Appendix I

Sensitivity Analysis – Effects of Alternate Upper Basin Demand Scenarios on Operations at Lake Powell and Lake Mead

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Appendix I. Sensitivity Analysis – Effects of Alternate Upper Basin Demand Scenarios on Operations at Lake Powell and Lake Mead

I.1 Introduction

Future water demands are required inputs to the Colorado River Simulation System (CRSS) and are one of the key future uncertainties for which assumptions must be developed. This appendix presents a sensitivity analysis that evaluates how future demand assumptions influence modeled system conditions and vulnerabilities. Because of hydrologic and institutional differences between the Upper and Lower Basins, demand scenarios are treated differently for each basin.

In the Upper Basin, hydrology varies significantly both geographically and from year-to-year, and water users are often shorted when the available supply cannot meet demands. The Upper Basin is also currently using less than its 7.5 maf apportionment, so future scenarios generally assume increasing future demands. In contrast, the baseline for Lower Basin demands is full apportionment and is largely met through deliveries from Lake Mead (as adjusted for tributary inflows and losses below Lake Mead). Shortages in the Lower Basin arise primarily through prescribed delivery reductions under existing operational guidelines and agreements—such as shortage tiers in the 2007 Interim Guidelines and additional contributions under the 2019 DCP—rather than through hydrologic shortfalls.

Long-term planning studies in the Basin have typically used narrative-based scenarios to project future demand, often incorporating estimates of increasing Upper Basin demand and fixed apportionments for the Lower Basin and Mexico (7.5 maf and 1.5 maf, respectively), with reductions implemented according to operating policies. While useful, narrative scenarios embed assumptions about the timing and magnitude of future change, which can obscure relationships between input assumptions and modeled system vulnerabilities.

The purpose of this sensitivity analysis is to analyze how robustness and vulnerability results respond to different Upper Basin demand assumptions (differences in Lower Basin demands are already represented through the alternatives' shortage and surplus provisions). To more transparently examine how combinations of supply, demand, and initial conditions affect system vulnerability, this appendix evaluates multiple Upper Basin demand scenarios, including several steady-state demand levels. These steady-state scenarios span a broad range of plausible future demands without relying on narrative assumptions describing how demands might evolve.

The analysis performed in this appendix is designed to inform a comparison among alternatives in this Draft EIS and is not an interpretation or determination of the quantity of water legally available for use in the Upper Basin under the Law of the River and existing legal frameworks.

The demand scenarios evaluated in this sensitivity analysis are:

- Upper Colorado River Commission's updated 2016 Depletion Demand Schedule (2016 UCRC)[1]
- 90% 2016 UCRC
- Steady State 4.5 maf
- Steady State 5.0 maf
- Steady State 5.5 maf
- Steady State 6.0 maf

These scenarios are described in more detail in the next section, followed by modeling results, and analyses on the impacts the demand scenarios have on system metrics, robustness, and vulnerability across the alternatives explored in this Draft EIS.

I.2 Alternative Upper Basin Demand Scenarios

The 2016 UCRC demand schedule, adopted by the Upper Colorado River Commission on June 14, 2022, is the demand scenario used in the official version of CRSS and the demand scenario used in the Post-2026 DEIS modeling outside of this sensitivity analysis[2]. This demand schedule is provided by the Upper Basin States and the UCRC on a decadal and sector basis; Reclamation then works with the states to disaggregate to the spatial (sector by CRSS sub-basin) and temporal (monthly) level necessary for CRSS (see **Appendix L**, Upper Division States Depletion Schedules, for additional detail).

For this sensitivity analysis, five additional demand scenarios were developed using the updated 2016 UCRC depletion demand schedule as the baseline. The "90% 2016 UCRC" demand scenario was generated by multiplying the updated 2016 UCRC depletion demand schedule by 90% for all months. Finally, four steady state demand levels are used to span a range of plausible future demands from 4.5 to 6.0 million acre-feet (maf) in 0.5-maf increments. The steady state demand levels are generated by scaling the 2042 demands from the updated 2016 UCRC depletion demand schedule so that the total Upper basin demand is equal to the desired steady state volume. The year 2042 was chosen because it is the mid-point of a 30-year simulation period[3]. Using these

[1] Upper Colorado River Commission (UCRC) & Upper Division States. (2022, June 14). *Combined Resolution and Updated 2016 Depletion Demand Schedule*. Upper Colorado River Commission. Retrieved from http://www.ucrcommission.com/wp-content/uploads/2022/06/UCRC-and-Upper-Division-States-Combined-Resolution-and-Updated-2016-Depletion-Demand-Schedule-June-14-2022-1.pdf.

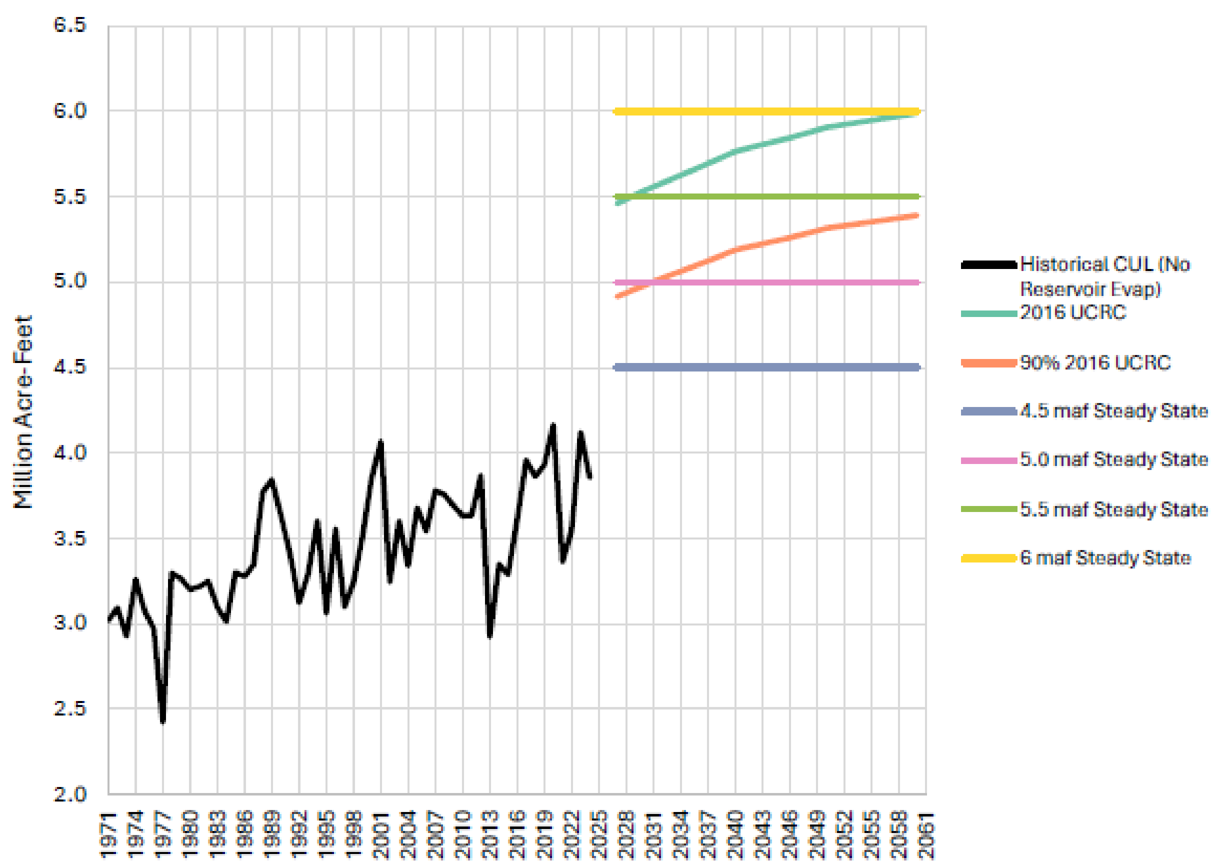
[2] CRSS explicitly models select reservoir evaporation, so the demand schedules used in CRSS do not include reservoir evaporation from Lake Powell, Flaming Gorge, Blue Meas, Morrow Point, Navajo, McPhee, Dillon, Granby, Homestake, and Willow Creek reservoirs.

