Boise River Basin Feasibility Study Water Operations Technical Memorandum

Boise Project, Idaho
Columbia Pacific Northwest Region

U.S. Department of the Interior July 2020

Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: Anderson Ranch Dam, Boise Project, Idaho.

Table of Contents

List of Tables

List of Figures

Executive Summary

The Bureau of Reclamation (Reclamation) is evaluating the potential benefits and impacts of three storage alternatives in the Boise River System. To ensure that Reclamation evaluated a reasonable range of alternatives for the National Environmental Policy Act compliance process, the Environmental Impact Statement includes a 3-foot dam raise of Anderson Ranch Dam as an alternative; this alternative was not further evaluated as a structural alternative for the Feasibility Study. This approach is supported by Reclamation Manual, Directives and Standards CMP 09-02, *Water and Related Resources Feasibility Studies*.

The three storage alternatives evaluated are the No Action alternative, a 6-foot Raise of Anderson Ranch Dam (Preferred Alternative), and a 3-foot Raise of Anderson Ranch Dam. The 6-foot Raise would increase storage space in the reservoir by approximately 29,000 acre-feet and the 3-foot Raise would increase the storage space by approximately 14,400 acre-feet. Potential changes in reservoir storage and streamflow associated with new storage space in Anderson Ranch Reservoir were evaluated using historical and climate change hydrology and a range of possible release rates and timing for water accrued to the new storage space. Potential impacts during the construction phase of the proposed project were also considered.

Hydrologic Analysis with Historical Hydrology

Model results using historical inflow hydrology indicate that additional storage space in Anderson Ranch Reservoir has the potential to store additional water in the system but will not likely change system operations outside the historical operating range. Table ES-1 summarizes the key findings for the historical period for each of the reservoir and streamflow locations analyzed.

Table ES-1. Summary of key findings, by location, associated with modeling of the 6-foot Raise and the 3-foot Raise of Anderson Ranch Dam using historical hydrology.

Location	Key Findings	
	6-foot Raise	3-foot Raise
Anderson Ranch Reservoir	Year-round potential for increased storage and pool elevation in Anderson Ranch Reservoir up to 29,000 acre-feet.	Year-round potential for increased storage and pool elevation in Anderson Ranch Reservoir up to 14,400 acre-feet.
Arrowrock Reservoir	No change to the ability to meet minimum pool objectives as additional water is released from Anderson Ranch Reservoir to backfill Arrowrock Reservoir on an as-needed basis.	No change to the ability to meet minimum pool objectives as additional water is released from Anderson Ranch Reservoir to backfill Arrowrock Reservoir on an as-needed basis.

<table>
<tr><th rowspan="2">Location</th><th colspan="2">Key Findings</th></tr>
<tr><th>6-foot Raise</th><th>3-foot Raise</th></tr>
<tr><td>Lucky Peak Reservoir</td><td>No change to the ability to meet winter pool elevation objectives.</td><td>No change to the ability to meet winter pool elevation objectives.</td></tr>
<tr><td>South Fork Boise River below Anderson Ranch</td><td>a) No change to the ability of Anderson Ranch Dam to continue meeting downstream minimum streamflow objectives.
b) Potential for up to 9 days of increased flows below Anderson Ranch Dam in the late summer when releases from Anderson Ranch Reservoir are called upon to backfill Arrowrock Reservoir.
c) Summer releases from Anderson Ranch Reservoir will be made at the power plant capacity of approximately 1,600 cubic feet per second (cfs).
d) Potential for decreased water temperature during times of year when water temperatures are typically the highest.</td><td>a) No change to the ability of Anderson Ranch Dam to continue meeting downstream minimum streamflow objectives.
b) Potential for up to 4.5 days of increased flows below Anderson Ranch Dam in the late summer when releases from Anderson Ranch Reservoir are called upon to backfill Arrowrock Reservoir.
c) Summer releases from Anderson Ranch Reservoir will be made at the power plant capacity of approximately 1,600 cfs.
d) Water temperatures are similar to the baseline under this Alternative.</td></tr>
<tr><td>Boise River at Glenwood</td><td>Potential for increased summer flows depending on demand (rate, timing, and use location) for water accrued to the new storage space.</td><td>Potential for increased summer flows depending on demand (rate, timing and use location) for water accrued to the new storage space.</td></tr>
</table>

In order to better understand the sensitivity of the results to period selection, impacts were analyzed using two different historical periods: a full 50-year simulation period spanning 1958 through 2008, and the more recent 28-year subset spanning 1980 through 2008. Comparison of these two periods shows an increased proportion of years with low runoff volumes and earlier runoff recession (lower June and July runoff) in the 1980 through 2008 period compared to the 1958 through 2008 period. As a result of these differences, the system exhibits reduced carryover, less-frequent fill, and smaller flood releases in the later 1980 through 2008 period. There is also an increased number of years in the later period where storage accounts providing water for flow augmentation do not fill, resulting in decreased releases for flow augmentation in early summer. Differences between the 6-foot Raise and 3-foot Raise Alternatives (Alternatives) and No Action storage conditions are similar or slightly larger in magnitude in the longer analysis period. Both periods exhibit operations under the Alternatives falling within the historical operating range.

