

Appendix Q

Modeling Assumptions with Regard to Future Water Deliveries to Mexico Sensitivity Analysis

This appendix provides a comparative analysis of the sensitivity of the hydrologic resources to different modeling assumptions with regard to how Mexico may incur future water delivery reductions. Two methodologies for determining future water delivery reductions to Mexico are described. The modeling assumptions used to implement the methodologies are also presented.

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Q.1 Introduction

The proposed federal action includes the adoption of specific interim guidelines for Lower Basin shortages. The interim guidelines would be used by the Secretary to determine those circumstances under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead to the Colorado River Lower Division states (Arizona, California, and Nevada) (Section 1.7) below 7.5 million acre-feet (maf) (a “Shortage”) pursuant to Article II(B)(3) of the Consolidated Decree. The determination of deliveries to Mexico is not a part of the proposed federal action. Any such determination would be made in accordance with the 1944 Treaty. Nevertheless, modeling assumptions with respect to the distribution of shortages for the Lower Division states include water delivery reductions to Mexico in order to analyze potential impacts to hydrologic and other environmental resources (Section Q.2.2.1 and Appendix A)¹. These modeling assumptions were applied to the No Action Alternative as well as the action alternatives, i.e., the modeling assumptions with regard to the distribution of shortages to the Lower Division states include water delivery reductions to Mexico and are identical in all alternatives.

This appendix provides a comparative analysis of the sensitivity of the hydrologic resources to different modeling assumptions with regard to how Mexico would be impacted by future water delivery reductions. Two methodologies for determining future water delivery reductions to Mexico are described. The modeling assumptions used to implement the methodologies are also presented.

Q.2 Description of Methodologies

Although many possible methodologies exist that would result in different volumes of potential future water delivery reductions to Mexico, two methodologies were considered in this analysis in order to assess the sensitivity of the hydrologic resources to a wide range of possible water delivery reductions. Both methodologies are similar and both assume that the water deliveries to Mexico would be reduced in the same proportion as reductions in consumptive uses in the United States (shortages). The difference between the methodologies is whether shortages in both the Upper Basin and Lower Basin in the United States are considered when applying water delivery reductions to Mexico. Methodology A applies water delivery reductions to Mexico only when shortages to United States users in the Lower Basin occur, and water deliveries to Mexico are reduced in the same proportion as the reduction to United States users in the Lower Basin. This is the methodology that was used for the resource analyses in Volume I of this Final EIS. Methodology B applies water delivery reductions to Mexico when shortages to United States

¹ Reclamation’s modeling assumptions are not intended to constitute an interpretation or application of the 1944 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 Treaty with Mexico through the IBWC in consultation with the Department of State.

users in either the Upper Basin or Lower Basin or both occur, and water deliveries to Mexico are reduced in the same proportion as the reduction to United States users in both the Upper and Lower Basins. These methodologies are described below along with comparisons of the results of the methodologies.

Q.2.1 Methodology A

Under Methodology A, water delivery reductions to Mexico are triggered only when deliveries to United States users in the Lower Basin are reduced. When triggered, the water deliveries to Mexico are reduced in the same proportion as the reduction to the United States users in the Lower Basin. The methodology is as follows:

- 1) Determine the shortage to be applied to United States users in the Lower Basin. Under the Preferred Alternative, shortages of specific magnitudes are triggered by specific Lake Mead elevations.
 - Example: for the Preferred Alternative, if Lake Mead elevation is below 1,025 feet msl, the shortage to United States users in the Lower Basin is 500 kaf
- 2) Compute the proportional reduction to United States users in the Lower Basin by dividing the shortage to be applied to United States users in the Lower Basin by the total United States Lower Division states apportionments (7.5 maf).
 - Example: assuming a shortage to United States users in the Lower Basin of 500 kaf, the proportional reduction would be computed as:

$$500 \text{ kaf} / 7.5 \text{ maf} = 6.7 \text{ percent}$$

- 3) Compute the water delivery reduction to Mexico by applying the same proportional reduction to United States users in the Lower Basin to Mexico. This is computed by multiplying Mexico's annual Colorado River allotment (1.5 maf) by the proportional reduction to United States users in the Lower Basin.²
 - Example: assuming the proportional reduction to United States users in the Lower Basin is 6.7 percent, the water delivery reduction to Mexico would be computed as:

$$1.5 \text{ maf} * 6.7 \text{ percent} = 100 \text{ kaf}$$

A summary of shortages to United States users in the Lower Basin and water delivery reductions to Mexico for the three levels of shortages under the Preferred Alternative is provided in Table Q-1 and Table Q-2 respectively.

² Alternatively, under Methodology A, the same volume of the reduction to Mexico may be computed by taking 16.7 percent of the total water reduction applied to the United States and Mexico. This percentage is computed by taking the ratio of Mexico's allotment to the sum of the Lower Basin United States apportionments and Mexico's allotment ($1.5 \text{ maf} / (7.5 \text{ maf} + 1.5 \text{ maf}) = 0.167$ or 16.7 percent). This approach results in the same proportional reduction to Mexico as occurs to the United States users in the Lower Basin (see Attachment A).

