Appendix M

International Border Region of the Colorado River

This page intentionally left blank.

Contents

Tables

Figures

Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
af	acre-feet
CAP	Central Arizona Project
CCS	Continued Current Strategies
CRIR	Colorado River Indian Reservation
CRSS	Colorado River Simulation System
DPOC	Drainage Pump Outlet Channel
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
ha	Hectares
IBWC	International Boundary and Water Commission
IID	Imperial Irrigation District
ISG	Interim Surplus Guidelines
kaf	thousand acre-feet
LB	Lower Basin
LBDCP	Lower Basin Drought Contingency Plan
LDS	Lower Division States
maf	million acre-feet
maf/year	million acre-feet per year
mg/L	Milligrams per liter
MODE	Main Outlet Drain Extension
msl	mean sea level
NDVI	Normalized Difference Vegetation Index
NIB	Northerly International Boundary
PDEIS	Preliminary Draft Environmental Impact Statement
ppm	parts per million
PVID	Palo Verde Irrigation District
SAM	Shortage Allocation Model
SIB	Southerly International Boundary
TDS	Total dissolved solids
UB	Upper Basin
USGS	United States Geologic Survey
USIBWC	United States Section, International Boundary and Water Commission
YAO	Bureau of Reclamation, Yuma Area Office

This page intentionally left blank.

Appendix M. International Border Region of the Colorado River[1]

M.1 Introduction

The United States has a delivery obligation to the country of Mexico (Mexico) for certain waters of the Colorado River pursuant to the February 3, 1944 Water Treaty between the United States and Mexico Relating to the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty). The U.S. Section of the International Boundary and Water Commission (USIBWC) is the United States component of a binational organization responsible for administration of the provisions of the 1944 Water Treaty, which includes the Colorado River waters allotted to Mexico. The International Boundary and Water Commission (IBWC) consists of the United States Section and the Mexican Section, which have their headquarters in the adjoining cities of El Paso, Texas and Ciudad Juarez, Chihuahua, respectively. Other Colorado River responsibilities identified in the 1944 Water Treaty relate to water delivery, border sanitation, and construction of the Mexican diversion dam (Morelos Dam), stream gaging stations, and flood control levees. The treaty also gives the Commission the power to settle all differences with respect to the interpretation or application of the treaty, subject to the approval of the two Governments.

The proposed federal action is for the purpose of adopting additional operational guidelines to improve the U.S. Bureau of Reclamation's (Reclamation) annual management and operation of key Colorado River reservoirs for an interim period. The objective of this appendix is to consolidate and summarize analyses related to the International Border Region throughout this Draft Environmental Impact Statement (EIS), which are discussed in Technical Appendices titled **TA 3**, Hydrologic Resources, **TA 4**, Water Deliveries, and **TA 6**, Water Quality. Each of the referenced sections utilizes a simulation model to characterize the implications of the baselines and proposed alternatives on the parameters relevant to these resources.[2] To assess the proposed federal action in the EIS, certain modeling assumptions are used to evaluate potential effects on water deliveries to Mexico and on hydrologic and other environmental resources between the Northerly and Southerly International Boundaries (International Border Region). This geographic area is called the

[1] For purposes of this Appendix, the International Border Region is defined as the geographic area between the Northerly International Boundary and the Southerly International Boundary along the Colorado River. This area serves as the international boundary between the U.S. and Mexico.

[2] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Limitrophe as the Colorado River is the U.S./Mexico international boundary between those two locations.

M.2 Overview

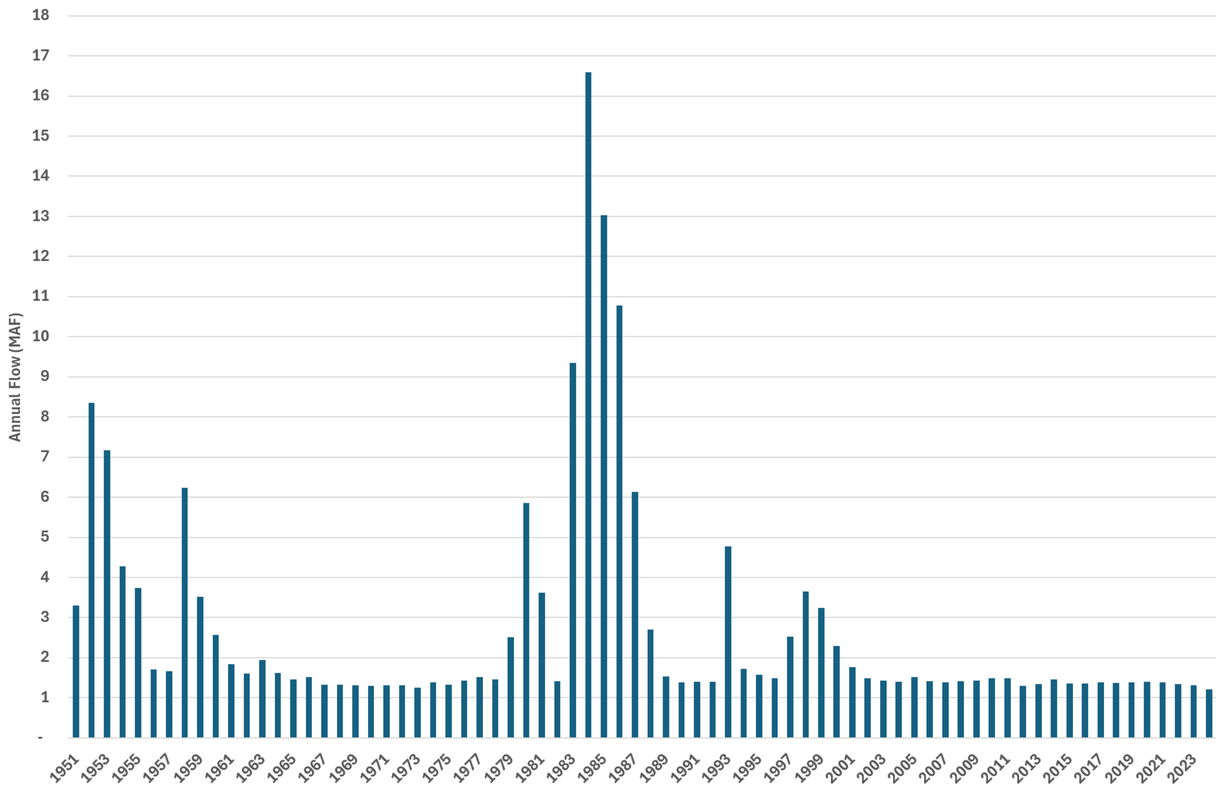
M.2.1 Affected Environment

The international border region of the Colorado River extends from the Northerly International Boundary (NIB) to the Southerly International Boundary (SIB) where the river channel forms the international boundary between the United States (the State of Arizona) on the eastern side of the bank and Mexico (the State of Baja California) on the western side of the bank (**Figure M-1**). Approximately 25 miles (40.2 km) upstream of the NIB sits the Imperial Dam, where diversions are made into the Gila Gravity Main Canal and All-American Canal, the latter of which feeds into the Coachella Canal, East Highline Canal, and Central Main Canal before terminating at the western end of the Imperial Valley where it drains into the Westside Main Canal. Some deliveries to Mexico are channeled through the All-American Canal and then diverted either through the Pilot Knob Power Plant (PKPP) or through Siphon Drop and the Yuma Main Canal before returning to the mainstem channel above NIB. Another route is to direct water from Imperial Dam to Laguna Dam before returning to the mainstem channel. Approximately 1.08 miles (1.75 km) downstream of the NIB along the main Colorado River channel is the Morelos Diversion Dam, which diverts water into the Reforma Canal for use in Mexico.

Figure M-1
Colorado River Infrastructure and Hydrologic Features near the U.S./Mexico Border

Flows at the NIB reflect releases made from Hoover Dam to meet delivery obligations to Mexico, local runoff sources such as irrigation return flows, flood control releases from Hoover Dam, unexpected flooding from the Gila River, inadvertent overruns of water deliveries that could not be diverted as intended into the Gila Gravity Main Canal or All American Canal, and any water released for environmental purposes of the Colorado River Delta region. Under most years, the volume meets or slightly exceeds the delivery obligations to Mexico at NIB, but exceptionally large volumes have occurred in past years primarily due to flood control releases (**Figure M-2**).

Figure M-2
Colorado River Flows at NIB, Above Morelos Dam, AZ



Source: USGS Gage 09522000

The reach between the NIB and SIB is referred to as the Limitrophe. From NIB to the Morelos Dam, approximately 1.36 maf passes annually. Under normal operations, the Morelos Dam diverts the entirety of the remaining Colorado River into the Reforma Canal. Releases or spillway discharges from the Morelos Dam for flood control purposes or environmental restoration have been an infrequent but important source of downstream flows. In recent years, only seepage under and around the dam remains in the natural river channel.

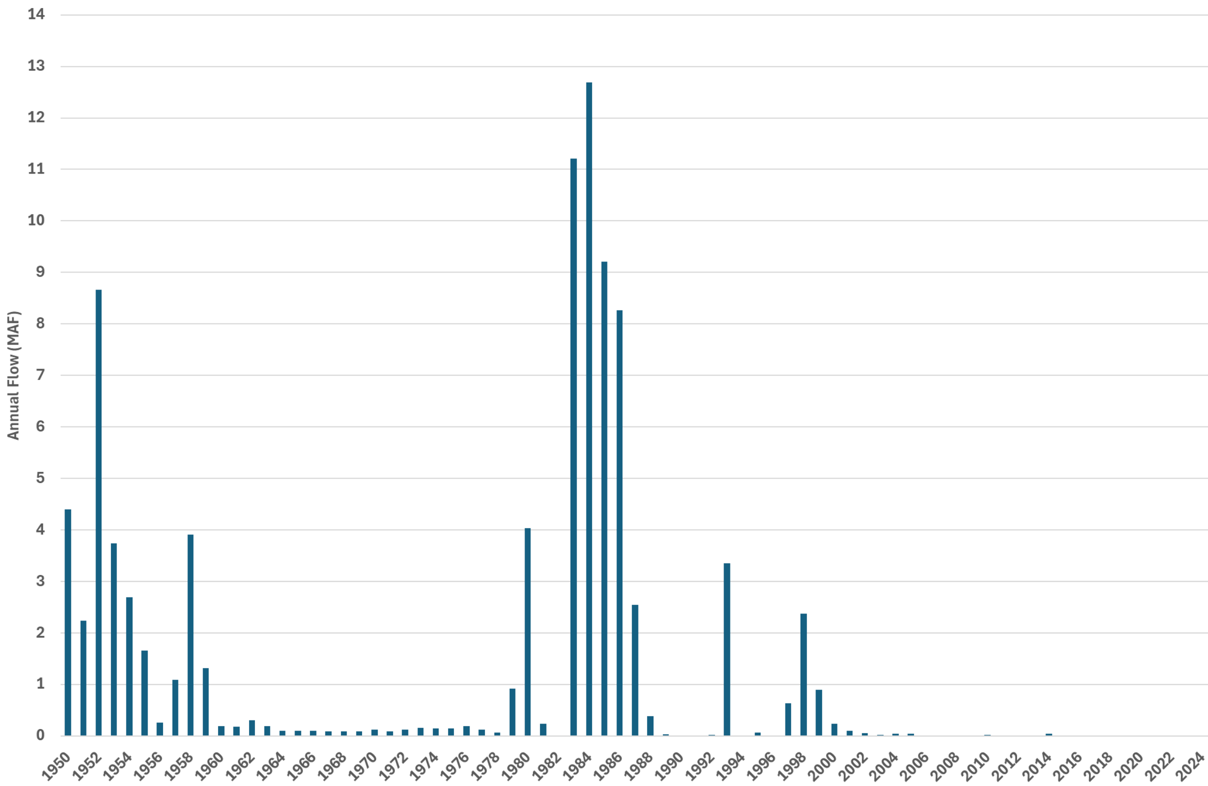
Below Morelos Dam, the Colorado River is characterized by a minimally flowing or dry streambed. Seepage from the dam is joined by agricultural return flows from both the United States and Mexico, originating from irrigated fields percolating water into the subsurface alluvium and contributions from three U.S. wasteways (11 Mile Wasteway off levee road and County 11th, 21 Mile near Hunters Hole, and a Diversion Channel at SIB near the border at San Luis, AZ). The Limitrophe is typically considered to be the northernmost reach of the Colorado River Delta and receives less than 3 inches of annual rainfall. Major flows in the Limitrophe have not regularly occurred since the 1980s and to a lesser degree in the 1990s when the reservoirs of Lake Mead and Lake Powell were nearly full and spilling water was required. One notable flood event occurred from the Gila River 1993. A pilot project introduced environmental restoration flows in 2014 under Minute 319 as described below.