Climate Change Hydrology

The RMJOC-II Climate Change Study notes overall trends of increased fall and winter streamflow, earlier and higher spring peak runoff, and earlier streamflow recession. The study also suggests the potential for increased rain-on-snowpack events during the winter and spring and annual flow peaks shifting several weeks earlier compared to historical conditions. The climate change conditions simulated in this study demonstrated a stronger influence on operations compared to the proposed increase in storage at Anderson Ranch Reservoir. Both climate change scenarios showed wetter conditions (higher streamflow and storage content) during the winter and spring months compared to historical hydrology. Model results also suggest that that the storage benefit associated with the Alternatives may still be realized under future hydrologic conditions. However. it must be noted that these simulations utilize perfect forecasts[1] and current operational objectives. This study does not consider forecast uncertainty, nor how that uncertainty may change going into the future as warming conditions influence the proportion of precipitation that falls as rain rather than accumulating as snowpack.

Water Availability and Refill Probability

A summary of the water availability analysis is shown in Table ES-2. This analysis considered the new potential storage space in Anderson Ranch Reservoir along with two other proposed water rights for Elmore County and Cat Creek Energy (CCE).

Table ES-2. Probability of complete refill for the Alternatives and analysis time periods 1958-2008 (50-year) and 1980-2008 (28-year).

Scenario	6-foot Raise (29,000 acre-feet)	3-foot Raise (14,400 acre-feet)
Elmore County > CCE > Anderson Ranch	38%	42%
Anderson Ranch only	62%	64%

Construction Phase

Drawdown of Anderson Ranch Reservoir during the construction period for both Alternatives has the potential to result in reduced fill to reservoir storage accounts depending on runoff conditions. This analysis indicates the maximum volume of shortfall per year would equate to approximately 55,000 acre-feet per year for a 4,184 foot pool elevation restriction and a shortfall of approximately 97,000 acre-feet per year for a 4,174 foot pool elevation restriction.

[1] Defined in Section 3.6

This page intentionally left blank.

1 Project Overview

The Bureau of Reclamation (Reclamation) is evaluating the potential benefits and impacts of storage alternatives in the Boise River System. The analysis presented in this technical memorandum is being used to support the Feasibility Study (Study), associated Environmental Impact Statement (EIS), and Biological Assessment. To ensure that Reclamation evaluated a reasonable range of alternatives for the National Environmental Policy Act compliance process, the EIS includes a 3-foot dam raise of Anderson Ranch Dam as an alternative; this alternative was not further evaluated as a structural alternative for the Study. This approach is supported by Reclamation Manual, Directives and Standards CMP 09-02, *Water and Related Resources Feasibility Studies*. The three alternatives described in Table 1 are consistent with information in the EIS.

Table 1. Alternatives evaluated.

Alternative	Name	Description
A	No Action	The No Action alternative reflects current system configurations, operations, and demands. It is used as a comparative baseline for Alternatives B and C.
B	6-foot Raise of Anderson Ranch Dam (Preferred Alternative) (6-foot Raise)	The 6-foot Raise of Anderson Ranch Dam adds approximately 29,000 acre-feet of storage to the system.
C	3-foot Raise of Anderson Ranch Dam (3-foot Raise)	The 3-foot Raise of Anderson Ranch Dam adds approximately 14,400 acre-feet of storage to the system.

Table 2 shows the total and active capacities of the Boise Reservoir System under both No Action (Alternative A; assumed as current condition) and the proposed dam-raise conditions. The 6-foot Raise and the 3-foot Raise would equate to 6.4 percent and 3 percent increases, respectively, in the active capacity of Anderson Ranch Reservoir, and to 3 percent and 1 percent increases, respectively, in system active capacity.

Table 2. Storage capacities of the Boise Reservoir System for the baseline condition and proposed 6-foot Raise and 3-foot Raise Alternatives. "Total capacity" includes 36,956 acre-feet of inactive (powerhead) space in Anderson Ranch Reservoir, whereas "active capacity" does not.

Reservoir	Total Capacity (acre-feet)			Active Capacity (acre-feet)		
	Alternative A No Action - Current	Alternative B Proposed 6-foot Raise	Alternative C Proposed 3-foot Raise	Alternative A No Action - Current	Alternative B Proposed 6-foot Raise	Alternative C Proposed 3-foot Raise
Anderson Ranch	450,030	479,030	464,430	413,074	442,074	427,474
Arrowrock	272,224	272,224	272,224	272,224	272,224	272,224
Lucky Peak	264,371	264,371	264,371	264,371	264,371	264,371
System	986,625	1,015,625	1,001,025	949,669	978,669	961,069

This technical memorandum describes the assumptions and results of this study, which involved an analysis of changes in storage and streamflow associated with the new space under four different demand scenarios. This evaluation was conducted using the Boise subbasin of the Upper Snake RiverWare Model and historical and future hydrologic datasets developed as part of the RMJOC-II Climate Change Study (RMJOC-II 2018). Potential impacts to temperature regimes downstream of Anderson Ranch Reservoir were evaluated using the Anderson Ranch Reservoir CE-QUAL-W2 model.