Table Q-1
Examples of Shortages to United States Users in the Lower Basin for Methodology A

Lake Mead Elevation (feet msl)	Reduction to United States Lower Basin users (kaf)	Delivery to United States Lower Basin Users (kaf)	Percent Reduction to United States Lower Basin Users
1,075 to 1,050	333	7,167	4.4
1,050 to 1,025	417	7,083	5.6
Less than 1,025	500	7,000	6.7

Table Q-2
Examples of Water Delivery Reductions to Mexico for Methodology A

Mead Elevation (feet msl)	Reduction to Mexico (kaf)	Delivery to Mexico (kaf)	Percent Reduction to Mexico
1,075 to 1,050	67	1,433	4.4
1,050 to 1,025	83	1,417	5.6
Less than 1,025	100	1,400	6.7

Q.2.2 Methodology B

Under Methodology B, water delivery reductions to Mexico are triggered by shortages to United States users in the Upper Basin, by shortages to United States users in the Lower Basin, or both. When triggered, the water deliveries to Mexico are reduced in the same proportion as the reduction to United States users in both the Upper and Lower Basins. The methodology is as follows:

- 1) Determine the shortage to be applied to United States users in the Lower Basin.
 - Example: for the Preferred Alternative, if Lake Mead elevation is below 1,050 feet msl, the shortage to United States users in the Lower Basin is 417 kaf

- 2) Determine the shortage to be applied to United States users in the Upper Basin. Shortages to United States users in the Upper Basin are assumed to occur when the delivery to those users is less than their scheduled use. Shortage is calculated as Upper Basin scheduled use minus Upper Basin actual use.
 - Example: in the year 2016, the Upper Basin scheduled use is 4.779 maf and under one hydrologic sequence, the model computed a delivery of 4.355 maf, resulting in a shortage to United States users in the Upper Basin of 424 kaf, in addition to the shortage to United States users in the Lower Basin of 417 kaf

- 3) Compute the proportional reduction to United States users in both the Upper and Lower Basins as the sum of shortages to United States users in the Upper and Lower Basins

divided by the sum of the Upper Basin scheduled use and the total United States Lower Basin apportionments (7.5 maf).

- Example: the proportional reduction to the United States users would be computed as:

$$(417 \text{ kaf} + 424 \text{ kaf}) / (7.5 \text{ maf} + 4.779 \text{ maf}) = 6.8 \text{ percent}$$

- 4) Compute water delivery reduction to Mexico by applying the same proportional reduction to United States users in both the Upper and Lower Basins to Mexico. This is computed by multiplying Mexico's annual Colorado River allotment (1.5 maf) by the proportional reduction to United States users in both the Upper and Lower Basins.

- Example: given the proportional reduction to United States users in both the Upper and Lower Basins is 6.8 percent, the water delivery reduction to Mexico would be computed as:

$$1.5 \text{ maf} * 6.8 \text{ percent} = 102 \text{ kaf}$$

Since Upper Basin scheduled use varies each year (Section 3.4.1 and Appendix C) and the computed shortages in the Upper Basin vary for each hydrologic sequence, a wide range of possible proportional reductions are simulated by Methodology B (from zero to approximately 11.7 percent resulting in water reductions to Mexico of zero to approximately 175 kaf as shown in Figure Q-9 and Q-7 respectively).

Table Q-3 shows some examples taken from the modeling results for year 2016. The scheduled Upper Basin uses in 2016 are 4.779 maf, resulting in the proportional reduction to the United States equal to the sum of Upper and Lower Basin United States shortages divided by 12.279 maf (7.5 maf plus 4.779 maf).

Table Q-3
Examples of Shortages to the United States Users for Methodology B

Example	Shortage to Upper Basin (kaf)	Shortage to Lower Basin (kaf)	Total Shortage to United States (kaf)	Total Use in the United States (kaf)	% Reduction to United States*
a) Upper and Lower Basin Shortage	424	417	841	11,438	6.8
b) Upper and Lower Basin Shortage	100	417	517	11,762	4.2
c) Upper Basin Shortage only	21	0	21	12,258	0.2
d) Lower Basin Shortage only	0	333	333	11,946	2.7

* Percent reduction on total delivery to United States of 7.5 maf + 4.779 maf = 12.279 maf

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Given the shortages examples in the United States in Table Q-3, the resulting equal proportional water delivery reductions to Mexico under Methodology B are provided In Table Q-4.

Example	Reduction to Mexico Delivery (kaf)	Total Delivery to Mexico (kaf)	% Reduction to Mexico
a) Upper and Lower Basin Shortage	102	1,398	6.8
b) Upper and Lower Basin Shortage	63	1,437	4.2
c) Upper Basin Shortage only	3	1,497	0.2
d) Lower Basin Shortage only	41	1,459	2.7