Groundwater below the riverbed is recharged from irrigated fields in the Yuma area to the east and from Mexico's irrigation fields and leakage from the Reforma Canal to the west. The depth to groundwater increases from north to south. In the upper reaches, the relatively high-water table allows for perennial flows to exist, while the water table declines significantly towards the SIB (Ramírez-Hernández, J., et al., 2013; Cohen, 2013). Low moisture conditions in the root zones makes surface vegetation sparse; however, by tapping into pumped groundwater in both countries and delivering water from canal infrastructure in Mexico, several restoration efforts exist along both sides of the riverbanks, such as Gadsden Bend, Miguel Aleman, Janitzio and Hunters Hole. These sites seek to re-establish and maintain vegetation along the riparian corridor in the Limitrophe and enhance habitat conditions for migratory and non-migratory birds and terrestrial species. A study of the composition of avian populations in the Colorado River Delta region demonstrates the high influence of the plant communities and land cover on the variability of bird species, as well as a positive relationship between cover of native riparian trees and shrubs and bird species with an affinity for riparian forests (Gonzales-Sargas et al., 2024). Two of the five focal reaches of this study are within the Limitrophe.

An extensive study conducted by Cohen (2013) indicated that groundwater conditions had deteriorated over the 57 years prior to their study. While upper reaches showed relatively steadier groundwater elevations, the deterioration was particularly noted in the lower reaches of the Limitrophe where water table elevations dropped around 27 feet between 1960 and 2009. This decline was attributed to several factors, including the decrease of surface flows below Morelos Dam, diminishing groundwater recharge, and increased well pumping along the Arizona-Sonora border. As water tables decline further resulting in decreasing unmanaged vegetation, the relative value of restoration areas to maintain a riparian habitat increases, such as Gadsden Bend, Miguel Aleman, Janzito, and Hunters Hole.

Flows reaching the SIB through the Limitrophe have been substantial in past years (**Figure M-3**). Notably in the 1980s, flood control releases from Lake Mead allowed over 12 million acre-feet (maf)/year (14,800 million cubic meters [mcm]/year) to be discharged through the Morelos Dam and down into the Colorado River Delta. In recent decades this flow has been minimal. As a product of Minute 319, an environmental pulse flow from Morelos Dam was released in 2014 that reached the Sea of Cortez (Pitt et al., 2017).

Figure M-3
Colorado River Flows at SIB Near San Luis, AZ



Sources: IBWC Annual Bulletins, USGS Gage 09522200, Glenn et al. 2008

M.2.2 Previous Binational Coordination

The United States and Mexico have a long history of cooperation and coordination with respect to the Colorado River, most notably starting with the 1944 Water Treaty. This treaty guarantees an annual quantity of 1.5 maf (1,850 mcm) to Mexico from the Colorado River under normal conditions, with the potential for up to a total of 1.7 maf (2,100 mcm) during times when surplus waters are available. It also provides for reduced volumes to Mexico under extraordinary drought.

The precise text of the 1944 Water Treaty is as follows:

Article 10(a) of the 1944 Water Treaty states:

> "(a) A guaranteed annual quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) to be delivered in accordance with the provisions of Article 15 of this Treaty"

Further, Article 10(b) of the 1944 Water Treaty states:

> "(b) Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner

> set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 acre-feet (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of waters of the Colorado River system, for any purpose whatsoever, in excess of 1,500,000 acre-feet (1,850,234,000 cubic meters) annually."

Additionally, Article 10 of the 1944 Water Treaty states:

> "In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 acre-feet (1,850,234,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced."

Since the 1944 Water Treaty was signed, a series of implementing agreements, or Minutes, have been agreed upon and signed to facilitate cooperation between the countries. Some of them are of particular relevance to the issues analyzed in this EIS.

Salinity of water is an important concern to users in the Lower Basin including those in the United States and Mexico. While some salinity sources naturally exist throughout the Colorado River Basin, agricultural return flows, that are often high in salinity, enter the Colorado River through surface and groundwater pathways. As a result of salinity accumulation, diversions downstream along the Colorado River mainstem are increasingly impacted relative to diversions upstream. Diversions taken by Mexico are often subject to the highest salinity concentrations. This concern over salinity led to Minute 242 of the 1944 Water Treaty.

Resolution 1(a) of Minute 242 explicitly address the salinity concerns of Mexico stating:

> "The United States shall adopt measures to assure that not earlier than January 1, 1974, and no later than July 1, 1974, the approximately 1,360,000 acre-feet (1,677,545,000 cubic meters) delivered to Mexico upstream of Morelos Dam, have an annual average salinity of no more than 115 p.p.m. ± 30 p.p.m. U.S. count (121 p.p.m. ± 30 p.p.m. Mexican count) over the annual average salinity of Colorado River waters which arrive at Imperial Dam, with the understanding that any waters that may be delivered to Mexico under the Treaty of 1944 by means of the All American Canal shall be considered as having been delivered upstream of Morelos Dam for the purpose of computing this salinity."

Today Reclamation meets the obligation of the United States to not violate this differential through several different means, including bypassing saline waters through the Main Outlet Drain Extension (MODE) canal around agricultural, municipal, and industrial systems in the United States and Mexico and blending water arriving at the NIB through additional upstream releases.

In 2012, the United States and Mexico signed Minute 319 to the 1944 Water Treaty, titled *Interim International Cooperative Measures in the Colorado Rier Basin Through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California*. This Minute established four coordination mechanisms that affected flows in the International Border Region of the Colorado River:

- Based on the framework established in the *Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a) following the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final EIS* (Reclamation 2007b), Mexico agreed to reduced deliveries during times of low elevation reservoir conditions, defined by projected pool elevations of Lake Mead falling below specified thresholds. Three tiers of reductions were defined as when Lake Mead is projected to fall at or below 1075 feet (ft) (327.66 meters[m]), 1050 ft (320.04 m), or 1025 ft (312.42 m) above mean sea level (msl) on January 1st of each year according to a 24-month study performed by Reclamation in the previous month of August. Each tier corresponds to reductions in deliveries to Mexico by 50 thousand acre-feet (kaf) (62 mcm), 70 kaf (86 mcm), and 125 kaf (154 mcm) respectively. The low elevation thresholds align with those used to trigger shortages to users in Lower Division States (LDS) and the volumes of reductions to Mexico were selected generally in proportion to shortage commitments by the Lower Division States in the 2007 Interim Guidelines. Minor adjustments were made to a strict proportionality to accommodate Mexico's preference for lower reductions under less severe conditions and greater reductions under more critical circumstances.
- Water deliveries to Mexico would increase during high elevation reservoir conditions as defined by projected pool elevations of Lake Mead exceeding 1145 ft (349.00 m), 1170 ft (356.62 m) or 1200 ft msl (365.76 m). In each of these cases, increases to annual releases to Mexico of 40 kaf (49 mcm), 55 kaf (68 mcm), and 80 kaf (99 mcm) respectively would be made. Only when flood control releases are required, Mexico would receive an annual increase of up to 200 kaf (247 mcm) not to exceed a total of 1.7 maf. The thresholds and the volumes of flows under high elevation reservoir conditions also mirrored those of Lower Division States.
- Extending an emergency measure put into place as Minute 318 (*Adjustment of Delivery Schedules for Water Allotted to Mexico for the Years 2010 Through 2013 as a Result of Infrastructure Damage in Irrigation District 014, Rio Colorado, Caused by the April 2010 Earthquake in the Mexicali Valley, Baja California*) that followed an earthquake in April 2010 that damaged Mexico's irrigation infrastructure, Minute 319 established a conservation and storage mechanism, known as Intentionally Created Mexican Allocation (ICMA), by which Mexico could defer delivery of a portion of their annual allotment of Colorado River water and deliver that water in a future year. This mechanism mirrored a similar program of Intentionally Created Surplus (ICS) that allows U.S. users in Lower Division States to bank water from one year to the next. Both the programs were established with clear rules for depositing and withdrawing water.
- Under the spirit of binational cooperation, a pilot program was initiated to dedicate water to enhance the environmental condition in the Colorado River Delta including its Limitrophe. Water created by conservation measures in Mexico and deferred in the U.S. system provided water for a 105,068 af (129.6 mcm) flow released from Morelos Dam on behalf of the U.S. and Mexican governments. A binational coalition of non-government organizations delivered a proportional amount through Mexico's irrigation canals to targeted restoration areas. Concurrently, this mechanism established the ability for water conserved as ICMA to be transferred to Lower Division States' ICS accounts and used in the United States.

The term of Minute 319 was 5 years, expiring on December 31, 2017. Prior to its expiration, Minute 323 was signed and entered into force on September 27, 2017, which built on and extended provisions of Minute 319 and added a complementary program to the Lower Basin Drought Contingency Plan (LBDCP) until December 31, 2026. Titled the *Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin*, Minute 323 provided a number of actions as follows:

- Reductions to deliveries to Mexico during low elevation Lake Mead reservoir conditions as specified in Minute 319 were extended.
- Additional deliveries to Mexico during high elevation Lake Mead reservoir conditions as specified in Minute 319 were extended.
- A Binational Water Scarcity Contingency Plan was established that provides for each country to save specified volumes of water at certain low reservoir elevations for recovery at a later date when reservoir conditions improve. Elevation thresholds for Mexico contributions match those developed in the *2019 Colorado River Drought Contingency Plans*, and volumes of savings contributions by Mexico match the percent of additional saved contributions above the required reductions by Lower Division States at each elevation tier.
- A Mexico Water Reserve expands on and incorporates volumes previously stored in the accounts established in Minute 318 and 319, incorporates water retained from any future emergency measures and provides a mechanism to defer delivery of a portion of Mexico's annual water allocation through 2026. Delivery and creation provisions are included in Minute 323.

Concurrent to the implementation of the *Near-term Colorado River Operations Record of Decision or Supplement to the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Record of Decision*, in March 2024, Minute 330, titled *Expansion of Colorado River Temporary Measures*, was signed between the United States and Mexico that requires Mexico to conserve 400 kaf between 2023 and 2026, which were in addition to conservation requirements specified in Minute 323. Of this amount, at least 250 kaf is water for the Colorado River system, and the remainder is for Mexico's Water Reserve. Any volume in Mexico's Water Reserve shall remain there through December 31, 2026.