2 Description of Models

2.1 Boise Planning Model

The Boise Planning Model is derived from the larger Upper Snake RiverWare Model. RiverWare® ver. 7.5 is a generalized river basin modeling tool that can be used to simulate detailed, site-specific river and reservoir operations. The Boise Planning Model and the Upper Snake RiverWare Model include logic to simulate competing water demands in the system while adhering to legal water right and physical constraints. A schematic of the Boise Planning Model is shown in Figure 1. Competing water demands include irrigation, Flood Risk Management (FRM), minimum-flow targets, ecological flow releases, and ecological storage constraints.

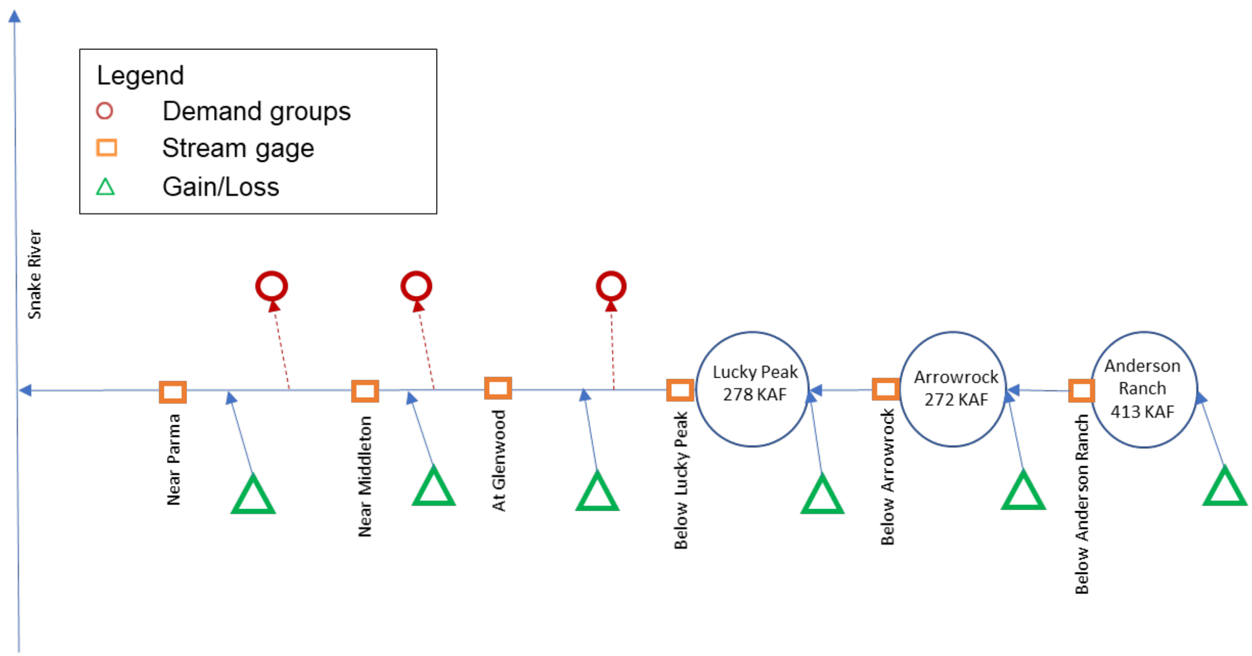

Figure 1. Boise Planning Model schematic; reservoir storage volumes reflect current active storage capacity.

Figure 2 through Figure 5 show baseline model (No Action model) simulated storage conditions, along with the observed historical storage in the Boise Reservoir System. Figure 6 and Figure 7 illustrate simulated and observed streamflow conditions below Anderson Ranch Dam and the Boise River at Glenwood Bridge locations. Differences between simulated and observed conditions can be attributed to updated operational objectives, the use of perfect foresight on future inflow volumes (vs. imperfect real-time forecasts), and the fact that actual, real-time operations may not adhere strictly to the objectives outlined in the model logic. An example of the model strictly adhering to FRM objectives that may have differed in actual operations can be seen in Figure 2 and Figure 3, where modeled storage volumes are lower than historical in the early 1980s prior to the 1985 Water Control Manual for Boise River Reservoirs.

Operational objectives have changed over the course of the simulation period. The current version of the model has been calibrated to simulate current operational objectives. These include, when possible:

1) Maintaining a minimum storage elevation in Arrowrock Reservoir of 3,100 feet (37,912 acre-feet)[2];

2) Keeping Lucky Peak Reservoir near full (approximately 264,000 acre-feet) from May 31st through September 1st for recreation;

[2] Real-time operations and the model use 50,000 acre-feet for this target to ensure the storage in the reservoir does not drop below the target.

3) Managing peak flows at Glenwood gage to be 6,500 cubic feet per second (cfs) (flood action flow) or less;

4) Reaching and maintaining the "elk pool"[3] (approximately 60,000 acre-feet) in Lucky Peak Reservoir from the end of the irrigation season through the middle of February;

5) Meeting minimum flow targets in the South Fork Boise River and at the Boise River at Glenwood Bridge location; and

6) Releasing a portion of stored water for flow augmentation (see Section 5 for a description of flow augmentation).