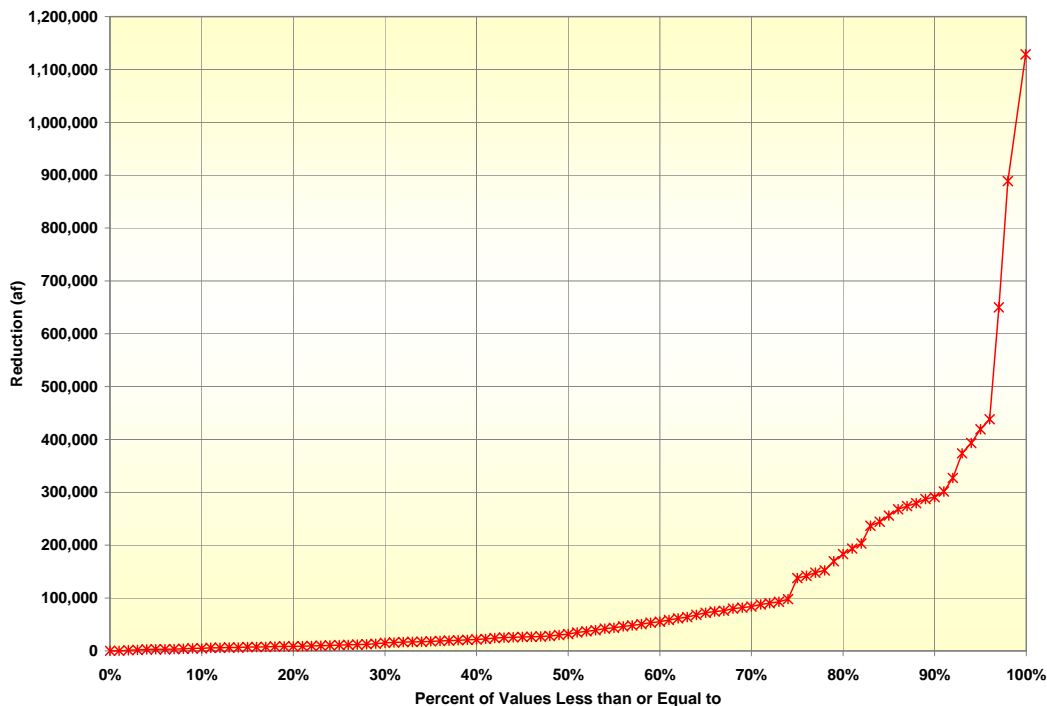
Q.3 Modeling Results

An analysis was performed to test the sensitivity of the hydrologic resources to these two sets of modeling assumptions (Methodology A and B). The Colorado River Simulation System (CRSS) model was used to simulate water deliveries to Mexico under these two methodologies with all other modeling assumptions held constant. The modeling assumptions under the Preferred Alternative were used for this assessment with one major exception. It was assumed that there was no storage and delivery mechanism in place in order to isolate the effects of each methodology. Also, the sensitivity analysis also only considers the interim period (years 2008 through 2026).

Q.3.1 Upper Basin Shortages

CRSS assumes that shortages in the Upper Basin occur only when there is not sufficient water within a given reach to meet a user’s demand. As described previously, the total Upper Basin shortage for any year is computed as the total Upper Basin delivery subtracted from the Upper Basin scheduled use for that year. Figure Q-1 provides a cumulative distribution of Upper Basin shortage amounts generated by CRSS over the period 2008 through 2026. The computed shortages to the Upper Basin users are dependent solely upon the hydrologic sequences and are therefore identical under Methodology A and Methodology B.

Figure Q-1
Upper Basin Shortages
Years 2008 to 2026



From this figure, it can be seen that modeled Upper Basin shortages range from approximately 1.05 kaf to 1,130 kaf and are frequent, occurring approximately 98 percent of the time. Approximately 75 percent of the shortages are of magnitudes less than 100 kaf. Shortages of magnitudes between 100 kaf and 400 kaf occur about 20 percent of the time and shortages of magnitudes above 400 kaf occur about five percent of the time. As a point of reference, Upper Basin shortages of 100 kaf and 400 kaf represent about two percent and eight percent of the average scheduled Upper Basin depletion over the interim period, respectively.

Q.3.2 Lake Powell and Lake Mead Water Surface Elevations

Figure Q-2 compares the 10th, 50th and 90th percentile elevations at Lake Powell under Methodology A and B.

The effect of the Methodology B water delivery reduction assumption on elevations at Lake Powell is negligible. The elevations of Lake Powell under Methodology B are higher than for Methodology A by approximately 0.001 feet at the 10th percentile and lower than under Methodology A by approximately 0.1 feet at the 50th percentile.

Figure Q-2
Lake Powell End-of-December Elevations
Comparison of Methodologies A and B
90th, 50th and 10th Percentile Values

