanr.edu/Custom_Program275/Salton_Sea_and_Salinity/?sharing=yes#::text=Colorado%20River%20water%20salinity%20is%20about%20650-700%20mg%2F,L,is%20approximately%20four%20million%20tons%20of%20salts%20annually.


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Acronyms
AF  acre-feet  
AFY  acre-feet per year  
BTU  British thermal unit  
Cu-Ni  Copper-Nickel  
ft  feet  
gpd  gallons per day  
gpm  gallons per minute  
HDPE  High-density polyethylene  
kgallon  kilogallon  
kW  kilowatts  
kWh  kilowatts per hour  
lb  pound  
lb/h  pound per hour  
LRP  Long-Range Plan  
MED  multi-effect distillation  
MGD  million gallons per day  
NaCl  sodium chloride  
NDP  net driving pressure  
NF  nanofiltration  
ppb  parts per billion  
ppm  parts per million  
Psi  pounds per square inch  
RO  Reverse Osmosis  
SHC  Saline Habitat Complex  
TDS  total dissolved solids  
TVC  thermal vacuum compressor  
UF  ultrafiltration  
VTE-MED  vertical tube evaporators – multi-effect distillation  
ZLD  zero liquid discharge
Appendix G: Investigation of Desalination Methods

As part of the Long-Range Plan (LRP), desalination methods are being investigated as a means to lower the salinity of the Salton Sea and to re-establish the diversity and abundance of wildlife at the Sea. Two approaches have been considered:

- **Conventional Reverse Osmosis (RO) or other similar processes.**
- **The Salton Sea Water Recycling process proposed by Sephton Water Technology**, which includes salinity reduction through distillation and other components to make a complete restoration concept for the Salton Sea (including additional groundwater supply, treated water conveyance, and brine ponds for evaporation of residual brines from the desalination system).

Each of these two alternatives is discussed below. Cost analyses described in this appendix were prepared by Tetra Tech engineers, working under contract to the California Department of Water Resources.

### 1.1. Reverse Osmosis

In the RO process, high feed water pressure drives the water through semi-permeable membranes, producing permeate water and leaving the salts on the feed side of the membranes as a concentrate. The concentration of salts in the RO concentrate depends on the rate of conversion of the feed water to permeate (recovery rate). The seawater RO systems usually operate at a recovery rate of ~50%. At this rate of recovery, the flow rate of the concentrate is about 50% of the flow rate of the feed flow, and salt concentration will be about twice the concentration of salts in the feed water.

Producing permeate water of low salinity from high salinity feed water requires the feed pressure, at any point of the RO membrane unit, to be higher than the osmotic pressure of the water on the feed side of the membrane. For effective operation of a seawater RO system, the pressure of the concentrate stream leaving the RO membrane unit should be at a minimum of 50 pounds per square inch (psi) higher than the osmotic pressure of the concentrate stream. This pressure differential, between feed pressure and osmotic pressure, is called the net driving pressure (NDP). The osmotic pressure of the water solution is directly proportional to the concentration of dissolved salts. The salinity of the Salton Sea water is reported as about 75,000 parts per million (PPM). This salinity corresponds to an osmotic pressure of about 800 psi.

The operation of a conventional commercial seawater RO system is limited by the allowable feed pressure, not exceeding 1,200 psi. Considering the required NDP of 50 psi, at the concentrate exit from the RO unit, the salinity of the concentrate should not be higher than about 110,000 PPM. This is to maintain the osmotic pressure of the concentrate below 1,150 psi.
Starting with feed seawater of salinity 75,000 PPM, the limit of 110,000 PPM salinity of the concentrate stream (corresponding to 1,150 psi osmotic pressure), would limit the recovery rate of the RO process, treating feed water from Salton Sea, to about 30%.

With the expected increase of water salinity in the Salton Sea, the rate of conversion of Salton Sea feed water to permeate, would have to be reduced in the future.

New, semi-commercial, ultra-high pressure RO membrane modules are being introduced to the market. These membrane elements have a feed pressure limit of about 1,700 psi. Operation of the RO unit at a feed pressure of 1,700 psi would allow concentrate stream salinity up to about 150,000 PPM. This higher limit of concentrate concentration would allow operation of the RO unit, treating a feed water salinity of 75,000 PPM at a recovery rate of about 50%. With a feed salinity of 100,000 PPM, the recovery rate would have to be reduced to about 35%, and if a higher salinity occurred, the recovery rate would have to be reduced to an even lower value.

The recovery rate of the desalination process strongly affects the economics of water production. A lower recovery rate would result in a proportionally higher flow rate of feed water pumped from the Sea, which would increase the size of the pretreatment system, the power consumption, usage of water treatment chemicals, and the size of the system required to treat the process wastewater. The seawater RO desalination plant at Carlsbad, CA, which operates at a 50% recovery rate, treats seawater at a salinity of about 35,000 PPM total dissolved solids (TDS), produces potable water at a price of about $2,000/(acre-feet) AF.

The product water from an RO system that would treat Salton Sea water of salinity of 75,000 – 100,000 PPM at a recovery rate of ~30% would be significantly more expensive than the one produced by the Carlsbad desalination plant. Therefore, the application of RO technology to desalinate the Salton Sea saline water does not appear to be economically feasible. Furthermore, with the possibility of inflows to the Sea being reduced further by droughts and climate change, the feed water salinity could exceed 110,000 PPM, which would exceed the accepted technical limit of the RO process.