Flow augmentation deliveries are also simulated by the model. Flow augmentation water is defined as water released at targeted times and places to increase streamflows to benefit migrating salmon and steelhead. This water is partially delivered from stored water in the Boise System. More discussion about flow augmentation can be found in Section 4.

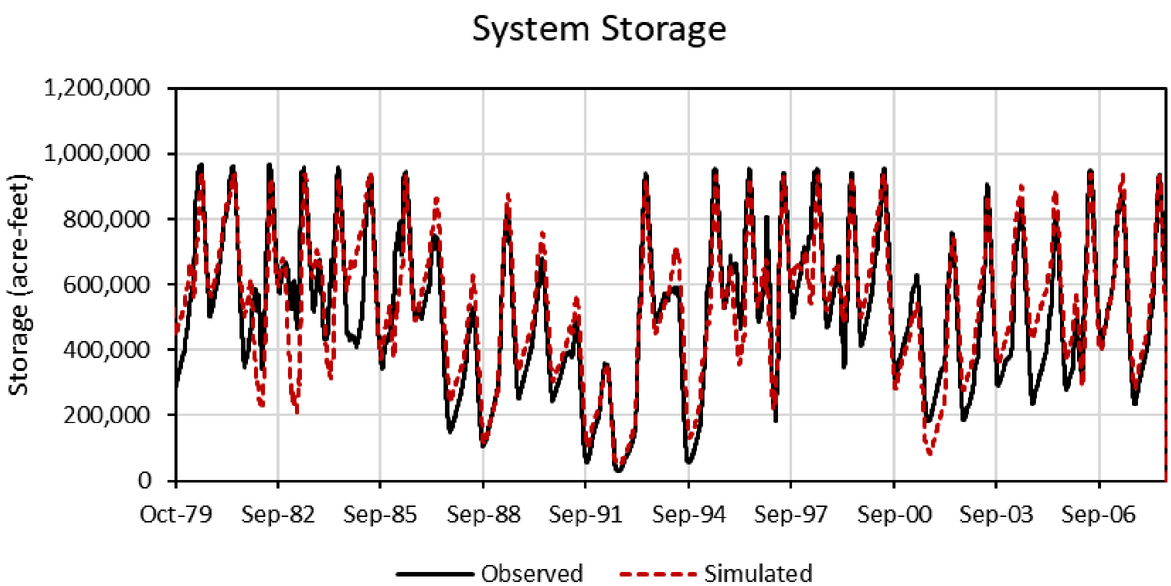

Figure 2. Simulated storage (red dashed line) and observed storage (black solid line) in the Boise Reservoir System for the 1980 through 2008 water years. Storage values depicted represent total system storage (excluding 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir).

[3] The term "elk pool" refers to a soft operational target of holding the water surface elevation of Lucky Peak at a level no higher than 2,960 feet (63,600 acre-feet content) during January and February each year to reduce potential elk mortality while crossing the Mores Creek arm of the reservoir. This soft operational target cannot always be met, particularly in late February when Arrowrock Reservoir approaches full and begins to pass inflow into Lucky Peak Reservoir, causing it to fill above the 2,960-foot level.