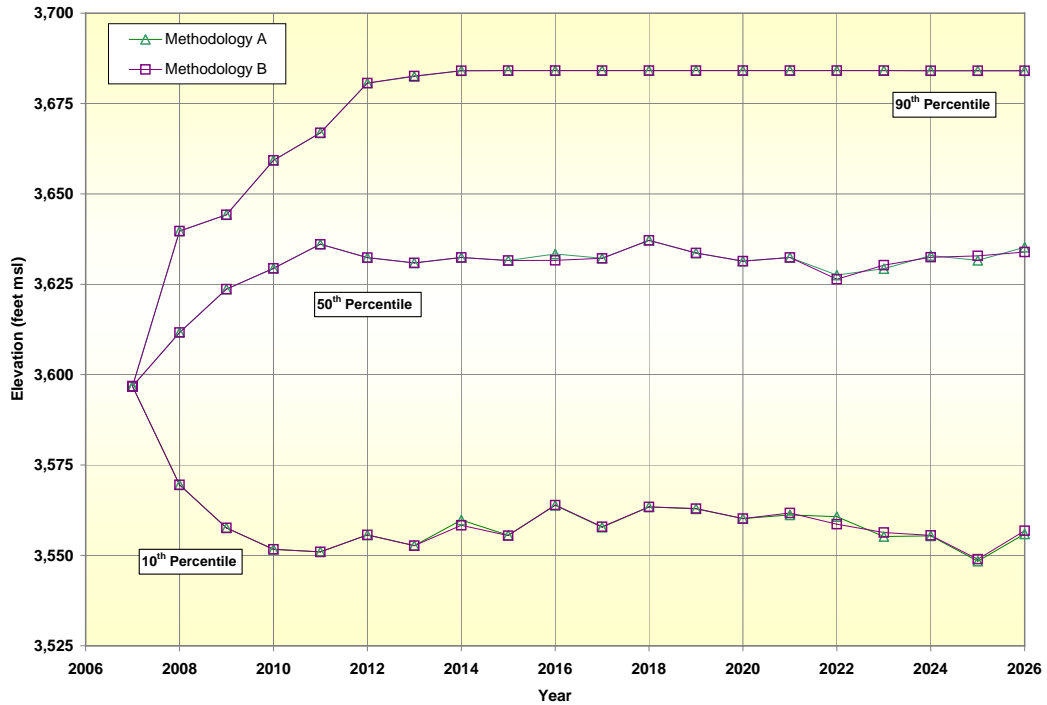
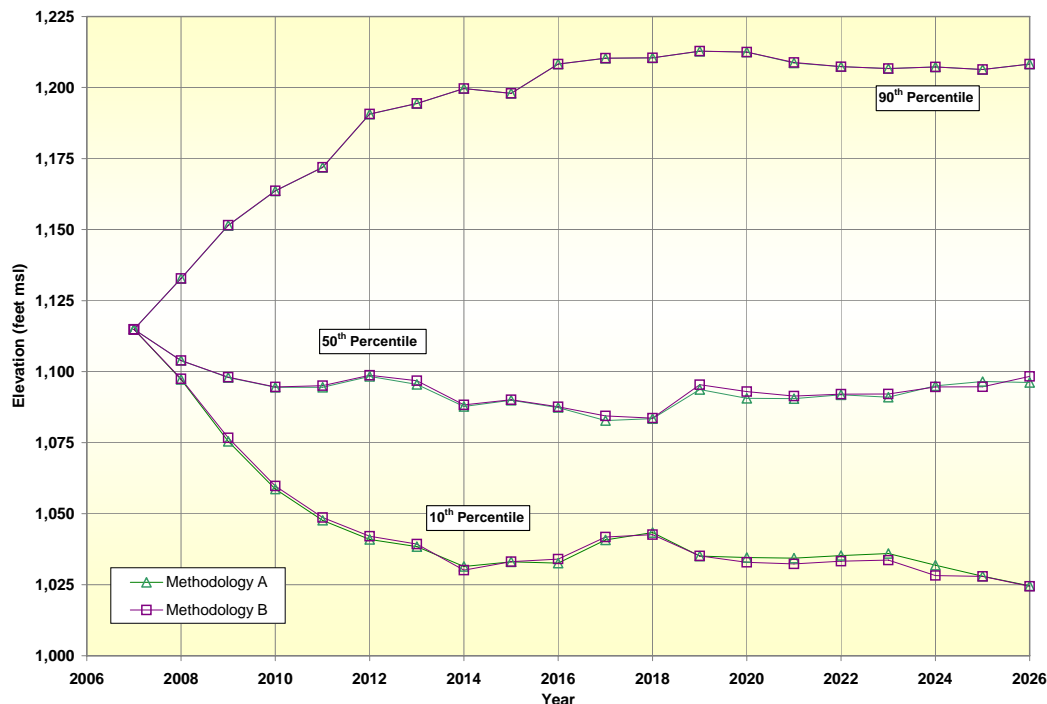


Figure Q-3 compares the 10th, 50th and 90th percentile elevations at Lake Mead under Methodology A and B. Methodology B results in somewhat lower elevations at the 10th percentile (a maximum of 3.6 feet in 2024) and slightly higher elevations at the 50th percentile (a maximum of 2.4 feet in 2020). Because the majority of the Upper Basin shortages are relatively small, Mexico may incur smaller water delivery reductions under Methodology B as compared to those observed under Methodology A when Lake Mead is relatively low (i.e., when United States users in the Lower Basin incur shortages), resulting in lower elevations at the 10th percentile. However, due to the higher frequency of Upper Basin shortages, Mexico experiences more frequent water delivery reductions under Methodology B, resulting in slightly higher Lake Mead elevations at the 50th percentile.

Figure Q-3
Lake Mead End-of-December Elevations
Comparison of Methodologies A and B
90th, 50th and 10th Percentile Values



Q.3.3 Comparison of Water Deliveries to Mexico

As described in Section 4.2, water deliveries to Mexico are assumed to be 1.5 mafy, except when the model assumes that additional deliveries of up to 200 kaf have been scheduled or a water delivery reduction has been incurred. Additional deliveries to Mexico of up to 200 kaf are assumed to occur when Lake Mead is in flood control operations. Reductions in the water deliveries to Mexico are simulated consistent with the modeling assumptions described previously under each methodology. Consequently, simulated water deliveries to Mexico are expected to fluctuate throughout the interim period (2008 through 2026) reflecting variations in hydrologic conditions under these assumptions.

Figure Q-4 displays the 10th, 50th and 90th percentile values for Mexico's water deliveries under Methodology A and Methodology B. At the 90th percentile, the results are essentially the same.

Water deliveries are 1.5 mafy at the 50th percentile under Methodology A. Water deliveries are less than 1.5 mafy at the 50th percentile under Methodology B, with an average reduction of approximately 25 kafy over the interim period. The more frequent reductions under Methodology B are due to the fact that Upper Basin shortages occur frequently and are included in the calculation of the proportional reduction under Methodology B.

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At the 10th percentile, water deliveries to Mexico are higher under Methodology B after 2010, averaging approximately 16 kafy higher compared to Methodology A over the interim period. This result can be explained as follows. For a specific shortage to Lower Basin United States users, Upper Basin shortages are often small enough in magnitude to result in a proportional reduction to United States users (and to Mexico) under Methodology B that is less than the proportional reduction computed under Methodology A for the same shortage to Lower Basin United States users. These occurrences result in higher water deliveries to Mexico under Methodology B at the 10th percentile.

This occurrence is illustrated in Table Q-1 through Table Q-4. As shown in Table Q-1, a shortage of 417 kaf to Lower Basin United States users results in a proportional reduction of 5.6 percent under Methodology A. As shown in Table Q-2, applying the same proportional reduction to Mexico would result in a reduction of 83 kaf. The same shortage to Lower Basin United States users (417 kaf), coupled with shortages to Upper Basin United States users of 100 kaf (Example (b) in Table Q-3), results in a smaller proportional reduction of 4.2 percent under Methodology B. As shown in Table Q-4, applying the same proportional reduction to Mexico would result in a reduction of 63 kaf.