[3] This was selected before it was known if the DEIS would analyze 30 or 34 years.

incremental, steady state demand scenarios allows for a more systematic analysis of how combinations of supply, demand, and initial conditions affect system vulnerability.

Figure I-1 shows these six Upper Basin demand scenarios used in this sensitivity analysis. The 2016 UCRC and 90% 2016 UCRC demand scenarios are the two scenarios that vary with time. The 2016 UCRC demand scenario starts with a scheduled demand of 5.46 maf in 2027 and grows to a maximum scheduled demand of 5.99 maf in 2060. The 90% 2016 UCRC demand schedule is 10% lower, with a starting scheduled demands of 4.91 maf in 2027 and reaching a maximum scheduled demand of 5.39 maf in 2060. The schedules represent demands given ideal climate and hydrology conditions, however, consumptive use represents historical use under actual conditions. Under these actual conditions demands are typically shorted every year, which prevents users from achieving demands sought under ideal climate and hydrology conditions.

Figure I-1
Annual Upper Basin Historical Consumptive Uses and Losses and Future Demand Schedules



Note: Historical CUL does not include reservoir evaporation undistributed by state. Future demand schedules exclude reservoir evaporation volumes from reservoirs undistributed by state and other reservoirs where CRSS explicitly models reservoir evaporation. CRSS will simulate consumptive use based on the provided demand scenarios, and the available supply in each year of each simulation.

The demand schedules for the Lower Basin were held constant at full apportionment for each state and Mexico between the different demand scenarios and match the Lower Basin demand schedules used for the Post-2026 EIS. More information can be found in **Appendix N**, Lower Division States Depletion Schedules.

For this sensitivity analysis, the six demand scenarios are coupled with six different reservoir operating policies – the five alternatives and comparative baseline analyzed in this DEIS:

- No Action
- Basic Coordination
- Enhanced Coordination
- Maximum Flexibility
- Supply-Driven (LB Priority)
- Continued Current Strategies (CCS)

Each model was run with the full hydrologic ensemble and all three initial conditions included in this DEIS. See **Appendix A**, CRSS Modeling Documentation, for modeling assumptions associated with each alternative and **Appendix F**, Approach to Hydrologic Uncertainty and **Appendix G**, Initial Reservoir Conditions, for additional details on hydrology and initial condition assumptions.

The results were analyzed across a set of metrics to better understand the impact of the six demand scenarios on Lakes Powell and Mead and their operations across the alternatives. These metrics include:

- Upper Basin modeled depletions
- Lake Powell and Lake Mead pool elevation
- Lee Ferry Compact Point 10-Year Flow
- Total Lower Basin Reductions (Shortage plus Lake Mead Dead Pool-Related Reductions)

Projected future conditions were analyzed over five flow categories across the metrics to see how the alternatives respond to different flow categories of preceding hydrology, based off the preceding 3-year average Lees Ferry Natural Flow. These flow categories include:

- Wet: preceding flow is greater than 16 maf
- Moderately Wet: preceding flow ranges 14 maf to 16 maf
- Average (based on 21st century average): preceding flow ranges 12 maf to 14 maf
- Dry: preceding flow ranges 10 maf to 12 maf
- Critically Dry: preceding flow is less than 10 maf

A robustness analysis was performed to assess the ability of each alternative to keep Lake Powell and Lake Mead above critical elevations. For this analysis, the concept of robustness refers to the ability of an alternative to meet a specified level of performance in a wide range of potential future conditions when paired with a given demand scenario. The specified level of performance in this analysis is the ability to keep Lake Powell and Lake Mead above the critical elevations of 3,500 ft at Lake Powell and 975 ft at Lake Mead in all months over the 34-year simulation period. When a modeled future meets the specified level of performance it is considered a "successful future". All successful futures are reported as a percentage of the 1,200 modeled futures for each alternative/demand scenario combination.

Finally, a vulnerability analysis is used to find hydrologic conditions that likely lead to an undesirable outcome. For this analysis it is undesirable to fall below elevation 3,500 feet at Lake Powell and 975 feet at Lake Mead any time across the 34-year simulation period. Vulnerability provides a complementary analysis to the robustness analysis by relating information about hydrologic conditions to the likelihood of a future being successful or unsuccessful, under a given alternative and demand scenario, by using information about both the successful and unsuccessful futures to identify a skillful hydrology predictor of different outcomes. This type of analysis is useful because the alternatives-demand scenario combinations can be described in terms of the hydrologic conditions that are likely to cause undesirable performance, i.e., the conditions that are likely to cause vulnerability.

Refer to **Appendix E**, DMDU Overview and Approach for more details on robustness and vulnerability.

An elevation of 3,500 feet at Lake Powell and an elevation of 975 feet at Lake Mead are used for both robustness and vulnerability analyses. Elevation 3,500 feet is important because it provides a 10-foot buffer for water delivery and hydropower, which are critically impacted at an elevation of 3,490 feet. Elevation 975 feet is important because it provides a 25-foot buffer to protect critical infrastructure for water delivery and hydropower, which can no longer be produced at elevation 950 feet.

I.3 Analysis

The analysis is organized into four different sections to explore the Upper Basin modeled depletions, impact on reservoir operations, robustness, and vulnerability, for each alternative and the six demand scenarios.

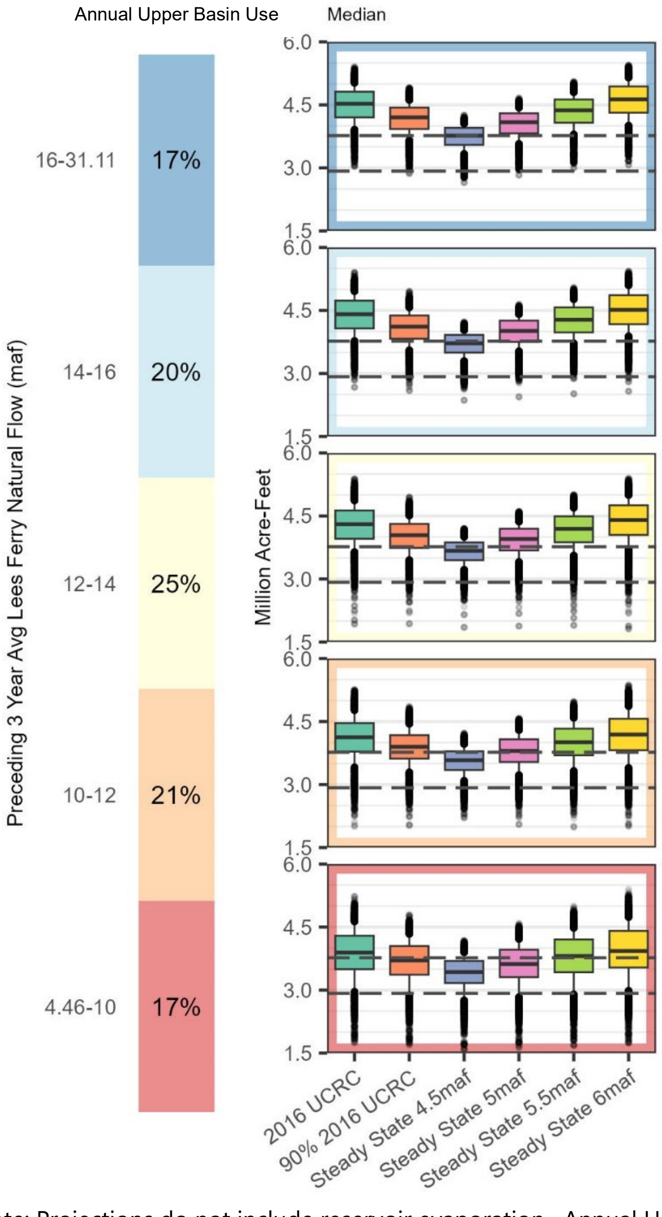
I.3.1 Upper Basin Modeled Depletions

Upper Basin modeled depletions are only shown for CCS because Upper Basin activities above Lake Powell are very similar for each demand scenario across all alternatives due to the similarities in hydrology, demands, and modeled operations in reservoirs and reaches above Lake Powell. The only differences in modeled Upper Basin depletions occur when Powell Infrastructure Protection releases are made from Flaming Gorge, Blue Mesa, or Navajo. Since the emphasis is on comparing Upper Basin depletions for a given alternative across the six demand scenarios, only results CCS are included in the analysis.