M.2.3 Environmental Enhancement Activities

Continuing the binational collaboration initiated in Minute 306 (*Conceptual Framework for United States – Mexico Studies for Future Recommendations Concerning the Riparian and Estuarine Ecology of the Limitrophe Section of the Colorado River and its Associated Delta*), Minute 319 and Minute 323 operationalized environmental cooperation regarding the Colorado River Delta including the shared Limitrophe. Pilot efforts to plan and design water releases through the Limitrophe as well as enhance habitat conditions through re-vegetation have provided in-situ testing of restoration approaches. Over many decades much of the native habitat that was once found in the Limitrophe region is no longer present, or greatly degraded, due to a variety of factors including fire, mechanical removal, and lack of water. In the Limitrophe most of the native habitat now present is in the form of managed restored sites that are irrigated with groundwater. These sites will not be affected by any changes in the system as they have their own independent sources of water and are actively maintained.

The Minute 319 pulse flow of 2014 inundated approximately 4,000 acres (1,600 ha) of the main channel and adjacent terraces of the Colorado River Delta, achieving connectivity to the Sea of Cortez for the first time since 2001 (Pitt et al., 2017). The pulse flow did not widen the channel or significantly result in geomorphic changes such as scouring sediments beyond 1 meter or bury existing vegetation. However, it did temporarily elevate water tables by as much as 9 m (30 ft) locally and produced a 17 percent increase in Normalized Difference Vegetation Index (NDVI) or "Greenness" throughout the riparian corridor during the following growing season. This elevated NDVI decreased to pre-pulse levels in all reaches by 2018 (IBWC 2018). Although significant amounts of water infiltrated into the dry streambed and only a small amount of water reached the Sea of Cortez, the pulse flow of 2014 helped to reverse a decline in evapotranspiration from 2011 to 2013 (Jarchow, 2017a; Jarchow, 2017b).

Following targeted restoration efforts of Minute 323, Nagler et al. (2022) reported positive results measured by Landsat images of two-band Enhanced Vegetation Index (EV12) and evapotranspiration indicators (EVI2 and potential ET (ETo)), while non-restored areas declined notably. Furthermore, bird diversity and abundance of indicator species were 20 percent and 74 percent higher, respectively, in the restoration sites than in unrestored control sites (IBWC 2022). These studies assess conditions across sites throughout the Colorado River Delta, which include sites along the Limitrophe as well as locations outside of the geographic scope of this EIS.

M.2.4 Limits of Analysis

The proposed federal action is for the purpose of adopting additional operational guidelines to improve Reclamation's annual management and operation of key Colorado River reservoirs for an interim period. The scope is limited to evaluating potential impacts of the various alternatives within the United States and the Limitrophe reach shared with Mexico. The impacts within Mexico, including reaches downstream of the Limitrophe, is outside of the scope of this EIS. However, to assess the potential effects of the proposed federal action in this EIS, certain assumptions are used that would potentially affect water deliveries and flows into Mexico. It is therefore necessary that modeling assumptions are used regarding the volume of water deliveries to Mexico as well as potential water releases into the Limitrophe as specified by the alternatives being considered.

Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

M.3 Methodology

This appendix compiles and describes a collection of analyses throughout the Environmental Impact Statement that pertain to the International Border Region. No new analysis is provided in this Appendix but instead gathers results from relevant Technical Appendices including **TA 3**, Hydrologic Resources, **TA 4**, Water Deliveries, and **TA 6**, Water Quality and presents them in a format to show the relative impacts of the proposed alternatives for Mexico, given the assumptions described in **Section M.3.2** and elsewhere. **Chapter 2** describes the alternatives that are simulated, **Appendix A** describes the CRSS modeling process and assumptions in detail, and **Appendix C** describes the use of the Shortage Allocation Model. Refer to those sections for an understanding of the overall modeling processes. Assumptions and terminology used that are unique to the results provided for the International Border Region are described below.

M.3.1 Impact Indicators

Three key areas are considered when evaluating the impacts in the International Border Region. These include the following:

- Impacts on water deliveries and reductions to deliveries to Mexico (equivalent to shortages to Lower Division State users)
- Impacts on salinity/total dissolved solids (TDS)
- Impacts on hydrologic flows in the Limitrophe

Hydrologic flows in Limitrophe are used as a proxy for environmental conditions in this river reach shared by the United States and Mexico.

M.3.2 Assumptions for the International Border Region

M.3.2.1 Colorado River Simulation System (CRSS)

Aspects unique to the international border region, including terminology used, are described in this section. The general assumptions in CRSS are described in **Appendix A**.

Deliveries and reductions to Mexico

The relationship between water deliveries and reductions for Mexico is as follows:

$$\text{Mexico's annual allotment (1.5 maf)} = \text{Annual water delivery to Mexico} + \text{Annual water delivery reduction to Mexico}$$

The annual delivery reduction to Mexico can be the result of a policy explicitly specified in an alternative, described hereafter as a *water delivery reduction* for Mexico (as opposed to a shortage as used for Lower Division States) or Lake Mead reaching critically low elevations when the volume of water that can be released from Hoover Dam is insufficient to meet all downstream demands. In this case, modeling assumptions are made to further reduce water deliveries to users in what is termed a dead pool-related reduction. The combination of a water delivery reduction for Mexico and a dead pool-related reduction for Mexico comprises the total water delivery reductions for Mexico.

$$\text{Annual water delivery reduction to Mexico} = \text{Water delivery reduction to Mexico} + \text{Dead pool-related reduction to Mexico}$$

In all alternatives, both types of water delivery reductions to Mexico occur simultaneously with the equivalent reductions to deliveries to Lower Division States (i.e., shortages). When shortages occur in the Lower Division States, reductions simultaneously occur for Mexico's water deliveries. In all alternatives, except for the Continued Current Strategies (CCS) Comparative Baseline[3], 16.67 percent of any shortage for the entirety of the Lower Basin is applied to Mexico on an annual basis. **Appendix K**, Sensitivity Analysis – Effects of Modeling Assumptions with Regard to Future Water Deliveries to Mexico, compares the effects of varied assumptions.

Lower Basin Shortages (100 percent)	=	Shortages to Lower Division States (83.33 percent)	+	Water Reductions to Mexico (16.67 percent)

There are no guarantees that shortages will be sufficient to keep Lake Mead from approaching dead pool when the water available is insufficient to meet downstream demands, so in this case, dead pool-related reductions are applied to users in Mexico concurrently with users in the Lower Division States. In all alternatives, including the CCS Comparative Baseline, 16.67 percent of any required basin-wide dead pool-related shortage is applied to Mexico as a water delivery reduction on a monthly basis.

Lower Basin dead pool-related Reductions (100 percent)	=	Dead pool-related Reductions to Lower Division States (83.33 percent)	+	Dead pool-related Reductions to Mexico (16.67 percent)

The assumption of 16.67 percent of any Lower Basin shortage or dead pool-related reduction being applied to Mexico occurs regardless of the allocation method used among water users within the United States. The value of 16.67 percent reflects the fraction of water allocated to Mexico (1.5 maf) relative to the combined allocation for the Lower Division States and allotment Mexico (9.0 maf).

Salinity Assumptions

The CRSS model includes salinity tracking capability, which was introduced specifically for the purpose of the International Border Region analyses in this EIS. Using an equation developed by the United States Geological Survey (USGS, 2018), which can be classified as a hybrid between a mechanistic and statistical model, salinity at Imperial Dam is calculated as a function of Hoover Dam salinity, Parker Dam releases, and diversions by Colorado River Indian Reservation (CRIR) and Palo Verde Irrigation District (PVID). Salinity at the NIB is calculated as a function of simulated salinity at Imperial Dam and assumed monthly base flows accruing to the Colorado River between Imperial Dam and the NIB. While CRSS does simulate flows between Imperial Dam and NIB, historical, average monthly base flows between Imperial Dam and the NIB are specified and used for the sole purpose of determining salinity at NIB.

The base flows accruing to the river between Imperial Dam and NIB, which are used to estimate the salinity at the NIB, vary for each month but are the same for every year of the analysis. Base flow data includes monthly average volume and salinity estimated using historical data from the period of 2018 through 2022. Base flows include uncontrolled and unmeasured return flows from

[3] The only exception to the consistent approach of applying 16.67% of shortages to Mexico is in the CCS Comparative Baseline. In this case reductions to Mexico's water deliveries follow logic derived from Minute 323 including Mexico's contributions to the Binational Water Scarcity Contingency Plan. This provides a point of comparison and is not considered an alternative in this EIS.

groundwater, measured irrigation return flows and canal wasteway flows, discharges to the Colorado River from pumped groundwater originating in the South Gila Valley and discharging through the Drainage Pump Outlet Channels (DPOCs), and pumped groundwater from the Yuma Mesa, Yuma Valley, and eastern end of the 242 well field, which discharge to the Colorado River by way of the Yuma Mesa Conduit. The salinity at the NIB is calculated via a simple monthly mass balance using the volume of Colorado River water delivered to Mexico by way of Imperial Dam (using the associated Imperial Dam salinity value) plus the base flows and their associated salinity values. The analysis conducted for this EIS does not include simulated operations by Reclamation’s Yuma Area Office (YAO) to ensure compliance with the Minute No. 242 salinity differential (IBWC, 1973). The NIB salinity data provided in this appendix should not be used as projected actual salinity at NIB but instead used to compare between alternatives.

Environmental Restoration Releases

Regarding alternatives that specify releases for habitat restoration in the Colorado River Delta, water could be provided as discharges into the Limitrophe through or around the Morelos Dam or as additional diversions to Mexico that are strategically discharged back into the Limitrophe or further downstream to support restoration efforts. For modeling purposes used in this EIS, water dedicated for environmental restoration is assumed to be diverted by Mexico at the Morelos Dam and reflected as periodic additions to Mexico’s diversion and not as flows downstream of the Morelos Dam or flows in the Limitrophe.

M.3.2.2 Shortage Allocation Model and Pro-rata Alternative Distribution Model

In the spreadsheet models used by Reclamation to represent the allocation of shortages to individual Lower Basin water users, the reduction volumes assigned to Mexico are identical to those in CRSS but use slightly different approaches depending on assumptions of priority vs. pro-rata allocation schemes. In the priority-based Shortage Allocation Model (SAM), the basin-wide shortage is separated into shortages to Lower Division States and water delivery reductions to Mexico so that the percent reduction from full allocation or allotment (7.5 maf and 1.5 maf) is identical, which is similar to the process used in CRSS. In the pro-rata Alternative Distribution Model, each user in the Lower Division States is reduced by a proportion of the basin-wide shortage based on the total consumptive use of that user relative to the basin-wide use. The water delivery reductions allocated to Mexico are then simply the remainder of basin-wide shortages not allocated to the Lower Division States. In both the Shortage Allocation Model and Pro-rata Alternative Distribution Model, the allocation of basin-wide water delivery reductions to Mexico is 16.67 percent, which is identical to the assumption used in CRSS. Refer to **Appendix C** for further information about the Shortage Allocation and Alternative Distribution Models.