Figure Q-4
Mexico Modeled Annual Depletions
Comparison of Methodologies A and B
90th, 50th and 10th Percentile Values

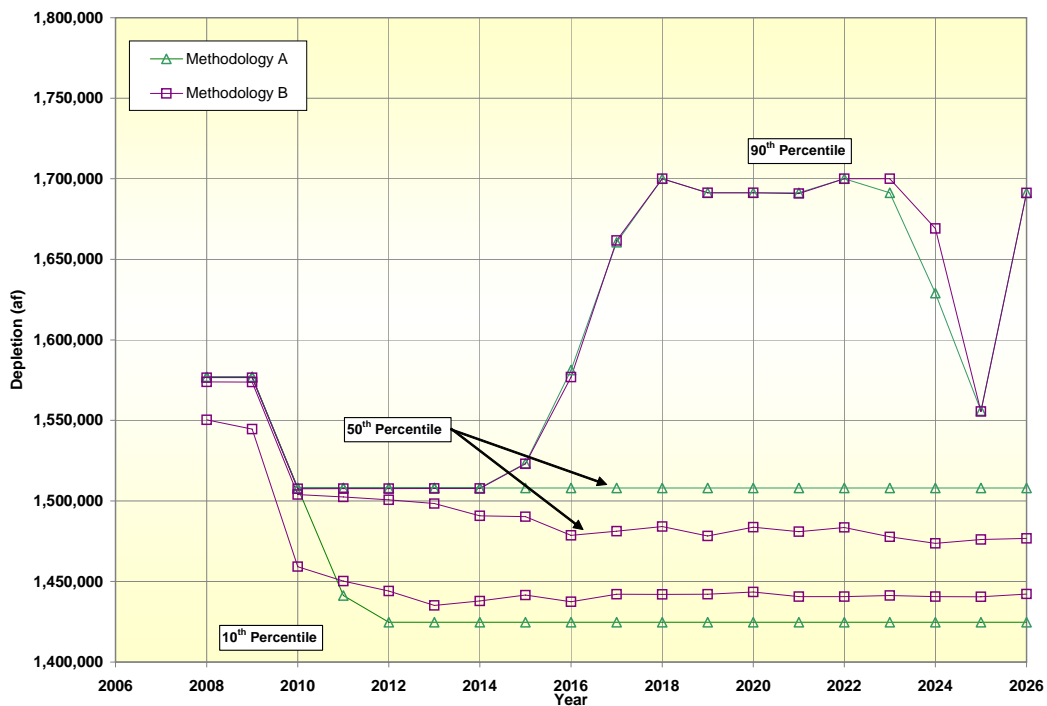


Table Q-5 provides a comparison of the information presented in Figure Q-4 for specific years in the interim period.

Year	Methodology A			Methodology B		
	90 th Percentile	50 th Percentile	10 th Percentile	90 th Percentile	50 th Percentile	10 th Percentile
2008	1,577,000	1,577,000	1,577,000	1,576,571	1,573,935	1,550,313
2016	1,581,288	1,508,000	1,424,668	1,576,830	1,478,643	1,437,371
2026	1,691,360	1,508,000	1,424,668	1,691,215	1,476,758	1,442,230

Figure Q-5 provides a comparison of the cumulative distribution of Mexico's water deliveries under Methodology A and Methodology B. The results presented in Figure Q-5 can be used to compare how often Mexico might expect deliveries in excess of, or less than, 1.5 maf under these different modeling assumptions. The occurrence of water deliveries to Mexico greater than 1.5 maf reflect years when additional water up to 200 kaf is made available when Lake Mead is in flood control operations. Deliveries less than 1.5 maf reflect the modeling assumptions regarding water delivery reductions to Mexico. Again, because Upper Basin shortages occur more frequently than Lower Basin shortages, there are also more frequent water delivery reductions to Mexico under Methodology B relative to Methodology A.

Figure Q-5
Mexico Modeled Annual Depletions
Comparison of Methodologies A and B
Years 2008 to 2026