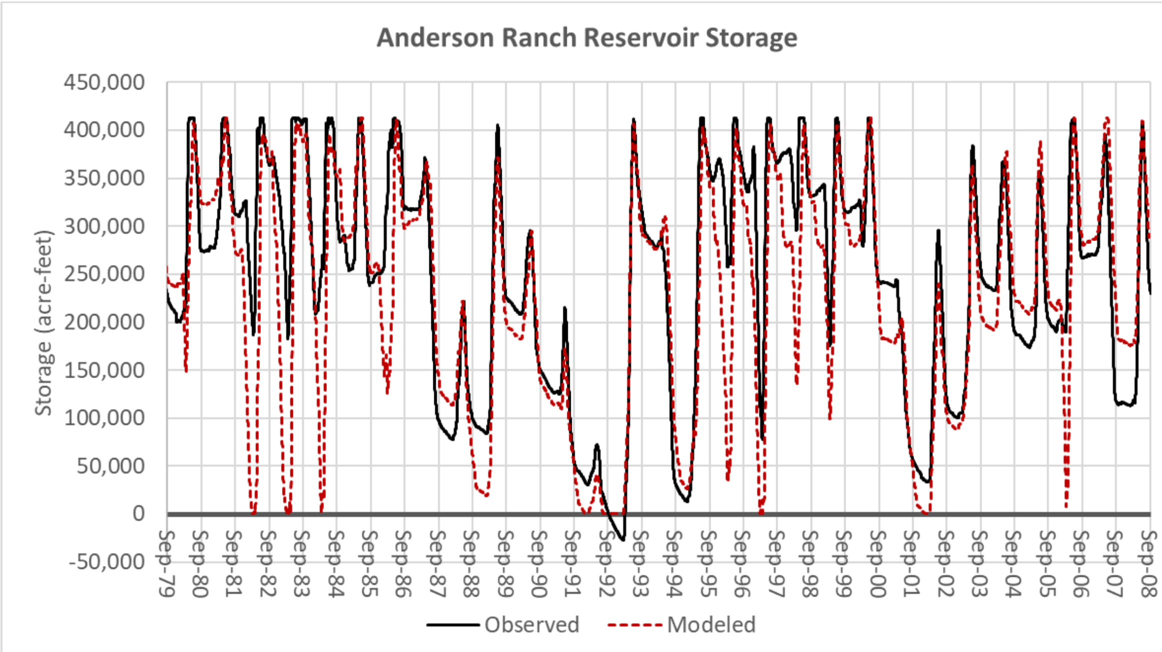

Figure 3. Simulated storage (red dashed line) and observed storage (black solid line) in Anderson Ranch Reservoir for the 1980 through 2008 water years. The 0 acre-feet storage line corresponds to the minimum storage target of maintaining 62,000 acre-feet of dead and inactive space in the reservoir, including 36,956 acre-feet of inactive powerhead space. Storage values going negative as in 1992 indicate that the reservoir was lowered into the powerhead space.

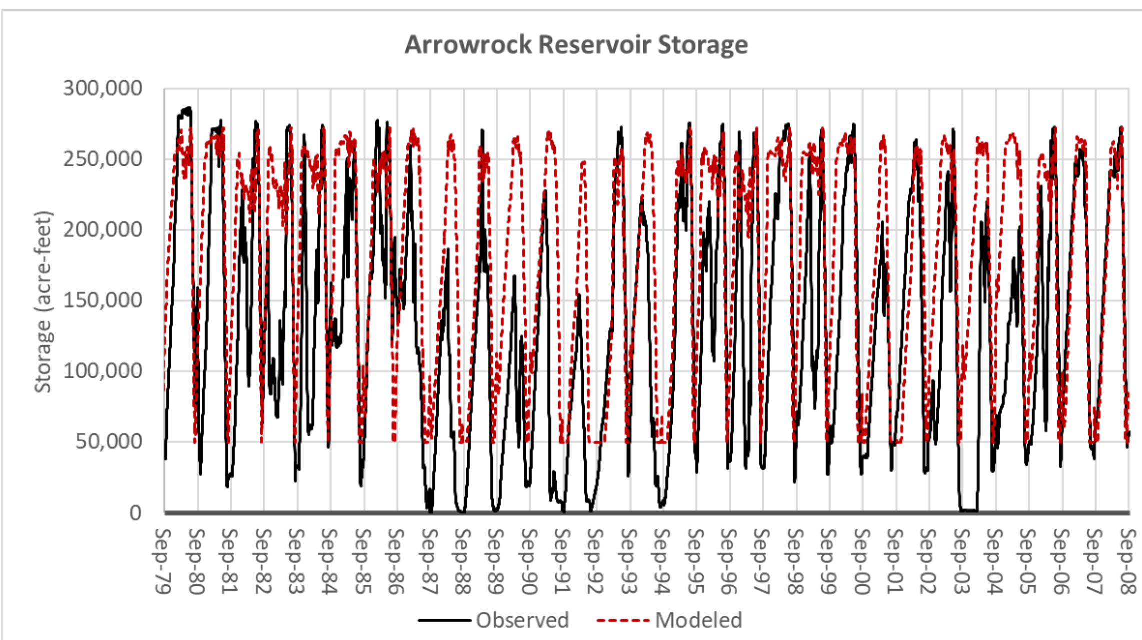

Figure 4. Simulated storage (red dashed line) and observed storage (black solid line) in Arrowrock Reservoir for the 1980 through 2008 water years.