Figure I-2 shows annual Upper Basin modeled depletions for CCS across all demand scenarios organized by the preceding three-year average Lees Ferry natural flow. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Dashed lines on the graph represent the previous 10-year average (3.77 maf) and the millennium drought minimum (2.92 maf) annual Upper Basin consumptive uses and losses, excluding reservoir evaporation.

Figure I-2
Projected annual Upper Basin depletions across the 2016 UCRC demand schedule and five alternate Upper Basin demand scenarios simulated using Continued Current Strategies operations



Note: Projections do not include reservoir evaporation. Annual Upper Basin depletions are broken out to show the 10th percentile projection (left), median projection (center), and 90th percentile projection (right).

For all demand scenarios, the modeled depletion is always less than the input demand. This is because CRSS simulates the depletions based on the available supply, and consistent with historical observations, there are always some areas in the Upper Basin where water use is limited based on the available supply.

In the Dry flow category, the median Upper Basin modeled depletion is greater than the 3.77 maf threshold for all demand scenarios except the Steady State 4.5 maf. For the Steady State 4.5 maf demand scenario, the 75th percentile is within 23 kaf of the average consumptive use over the last 10 years, while the median for this demand scenario is 190 kaf less than the historical average consumptive use.

The interquartile range of the Upper Basin modeled depletions increase as the average annual demand levels increase. In the dry and critically dry flow categories, the interquartile ranges show less differences between the demand scenarios. In drier conditions, limited water availability constrains depletions, so higher demands do not produce proportionally higher use. Across all flow categories the interquartile ranges remain above the minimum annual Upper Basin consumptive uses and losses with reservoir evaporation removed from the millennium drought. The Steady State 4.5 maf demand scenario is the only demand scenario with a 75th percentile that is less than the historical average consumptive use of 3.77 maf; this occurs in both the dry and critically dry flow categories.

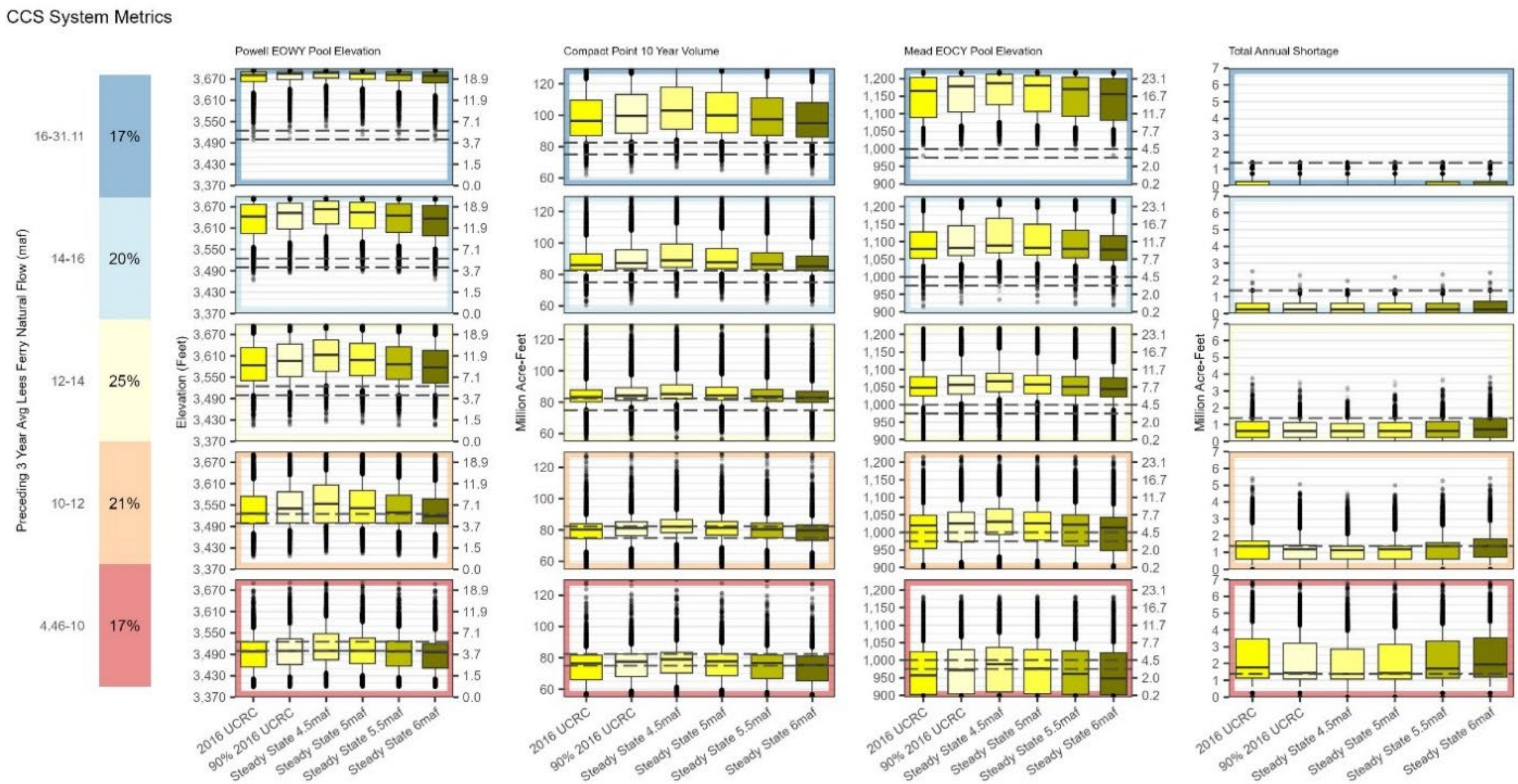
I.3.2 Impact on Reservoir Operations

Figure I-3 through **Figure I-8** show Lake Powell and Lake Mead end of calendar year pool elevations, Lee Ferry compact point 10-year flows and total Lower Basin reductions by flow category across all demand scenarios for CCS and all alternatives. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Dashed lines are included on the boxplots to identify significant elevations and thresholds. At Lake Powell, elevations 3,525 ft and 3,500 ft are included because of their importance to protecting infrastructure, power generation, and the ability to make downstream deliveries. At Lake Mead, elevations 1,000 ft and 975 ft are highlighted for the same reasons. The flow volumes of 82.5 maf and 75 maf are included in the Lee Ferry Compact Point 10-Year Flow for their significance to the Compact. Finally, the Total Annul Shortage for each alternative includes a dashed line to indicate the maximum shortage for the alternative. Total Annual Shortage can exceed that amount due to dead pool-constrained reductions.