M.4 Relevant Results

M.4.1 Issue 1: Water Deliveries and Reductions to Mexico

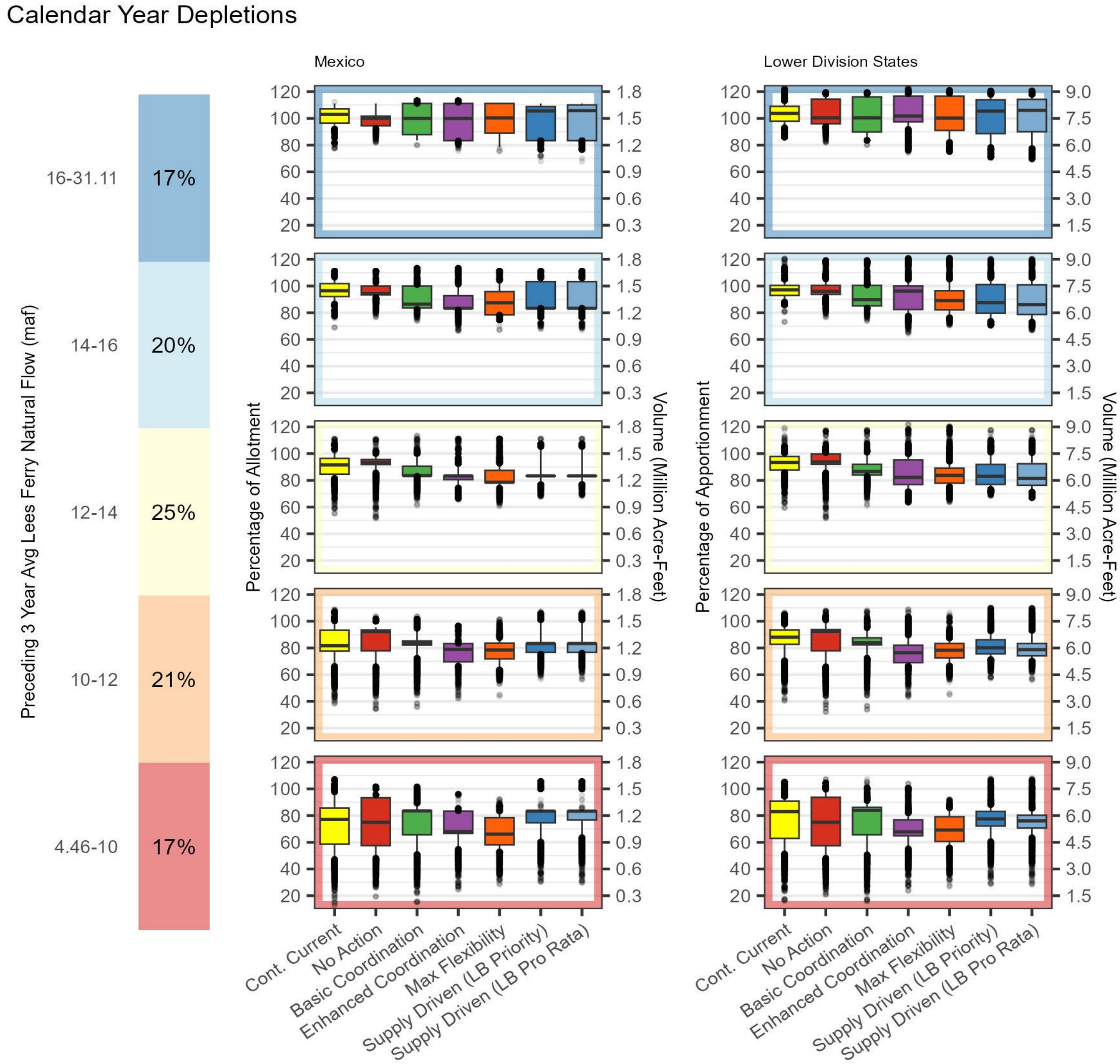
Water Deliveries to Mexico are described in **TA 4** and summarized here. Water deliveries to Mexico are a function of assumed reductions to Mexico and assumptions about the storage and delivery of conserved water to Mexico. Reclamation’s modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

M.4.1.1 Distributions of annual water deliveries to Mexico and Lower Division States

Figure M-4 presents conditional box plots of water deliveries to Mexico in comparison to deliveries to the combined Lower Division States of California, Arizona and Nevada. These deliveries reflect the total deliveries after shortages (i.e. water delivery reductions) and dead pool-related reductions have been subtracted from the total allotments of 1.5 maf for Mexico and 7.5 maf from the Lower Division States. The depletions are broken out by different hydrologic conditions, categorized by modeled preceding 3-year average Lees Ferry natural flows. The hydrologic analysis is framed using 5 flow categories to help to visualize the different potential states of the system throughout the 34-year period of analysis. The 5 flow categories are: Wet (16 maf and above), Moderately Wet (14-16 maf), Average (12-14 maf), Dry (10-12 maf), and Critically Dry (10 maf and below). The value of the left-hand vertical axes of the figure represents the percent of full allotment (terminology for Mexico) or allocation (for Lower Division States), therefore in the plot of deliveries for Mexico, 100 percent indicates when Mexico is receiving the annual 1.5 maf of delivery as specified in the 1944 Water Treaty, and in the plot for Lower Division States, 100 percent indicates when these states are receiving 7.5 maf. Scaling the vertical axis by percent allotment or apportionment allows direct comparability between Mexico and the LDS regarding the implications of the alternatives.

To evaluate the relative implications of the alternatives on deliveries to Mexico, an initial focus is on the Average Flow Category (12-14 maf preceding 3-year average), where the median percent of full allotment ranges from the least impactful No Action Alternative (93.3 percent) to the most impactful Maximum Flexibility Alternative (78.6 percent), with all other alternatives between this narrow range. In the Critically Dry Flow Category (4.46-10 maf preceding 3-year average), the median percent of full allotment ranges from the least impactful Basic Coordination Alternative (83.6 percent) to the most impactful Maximum Flexibility Alternative (66.1 percent), with all other alternatives between this expanding range.

Figure M-4
Conditional Box Plots of Calendar Year Water Deliveries to Mexico and Lower Division States



Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation’s modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

These values for Mexico are comparable to those of the combined Lower Division States, which in the Average Flow Category (12-14 maf preceding 3-year average) the median percent of full allocation ranges from the least impactful No Action Alternative (93.8 percent) to the most impactful Supply-Driven (LB Pro Rata approach) Alternative (81.5 percent). Similarly, for the Critically Dry Flow Category (4.46-10 maf preceding 3-year average) the median percent of full allocation ranges from the least impactful Basic Coordination Alternative (84.0 percent) to the most impactful Enhanced Coordination Alternative (67.8 percent).

Although the percent of any Lower Basin shortages or dead pool-related reductions is fixed as 16.67 percent among all the alternatives (except for the CCS Comparative Baseline), this does not necessarily equate to identical depletions as a percent of allotment (or apportionment) of reductions between the Lower Division States and Mexico. This is due to varied assumptions on banking parameters and banking activity between Mexico and the Lower Division States, and the monthly application of dead pool-related shortages. As seen in the analyses of annual water delivery reductions, the water delivery reductions (i.e. shortages) are identical as a percent of allotment (or apportionment) for Mexico and the Lower Division States. A comparison of median values of annual depletions under the middle and dry hydrologic categories is shown in **Table M-1**.

Table M-1
Annual depletions in Mexico and Lower Division States (as a percent of allotment or apportionment) at the median value of years in the average (12-14 maf preceding 3-year average) and critically dry (below 10 maf preceding 3-year average) hydrologic categories.

	Average Flow Category (12-14 maf preceding 3-year average)		Critically Dry Flow Category (4.46-10 maf preceding 3-year average)	
	Mexico	Lower Division States	Mexico	Lower Division States
Cont. Current	91.5	93.4	77.1	83.0
No Action	93.3	93.8	75.0	75.0
Basic Coordination	83.6	86.6	83.6	84.0
Enhanced Coordination	83.3	82.3	68.1	67.8
Max Flexibility	78.6	83.8	66.1	69.2
Supply-Driven (LB Priority)	83.3	83.1	83.3	77.5
Supply-Driven (LB Pro Rata)	83.3	81.5	83.3	76.0

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Due to the design of the No Action and Basic Coordination Alternatives having the lowest maximum shortages (0.6 maf and 1.48 maf respectively), these alternatives result in the lowest impact to diversions to Mexico or the Lower Division States, but at the cost of the largest impact on reservoir storage. The CCS Comparative Baseline has a similarly low maximum shortage (1.38 maf), but these levels of shortage do not begin until Lake Mead is below 1025 ft. The Maximum Flexibility Alternative has the highest maximum possible shortage (4.0 maf), thus resulting in the highest impacts to Mexico and the Lower Division States.

The variability of deliveries during dry conditions is another metric by which to evaluate the alternatives. To do this, the interquartile range (boxed areas representing the range from the 25th to 75th percentiles in **Figure M-4**) is highlighted within the Critically Dry Flow Category (4.46-10 maf). Three distinct groupings of alternatives are apparent (**Table M-2**). The CCS Comparative Baseline and the No Action Alternative have the widest interquartile range (27.1 percent and 35.8 percent respectively for Mexico, and 27.9 percent and 36.3 percent for the Lower Division States). The Basic Coordination, Enhanced Coordination, and Maximum Flexibility alternatives all have similar interquartile ranges (between 16.7 percent and 20.3 percent for Mexico and 11.9 percent and 20.5 percent for the Lower Division States). The Supply-Driven Alterative has the narrowest interquartile range, with 6.7 percent and 8.7 percent for the priority and pro-rata distribution approaches respectively for Mexico. In general, the narrower the variability, the more consistent the releases are, which is substantially influenced by the use of conservation and storage mechanisms that help to even out water deliveries. The alternatives with no or minimal banks have the greatest interquartile ranges or largest variability of flows near the median. On the other extreme, the Supply-Driven Alternative (both LB Priority and LB Pro Rata approaches) have the largest Lower Basin bank, resulting in the smallest interquartile ranges and least variability around the median. This highlights the benefits of conservation and banking mechanisms to reduce variability in water deliveries.

Table M-2
Interquartile range of annual depletions (as a percent of allotment or apportionment) for Mexico and Lower Division States at the Critically Dry Flow Category
(below 4.46-10 maf preceding 3-year average).

	Interquartile range	
	Mexico	Lower Division States
Cont. Current	27.1	27.9
No Action	35.8	36.3
Basic Coordination	17.9	20.5
Enhanced Coordination	16.7	11.9
Max Flexibility	20.3	18.5
Supply-Driven (LB Priority)	8.7	11.0
Supply-Driven (LB Pro Rata)	6.7	9.6

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Looking further into the distributions under the Critically Dry Flow Category (4.46-10 maf) (**Table M-3**), all alternatives show the possibility of deliveries to Mexico being reduced to extremely low percentages of their 1.5 maf apportionment, ranging from a minimum of 12.7 percent and 19.3

percent of apportionment (corresponding to 0.19 maf and 0.29 maf of deliveries to Mexico) under the Current Continued Strategies and the No Action Alternative respectively, to a minimum of 30.3 percent of apportionment (0.45 maf) for the Supply-Driven (LB Priority approach) Alternative. The relatively steady deliveries of 83.3 percent of apportionment for a wide range of 90th to 50th percentiles in the Supply-Driven Alternative (both LB Priority and LB Pro Rata approaches) reflects a comparatively greater reliability of deliveries to Mexico under the critically dry hydrologic conditions supported by the sizable conservation and banking mechanism.