It is therefore not recommended that RO desalination of Salton Sea water as a restoration concept be considered further unless there are technology improvements in the RO process that would make treating very high salinity water feasible.

1.2. Salton Sea Water Recycling Proposal (Sephton Water Technology)

Sephton Water Technology developed a complete proposal for restoration of the Salton Sea, which uses desalination as a core component. The evaluation of this proposal was performed as follows:

- The process of treating highly saline water from the Salton Sea to produce very low salinity water was described conceptually in the proposal (1).
- Some process steps, necessary for plant operation were omitted from the process description, as are some process parameters. This evaluation provides a review and an independent cost estimate of the system, adding in process steps that would be considered essential for a reasonably complete desalination system. The analysis was focused primarily on the desalination component of the restoration, recognizing that the
overall restoration concept proposed includes other components related to the management of the Salton Sea.

- The desalination equipment cost estimate presented here was prepared based on prices from recently received equipment quotes, cost parameters derived from equipment prices of recent desalination projects and economic information published by the US Bureau of Reclamation for similar processes. The values of system cost and product water cost provided in the process description in Reference (1) were significantly lower than this estimation.

- The overall cost estimate provided by Sephton Water technology includes a line item for a water distribution pipeline of $240 million. The proposal also includes a 50,000 acre-foot per year (AFY) groundwater supply, but no cost or other detail information was provided for this source of water. To address this gap, a capital and operating cost estimate was developed using reasonable estimates for well installation, pumping, and conveyance, as summarized in this appendix.

- A cost item was also added to account for the construction of the brine evaporation ponds that would be needed to manage the outflow from the desalination system.

The Salton Sea Water Recycling Proposal by Sephton Water Technology is focused on the removal of the salt from the saline Salton Sea water and the recovery of pure water. The treatment process outlined in the proposal Reference (1) has been reproduced in Figure 1. The objective of the treatment process is to remove divalent ions from the Salton Sea water, using nanofiltration (NF) membranes. The NF permeate is proposed to be concentrated using vertical tube evaporators – multi-effect distillation (VTE-MED) units to produce pure sodium chloride (NaCl) salt and very low salinity water as a distillate. The distillate is proposed to be returned to the Salton Sea to create low-salinity areas in this body of water.

The process consists of a combination of different commercial water treatment technologies that are expected to work individually. However, combining these technologies into one operating system may create significant challenges for process integration. Except for the VTE–MED equipment that is described in some detail in the Sephton Water Technology proposal, other plant equipment and treatment processes are described in broad terms, without the engineering details and without listing relevant process parameters. Some plant equipment (the water intake, for example) was missing essential components. Other, important plant subunits were omitted completely and not accounted for in the plant budget. For example, the solids management system, required for treating of the filtration system backwash water and sludge from lime precipitation unit, was not included in the system description and system cost in the document provided for review. Another example is the cooling water flow, essential for operation of the VTE–MED system, which was indicated on the schematic flow diagram (Figure 1, Reference 1), but the seawater cooling flow rate was not included in the process flow balance and calculation of the total recovery rate. Chemical storage and dosing systems were also omitted.

All the equipment prices, listed in the Sephton Water Technology proposal in Reference (1), are significantly lower than the equipment prices derived from recent and historical quotes or what would generally be considered as acceptable in the commercial desalination field.
1.2.1. Process recovery rate

The process concept, showing the relevant flow rate was included in the Sephton Water Technology proposal (1), Figure 1. According to this flow diagram, 20,000 AF of water will be pumped from the Salton Sea to produce 6,992 AF + 1,425 AF of low salinity water, which will be returned to the Salton Sea. Accordingly, the process recovery rate will be about 42%, 8,417/20,000 = 0.42085.

Therefore, based Figure 1, a system that would produce 20 million gallons per day (MGD) of low salinity water, would require pumping of 47.5 MGD of water from the Salton Sea. In this evaluation of the process proposed by Sephton Water Technology, we applied parameters for modern membrane filtration processes that would reduce the rate of feed water required for the process to 30.7 MGD (for production of 20 MGD of low salinity water). The result was an increase of the overall process recovery rate to 65%. Without accounting for this process optimization, developed by Tetra Tech, the power requirement for the process proposed by Sephton Water Technology would be significantly higher per unit of water produced.

More recent correspondence from Sephton Water Technology, after the submission of the original proposal in April 2022, includes a suggestion that the overall system process recovery rate should be the same as the recovery rate for the VTE-MED system, which was proposed to be 86%. This would assume that the VTE-MED treats Salton Sea water without any pretreatment.
However, the process flow diagram provided by Sephton Water Technology, reproduced in Figure 1, shows additional treatment steps, prior to VTE–MED: media filtration and membrane filtration. Operation of each of these steps would result in water loss for backwash of media filtration and membrane filtration units in addition to some water loss for membrane cleaning. In addition, there would be some water loss in the calcium sulfate precipitation unit. The combined raw water losses would be close to 35%.

Another component of water use, essential in evaporation desalination systems, is the cooling water for reducing temperature of the water vapor in the last evaporation stage. The process diagram showed in Figure 1 indicates cooling loops, but the cooling water was not included in the calculation of the system recovery rate provided by Sephton Water Technology (1). Including seawater usage in the cooling loop would reduce the value of the calculated process recovery rate.