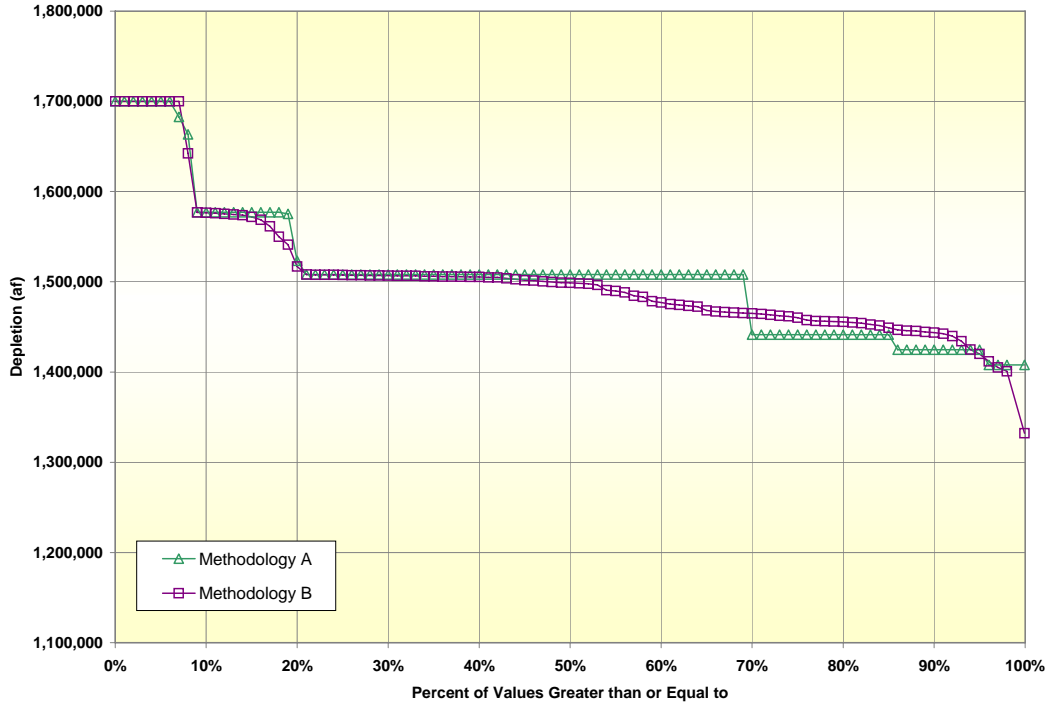


Table Q-6 provides a comparison of the information presented in Figure Q-5 in tabular format. Again, the data presented in this table shows that the modeling of the Preferred Alternative using Methodology B will generally result in lower water deliveries to Mexico during the interim period as compared to the modeled conditions using Methodology A.

Table Q-6
Mexico Modeled Annual Depletions
Comparison of Methodologies A and B
Years 2008 to 2026

Percent Exceedence	Mexico Annual Depletions (afy)	
	Methodology A	Methodology B
Maximum	1,700,000	1,700,000
10	1,577,000	1,576,354
25	1,508,000	1,507,411
50	1,508,000	1,498,902
75	1,441,332	1,460,289
90	1,424,668	1,443,716
Minimum	1,408,000	1,332,081

Figure Q-6 shows a comparison of the probability of annual deliveries to Mexico less than 1.5 maf under Methodologies A and B. The modeling assumptions under Methodology B provide higher probabilities that Mexico will receive less than 1.5 maf. The average probability of deliveries less than 1.5 maf to Mexico under Methodology A is 31 percent and the average probability under Methodology B is 89 percent. The more frequent occurrence of reduced deliveries under Methodology B reflects the more frequent occurrence of shortages due to drought conditions in the Upper Basin.

Figure Q-6
Mexico Modeled Annual Depletions
Comparison of Methodologies A and B
Probability of Depletions Less than 1.5 kaf

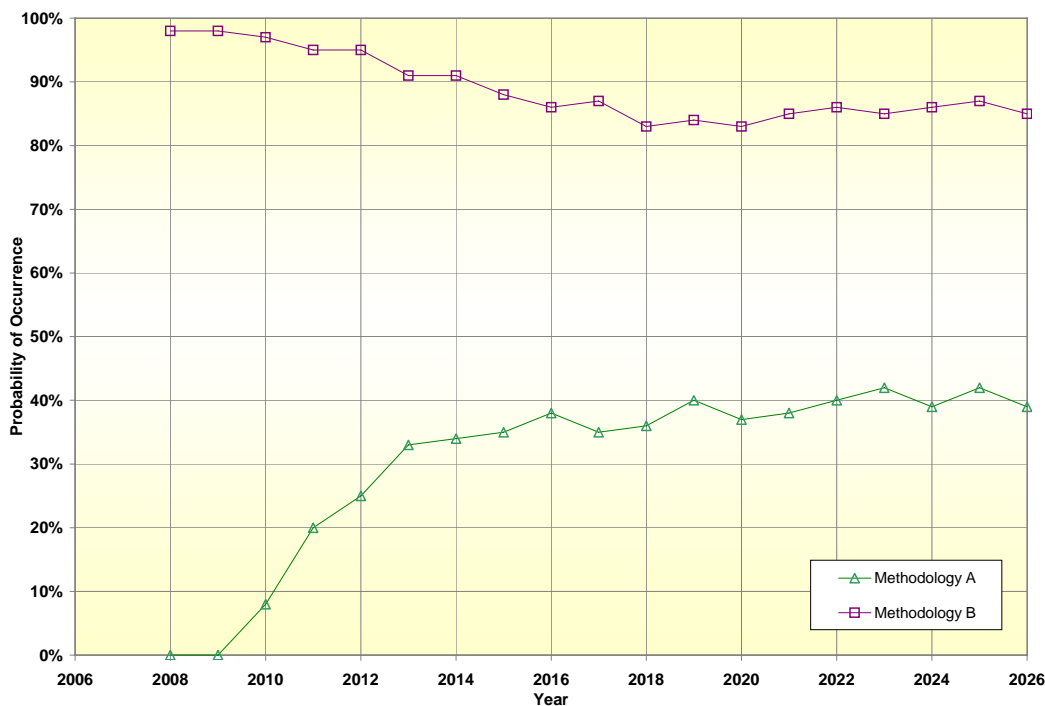
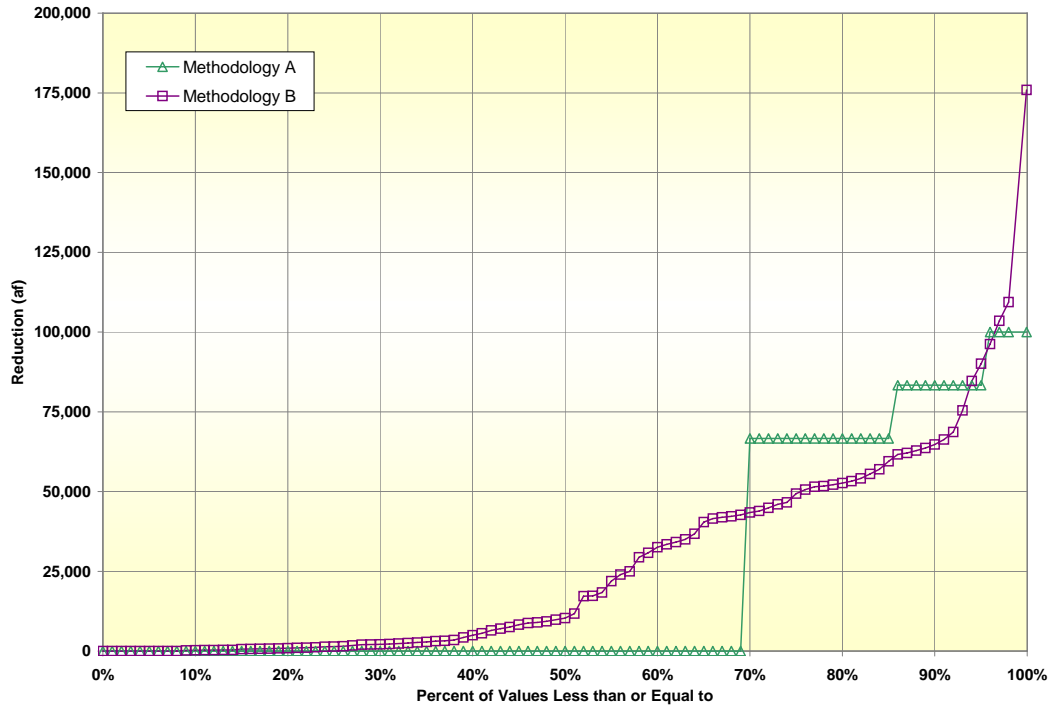