Table M-3
Annual depletions in Mexico (as a percent of allotment) at the Critically Dry Flow Category (4.46-10 maf preceding 3-year average)

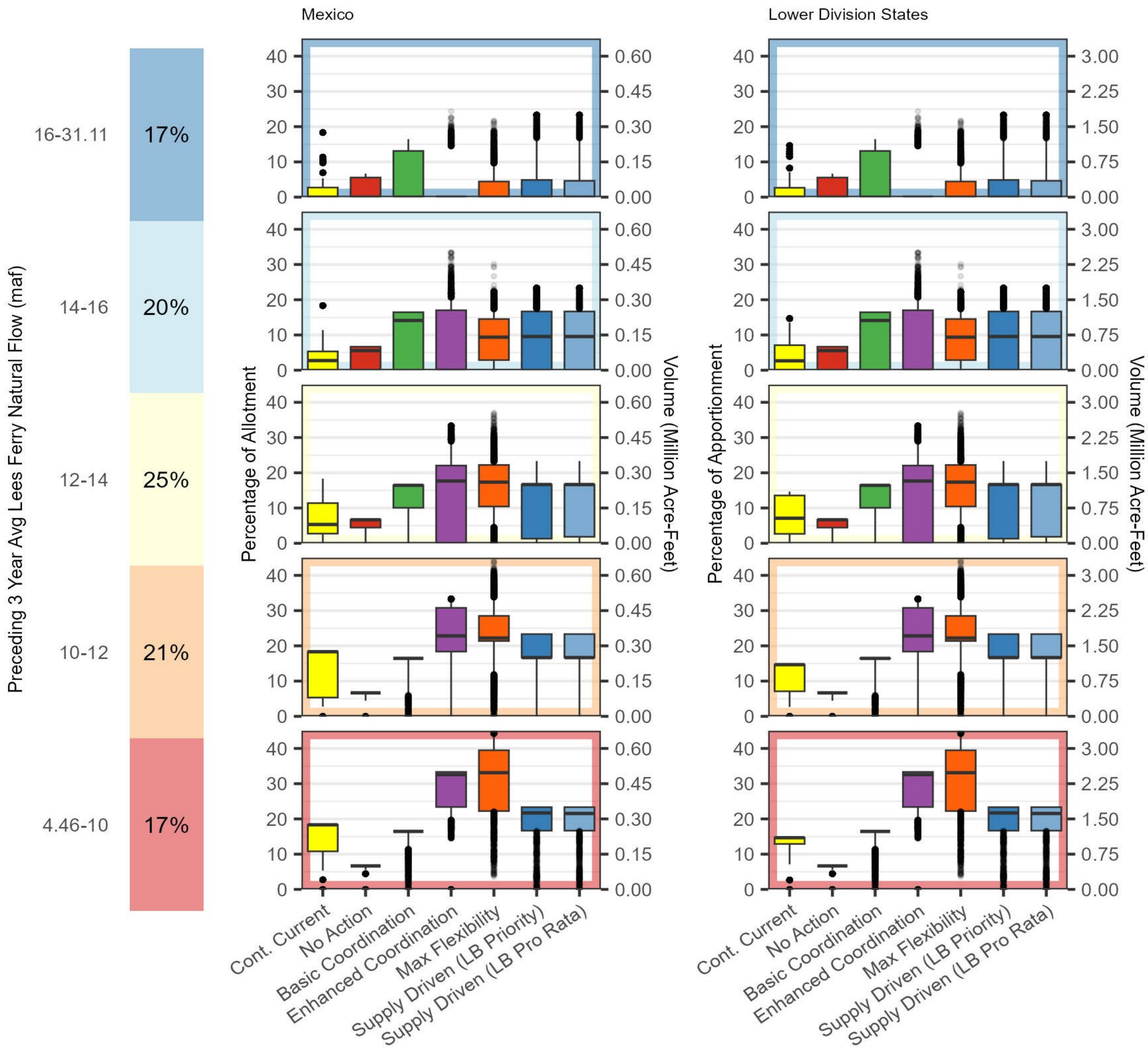
	Percentile						
	max	90th	75th	50th	25th	10th	min
Cont. Current	107.1	96.5	85.7	77.1	58.6	47.5	12.7
No Action	101.7	94.4	93.3	75.0	57.5	48.3	19.3
Basic Coordination	101.7	89.0	83.6	83.6	65.6	51.2	15.0
Enhanced Coordination	96.3	83.3	83.3	68.1	66.7	55.2	24.4
Max Flexibility	92.5	83.2	78.5	66.1	58.2	53.1	28.2
Supply-Driven (LB Priority)	105.6	83.3	83.3	83.3	74.7	60.5	30.3
Supply-Driven (LB Pro Rata)	105.6	83.3	83.3	83.3	76.7	63.9	29.7

Note: The modeled annual depletions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

M.4.1.2 Distributions of annual water delivery reductions to Mexico and Lower Division States

Using the same 5 preceding hydrologic flow categories to help to visualize the different potential states of the system throughout the 34-year period of analysis, **Figure M-5** shows the volume of water delivery reductions to Mexico alongside those of the combined Lower Division States. Due to the differences in magnitudes of use and corresponding shortages between Mexico and the Lower Division States, the left-hand axes show the percent of allotment or apportionment to allow comparability, and the right-hand axes show the volumes of water delivery reductions.

Figure M-5
Conditional Box Plots of Calendar Year Delivery Reductions to Mexico and Lower Division States



Note: The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

The magnitude of water delivery reductions to Mexico reflects the design of the policies as well as the hydrologic conditions. Under the Average Flow Category (12-14 maf preceding 3--year average), the Enhanced Coordination Alternative results in the largest median reduction value of 17.7 percent of apportionment for Mexico (**Table M-4**). The Maximum Flexibility Alternative and the Supply-Driven Alternative (both LB Priority and LB Pro Rata approaches) are similar with median values of

17.3 percent and 16.7 percent of Mexico's apportionment respectively. In contrast, both baselines reflect low water delivery reductions with the CCS Comparative Baseline resulting in a median of 5.3 percent and the No Action Alternative with a median of 6.7 percent of the apportionment to Mexico.

Table M-4
Water delivery reductions (as percent of allotment or apportionment) for Mexico and Lower Division States at the median value of years in the Average (12-14 maf preceding 3-year average) and Critically Dry (4.46-10 maf preceding 3-year average) Flow Categories.

	Average Flow Category (12-14 maf preceding 3-year average)		Critically Dry Flow Category (4.46-10 maf preceding 3-year average)	
	Mexico	Lower Division States	Mexico	Lower Division States
Cont. Current	5.3%	7.1%	18.3%	14.7%
No Action	6.7%	6.7%	6.7%	6.7%
Basic Coordination	16.4%	16.4%	16.4%	16.4%
Enhanced Coordination	17.7%	17.7%	32.6%	32.6%
Max Flexibility	17.3%	17.3%	33.1%	33.1%
Supply-Driven (LB Priority)	16.7%	16.7%	21.7%	21.7%
Supply-Driven (LB Pro Rata)	16.7%	16.7%	21.5%	21.5%

Note: The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Under the Critically Dry Flow Category (4.46-10 maf preceding 3-year average), the largest median water delivery reduction occurs using the Maximum Flexibility Alternative with a median of 33.1 percent of the apportionment to Mexico followed by the Enhanced Coordination Alternative with a median of 32.6 percent. The alternative with the lowest median water delivery reduction is the No Action Alternative (6.7 percent); however, as shown below, this low water delivery reduction results in the lowest avoidance of dead pool-related reductions.

The median water delivery reductions by a percent of apportionment are identical between Mexico and the Lower Division States under all alternatives. The one exception is the CCS Comparative Baseline, which is the result of current policies derived from the combination of actions specified in Minute 319 and Minute 323 for Mexico, and the combination of actions specified in the 2007 Interim Guidelines and 2019 Lower Basin Drought Contingency Plan for the Lower Division States.

All the modeled results that are used to develop the conditional box plots for Mexico in **Figure M-5** are shown in **Table M-5**. The values represent the percent of Mexico's 1.5 maf allotment that would be reduced by a water delivery reduction, and the shading represents the maximum possible water delivery reduction for each alternative. If a modeled scenario reaches this maximum water delivery reduction, any additional necessary water delivery reductions would result in dead pool-related reductions. With maximum shortage volumes of 0.6 maf for the No Action Alternative and 1.48 maf for the Basic Coordination Alternative, these reduction levels are reached in over half of the years (50th percentile) even within the Average Flow Category (12-14 maf). On the other extreme, the maximum shortage under the Maximum Operational Flexibility Alternative is infrequently reached, i.e. only during the Critically Dry Flow Category (4.46-10 maf) and then in less than 10 percent of those traces.

Table M-5
Modeled water delivery reductions (as a percent of 1.5 maf allotment) to Mexico within each flow category

Alternative	Streamflow Group	Max	90th	75th	50th	25th	10th	Min
Cont. Current (max water delivery reduction = 1.375 maf)	Wet (> 16)	18.3	5.3	2.7	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	18.3	11.4	5.3	2.7	0.0	0.0	0.0
	Average (12-14)	18.3	18.3	11.4	5.3	2.7	0.0	0.0
	Dry (10-12)	18.3	18.3	18.3	18.3	5.3	2.7	0.0
	Critically Dry (< 10)	18.3	18.3	18.3	18.3	10.8	5.3	0.0
No Action (max water delivery reduction = 0.6 maf)	Wet (> 16)	6.7	6.7	5.6	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	6.7	6.7	6.7	5.6	0.0	0.0	0.0
	Average (12-14)	6.7	6.7	6.7	6.7	4.4	0.0	0.0
	Dry (10-12)	6.7	6.7	6.7	6.7	6.7	4.4	0.0
	Critically Dry (< 10)	6.7	6.7	6.7	6.7	6.7	5.6	0.0
Basic Coordination (max water delivery reduction = 1.48 maf)	Wet (> 16)	16.4	16.4	13.1	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	16.4	16.4	16.4	14.1	0.0	0.0	0.0
	Average (12-14)	16.4	16.4	16.4	16.4	10.1	0.0	0.0
	Dry (10-12)	16.4	16.4	16.4	16.4	16.4	6.1	0.0
	Critically Dry (< 10)	16.4	16.4	16.4	16.4	16.4	11.5	0.0
Enhanced Coordination (max water delivery reduction = 3.0 maf)	Wet (> 16)	24.4	0.0	0.0	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	33.3	20.6	17.0	0.0	0.0	0.0	0.0
	Average (12-14)	33.3	28.8	22.1	17.7	0.0	0.0	0.0
	Dry (10-12)	33.3	33.2	30.8	22.8	18.4	0.0	0.0
	Critically Dry (< 10)	33.3	33.3	33.3	32.6	23.4	19.7	0.0
Max Flexibility (max water delivery reduction = 4.0 maf)	Wet (> 16)	21.7	9.6	4.4	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	30.1	17.3	14.5	9.4	2.9	0.0	0.0
	Average (12-14)	37.0	23.1	22.2	17.3	10.4	4.6	0.0
	Dry (10-12)	44.3	33.8	28.5	22.2	21.4	12.0	0.0
	Critically Dry (< 10)	44.5	44.1	39.5	33.1	22.2	22.2	3.5
Supply-Driven LB Priority (max water delivery reduction = 2.1 maf)	Wet (> 16)	23.3	16.7	4.9	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	23.3	17.4	16.7	9.6	0.0	0.0	0.0
	Average (12-14)	23.3	23.3	16.7	16.7	1.3	0.0	0.0
	Dry (10-12)	23.3	23.3	23.3	16.7	16.7	0.0	0.0
	Critically Dry (< 10)	23.3	23.3	23.3	21.7	16.7	16.7	0.0

Alternative	Streamflow Group	Max	90th	75th	50th	25th	10th	Min
Supply-Driven LB Pro Rata (max water delivery reduction = 2.1 maf)	Wet (> 16)	23.3	16.7	4.6	0.0	0.0	0.0	0.0
	Mod. Wet (14-16)	23.3	17.4	16.7	9.6	0.0	0.0	0.0
	Average (12-14)	23.3	23.3	16.7	16.7	1.8	0.0	0.0
	Dry (10-12)	23.3	23.3	23.3	16.7	16.7	0.0	0.0
	Critically Dry (< 10)	23.3	23.3	23.3	21.5	16.7	16.7	0.0