1.2.2. Sizing of the equipment components

In the updated cost estimation provided by Sephton Water Technology, there is a reduction of the size of the ultrafiltration (UF) and NF units according to an assumed higher recovery rate. In the last set of calculations provided, the UF system would produce a filtrate flow of 22.7 MGD. This flow is the feed to the combined system consisting of a number of NF units and VTE-MED units. According to the flows listed in Figure 1, the VTE system would operate at a recovery rate of 84.2% (10,000 AFY Salton Sea UF filtrate converted to 8,417 AFY of low salinity water). Accordingly, a 22.7 MGD of UF filtrate as a feed to the VTE-MED system would be capable of producing 19 MGD of low salinity water, or only 95% of the designed daily flow capacity of the low salinity product water.

1.2.3. Calculation of the electric power requirement and geothermal steam requirement for the proposed process

In the last submittal by Sephton Water Technology, the electric power requirement was adjusted according to their assumption of a higher recovery rate for the process. As explained above, this assumption is incorrect, and the electric power requirement should be updated. In Reference 2, the Sephton Water Technology submittal lists the geothermal steam requirement for the 20 MGD VTE–MED system as 120,000 pounds per hour (lbs/hr) at a temperature of 403°F, at a price of $0.0045/lb, calculated as an annual cost of $4,493,880. This amount was added to the annual operating cost. However, 403°F steam could be used effectively for the generation of electric power. The amount of geothermal steam, listed as required by the VTE–MED system, has the capability to produce 67,907,520 kilowatts per hour (kWh) of electricity annually. At the electric rate price of $0.12/kWhr this would amount to an annual cost of $8,148,902. If this electric equivalent value of geothermal steam cost was be used, the total water cost produced by the system proposed by Sephton Water Technology would increase by about $300/AF.

Another issue is the very high thermal performance efficiency assumed by Sephton Water Technology for the proposed VTE–MED system. The listed use of 120,000 lb/h of geothermal steam to produce 20 MGD of distillate (2), is equivalent to a Gain Output Ratio of 58 lb water/lb of steam. Two recently built MED units at Marafiq (Saudi Arabia), which have 7 MGD capacity each, have a Gain Output Ratio of 12.4 lb water/lb of steam (3). These MED units utilize a thermal vacuum compressor (TVC) to improve thermal performance of the MED units. The TVC unit has
not been included in the Sephton Water Technology proposal. The largest MED unit in the world is Shoaiba 2 (Saudi Arabia), built by Sasakura in 2018. The MED system has a distillate capacity of 24 MGD capacity with 10 thermal effects and the Performance Ratio of 14.6 lb distillate/1,000 BTU (British thermal unit) (3). By comparison, the energy provided by the geothermal steam listed by Sephton Water Technology as a sufficient energy source for production of 20 MGD of distillate (2) is equivalent to a Performance Ratio of 69.4 lb distillate/1,000 BTU. The above listed MED units (Marafiq and Shoaiba) operate at significantly less demanding process parameters (lower feed and concentrate salinity, lower recovery ratio) than the designed process conditions of the VTE-MED unit, proposed by Sephton Water Technology. Their thermal efficiency is much lower than the thermal efficiency projected for the future VTE-MED system, which will concentrate a very high salinity Salton Sea feed.

Clearly, there is a significant gap between the thermal efficiencies of the modern commercial thermal desalination units and the VTE-MED system proposed by Sephton Water Technology.

1.2.4. System Cost Provided by Sephton Water Technology

The total cost of the VTE-MED 60-effects unit designed to produce 20 MGD of distillate is listed as $30.64 M (in the Section: Cost Basis of Water and Salt Treatment Facilities, Reference 1, Figure 290. The total plant cost for production of 20 MGD distillate (VTE-MED cost plus additional construction-related costs) is provided by Sephton Water Technology as $49.85 M (Reference 1, Page 37). According to Reference (1), this amount will cover equipment and plant construction.

1.2.5. Revised VTE-MED System Cost Prepared by Tetra Tech

The cost estimation for the desalination system was limited to the equipment cost and the relevant miscellaneous cost items. The cost for development of the site infrastructure and providing necessary utilities was not included. To estimate the cost for the plant site preparation and construction work would require detailed specification of the site, development of plant layout, and survey of the local conditions (soil conditions, availability of electric power connections, waste disposal lines, etc.). Thus, the cost estimates provided below are a subset of the total costs that may be required to implement a desalination system for the proposed scale.

In the Sephton Water Technology submittal, the cost of a 20 MGD VTE-MED is listed at the initial value of $49,849,315. In comparison, the system cost estimated by Tetra Tech is $213,091,023. The Tetra Tech estimation of the VTE-MED cost is based on the cost information included in the “Brine-Concentrate Treatment and Disposal Options Report, Southern California Regional Brine-Concentrate Management, Study – Phase I, Lower Colorado Region, US Bureau of Reclamation (October 2009),” Reference 4. The Reclamation document lists the cost of a 5 MGD capacity brine concentrator. This cost was scaled up according to an empirical relationship, included in the report as a function of system capacity, and adjusted for the price escalation from 2009 to 2022 (6).

According to the experts in the field of the zero liquid discharge (ZLD) applications, the largest brine concentrator units operating in the U.S. are in the range of 1-1.5 MGD. Also, in their opinion, the cost of brine concentrators listed in the Reclamation report are in the correct range for the market prices for this type of equipment. The summary of costs of brine concentrator
units is shown in Figure 2. This figure was provided by Mike Mickley, Ph.D., an internationally recognized expert in ZLD applications.