Figure Q-7 shows the cumulative annual water delivery reductions to Mexico under Methodologies A and B. Under Methodology A, there are only three water delivery reduction volumes that can occur: 67 kaf, 83 kaf or 100 kaf. Approximately 30 percent of the time there is a water delivery reduction to Mexico of at least 67 kaf. Approximately four percent of the time there is a water delivery reduction to Mexico of 100 kaf.

Figure Q-7
Mexico Water Delivery Reductions
Comparison of Methodologies A and B
Years 2008 to 2026



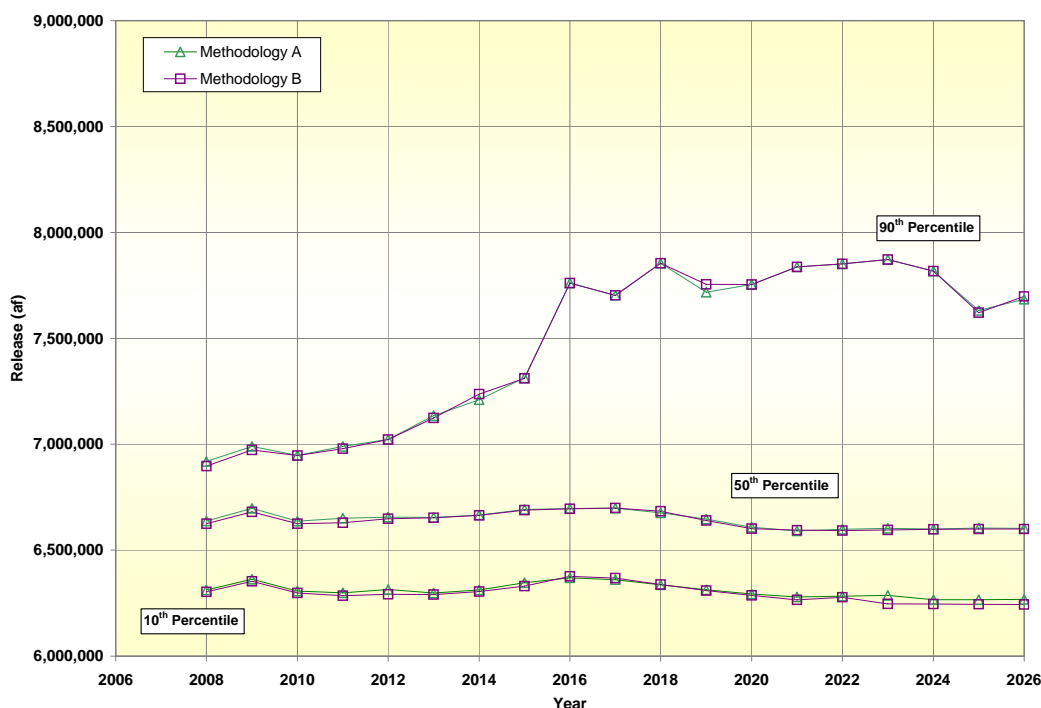
Under Methodology B, there is a water delivery reduction to Mexico approximately 92 percent of the time. This high frequency of water delivery reductions is due to the high frequency of shortages in the Upper Basin. However, 57 percent of these water delivery reductions are less than 25 kaf. Water delivery reductions of the magnitude 67 kaf or greater occur approximately nine percent of the time under Methodology B compared to approximately 30 percent under Methodology A. Methodology B results in a maximum water delivery reduction of 176 kaf compared to 100 kaf under Methodology A. A higher maximum reduction amount exists under Methodology B because shortages can occur simultaneously in both the Upper and Lower Basins, resulting in a larger volume reduction when compared to Methodology A.

Methodology B generates a larger range of water delivery reductions to Mexico when compared to Methodology A. Under Methodology B these reductions also occur more frequently due to the high frequency of Upper Basin shortages compared to the frequency of shortages in the Lower Basin.

Q.3.4 Parker Dam Releases

The flows in the river from Parker Dam to Imperial Dam result primarily from the controlled releases from Parker Dam. Figure Q-8 compares the 90th, 50th and 10th percentile releases from Parker Dam.