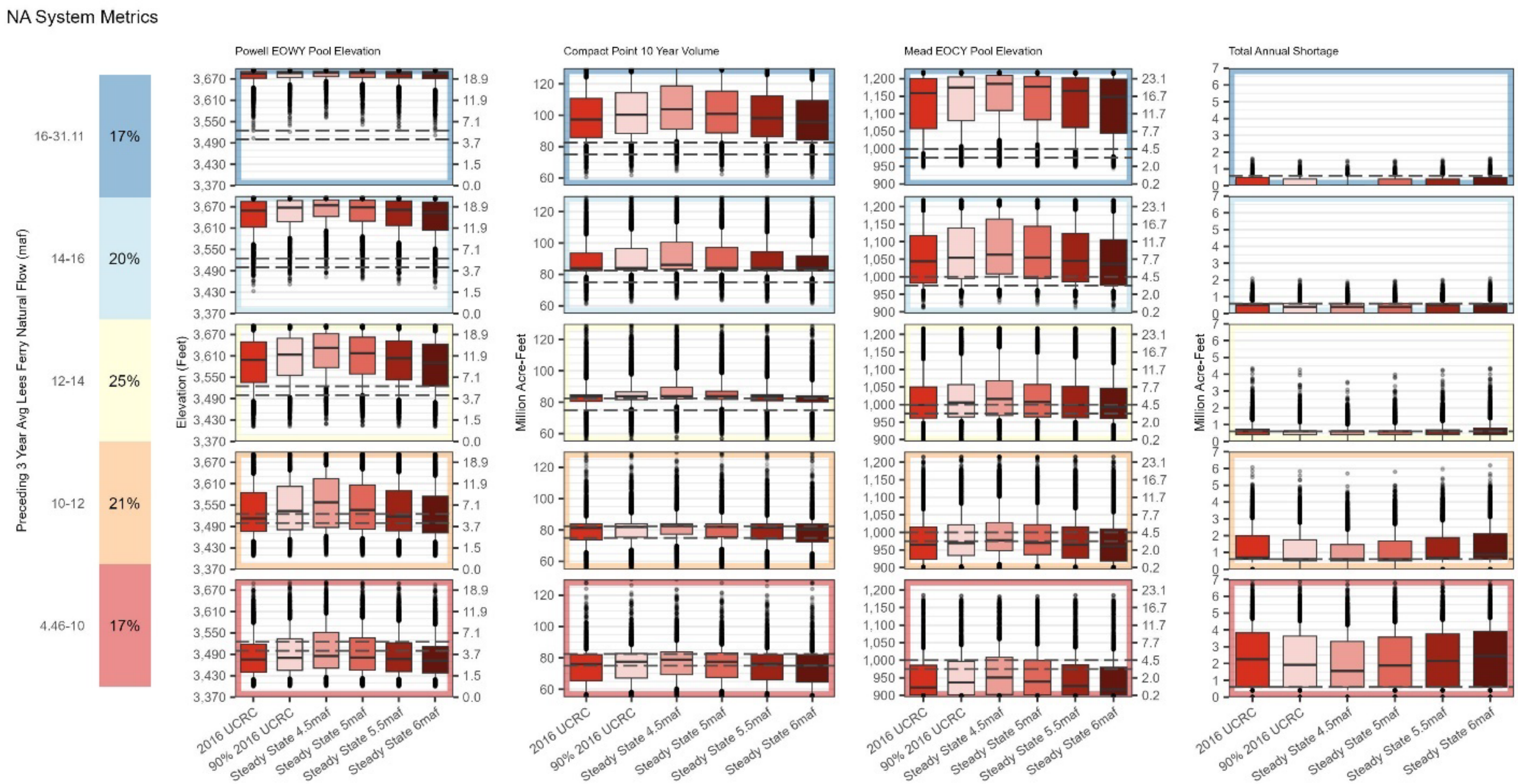
Except for the Supply-Driven results, the same general trends are observed for all alternatives and CCS: lower steady-state demand scenarios result in higher Lake Powell elevations, higher compact point 10-year flows, higher Lake Mead elevations and lower total shortages than higher steady-state demand scenarios. This same trend is true when comparing the 90% 2016 UCRC to the 2016 UCRC scenario.

Figure I-3
Boxplot of Projected Lake Powell Pool Elevation, Lee Ferry Compact Point 10-Year Flows, Lake Mead Pool Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead-Pool Constrained Reductions) for Continued Current Strategies across the Six Demand Scenarios



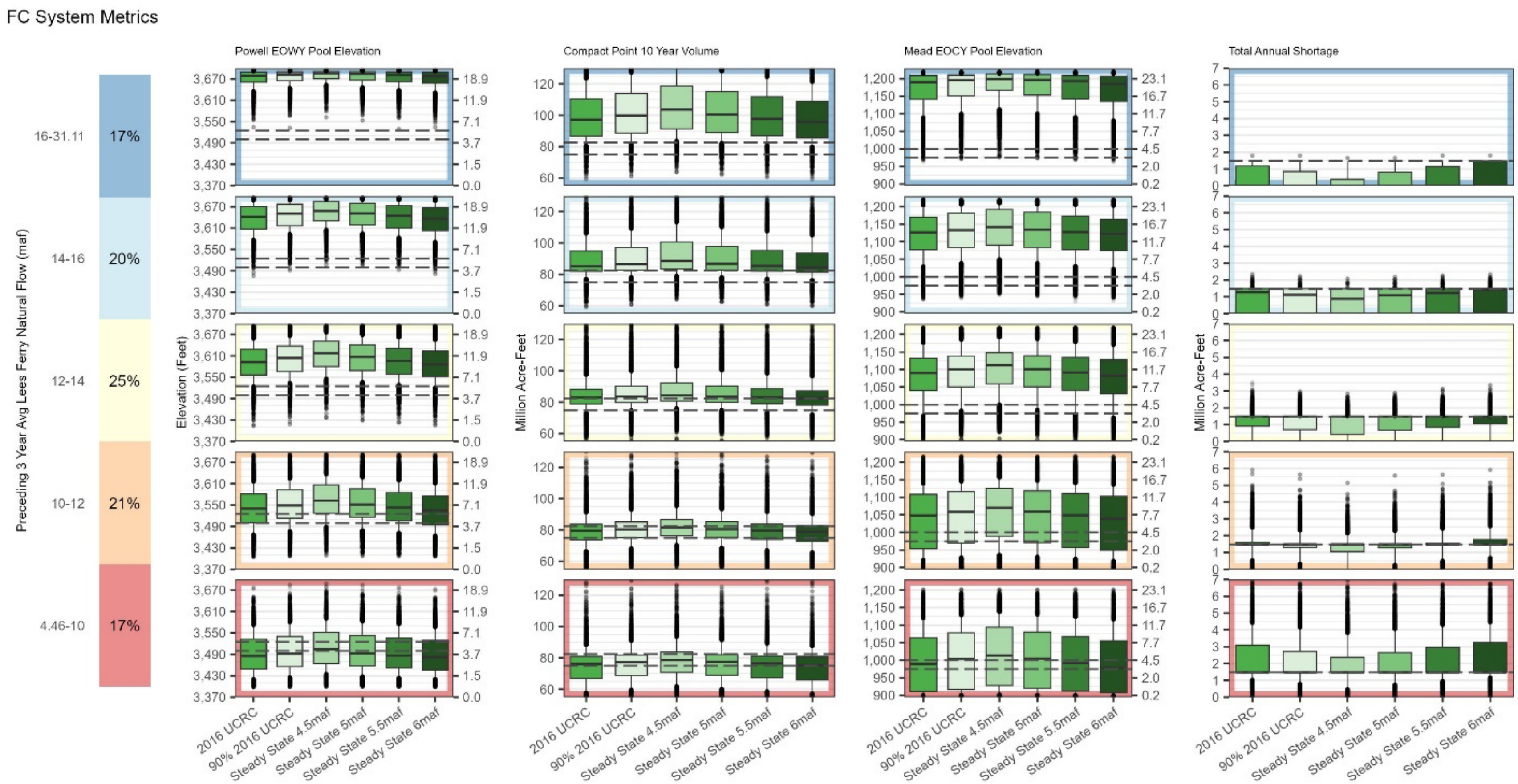
Note: Boxplots for each metric are broken out by flow categories based on the preceding 3-year average Lees Ferry natural flow. Dashed lines indicate significant elevations for infrastructure, power generation, and water delivery reliability at Lake Powell (3,525 ft, 3,500 ft) and Lake Mead (1,000 ft, 975 ft), volumes of interest with relation to the Lee Ferry Compact Point 10-year Flows (82.5 maf and 75 maf), and the maximum shortage (1.375 maf) on the Total Annual Shortage boxplots.