Notes:
- Percentiles indicate the range of distribution with each category and correspond to the box plots in **Figure M-5**. Shading indicates conditions in which the maximum water delivery reduction has been reached.
- The modeled annual delivery reductions in Mexico include modeling assumptions for reductions in water deliveries to Mexico and storage available to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

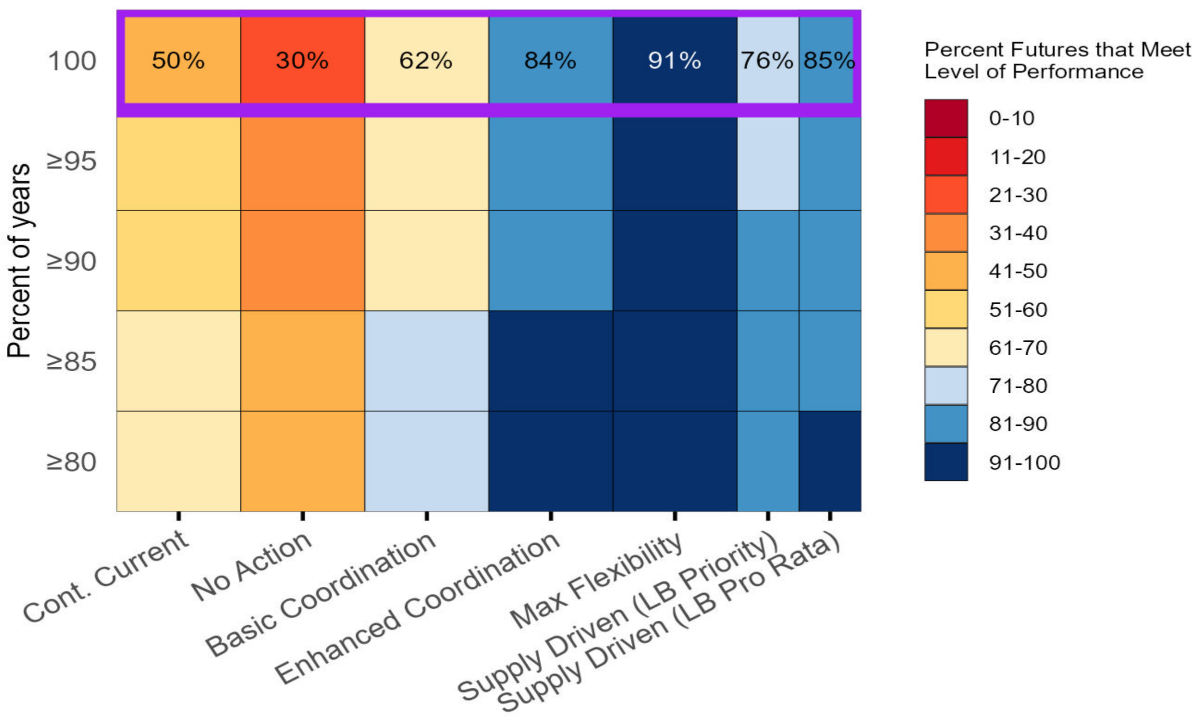
The values in **Table M-5** demonstrate how the magnitude of potential water delivery reductions generally increases based on the maximum reduction designed within the alternative, allowing a relative ranking of the alternatives from the lowest reductions in the No Action Alternative and increasing to the Maximum Flexibility alternative.

No Action	<	Basic Coord.	<	Current Cont. Strat.	<	Supply Driven Alternatives	<	Enhanced Coord.	<	Maximum Flexibility
Lowest Water Delivery Reductions										Highest Water Delivery Reductions

In contrast, the extent of shading in **Table M-5** demonstrates the relative susceptibility of each alternative to reach its maximum shortage. If the maximum water delivery reductions are reached and the reservoirs continue to decline due to supply-demand imbalances, Mexico, along with users in the Lower Division States, would be subject to dead pool-related reductions as Lake Mead elevations decline. Only by keeping Lake Mead above dead pool can water releases assuredly be made to Mexico that are only subjected to planned reductions.

To support this finding, **Figure M-6** shows the ability of each alternative (columns) to avoid dead pool-related reductions at Lake Mead in the specified percent of years (rows) using the 1200 futures analyzed in CRSS. The highlighted row in this robustness heatmap represents the percentage of futures that an alternative successfully avoids dead pool-related reductions in 100 percent of the years.

Figure M-6
Lake Mead Dead Pool-Related Reductions Robustness Heatmap
Percent of futures in which dead pool-related reductions are avoided in the percent of years specified in each row



As an example, the Maximum Flexibility Alternative keeps Mexico, along with all Lower Basin water users, from facing dead pool-related reductions in 91 percent of the 1200 futures assessed, while the No Action Alternative avoids dead pool-related reductions in only 30 percent of futures. Using the numbers in **Figure M-6** as a guide, a ranking of alternatives based on Mexico and Lower Division States' susceptibility to dead pool reductions is as follows.

Max. Flex.	<	Supply Driven Pro-rata	<	Enhanced Coord.	<	Supply Driven Priority	<	Basic Coord.	<	Cont. Current	<	No Action
Lowest suscept-ability to dead pool reductions												Highest suscept-ability to dead pool reductions

M.4.2 Issue 2: Quality of water delivered to Mexico

Water Salinity of deliveries to Mexico are described in **TA 06**, Water Quality and summarized here.

Due to natural and anthropogenic sources, high salinity in the Colorado River is an issue of concern for both the United States and Mexico and is actively managed. Minute 242 of the 1944 Waters

Treaty specifies a maximum differential of salinity between water that arrives at the Morelos Dam and that which arrives at the Imperial Dam. As described earlier, the Bureau of Reclamation meets this obligation through several different means, including bypassing saline waters through the MODE canal around agricultural, municipal, and industrial systems in the United States and Mexico and blending water arriving at the NIB through additional upstream releases. Relevant to the federal action addressed in this Draft EIS is a comparative assessment of the long-term implications of the proposed alternatives on salinity levels reaching both the Imperial Dam and NIB; however, an evaluation of the salinity differential as described in Minute 242 is not applicable because this is actively managed by Reclamation through various means at a smaller timescale than is required for this Draft EIS. As a result, the impacts of the alternatives are provided as concentrations at the principal points of diversion at the Imperial Dam and NIB and are not intended to be used to determine salinity differential requirements as specified in Minute 242.

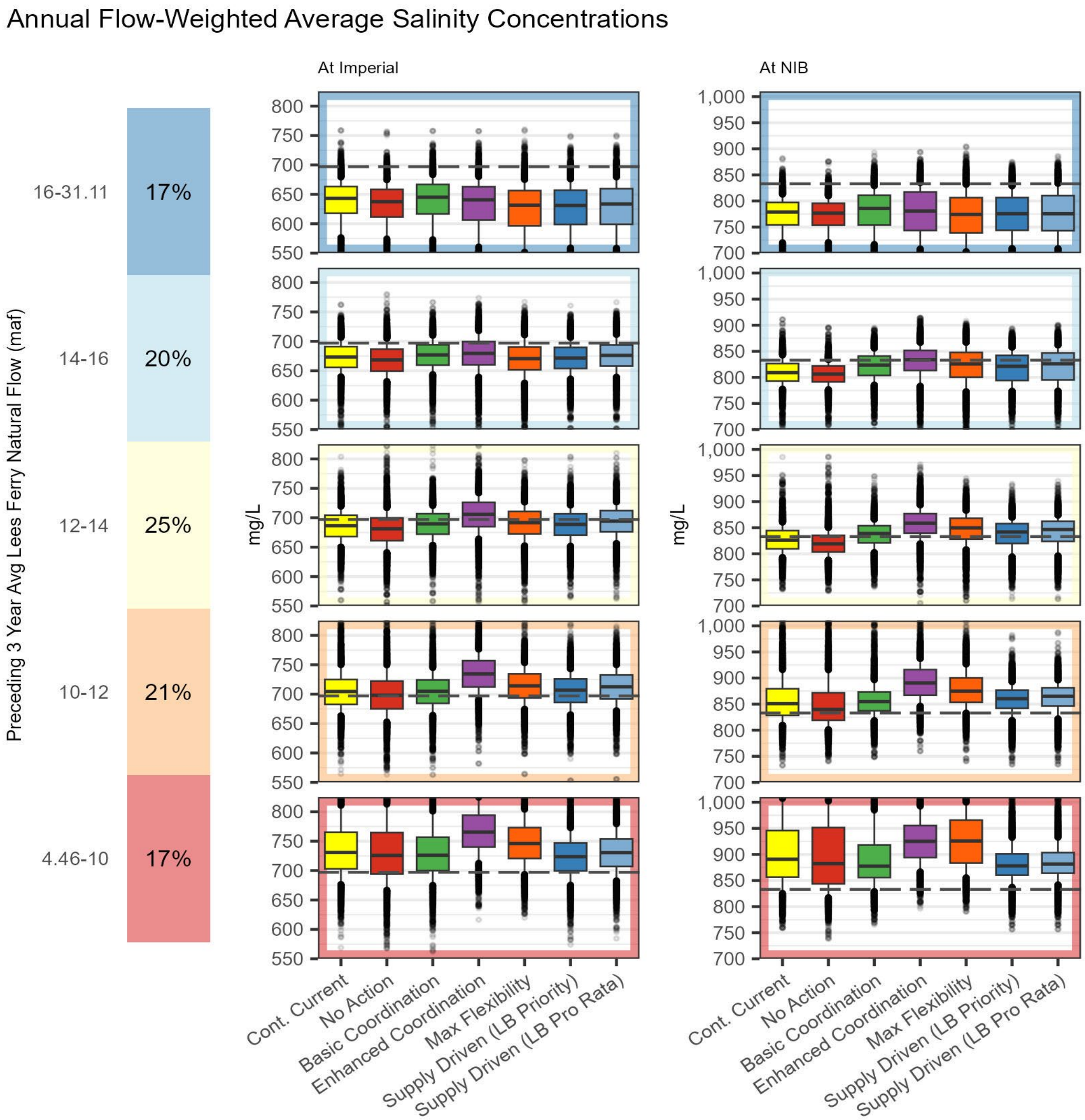
M.4.2.1 Salinity ranges at Imperial Dam and NIB

Average annual salinity ranges at Imperial Dam and NIB for the modeled alternatives are shown in **Figure M-7** using the same 5 preceding hydrologic flow categories to help to visualize the different relative impacts throughout the 34-year period of analysis. While these graphics suggest similar impacts across the scenarios on an annual flow-weighted average, relative differences between the alternatives can be seen and are attributed primarily to the frequency of shortages and secondarily to the shortage distribution method used among water uses along the reaches below Lake Mead. For reference purposes, the flow-weighted average annual salinity from 2012 to 2024 is 697 mg/L at the Imperial Dam and 833 mg/L at NIB, shown as horizontal dotted lines in the conditional box plots.

The magnitude of shortages has the effect of reducing releases and retaining more water in Lake Mead and Lake Powell in certain alternatives, thus assuming the downstream mass loading of salt is constant, results in increasing salinity concentrations anywhere downstream of the reservoirs where flows are diminished[4]. At both Imperial Dam and NIB, results from the Critically Dry Flow Category (4.46-10 maf preceding 3-year average) indicate that the highest median salinity values occur in the Enhanced Coordination and Maximum Flexibility alternatives, both of which have the highest shortage values 3.0 and 4.0 maf/year respectively (**Figure M-7**).