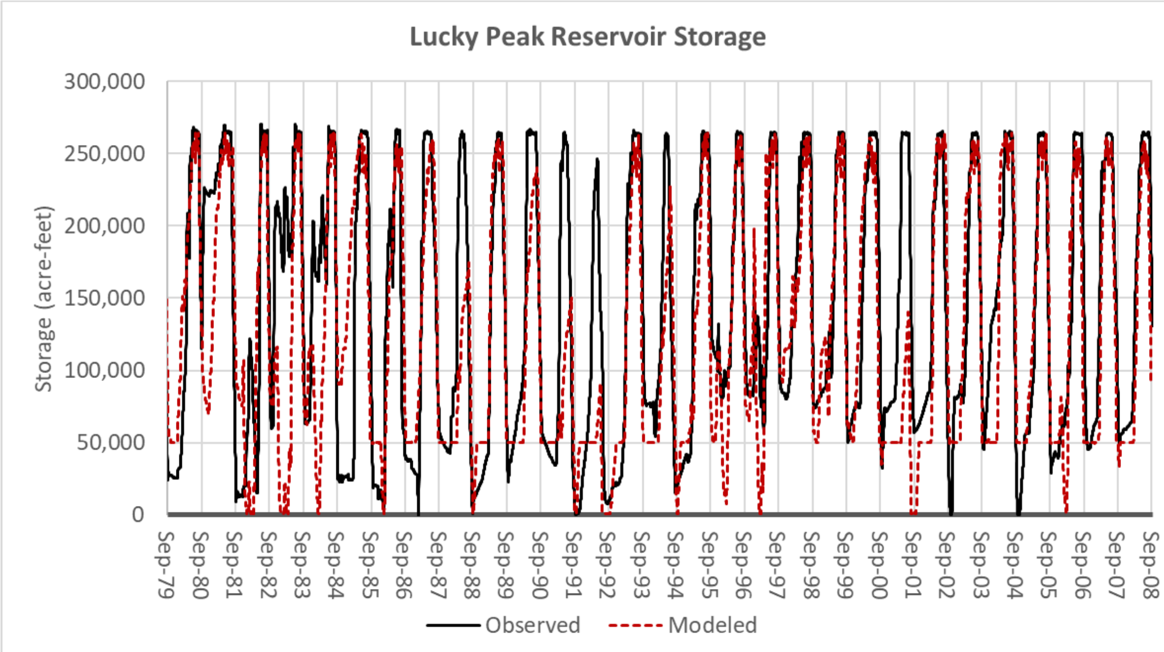

Figure 5. Simulated storage (red dashed line) and observed storage (black solid line) in Lucky Peak Reservoir for the 1980 through 2008 water years.

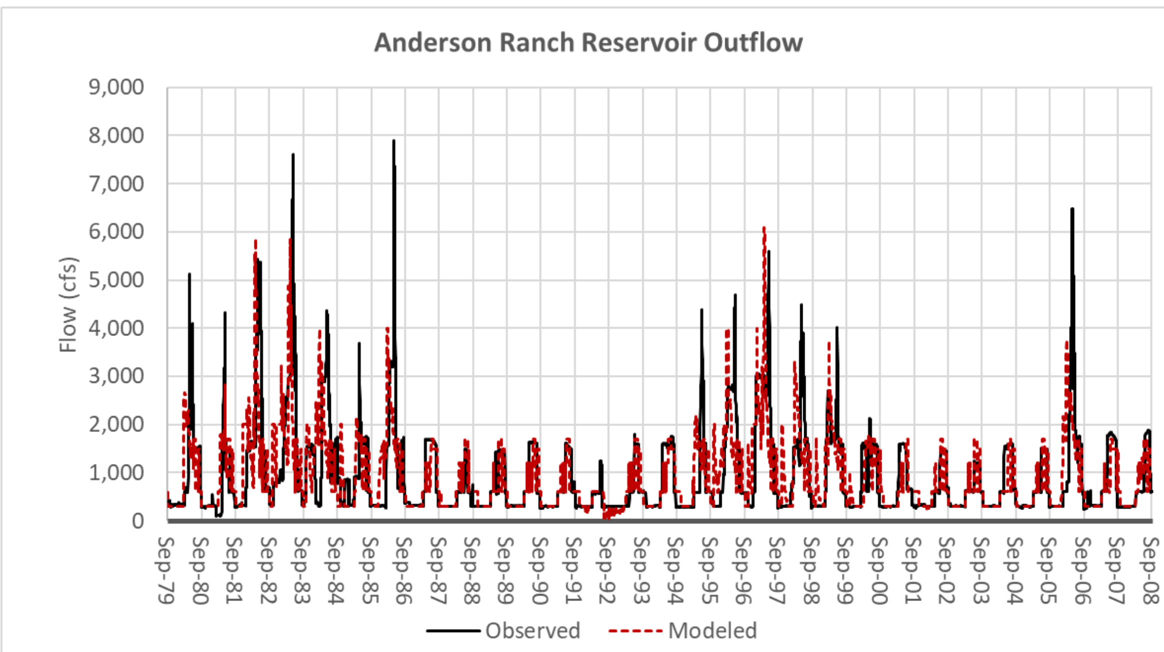

Figure 6. Simulated (red dashed line) and observed (black solid line) flow in the Boise River below Anderson Ranch Reservoir for the 1980 through 2008 water years.