Figure I-4
Boxplot of Projected Lake Powell Pool Elevation, Compact Point 10-Year Volume, Lake Mead Pool Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead-Pool Constrained Reductions) for the No Action Alternative across the Six Demand Scenarios



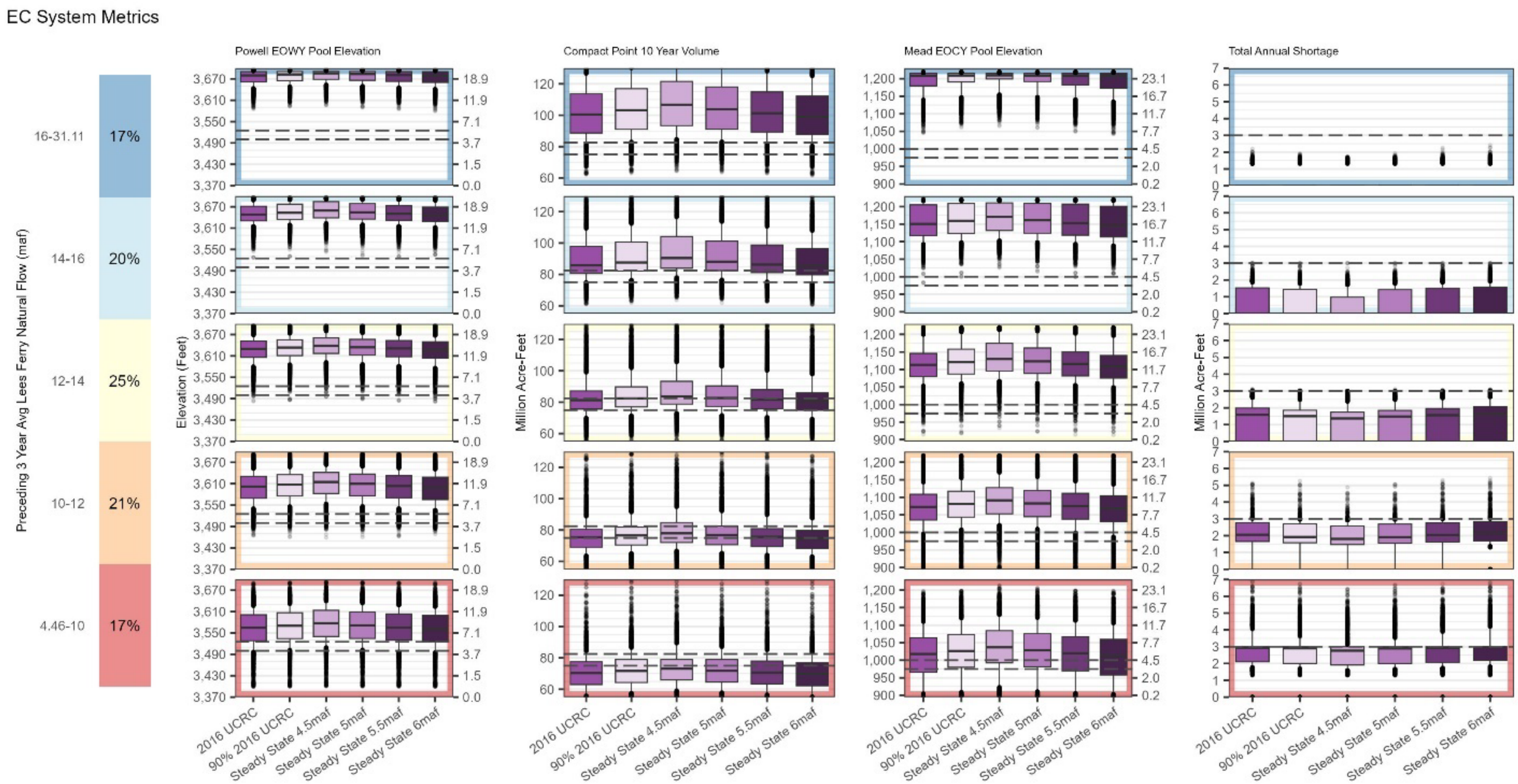
Note: Boxplots for each metric are broken out by flow categories based on the preceding 3-year average Lees Ferry natural flow. Dashed lines indicate significant elevations for infrastructure, power generation, and water delivery reliability at Lake Powell (3,525 ft, 3,500 ft) and Lake Mead (1,000 ft, 975 ft), volumes of interest with relation to the Lee Ferry Compact Point 10-year Flows (82.5 maf and 75 maf), and the maximum shortage (1.375 maf) on the Total Annual Shortage boxplots.

Figure I-5
Boxplot of Projected Lake Powell Pool Elevation, Compact Point 10-Year Volume, Lake Mead Pool Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead-Pool Constrained Reductions) for the Basic Coordination Alternative across the Six Demand Scenarios



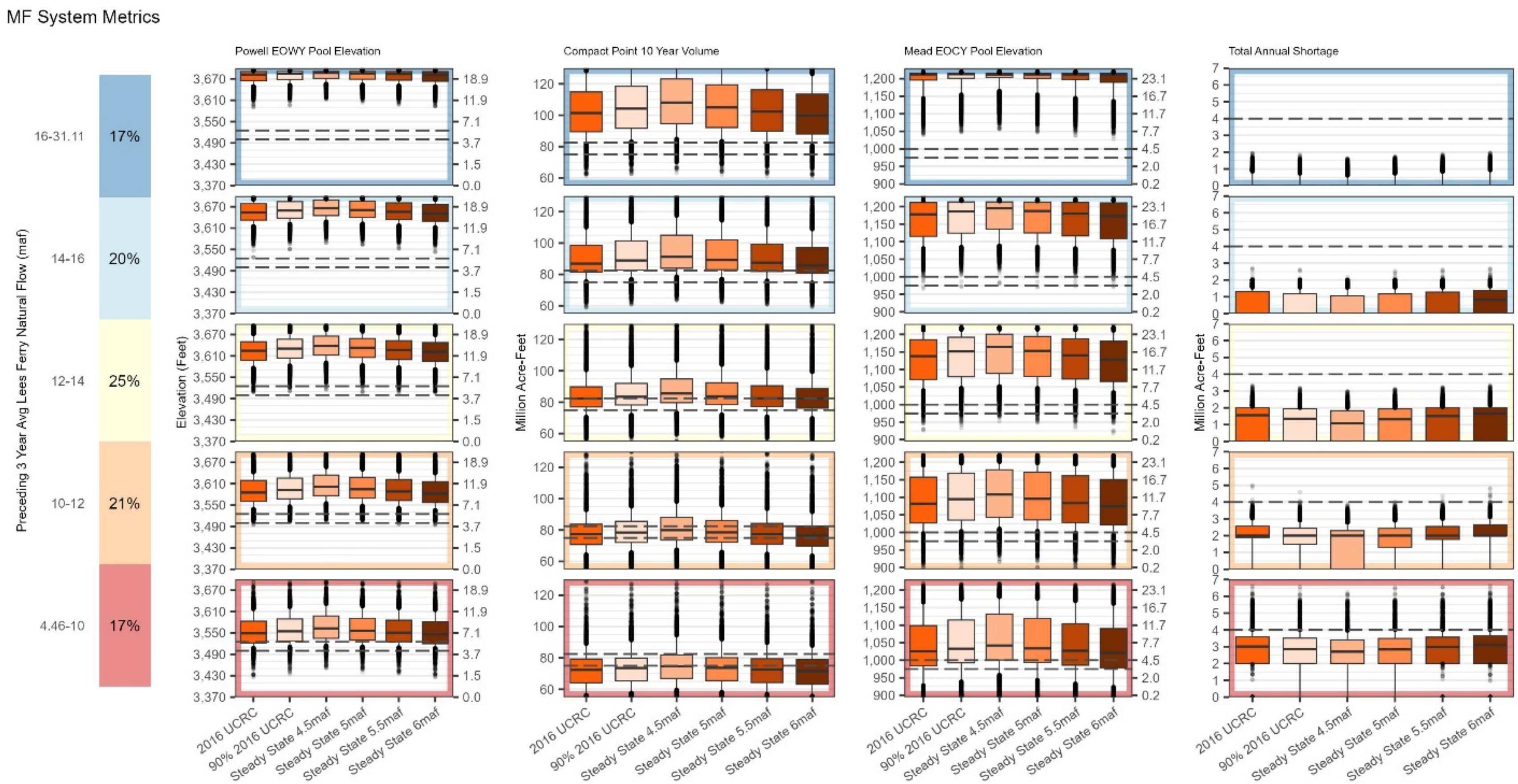
Note: Boxplots for each metric are broken out by flow categories based on the preceding 3-year average Lees Ferry natural flow. Dashed lines indicate significant elevations for infrastructure, power generation, and water delivery reliability at Lake Powell (3,525 ft, 3,500 ft) and Lake Mead (1,000 ft, 975 ft), volumes of interest with relation to the Lee Ferry Compact Point 10-year Flows (82.5 maf and 75 maf), and the maximum shortage (1.375 maf) on the Total Annual Shortage boxplots.