![Figure 2. Brine Concentrators Equipment Cost and Year of Construction (Data source: M. Mickley)](image)

The Sephton Water Technology installation cost for a 20 MGD VTE-MED ($49.85M) is similar to the 2009 cost of a 5 MGD brine concentrator, listed in the Reclamation report (4). Applying the index of the equipment cost increase from 2009 to 2022, the proposed cost of the VTE-MED 20 MGD unit would be about 60% lower than the cost of a 5 MGD brine concentrator, as published in the Reclamation report. Alternatively, for a VTE-MED 20 MGD system, the cost developed by Sephton Water Technology is only about 22% of the cost of the system derived from the Reclamation report data.

Another reference point could be the cost of regular MED systems used for desalination of seawater. The estimated cost of such systems manufactured from relatively inexpensive aluminum alloy is about $6/gallons per day (gpd) (8). Applying this cost to the system capacity of 20 MGD, a MED unit would result in a system cost of $120M. The estimated cost of MED systems consisting usually of 10-15 effects and using aluminum as the material of construction is significantly higher than the cost of the VTE-MED equipment, constructed from stainless steel and Copper-Nickel (Cu-Ni) alloys and consisting of 60 effects, provided by Sephton Water Technology.

Currently, the largest commercial MED unit is the Shoiba 2 unit with a capacity of 24 MGD and 10 thermal effects. No commercial MED unit with more than 15 thermal effects has been built and is operational (9).

Yet another issue related both to system cost and durability is the selection of construction materials. The Sephton Water Technology proposal lists stainless steel and Cu-Ni alloy as construction material for VTE-MED. These construction materials are adequate for an evaporation system producing distillate from seawater with salinity in the range of 35,000 – 45,000 PPM. In the case of the Salton Sea seawater, the inlet feed salinity is much higher, and the outlet brine salinity is at saturation. This level of salinity is very corrosive and more resistant alloys would be required as construction material for the system to operate reliably for a period of 20–
Appendix G: Investigation of Desalination Methods

Working Draft

30 years (7). For example, in brine concentrators manufactured by a commercial developer, RCC Thermal Products, which operate at a similar salinity range as the system proposed to treat Salton Sea seawater, the system components in contact with the high salinity brine are made exclusively from titanium alloy. These components include evaporators and heat exchangers (10, 11).

Additional supporting information regarding proper construction materials for the proposed application was received from the Nickel Institute (12). For treatment of water with a salinity in the range of the Salton Sea feed and system brine, the recommend alloy is Titanium grade 7 or 16. Some nickel alloys can be used but only if the feed water is fully de-aerated with dissolved oxygen concentration below 20 parts per billion (ppb). The process proposed by Sephton Water Technology does not include a deaeration step.

Based on the multiple factors above, the higher cost estimate for the VTE-MED system developed by Tetra Tech, as compared to the original Sephton Water Technology estimate (1), is considered justified. The results of calculation of the plant cost are summarized in Table 1.

### Table 1. Summary of Plant Cost Components

<table>
<thead>
<tr>
<th>System cost item</th>
<th>Flow rate or number of units</th>
<th>Equipment or system cost</th>
<th>Cost references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salton Sea intake flow, mgd</td>
<td>30.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salton Sea intake flow, gallons per minute (gpm)</td>
<td>21,296</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wedge screen heads + air burst</td>
<td>2</td>
<td>657,065</td>
<td>Johnson Screen quote 2022 (14)</td>
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<tr>
<td>Required minimum water depth, feet (ft)</td>
<td>10</td>
<td></td>
<td>Jonson screen specifications (14)</td>
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<tr>
<td>Intake screens weight, lb</td>
<td>10,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake barge</td>
<td></td>
<td>659,782</td>
<td>Poseidon Barge Quote (15)</td>
</tr>
<tr>
<td>Intake barge installation and modifications for intake function</td>
<td>500,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake pumps, gpm</td>
<td>21,296</td>
<td>1,991,493</td>
<td>From quotes for SWRO plant at Carlsbad (2009) multiplied by CCCI 1.667 (6)</td>
</tr>
<tr>
<td>Electric power supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake HDPE pipe, diameter, inches</td>
<td>48</td>
<td></td>
<td>Sephton Water Technology process concept</td>
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<tr>
<td>Intake pipe length, ft</td>
<td>5,280</td>
<td></td>
<td>Tom Sephton, Appendix_O_DesalPLant Seawater Intake Cost (13)</td>
</tr>
<tr>
<td>Intake pipe weight (111 psi), lb/ft</td>
<td>158.5</td>
<td></td>
<td>Jim Eagle catalog, page 10 (16)</td>
</tr>
<tr>
<td>Intake pipe total weight lb</td>
<td>836,880</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDPE polymer price, $/t</td>
<td>1,216</td>
<td></td>
<td>Global HPDE prices 2022 (17)</td>
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<tr>
<td>Additional components and installation, $/lb</td>
<td>1.0</td>
<td></td>
<td>Intake pipe components, intake pipe weights, connecting pipe segments and installation</td>
</tr>
<tr>
<td>System cost item</td>
<td>Flow rate or number of units</td>
<td>Equipment or system cost</td>
<td>Cost references</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>-----------------------------</td>
<td>--------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pipe placement and securing, $/lb</td>
<td>0.5</td>
<td></td>
<td>Placement of intake pipe and securing to sea floor, connecting to barge</td>
</tr>
<tr>
<td>Total intake pipe cost, $/lb</td>
<td>2.05</td>
<td>1,717,331</td>
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<tr>
<td>Beach crossing and siphon</td>
<td>1.0</td>
<td>1,500,000</td>
<td>Estimation from previous projects</td>
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<tr>
<td>Total intake</td>
<td>1.0</td>
<td>7,025,671</td>
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</tr>
<tr>
<td>Multimedia filtration feed, mgd</td>
<td>36.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multimedia filtration effluent, mgd</td>
<td>33.3</td>
<td>9,975,739</td>
<td>Based on media filtration system cost of $0.3/gpd</td>
</tr>
<tr>
<td>Filtration rate, gpm/ft²</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtration area required, ft²</td>
<td>8,553</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of filter cells</td>
<td>12.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UF membrane filtration feed, mgd</td>
<td>33.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UF membrane filtration effluent, mgd</td>
<td>29.9</td>
<td>13,467,248</td>
<td>Based on membrane filtration system cost of $0.45/gpd</td>
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<tr>
<td>UF filtration flux, gfd</td>
<td>45.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of UF elements</td>
<td>1,209</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st pass NF feed, mgd</td>
<td>29.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st pass NF permeate, mgd</td>
<td>27.17</td>
<td>32,608,696</td>
<td>Based on NF system equipment cost of $1.2/gpd</td>
</tr>
<tr>
<td>Average permeate flux rate, gfd</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of membrane elements (440 ft²)</td>
<td>4,117</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of pressure vessels (7 M)</td>
<td>588</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NF concentrate flow, mgd</td>
<td>2.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NF concentrate seeding system, mgd</td>
<td>2.75</td>
<td>42,284,646</td>
<td>Reference 4, price increase factor 1.667 CCCI (6)</td>
</tr>
<tr>
<td>2nd pass NF, feed, mgd</td>
<td>27.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd pass NF, permeate, mgd</td>
<td>21.74</td>
<td>26,086,957</td>
<td>Based on NF system equipment cost of $1.2/gpd</td>
</tr>
<tr>
<td>Average permeate flux rate, gfd</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of membrane elements (440 ft²)</td>
<td>2,470</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of pressure vessels (7 M)</td>
<td>353</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTE-MED System</td>
<td>20</td>
<td>213,091,023</td>
<td>Reference 4, price increase factor 1.667 CCCI (6)</td>
</tr>
<tr>
<td>Backwash streams to solids management, mgd</td>
<td>3.7</td>
<td>6,395,746</td>
<td>From quotes for SWRO plant at Carlsbad (2009) multiplied by CCCI 1.667 (6)</td>
</tr>
<tr>
<td>Electrical, VFD, MCC, instrumentation and control system</td>
<td>13970.1</td>
<td>14,557,961</td>
<td>From quotes for SWRO plant at Carlsbad (2009) multiplied by CCCI 1.667 (6)</td>
</tr>
</tbody>
</table>
### Appendix G: Investigation of Desalination Methods