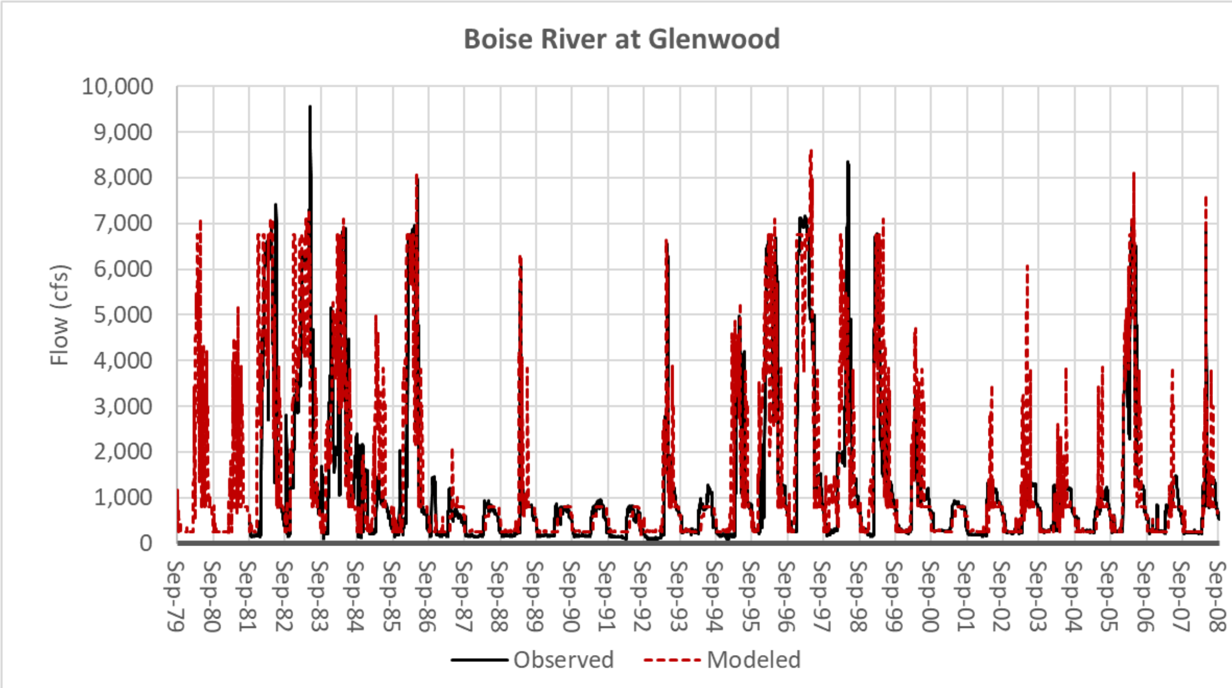

Figure 7. Simulated (red dashed line) and observed (black solid line) flow in the Boise River at Glenwood Bridge for the 1980 through 2008 water years.

2.2 Analysis Period

For this study, the model was run at a daily time-step over a 50-year period spanning October 1, 1958 through September 30, 2008. Preliminary water resource modeling conducted in 2017 used a previous version of the Boise Planning Model (Reclamation 2017) with a more limited simulation period (October 1, 1980 through September 30, 2008). Since this earlier work, Boise Planning Model improvements included extension of the simulation period further back in time to 1958. The longer period provides for a wider range of runoff and storage conditions and sequencing of year types (wet vs. dry). Figure 8 depicts comparisons of these two time periods in terms of January through July runoff volume exceedance for the Boise Reservoir System above Lucky Peak Dam and above Anderson Ranch Dam. As shown by these panels, the hydrologic regimes for the two periods have similar distribution of flows; however, the later period exhibits an increased occurrence of lower volume runoff years as indicated by the red line being below the black line over 50 percent of the time.

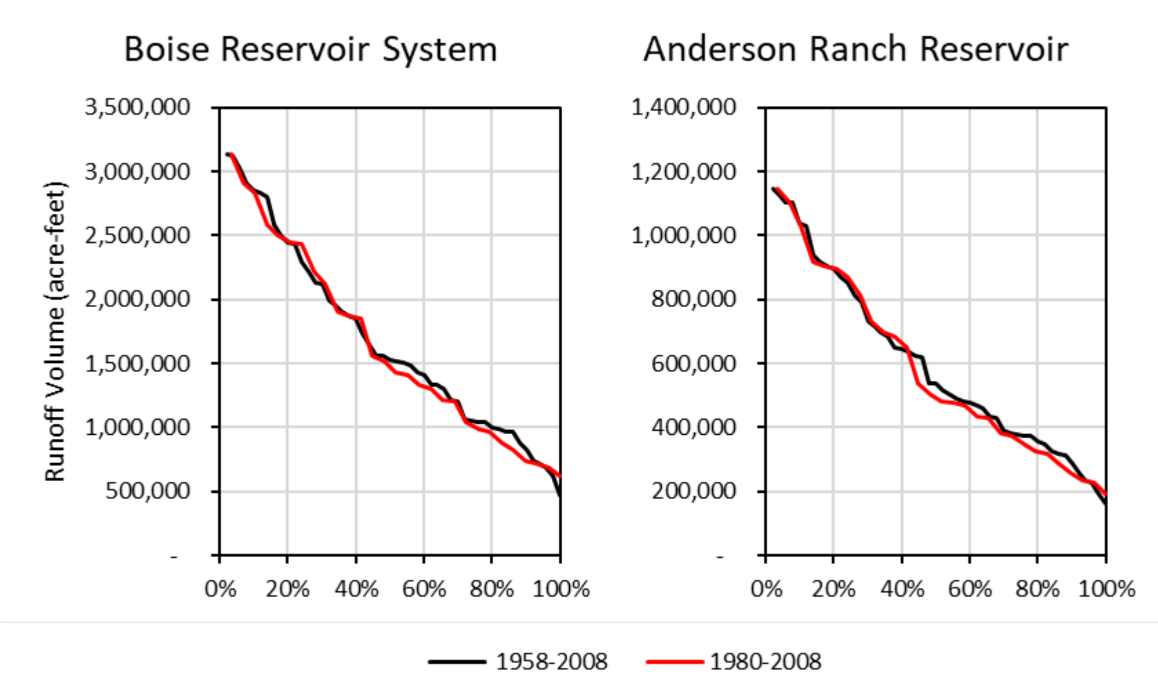

Figure 8. January through July runoff volume exceedance probabilities for the Boise Reservoir System above Lucky Peak Dam and above Anderson Ranch Reservoir. Black lines represent the 1958 through 2008 analysis period, while the red lines represent the shorter 1980 through 2008 period.