Figure I-6
Boxplot of Projected Lake Powell Pool Elevation, Compact Point 10-Year Volume, Lake Mead Pool Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead-Pool Constrained Reductions) for the Enhanced Coordination Alternative across the Six Demand Scenarios



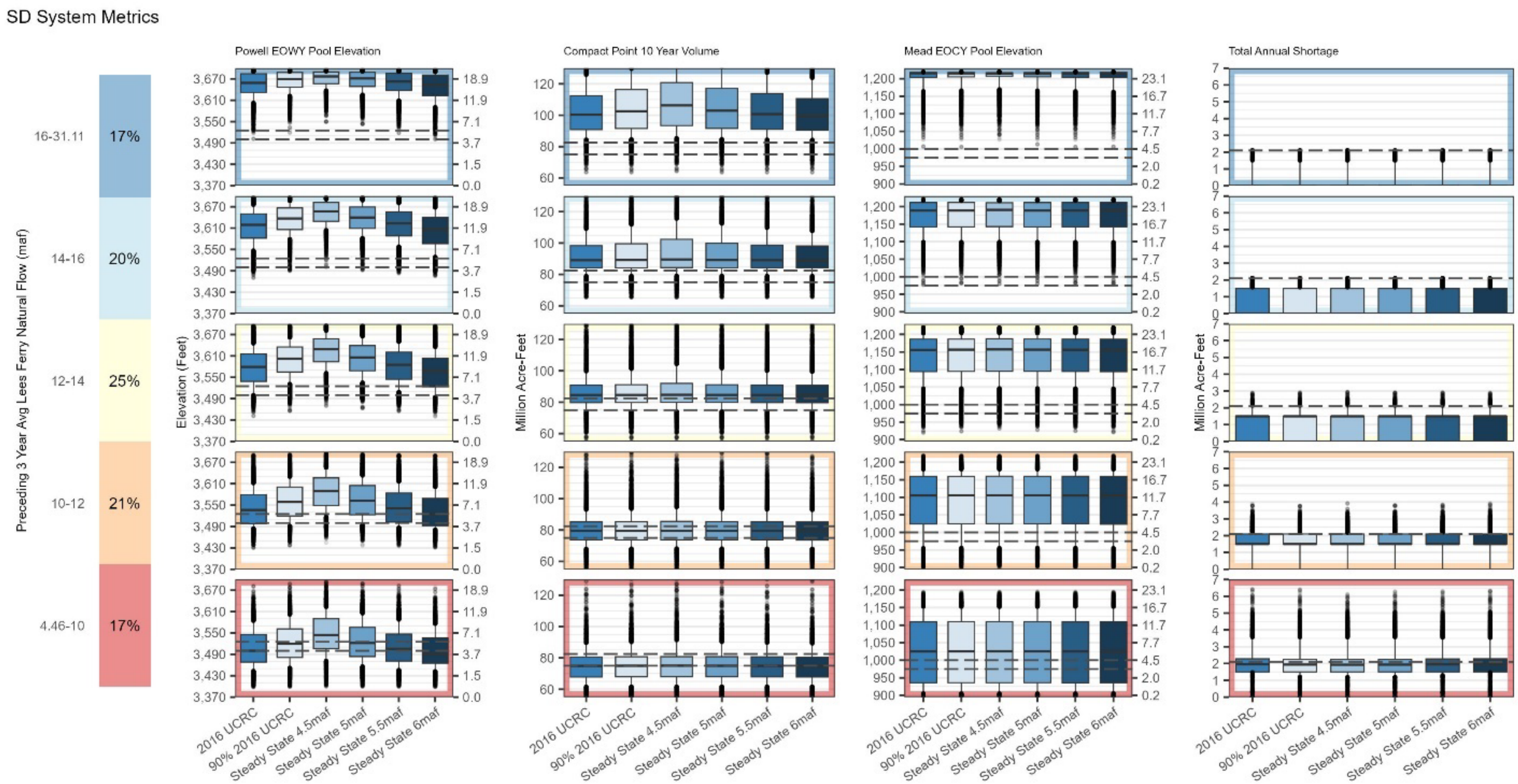
Note: Boxplots for each metric are broken out by flow categories based on the preceding 3-year average Lees Ferry natural flow. Dashed lines indicate significant elevations for infrastructure, power generation, and water delivery reliability at Lake Powell (3,525 ft, 3,500 ft) and Lake Mead (1,000 ft, 975 ft), volumes of interest with relation to the Lee Ferry Compact Point 10-year Flows (82.5 maf and 75 maf), and the maximum shortage (1.375 maf) on the Total Annual Shortage boxplots.

Figure I-7
Boxplot of Projected Lake Powell Pool Elevation, Compact Point 10-Year Volume, Lake Mead Pool Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead-Pool Constrained Reductions) for the Max Flexibility Alternative across the Six Demand Scenarios



Note: Boxplots for each metric are broken out by flow categories based on the preceding 3-year average Lees Ferry natural flow. Dashed lines indicate significant elevations for infrastructure, power generation, and water delivery reliability at Lake Powell (3,525 ft, 3,500 ft) and Lake Mead (1,000 ft, 975 ft), volumes of interest with relation to the Lee Ferry Compact Point 10-year Flows (82.5 maf and 75 maf), and the maximum shortage (1.375 maf) on the Total Annual Shortage boxplots.

Figure I-8
Boxplot of Projected Lake Powell Pool Elevation, Compact Point 10-Year Volume, Lake Mead Pool Elevation, and Total Annual Shortage (Lower Basin Shortage and Dead-Pool Constrained Reductions) for the Supply Driven (LB Priority) Alternative across the Six Demand Scenarios



Note: Boxplots for each metric are broken out by flow categories based on the preceding 3-year average Lees Ferry natural flow. Dashed lines indicate significant elevations for infrastructure, power generation, and water delivery reliability at Lake Powell (3,525 ft, 3,500 ft) and Lake Mead (1,000 ft, 975 ft), volumes of interest with relation to the Lee Ferry Compact Point 10-year Flows (82.5 maf and 75 maf), and the maximum shortage (1.375 maf) on the Total Annual Shortage boxplots.

For the Supply-Driven alternative (**Figure I-8**), lower steady-state demand scenarios result in higher Lake Powell elevations than higher steady-state demand scenarios. Because Lake Powell's release is based on 65% of the preceding 3-year average natural flow, there are slight to no differences across demand scenarios for Lake Mead's elevation – the Supply Driven alternative requires the same Lake Powell release irrespective of Lake Powell's elevation. Similarly, there are almost no differences in shortage across the demand scenarios because they are based on Lake Mead elevation. There are some differences in the compact point 10-year flows across demand scenarios, largely due to infrastructure constraints at high and low elevations. At higher elevations (more prevalent in the moderately wet and wet flow categories), lower steady-state demand levels result in more instances where Lake Powell makes spill avoidance releases, which increases the compact point 10-year flows.

I.3.3 Robustness

The robustness of each alternative and all demand scenarios for elevation 3,500 feet at Lake Powell and 975 feet at Lake Mead are compared in **Table I-1** and **Table I-2**, respectively. Elevation 3,500 feet is important because it provides a 10-foot buffer for water delivery and hydropower, which are critically impacted at an elevation of 3,490 feet. Elevation 975 feet is important because it provides a 25-foot buffer to protect critical infrastructure and hydropower, which can no longer be produced at elevation 950 feet. For this sensitivity analysis, a future is considered robust if it avoids falling below the threshold elevation in all months for the full modeling period (2027-2060). **Table I-1** and **Table I-2** report the percentage of futures that are robust, based on these definitions.