#### System cost item

<table>
<thead>
<tr>
<th>System cost item</th>
<th>Flow rate or number of units</th>
<th>Equipment or system cost</th>
<th>Cost references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypochlorite storage and dosing unit</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypochlorite dosing rate, ppm</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium bisulfite storage and dosing unit</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium bisulfite dosing rate, ppm</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid storage and dosing unit (for coagulation)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid dosing rate, ppm</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coagulant storage and dosing system</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coagulant dosing rate, ppm</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime storage and dosing system</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime dosing rate, ppm</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid storage and dosing unit (for pH adjustment)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid dosing rate, ppm</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale inhibitor for NF dosing unit</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale inhibitor dosing rate, ppm</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale inhibitor for VTE dosing unit</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale inhibitor dosing rate, ppm</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment cost for combined dosing units</td>
<td>491,149</td>
<td>Calculated from (seawater RO) SWRO plant at Carlsbad (2009)</td>
<td></td>
</tr>
<tr>
<td>Equipment contingency</td>
<td>20%</td>
<td>74,503,872</td>
<td></td>
</tr>
<tr>
<td>Total equipment cost</td>
<td></td>
<td>440,488,707</td>
<td></td>
</tr>
<tr>
<td>State taxes (California)</td>
<td>7.25%</td>
<td>31,935,431</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Engineering</td>
<td>8.00%</td>
<td>35,239,097</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Contractor markup</td>
<td>8.00%</td>
<td>35,239,097</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Startup energy + chemicals</td>
<td>2.00%</td>
<td>8,809,774</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Insurance and bonds</td>
<td>5.00%</td>
<td>22,024,435</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>133,247,834</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Contingency</td>
<td>15.00%</td>
<td>19,987,175</td>
<td>Derived from the budget of the SWRO at Carlsbad (2009)</td>
</tr>
<tr>
<td>Total plant cost, 20 MGD of treated water production, excluding site work</td>
<td></td>
<td>593,723,716</td>
<td></td>
</tr>
</tbody>
</table>
1.2.6. Operating Costs and Derived Water Cost

The parameters and calculated values for operating cost components are listed in Table 2. The calculations for the water cost components are based on cost parameters listed in Table 2.

In the calculation of the electric power required for plant operation of the VTE unit, the value listed in Reference 1 was used. For other process equipment, the required electric power was calculated according to common engineering practice.

For thermal energy required to operate the VTE-MED system, the assumption that there will be available low-pressure steam from a local geothermal plant (Reference 1) was utilized. However, there is no independent assessment to confirm if sufficient geothermal steam will be available for the operation of the evaporation unit for product water with a capacity of 20 MGD and eventually a 100 MGD.