[4] In the case of NIB, operational modifications on a smaller timescale by Reclamation's Yuma Area Office can be made to ensure that the Minute 242 salinity differential is met.

Figure M-7
Conditional Box Plots of Annual Flow-Weighted Average Salinity Concentrations at Imperial Dam and at the Northerly International Border (NIB). Horizontal lines represent the flow-weighted average annual salinity from 2012 to 2024 (697 mg/L at Imperial Dam and 833 mg/L at NIB)



The second factor affecting salinity levels is the distribution and locations of shortages taken by users in the Lower Division States. Any reduction to water deliveries reduces the flows downstream of Lake Mead; however, shortages applied to users further downstream result in reduced overall flow volumes for longer stretches of the river, including at the point of diversion, as compared to the case when shortages are applied to users higher in the basin. As a conceptual example and strictly for the purpose of understanding this geographical aspect, reductions resulting in shortages to users only on the Central Arizona Project (CAP) would reduce flows between Lake Mead and

Lake Havasu but allow the same volume of water (and salinity dilution resulting from salt introduced) downstream of Lake Havasu and entering the All-American Canal at Imperial Dam as would occur without any shortages. However, reductions of the same magnitude taken only from the Imperial Irrigation District would result in lower flows from Lake Mead to the Imperial Dam resulting in higher salinity values into the All-American Canal and at the Morelos Dam resulting from salt introduced between Lake Havasu and the Imperial Dam. When considering these spatial relationships of the users alongside the priority system with more junior users upstream (i.e., CAP) and more senior users downstream (i.e. IID), an alternative with priority distribution would tend to result in lower salinity levels at Imperial Dam while a pro-rata distribution would result in higher salinity levels at Imperial Dam. This result is apparent in the Supply-Driven (LB Pro Rata approach) Alternative resulting in higher salinity levels compared to the Supply Driven (LB Priority approach) Alternative at Imperial Dam. Even more pronounced is the higher salinity levels resulting from the Enhanced Coordination Alternative, which uses a basin-wide pro-rata shortage allocation, relative to the Maximum Flexibility Alternative which uses a priority-based shortage allocation.

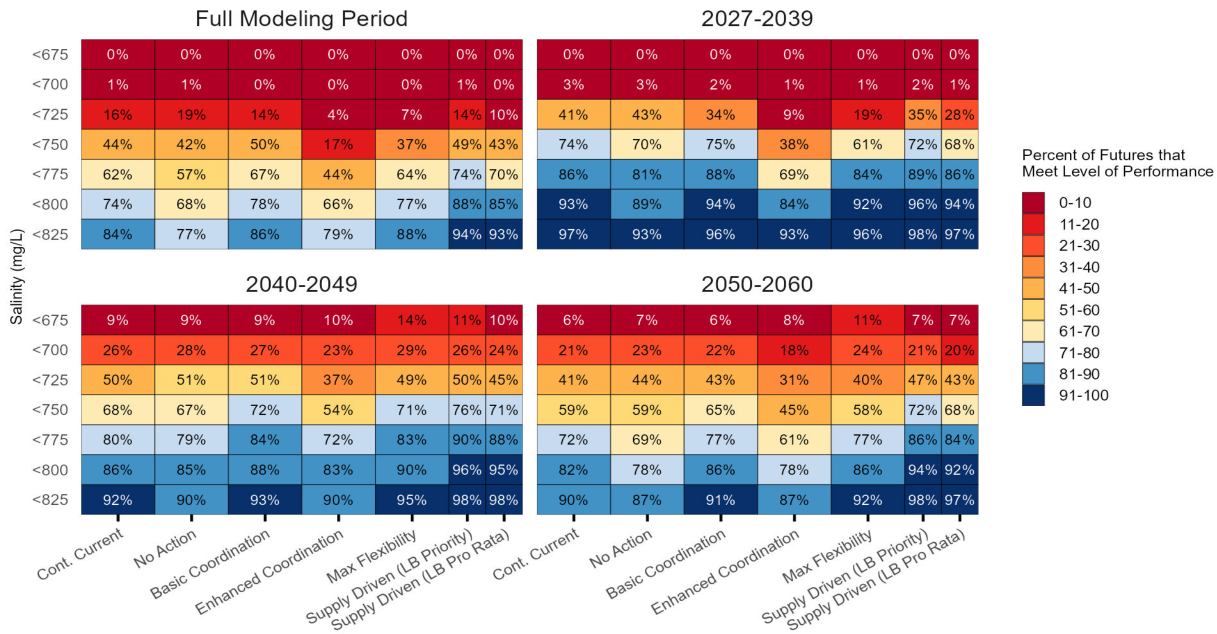
Differences in salinity levels using priority vs. pro-rata alternatives are not apparent at NIB because of two reasons. First, both distribution methods assume that a 16.67 percent water delivery reduction to Mexico is applied from any shortage that occurs and is therefore not subject to the choice of distribution method. In other words, the volume of water that flows past the Imperial Dam and reaches the NIB is the same regardless of the decision of priority vs. pro-rata among users in the Lower Division States. Second, salt loading introduced below Imperial Dam only affects salinity levels at Morelos dam and are not affected by distribution methods upstream in the USA. The lack of effect of distribution method on salinity at NIB reveals that salinity sources between Imperial and NIB dominate the effects of varying salinity concentrations further upstream.

M.4.2.2 Number of traces that average annual salinity at Imperial Dam and NIB exceed tolerances[5]

The differences in policies over levels of salinity is also shown in **Figure M-8** for Imperial Dam and **Figure M-9** for NIB. These heatmaps demonstrate the percent of futures that meet a level of performance as defined by the maximum salinity levels on the y-axis, with the most difficult criteria to achieve being a lower salinity concentration (top row) and the easiest criteria to achieve being a larger salinity number (bottom row). The heatmaps are provided considering the full modeled period (2027-2060) as well as three incremental periods (2027-2039, 2040-2049, and 2050-2060), allowing an understanding of the ability to stay below thresholds over time. A range of average annual salinity thresholds are provided at each location to accommodate the impacts on different uses.

[5] The salinity analysis provided by CRSS is on a monthly basis and on a course spatial resolution and therefore does not capture the operational options that the Bureau of Reclamation has to manage salinity to meet the differential as described in Minute 242. The value of this analysis is also not in the absolute numbers which are an aggregation of multiple hydrologic scenarios and across time, but instead to compare the alternatives considered in this EIS based on the relative implications for salinity levels at key locations.

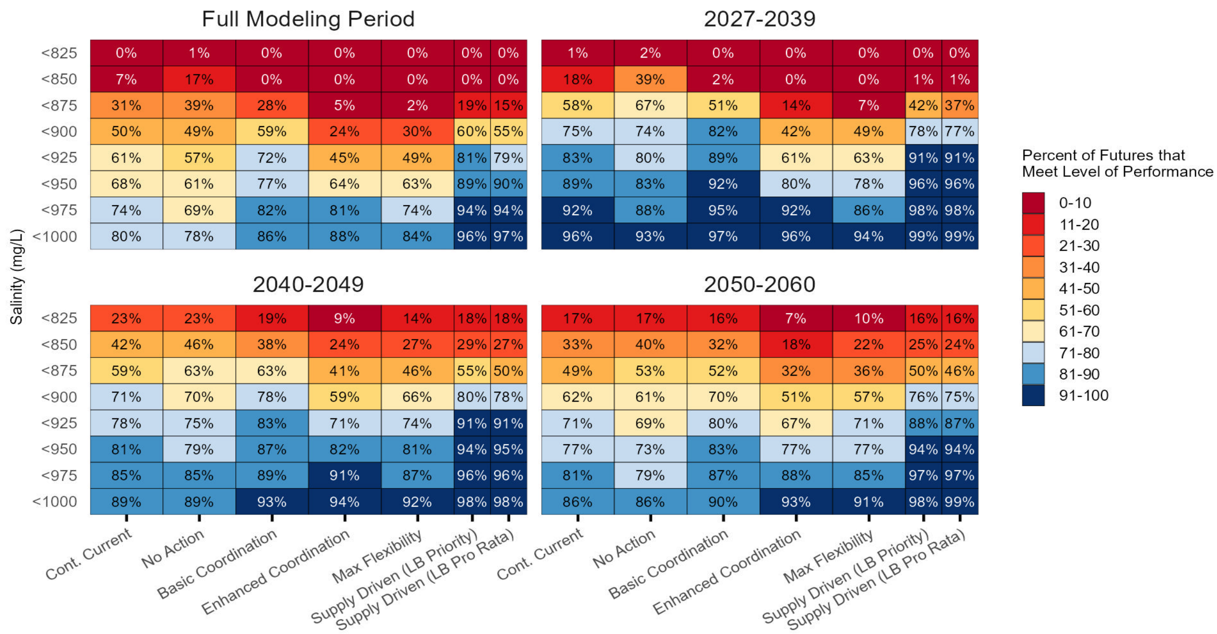
Figure M-8
Salinity at Imperial: Robustness
Percent of futures in which the concentration is below the specified value in every year



As described earlier, the flow-weighted average annual salinity at the Imperial Dam from 2012 to 2024 is 697 mg/L. To evaluate alternatives with this criterion using **Figure M-8**, one can see that all alternatives rarely are below 700 mg/L when considering the entire modeling time horizon of 2027 to -2060. However, when looking at time ranges into the future when initial reservoir conditions are less influential on the results, the alternative with the highest number of futures that are below 700 mg/L is the Maximum Flexibility Alternative with 29 percent of futures from 2040-2049 and 24 percent of futures from 2050-2060 meet this criteria. The alternative with the least number of futures that are below 700 mg/L is the Enhanced Coordination Alternative, which uses a basin-wide pro-rata shortage distribution method. The influence of the distribution method is also demonstrated by observing the two approaches of the Supply-Driven Alternative and noting the LB Pro Rata approach consistently has fewer futures that do not exceed any of the thresholds provided in **Figure M-8.**

Figure M-9 shows the relative impacts of the modeled alternatives on salinity at NIB. As described earlier, the flow-weighted average annual salinity at the NIB from 2012 to 2024 is 833 mg/L. Although this specific value is not listed in along the y-axis of **Figure M-9**, the figure reveals that avoiding salinity levels that exceed this concentration is most likely to occur in the No Action Alternative, CCS Comparative Baseline, and Basic Coordination ability is not significantly affected by the choice of shortage distribution method, which can be seen with the nearly equal percent of futures between the LB Priority and LB Pro Rata approaches of the Supply-Driven Alternative.