Table I-1 shows that across all alternatives, the Steady State 4.5 maf demand scenario is consistently the most robust, while the Steady State 6.0 maf scenario is the least robust at keeping Lake Powell above 3,500 feet. For most alternatives, the different demand scenarios exhibit similar levels of robustness, with differences typically ranging from 6% to 13%. The Supply-Driven (LB Priority) alternative is the clear outlier. Its robustness varies by 43%, ranging from 62% of futures for the Steady State 4.5 maf scenario to 19% of futures for the Steady State 6.0 maf scenario. Because Lake Powell's release is based on 65% of the preceding 3-year average natural flow, the Supply-Driven alternative requires the same Lake Powell release irrespective of Lake Powell's elevation, which leads to this large difference in robustness at Lake Powell, depending on the assumed Upper Basin demands.

Table I-1
Robustness of Lake Powell Elevation 3,500 Feet

	Continued Current	No Action	Basic Coordination	Enhanced Coordination	Max Flexibility	Supply-Driven (LB Priority)
2016 UCRC	29%	20%	25%	82%	87%	24%
90% 2016 UCRC	34%	23%	32%	84%	92%	39%
Steady State 4.5 maf	40%	28%	37%	86%	95%	62%
Steady State 5.0 maf	37%	24%	34%	84%	93%	44%
Steady State 5.5 maf	31%	21%	27%	82%	91%	27%
Steady State 6.0 maf	27%	18%	24%	80%	88%	19%

Note: Percent of futures in which Lake Powell is at least 3,500 feet in 100% of months in the full modeling period

Table I-2 compares the robustness of alternatives with respect to Lake Mead's monthly pool elevation remaining above elevation 975 feet in all months. Like robustness at Lake Powell, the Steady State 4.5 maf scenario is the most robust and the Steady State 6 maf scenario is the least robust at keeping Lake Mead above 975 feet. Also like the robustness at Lake Powell, for all alternatives except Supply-Driven (LB Priority) the different demand scenarios exhibit similar levels of robustness, with differences typically ranging from 9% to 12%. In contrast to the robustness at Lake Powell, the Supply-Driven (LB Priority) alternative shows no change in robustness at Lake Mead across the demand scenarios. This occurs because Lake Powell's release is computed as 65% of the preceding 3-year average natural flow, which produces the same release across all demand scenarios for a given hydrologic year.

Table I-2
Robustness of Lake Mead Elevation 975 Feet

	Continued Current	No Action	Basic Coordination	Enhanced Coordination	Max Flexibility	Supply Driven (LB Priority)
2016 UCRC	45%	25%	58%	75%	79%	71%
90% 2016 UCRC	49%	28%	63%	78%	83%	71%
Steady State 4.5maf	54%	32%	67%	81%	87%	71%
Steady State 5maf	50%	28%	64%	78%	84%	71%
Steady State 5.5maf	46%	25%	60%	75%	80%	71%
Steady State 6maf	42%	22%	55%	72%	77%	71%

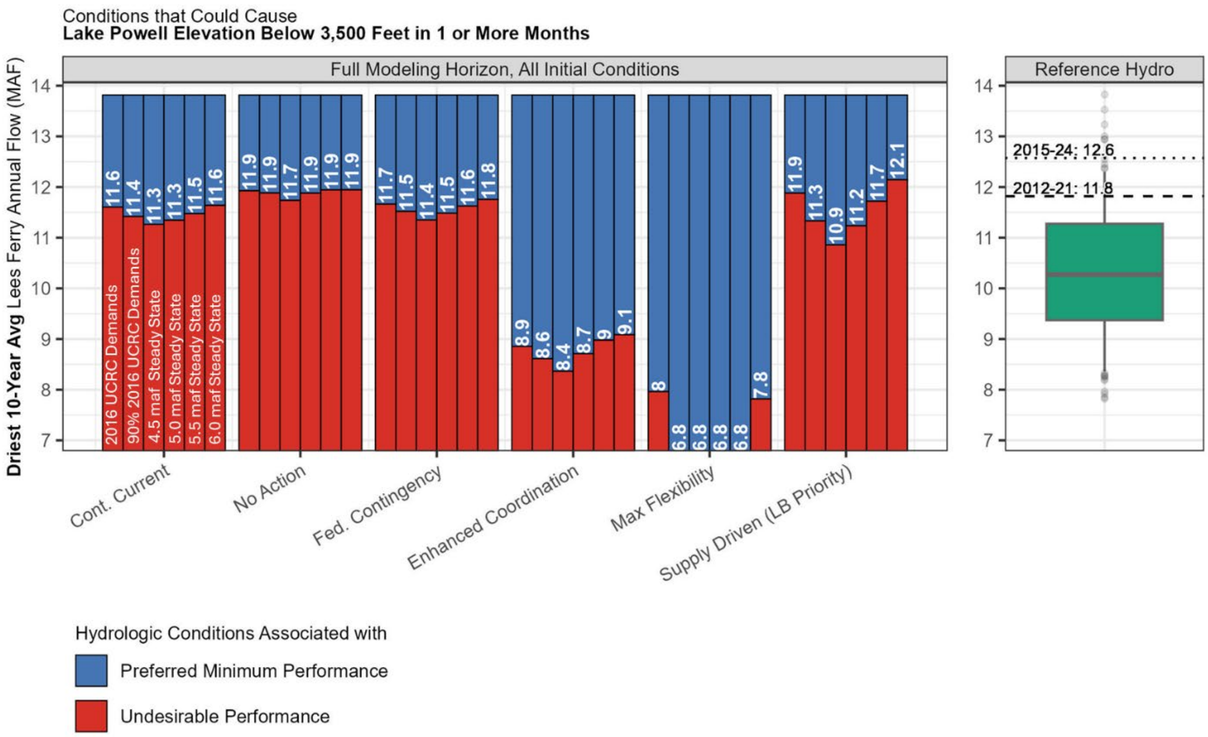
Note: Percent of futures in which Lake Mead is at least 975 feet in 100% of months in the full modeling period

I.3.4 Vulnerability

The robustness analysis (**Table I-1** and **Table I-2**) highlighted the percent of traces in which Lake Powell and Lake Mead remained above elevations 3,500 ft and 975 ft, respectively, in all months. The vulnerability analysis identifies the hydrologic conditions that could cause this undesirable performance, i.e., the pool elevations dropping below these elevations in at least one month out of the 34-year modeling period.

The driest 10-year average Lees Ferry natural flow was identified as a good predictor of undesirable performance at Lake Powell. **Figure I-9** shows what flow conditions are likely to cause Lake Powell's monthly elevation to fall below an elevation of 3,500 feet in at least one month across a 34-year future for each alternative and demand scenario combination. The reference hydrology panel to the right of the bar chart shows the range of driest 10-year average flows represented along with the most recent and driest observed 10-year periods. If the future includes a 10-year minimum flow of the number indicated on the individual bars in the bar chart or lower, the alternative and demand scenario is likely to result in undesirable performance. Looking across the demand scenarios for all alternatives, the Steady State 4.5 maf demand scenario has the lowest vulnerability threshold while the Steady State 6 maf demand scenario has the highest vulnerability threshold.