The derived operating cost is $4.04/kilogallon (kgallon) or $1,316/AF. Therefore, the capital cost is $6.35 kgallon or 2,069/AF and the total water cost is thus $10.39/kgallon or $3,385/AF.

For comparison the total water cost listed in the Salton Sea Recycling Project Report (1) is $582/AF.

<table>
<thead>
<tr>
<th>Table 2. Operating Cost Components and Total Water Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Interest rate</td>
</tr>
<tr>
<td>Plant life, year</td>
</tr>
<tr>
<td>Discount rate</td>
</tr>
<tr>
<td>Plant load factor</td>
</tr>
<tr>
<td>Annual water production, kgallon</td>
</tr>
<tr>
<td>Number of operators</td>
</tr>
<tr>
<td>Operators’ annual salary + G&amp;A</td>
</tr>
<tr>
<td>Chief operator</td>
</tr>
<tr>
<td>Chief operator’s annual salary + G&amp;A</td>
</tr>
<tr>
<td>Maintenance staff</td>
</tr>
<tr>
<td>Maintenance staff annual salaries</td>
</tr>
<tr>
<td>UF elements cost, $/element</td>
</tr>
<tr>
<td>UF membranes warranty period, year</td>
</tr>
<tr>
<td>NF elements cost, $/element</td>
</tr>
<tr>
<td>NF membrane elements warranty, year</td>
</tr>
<tr>
<td>Sulfuric acid, $/t (100%)</td>
</tr>
<tr>
<td>Ferric coagulant, $/t (100%)</td>
</tr>
<tr>
<td>Scale inhibitor, $/t (100%)</td>
</tr>
<tr>
<td>Sodium bisulfite, $/t (100%)</td>
</tr>
<tr>
<td>Sodium hypochlorite, $/t (100%)</td>
</tr>
<tr>
<td>Lime, $/t (100%)</td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Annual maintenance cost, % of equipment</td>
</tr>
<tr>
<td>Regulatory compliance, $/year</td>
</tr>
<tr>
<td>Pumps efficiency</td>
</tr>
<tr>
<td>Motors efficiency</td>
</tr>
<tr>
<td>VFD efficiency</td>
</tr>
<tr>
<td>ERD efficiency</td>
</tr>
<tr>
<td>Electricity rate, $/Kwh</td>
</tr>
<tr>
<td>Seawater delivery, kW</td>
</tr>
<tr>
<td>UF membrane feed, kW</td>
</tr>
<tr>
<td>1st pass NF membrane feed, kW</td>
</tr>
<tr>
<td>Concentrate seeding &amp; precipitation, kW</td>
</tr>
<tr>
<td>2nd pass NF feed</td>
</tr>
<tr>
<td>VTE-MED</td>
</tr>
<tr>
<td>Solids management system</td>
</tr>
<tr>
<td>Chemical dosing units</td>
</tr>
<tr>
<td>Air conditioning</td>
</tr>
<tr>
<td>Lightning</td>
</tr>
<tr>
<td>Controls and Automation</td>
</tr>
<tr>
<td>Other Miscellaneous/Contingency transformation and cable losses (2%)</td>
</tr>
<tr>
<td>Total power, kW</td>
</tr>
<tr>
<td>Annual electric power cost, $/year</td>
</tr>
<tr>
<td>Geothermal steam cost, $/year</td>
</tr>
<tr>
<td>UF elements replacement cost, $/year</td>
</tr>
<tr>
<td>NF elements replacement cost, $/year</td>
</tr>
<tr>
<td>Sulfuric acid, $/year</td>
</tr>
<tr>
<td>Ferric coagulant, $/year</td>
</tr>
<tr>
<td>Scale inhibitor, $/year</td>
</tr>
<tr>
<td>Sodium bisulfite, $/year</td>
</tr>
<tr>
<td>Sodium hypochlorite, $/year</td>
</tr>
<tr>
<td>Lime, $/year</td>
</tr>
<tr>
<td>Other chemicals, $/year</td>
</tr>
<tr>
<td>Labor, $/year</td>
</tr>
<tr>
<td>Maintenance, $/year</td>
</tr>
<tr>
<td>Regulatory compliance, $/year</td>
</tr>
<tr>
<td>Total annual operation cost, $/year</td>
</tr>
<tr>
<td>Operating cost, $/kgallon</td>
</tr>
<tr>
<td>Annual capital cost</td>
</tr>
</tbody>
</table>
Appendix G: Investigation of Desalination Methods

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost, $/k gallon</td>
<td>6.35</td>
<td>Does not include the site development cost</td>
</tr>
<tr>
<td>Total water cost, $/k gallon</td>
<td>10.39</td>
<td></td>
</tr>
<tr>
<td>Total water cost, $/AF</td>
<td>3,385</td>
<td></td>
</tr>
</tbody>
</table>

(*) Cost of geothermal steam at 403°F, 120,000 lb/hr, provided by Sephton Water Technology for a 5 MGD and 20 MGD distillate capacity. However, 403°F steam could be used for electric power generation. This amount of geothermal steam has the capability to produce 67,907,520 kWh of electricity annually. At an electric rate of $0.12/kW-hr this will amount to an annual cost of $8,148,902. If this electric equivalent value of geothermal steam cost would be used, the total water cost produced by the system, proposed by Sephton Water Technology, would increase to ~$3,600/AF.

1.2.7. Purity of water harvested from the Salton Sea

According to a report submitted by Sephton Water Technology (1) as well as other published information about the Salton Sea, its water has been degraded and is contaminated. The report submitted by Sephton Water Technology (1) indicates the following:

Page 3: “The locations where Salton Sea water will be recycled will also produce a stream of concentrated Salton Sea brine containing a mixture of salts and small organic molecules.”