Figure Q-8
Parker Dam Annual Releases
Comparison of Methodologies A and B
90th, 50th and 10th Percentile Values



The effect of the Methodology B water delivery reduction assumptions on releases from Parker Dam is minor. The releases under Methodology B are slightly lower due to the increased frequency of water delivery reductions to Mexico. This results in less water being delivered to Mexico when compared to Methodology A. The maximum difference at the 10th and 50th percentiles is about 40 kaf (in 2023) and 22 kaf (in 2011), respectively. The average difference at the 10th and 50th percentiles is approximately 11 kaf and 5 kaf, respectively.

Attachment A

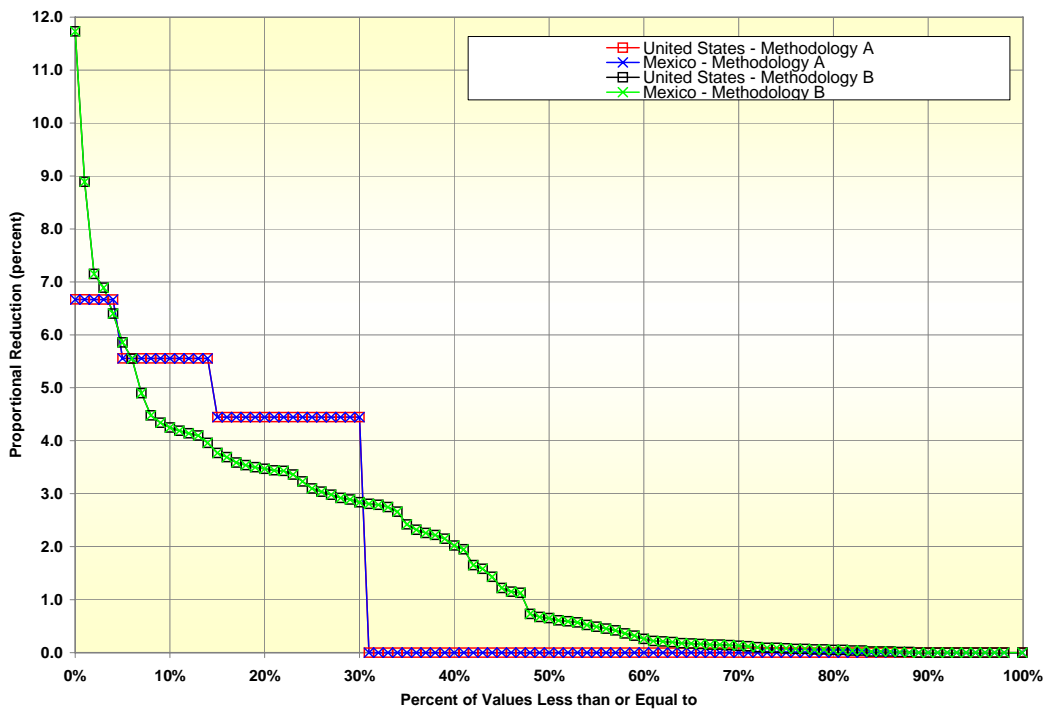
Verification of Equal Proportional Reductions to United States and Mexico for Methodology A and Methodology B

Both Methodology A and Methodology B assume that the water deliveries to Mexico would be reduced in the same proportion as reductions in consumptive uses in the United States (shortages). This attachment provides additional information with regard to equal proportional reductions.

Model Verification

In order to verify that the model was accurately computing equal proportional water delivery reductions to Mexico, output from the model included the computed proportional reduction for both the United States and Mexico each time a shortage occurred in the United States. Figure Att. A-1 provides a comparison of the cumulative distribution of these computed values using Methodology A and Methodology B for the United States and Mexico. Figure Att. A-1 verifies that under both methodologies, deliveries to Mexico are reduced in the same proportion as deliveries to the United States.

Figure Att. A-1
 Proportional Reductions to United States and Mexico
 Comparison of Methodologies A and B
 Years 2008 to 2026



Alternative Representation of Methodology A

Under Methodology A, water delivery reductions to Mexico are triggered only by shortages to United States users in the Lower Basin. When triggered, the water deliveries to Mexico are reduced in the same proportion as the reduction in the United States users in the Lower Basin. Alternatively, the volume of the reduction to Mexico may be computed by taking 16.7 percent of the total water reduction applied to both the United States and Mexico. This percentage is computed by taking the ratio of Mexico's allotment to the sum of the Lower Basin United States apportionments and Mexico's allotment ($1.5 \text{ maf} / (7.5 \text{ maf} + 1.5 \text{ maf}) = 0.167$ or 16.7 percent).

It can be shown algebraically that this approach results in the same proportional reduction to Mexico as occurs to the United States users in the Lower Basin.

Define:

TS = total water delivery reduction to Lower Division states and Mexico
% reduction to United States or Mexico = amount of reduction / apportionment or allotment * 100

Assume:

The percentage of the total water delivery reduction applied to the Lower Division states = $7.5/9.0 * 100 = 83.3\%$
The percentage of the total water delivery reduction applied to Mexico = $1.5/9.0 * 100 = 16.7\%$

Then:

% reduction to United States = $TS * (7.5/9.0)/7.5 = TS/9.0$
% reduction to Mexico = $TS * (1.5/9.0)/1.5 = TS/9.0$
Clearly yielding the same proportional reduction

Example: (with rounding)

Total shortage = 0.400 maf
Shortage to Lower Division states = $0.400 * 0.833 = 0.333 \text{ maf}$
Water delivery reduction to Mexico = $0.400 * 0.167 = 0.067 \text{ maf}$
% reduction to United States = % reduction to Mexico = $0.400/9.0 = 4.4\%$

Check:

% reduction to United States = $0.333 / 7.5 * 100 = 4.4\%$
% reduction to Mexico = $0.067 / 1.5 * 100 = 4.4\%$