Figure I-9
Conditions that Could Cause Lake Powell's Pool Elevation to Drop below Pool Elevation 3,500 feet in One or More Months across All Demand Scenarios and All Alternatives

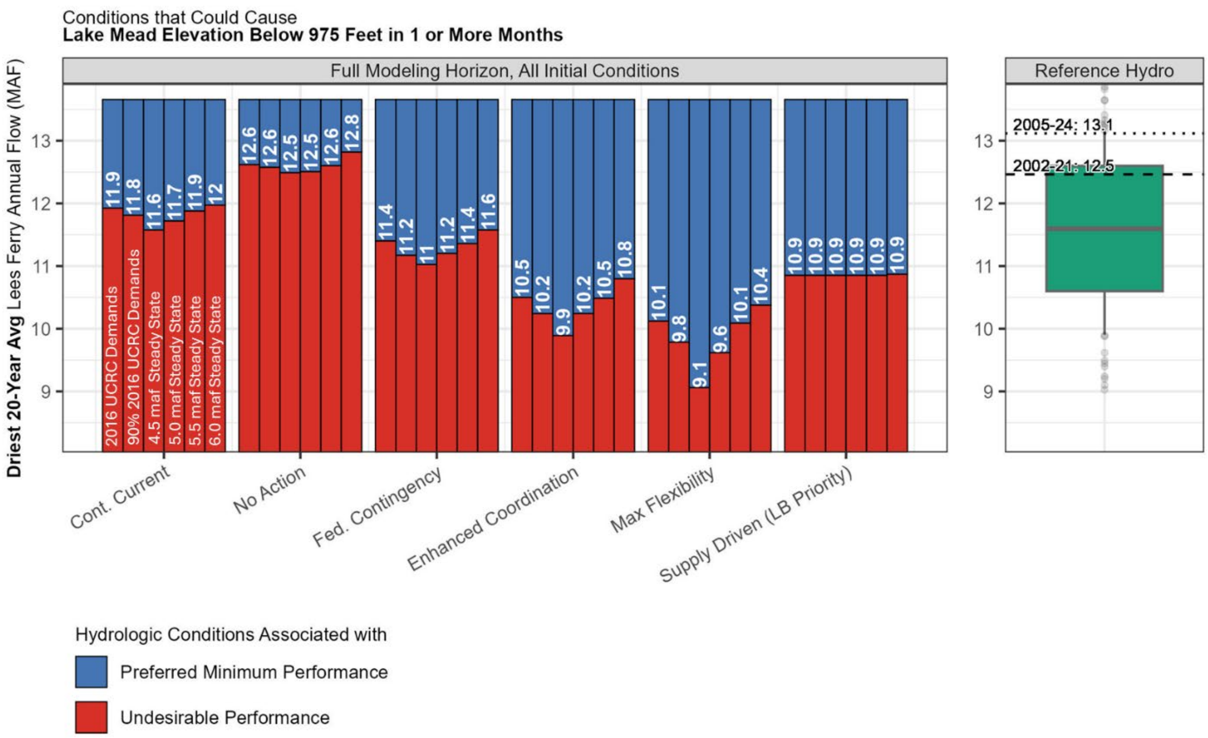


Note: Bar chart on the right side shows the distribution of the average 10-year Lees Ferry annual Natural Flow of the reference hydrology, with dashed lines indicating the minimum average and most recent average 10-year Lees Ferry annual flow.

The range of vulnerability thresholds across the demand scenarios indicates how sensitive each alternative is to the assumed Upper Basin demands. The CCS comparative baseline, No Action, and Basic Coordination alternatives show similar ranges—0.3, 0.2, and 0.4 maf, respectively—indicating relatively low sensitivity to demand assumptions. The Enhanced Coordination and Maximum Flexibility alternatives have larger ranges of 0.7 and 1.0 maf. For Maximum Flexibility, the vulnerability threshold is identical for the 4.5, 5.0, and 5.5 maf Steady State demand scenarios, then increases by 1.0 maf under the 6.0 maf scenario. This pattern suggests that the alternative is relatively insensitive to demand levels until a threshold is crossed, somewhere between 5.5 and 6.0 maf. Consistent with the robustness results shown in **Table I-1**, the Supply-Driven (LB Priority) alternative exhibits the greatest range, with a 1.2 maf difference in vulnerability thresholds across the demand scenarios.

The driest 20-year average Lees Ferry natural flow was identified as a good predictor of undesirable performance at Lake Mead. **Figure I-10** shows what flow conditions are likely to cause Lake Mead's monthly elevation to fall below an elevation of 975 feet in at least one month across a 34-year future for each alternative and demand scenario combination. The reference hydrology panel to the right of the bar chart shows the range of driest 20-year average flow represented along with the most recent and driest observed 20-year periods. Looking across the demand scenarios for all alternatives except for the Supply-Driven (LB Priority), the Steady State 4.5 maf scenario again has the lowest vulnerability threshold, while the Steady State 6.0 maf has the highest vulnerability threshold.

Figure I-10
Conditions that Could Cause Lake Mead's Pool Elevation to Drop below Pool Elevation 975 feet in One or More Months across All Demand Scenarios and All Alternatives



Note: Bar chart on the right side shows the distribution of the average 20-year Lees Ferry annual Natural Flow of the reference hydrology, with dashed lines indicating the minimum average and most recent average 20-year Lees Ferry annual flow.

The range of vulnerability thresholds across the demand scenarios indicates how sensitive each alternative is to the assumed Upper Basin demands. For the Supply-Driven (LB Priority) alternative, the same 20-year drought is identified as the point at which Lake Mead falls below 975 feet, regardless of the demand scenario. The CCS comparative baseline, No Action, and Basic Coordination alternatives show relatively small ranges—0.4, 0.3, and 0.6 maf, respectively—suggesting low sensitivity to demand assumptions. The Enhanced Coordination alternative shows a larger range of 0.9 maf, while the Maximum Flexibility alternative exhibits the greatest sensitivity with a range of 1.3 maf, indicating it is the most sensitive to Upper Basin demand assumptions for the conditions that lead to Lake Mead falling below 975 feet.

I.4 Summary and Conclusions

This sensitivity analysis examined how sensitive the different alternatives are to different Upper Basin demand assumptions (differences in Lower Basin demands are already represented through the alternatives' different shortage and surplus provisions). Multiple demand scenarios, including steady-state demand levels ranging from 4.5 maf to 6.0 maf, were evaluated with all combinations of supply, initial conditions, and for all alternatives and the CCS comparative baseline. The Upper Basin modeled depletions, impact on reservoir operations, robustness, and vulnerability were compared providing an overall comparison of the sensitivity of these different results and analyses to Upper Basin demand assumptions.

Across nearly all alternatives and performance metrics, lower steady-state demand scenarios (e.g., 4.5 maf) produced higher elevations at Lakes Powell and Mead, greater Lee Ferry 10-year flows, and lower Lower Basin shortages than higher steady state demand scenarios. Correspondingly, the Steady State 4.5 maf scenario was the most robust, and Steady State 6.0 maf the least robust, at maintaining Lake Powell above 3,500 feet and Lake Mead above 975 feet.

The CCS comparative baseline, No Action, and Basic Coordination alternatives behaved similarly, with small differences in both robustness and vulnerability across demand scenarios. These alternatives consistently showed only minor changes in the percent of robust futures or in the drought severity needed to trigger vulnerability (typically ranging from 0.2-0.6 maf), confirming that their performance is less sensitive to assumed Upper Basin depletions than other alternatives.

The Enhanced Coordination alternative showed moderate sensitivity, with robustness and vulnerability ranges somewhat larger than those above but still within a relatively narrow band (ranges of 0.7 and 0.9 maf for vulnerability thresholds at Lake Powell and Lake Mead, respectively).

The Maximum Flexibility alternative exhibited a threshold effect: the vulnerability at Lake Powell changed modestly across the lower demand scenarios but changed sharply at the 6.0 maf demand level, and its vulnerability threshold at Lake Mead varied by 1.3 maf, the largest range among the alternatives. This makes Maximum Flexibility the most sensitive to Upper Basin demand assumptions with respect to conditions leading to critically low elevations at Lake Mead second most sensitive at Lake Powell. The Maximum Flexibility alternative reservoir operations include a higher degree of coordination and incorporate a combined Lake Powell and Lake Mead conservation mechanism that allows conserved water to be transferred between reservoirs to satisfy environmental objectives and protect reservoir infrastructure, increasing the alternative's sensitivity to Upper Basin demand assumptions.

The Supply-Driven (LB Priority) alternative behaved differently from all others. Because its Lake Powell release is fixed at 65% of the preceding 3-year average natural flow, Powell releases are typically the same for all demand scenarios. As a result, at Lake Powell, robustness exhibited the largest spread of any alternative (a 43% range between Steady State 4.5 and 6.0 maf demand scenarios), and vulnerability thresholds varied widely (a 1.2 maf range). In contrast, at Lake Mead, both robustness and vulnerability were identical across all demand scenarios, making Supply-Driven the least sensitive alternative at Lake Mead to Upper Basin demand assumptions.