Page 4: “In the last century the quality of the salt dissolved in the Salton Sea has been degraded by agricultural drainage and some industrial waste. The sodium chloride in the Salton Sea is now mixed with a substantial portion of sulfate from agricultural drainage, significant amounts of magnesium, and a modest amount of calcium, potassium, and bicarbonate, plus trace amounts of a wide range of elements. Fertilizer runoff stimulates a massive growth of microorganisms that decay to release a wide range of organic molecules.”

Notably, fertilizers and pesticides in agricultural runoff could have resulted in the contamination of the seawater. Some residual ionic components of the fertilizers and small molecular size organics are not well rejected by the open-type NF membranes, proposed for this process. There is a concern that the above contaminants will end up in the dried salt, affecting its purity and market value. At this time, potential presence of these impurities is considered to be an uncertainty for evaluating the future economic value of this salt.

1.2.8. Groundwater Supply System

We have developed this evaluation of proposed costs for a groundwater well field system to provide a total of 50,000 acre-feet per year (AFY) of water to the Salton Sea. This proposed well field is expected to be located within two miles of a discharge point into Salton Sea.

Several key issues regarding this potential source of low salinity water to the Salton Sea remain to be identified. These items include:

- Location of the groundwater aquifer
- Water quality, depth, and production values for the groundwater aquifer
- Land availability and cost for well sites, pipelines, power service, etc.
Appendix G: Investigation of Desalination Methods  Working Draft

- Required permits, water rights and environmental approvals.

The following sections outline our assumed design criteria based on past projects our staff has performed in Southern California. Extensive further study would be required to develop a more accurate estimated total cost for such a project.

**Design Criteria** Table 3 contains the proposed capacity of the project used to develop our design criteria. Our proposed design criteria are included in Table 4.

### Table 3. Project Capacity

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Production</td>
<td>50,000 AFY</td>
</tr>
<tr>
<td>Maximum Flow</td>
<td>31,000 GPM</td>
</tr>
<tr>
<td>Operating Time</td>
<td>24 Hours per day</td>
</tr>
<tr>
<td>Year Operations</td>
<td>365 days</td>
</tr>
</tbody>
</table>

### Table 4. Design Criteria

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Well</td>
<td>22 (20 + 2 standby)</td>
</tr>
<tr>
<td>Well Flow</td>
<td>1500 GPM</td>
</tr>
<tr>
<td>Static Water Level</td>
<td>60 ft</td>
</tr>
<tr>
<td>Drawdown</td>
<td>40 ft</td>
</tr>
<tr>
<td>Total Lift</td>
<td>100 ft</td>
</tr>
<tr>
<td>Pipeline Head Loss</td>
<td>14 ft</td>
</tr>
<tr>
<td>Minimum Pipeline Pressure</td>
<td>23 ft</td>
</tr>
<tr>
<td>Total Dynamic Head</td>
<td>137</td>
</tr>
<tr>
<td>Pump &amp; Motor</td>
<td>75 HP</td>
</tr>
<tr>
<td>Power Usage @ 1,500 GPM</td>
<td>43 KW</td>
</tr>
<tr>
<td>Pipeline Length</td>
<td>10,560 ft</td>
</tr>
<tr>
<td>Pipeline Diameter</td>
<td>54 In</td>
</tr>
</tbody>
</table>

**Capital Cost Estimate** We have assumed that a total of 20 wells would be required to produce the total flow of 31,000 GPM. Two additional wells would be needed for standby wells. Each well was assumed to have a total depth of 200 feet and a static water level of 60 feet below ground surface. The wells should be constructed of 304 stainless steel with louvered screens. A 50-ft sanitary seal should also be installed. A 1,000-ft long 12-inch connector pipe was included to connect the well to the 54-inch pipeline.

The wells would be equipped with 75-HP vertical turbine pumps, above ground piping, valves, electrical, and instrumentation. All equipment would be on a concrete pad and weatherproof. The pipeline would be sized to minimize head loss and reduce energy costs. It is assumed that the pipeline would be constructed in open ground with only minor utility crossings. The average depth of the pipeline would be assumed to be 4 feet below ground surface.
Table 5 contains the estimated capital cost of the project based on similar projects contracted in Southern California.

**Table 5. Capital Cost Estimate**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Well Field</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well Drilling</td>
<td>$403,000</td>
<td>22</td>
<td>$8,866,000</td>
</tr>
<tr>
<td>Well Equipping</td>
<td>$628,000</td>
<td>22</td>
<td>$13,160,000</td>
</tr>
<tr>
<td>Mobilization, Permits, Startup</td>
<td>$92,000</td>
<td>22</td>
<td>$2,024,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td>$24,050,000</td>
</tr>
<tr>
<td>54-inch Pipeline</td>
<td>$865</td>
<td>10,560</td>
<td>$9,134,000</td>
</tr>
<tr>
<td>12-inch Well Connector Pipe</td>
<td>$85</td>
<td>22,000</td>
<td>$1,870,000</td>
</tr>
<tr>
<td>Valves &amp; Appurtenances</td>
<td>Lump Sum</td>
<td>1</td>
<td>$200,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td>$11,204,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>$35,254,000</td>
</tr>
<tr>
<td><strong>Contingency 25%</strong></td>
<td></td>
<td></td>
<td>$8,814,000</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td>$44,068,000</td>
</tr>
</tbody>
</table>

**Operating Cost Estimate** Operating costs are based on the calculated energy costs at a rate of $0.12 KWH for the wells to produce 50,000 AFY. We have assumed that the wells will need to be refurbished every 5 years at a cost of $225,000 to pull the pumps, clean the screens and pump the gravel pack. Labor, permits, and water quality sampling have also been included. The operating costs for pipeline labor and maintenance have been estimated based on costs per foot to operate pipeline systems in Southern California. Operating costs are included in Table 6.