Figure M-9
Salinity at the NIB: Robustness
Percent of futures in which the concentration is below the specified value in every year

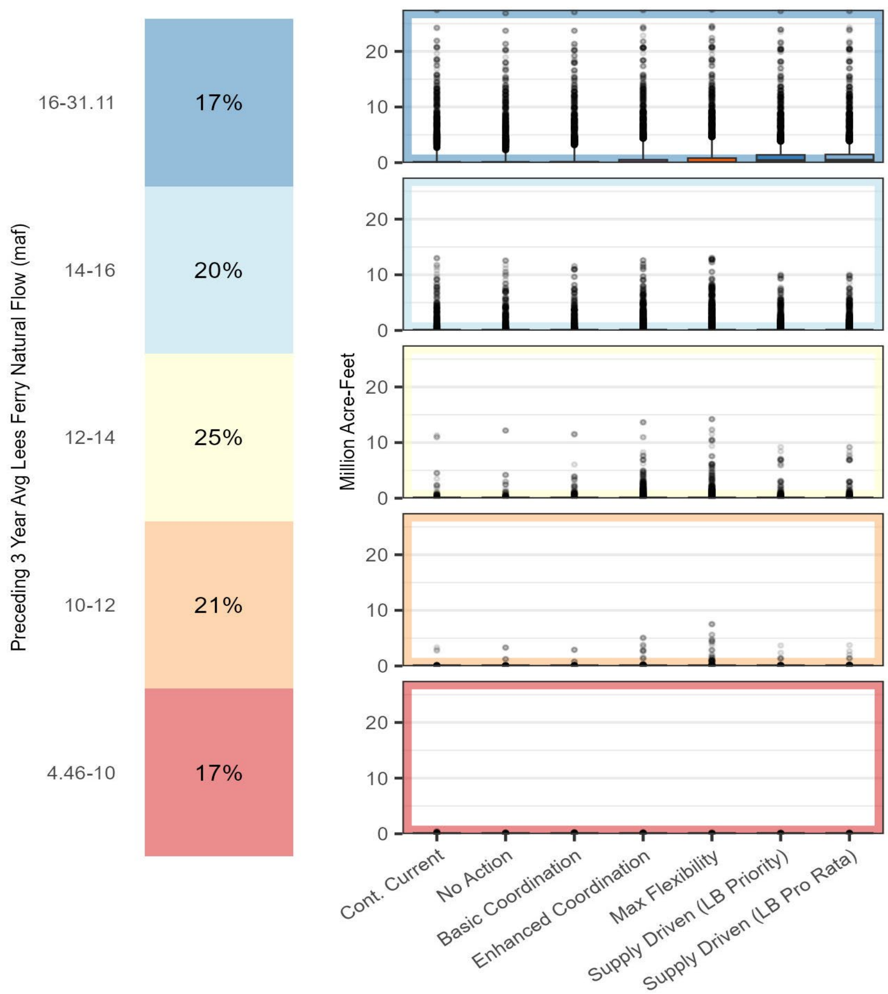


M.4.3 Issue 3: Flows below Morelos Dam

As shown previously in **Figure M-3**, flows in the Limitrophe were historically significant in the 1980s during flood control years; however, in recent years these flows have been limited to water passing Morelos Dam in excess of Mexico's scheduled delivery due to flood control operations at Hoover Dam or releases from Hoover Dam that cannot be used due to local circumstances such as unexpected rainfall, seepage from Morelos Dam, flows from the Gila River, irrigation return flows, groundwater inflow, or water released in 2014 specifically for the purpose of environmental enhancement related to Minute 319. Although not currently scheduled or planned, future flows in the Limitrophe could also occur due to any of these reasons. Habitat conditions in the Limitrophe are severely deteriorated from natural conditions, but restoration efforts have resulted in positive responses in Hunters Hole in the United States and Miguel Aleman in Mexico. A third site, initiated by the Cocopah Indian Tribe is beginning construction in late 2025 and will add a further 400 acres of native habitat. However, these sites are irrigated through pumped groundwater and hydrologically disconnected from the river channel. The implications of the alternatives for the Limitrophe differ primarily due to changes in the frequency and magnitude of possible future flood control releases. As reservoirs are maintained in higher elevations under different alternatives, there is an increased likelihood of wet hydrologic years causing such flood control releases from Lake Mead.

Figure M-10 shows the volumes of water released from Morelos Dam under the different alternatives analyzed and categorized by the same preceding 3-year Lees Ferry natural flows. These modeled flows are exclusively the result of flood control releases. Releases made for environmental purposes are not reflected in releases from Morelos Dam and are assumed to be diverted by Mexico at Morelos Dam and re-released into the Colorado River in Mexico after traveling south through Mexico's canal infrastructure.

Figure M-10
Calendar Year Total Annual Flow Volume Released Below Morelos Dam



Under the average, dry, and critically dry hydrologic categories (below 14 maf preceding 3-year average) flows below Morelos Dam into the Limitrophe only occur in 10 percent or less of the hydrologic futures and therefore can be considered infrequent and incidental. Even in the Moderately Wet Flow Category (14-16 maf preceding 3-year average), the 90th percentile is above zero only in the Enhanced Coordination, Maximum Flexibility and Supply-Driven (both LB Priority and LB Pro Rata approaches) Alternatives. In the Wet Flow Category (above 16 maf preceding 3-year average), the Supply-Driven Alternative (both LB Priority and LB Pro Rata approaches) result in small flows at the median.

Although infrequent, in all hydrologic categories except for the Critically Dry Flow Category (4.46-10 maf), there is always a possibility of short-duration large volume flows in the Limitrophe. These are the result of exceptionally high flows that could occur in some of the hydrologic futures considered in the modeling analysis.

Implications of the modeled alternatives on riparian vegetation and habitat conditions in the Limitrophe reach are not explicitly modeled for comparison, but one can surmise from the Minute 319 environmental pulse flow in 2014 that increased frequency of flows passing the Morelos Dam resulting from flood control releases from Lake Mead is beneficial for these conditions and reduced likelihood of flood flows and continued groundwater declines will cause further vegetation deterioration in this region. The intermittent nature of future natural flooding events reaching the Limitrophe suggests that the Maximum Flexibility Alternative, which provides for storing of water and periodic releases for habitat restoration, is the only alternative that is likely to have beneficial implications for this region.

M.5 References

Bureau of Reclamation (Reclamation). 2007a. Record of Decision: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Washington, D.C. Internet website: https://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf.

_____. 2007b. Final Environmental Impact Statement: Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Washington, D.C. Internet website: https://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html.

_____. 2019. Colorado River Drought Contingency Plans. May 2019. Internet website: https://www.usbr.gov/ColoradoRiverBasin/dcp/finaldocs.html.

_____. 2024. Near-Term Colorado River Operations, Final Supplemental Environmental Impact Statement. March 2024. Upper and Lower Colorado Basins Interior Regions 7 and 8. Internet website: https://www.usbr.gov/ColoradoRiverBasin/documents/NearTermColoradoRiverOperations/20240300-Near-termColoradoRiverOperations-FinalSEIS-508.pdf.

Cohen, M. 2013. Groundwater Dynamics in the Colorado River Limitrophe. Oakland, California Pacific Institute. Internet website: https://pacinst.org/publication/groundwater-dynamics-in-the-colorado-river-limitrophe/.

Glenn, E. P., K. Hucklebridge, O. Hinojosa-Huerta, P. L. Nagler, and J. Pitt. 2008. "Reconciling Environmental and Flood Control Goals on an Arid-Zone River: Case Study of the Limitrophe Region of the Lower Colorado River in the United States and Mexico." *Environmental Management* 41(3):322-335. Internet website: https://doi.org/10.1007/s00267-007-9056-4.

González-Sargas, E., M. Gómez-Sapiens, O. Hinojosa-Huerta, S. Villagomez-Palma, A. Calvo-Fonseca, J. Grand, T. D. Meehan, et al. 2024. "Avian communities respond to plant and landscape composition in actively revegetated floodplains of the Colorado River delta in Mexico." *Ecological Engineering* 205:107266. Internet website: https://doi.org/10.1016/j.ecoleng.2024.107266.

Ramírez-Hernández, J., O. Hinojosa-Huerta, M. Peregrina-Llanes, A. Calvo-Fonseca, and E. Carrera-Villa. 2013. "Groundwater responses to controlled water releases in the limitrophe region of the Colorado River: Implications for management and restoration." *Ecological Engineering* 59:93-103. Internet website: https://doi.org/10.1016/j.ecoleng.2013.02.016.

International Boundary Water Commission (IBWC). 1973. Minute No. 242: Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River. United States and Mexico. August 30, 1973. Internet website: https://www.ibwc.gov/wp-content/uploads/2023/05/Min242.pdf.

_____. 2010. Minute No. 318: Adjustment of Delivery Schedules for Water Allotted to Mexico for the Years 2010 Through 2013 as a Result of Infrastructure Damage in Irrigation District 014, Rio Colorado, Caused by the April 2010 Earthquake in the Mexicali Valley, Baja California. United States and Mexico. December 17, 2010. Internet website: https://www.ibwc.gov/wp-content/uploads/2023/03/Min_318.pdf.

_____. 2012. Minute No. 319: Interim International Cooperative Measures in the Colorado Rier Basin Through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California. United States and Mexico. November 20, 2012. Internet website: https://www.ibwc.gov/wp-content/uploads/2012/11/Minute_319.pdf.

_____. 2017. Minute No. 323: Extension of Cooperating Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin. United States and Mexico. September 21, 2017. Internet website: https://www.ibwc.gov/wp-content/uploads/2023/03/Min323.pdf.

_____. 2018. Minute 319 Colorado River Limitrophe and Delta Environmental Flows Monitoring Final Report, November 2018. Internet website: https://www.ibwc.gov/wp-content/uploads/2023/06/Minute_319_Monitoring_Report_112818_FINAL.pdf.

______. 2022. Minute 323 Colorado River Limitrophe and Delta Environmental Flows Monitoring Interim Report for 2018, February 2022. Internet website: https://www.ibwc.gov/wp-content/uploads/2024/06/FINAL_2018Min323MonitoringReport-2022-02-15-Clean.pdf.

______. 2024. Minute No. 330: Expansion of Colorado River Temporary Measures. United States and Mexico. March 21, 2024. Internet website: https://www.ibwc.gov/wp-content/uploads/2024/04/Minute-330-English-Spanish-Version-Signed-Clean.pdf.

Jarchow, C. J., P. L. Nagler, E. P. Glenn, J. Ramírez-Hernández, and J. E. Rodríguez-Burgueño. 2017a. "Evapotranspiration by remote sensing: An analysis of the Colorado River Delta before and after the Minute 319 pulse flow to Mexico." *Ecological Engineering* 106:725-732. Internet website: https://doi.org/10.1016/j.ecoleng.2016.10.056.

Jarchow, C. J., P. L. Nagler, and E. P. Glenn. 2017b. "Greenup and evapotranspiration following the Minute 319 pulse flow to Mexico: An analysis using Landsat 8 Normalized Difference Vegetation Index (NDVI) data." *Ecological Engineering* 106:776-783. Internet website: https://doi.org/10.1016/j.ecoleng.2016.08.007.

Nagler, P., I. Sall, A. Barreto-Muñoz, M. Gómez-Sapiens, H. Nouri, S. Chavoshi Borujeni, and K. Didan. 2022. "Effect of Restoration on Plant Greenness and Water Use in Relation to Drought in the Riparian Corridor of the Colorado River Delta." *Journal of the American Water Resources Association* 58(5):746-784. Internet website: https://doi.org/10.1111/1752-1688.13036.

Pitt, J., E. Kendy, K. Schlatter, O. Hinojosa-Huerta, K. Flessa, P. B. Shafroth, J. Ramírez-Hernández, et al. 2017. "It takes more than water: Restoring the Colorado River Delta." *Ecological Engineering* 106:629-632. Internet website: https://doi.org/10.1016/j.ecoleng.2017.05.028.

United States of America and Mexico. 1944. Treaty Relating to the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande. Washington DC, United States Govt Printing Office. Internet website: https://www.ibwc.gov/wp-content/uploads/2022/11/1944Treaty.pdf.

United States Geological Survey (USGS). 2018. Conceptual and Numerical Models of Dissolved Solids in the Colorado River, Hoover Dam to Imperial Dam, and Parker Dam to Imperial Dam, Arizona, California, and Nevada; Anning, David; Coes, Alissa; and Mason, Jon; Scientific Investigations Report 2018-5108, U.S. Geological Survey. Internet website: https://pubs.usgs.gov/sir/2018/5108/sir20185108.pdf.