**Table 6. Operating Cost Estimate**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Well Field</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well Pumping Energy</td>
<td>$0.12 KWH</td>
<td>7,534,000 KWH</td>
<td>$904,000</td>
</tr>
<tr>
<td>Well Refurbishment</td>
<td>$45,000/Well</td>
<td>22</td>
<td>$990,000</td>
</tr>
<tr>
<td>Operating Labor, Permits, Sampling</td>
<td>$40,000/Well</td>
<td>22</td>
<td>$880,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td>$2,774,000</td>
</tr>
<tr>
<td>54-inch Pipeline Labor</td>
<td>$8/ft</td>
<td>10,560</td>
<td>$84,000</td>
</tr>
<tr>
<td>12-inch Well Connector Pipe Labor</td>
<td>$6/ft</td>
<td>22,000</td>
<td>$132,000</td>
</tr>
<tr>
<td>Valves &amp; Appurtenances</td>
<td>Lump Sum</td>
<td>1</td>
<td>$50,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td>$266,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>$3,040,000</td>
</tr>
<tr>
<td><strong>Contingency 25%</strong></td>
<td></td>
<td></td>
<td>$760,000</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td>$3,800,000</td>
</tr>
</tbody>
</table>
1.2.9. Summary of System Costs for the Sephton Water Technology Concept

The total system costs show in Table 7 were estimated based on the need for five desalination plants, each with a water production of 20 MGD, brine evaporation ponds, treated water distribution pipeline, and a groundwater well system to provide an additional 50,000 AFY of water to the Salton Sea.

Table 7. Total System Cost Estimate

<table>
<thead>
<tr>
<th>Desalination System Capital Costs</th>
<th>2022 $</th>
<th>$M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost per Plant excluding site work</td>
<td>$593,723,716</td>
<td>$594 M</td>
</tr>
<tr>
<td>Number of Plants</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Factor assuming 10% economy of scale</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>Total Cost of Five Plants</td>
<td>$2,672 M</td>
<td></td>
</tr>
</tbody>
</table>

**Desalination System Operating Costs**

| Cost Per 1,000 gallons                           | $4.04  |      |
| Cost MGD                                         | $4,040 |      |
| MGD                                             | 100    |      |
| Cost per Day                                     | $404,000 |      |
| Days per year                                    | 365    |      |
| Cost per year                                    | $147,460,000 | $147 M |
| AFY                                             | 112,000 |      |
| Cost Per AF                                      | $1,317 |      |

**Brine Ponds Operating and Capital Costs**

| Yearly Brine Flow (10.7 MGD per plant)           | 71,969 | AFY  |
| Monthly Brine Flow (10.7 MGD per plant)          | 5,997  | AFM  |
| Winter Evaporation Plus Seepage                  | 0.5    | ft/month |
| Area of Brine Ponds (acres)                      | 11,995 |      |
| Cost per acre of brine ponds                     | $33,000 | Based on DWR estimate of Saline Habitat Complex (SHC) in 2022 Dollars |
| Total Cost of Ponds ($)                          | $395,827,307 | $396 M |
| Discount (20%)                                   | 0.8    | Some SHC elements not needed |
### Desalination System Capital Costs

<table>
<thead>
<tr>
<th></th>
<th>2022 $</th>
<th>$M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond Operations (5% of Capital Cost)</td>
<td>5%</td>
<td>Consistent with DWR estimate for operating SHC</td>
</tr>
<tr>
<td>Pond Operations</td>
<td></td>
<td>$ 16 M</td>
</tr>
<tr>
<td>Distribution Pipeline</td>
<td></td>
<td>$ 240 M, Sephton Water Technology estimate</td>
</tr>
<tr>
<td>Groundwater Well and Conveyance Pipeline Capital Cost (50,000 AFY)</td>
<td></td>
<td>$ 44 M</td>
</tr>
<tr>
<td>Groundwater Well System Operating Cost</td>
<td></td>
<td>$ 4 M</td>
</tr>
<tr>
<td><strong>Total Capital Cost ($M)</strong></td>
<td></td>
<td>$ 3,272 M</td>
</tr>
<tr>
<td><strong>Total OMER ($M)</strong></td>
<td></td>
<td>$ 167 M</td>
</tr>
</tbody>
</table>

### 1.3. References

2. Tom Sephton, Appendix D_SSWRP_VTE-MED_CostCalculation_2022_v03.
3. Mark Wilf, Personal communication with thermal process desalination experts.
5. Equipment quotes and desalination plant budget for the 50 MGD Seawater RO Desalination Plant, Carlsbad, CA (2009)
6. DGS California Construction Cost Index (CCCI) (years 2009–2022)
8. Information provided by the manufacturer of large MED systems (personal communication).
9. Personal communication with thermal process desalination experts.
10. GE offer for supply brine concentrators for Ft. Irwin project (2012)

12. Information provided by the Nickel Institute

13. Tom Sephton, Appendix_O_DesaltPlantSeawaterIntakeCost


15. Poseidon Barge Ltd quote