Figure 9 depicts the summary hydrographs for runoff above Lucky Peak Dam and above Anderson Ranch Dam. Both panels in this figure exhibit earlier runoff recession in June and July for the shorter analysis period as indicated by the red line falling below the black line in June and July, a critical period for refilling the reservoir system following winter FRM operations.

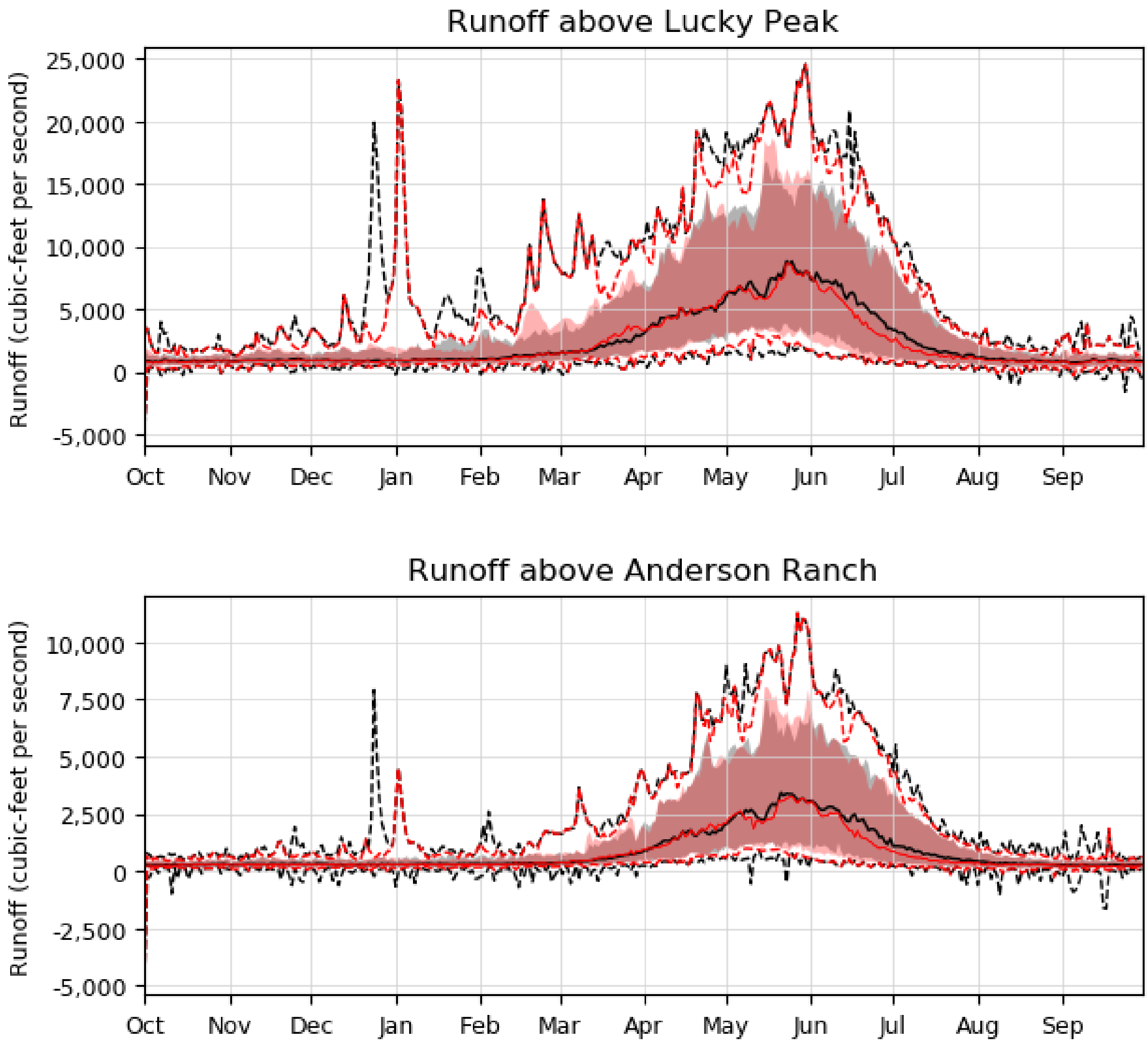

Figure 9. Summary hydrographs depicting the daily runoff conditions for the Boise Reservoir System above Lucky Peak Dam (top panel) and above Anderson Ranch Dam (bottom panel). The black lines and gray region represent the full 1958 through 2008 analysis period, while the red lines and shaded red region represent the shorter 1980 through 2008 analysis period. Solid lines represent the daily median runoff values, shaded regions are bound by the 10th-percentile to 90th-percentile values, and dashed lines represent the daily minimum and maximum values.

The combination of increased low-volume years and earlier streamflow recession in the shorter 1980 through 2008 period creates conditions where the reservoir system refills less frequently. This is shown in Figure 10 and Figure 11, where annual maximum storage volume is plotted relative to January through July runoff volume. Note that the 1980 through 2008 period is a subset of the 1958 through 2008 period; therefore, the black dots in these figures represent the 1958 through 1980 period, the red dots represent the 1980 through 2008 period, and the full 1958 through 2008 period is represented by the red and black dots combined. In the earlier part of the 1958 through 2008 period (black dots), the system consistently fills in years where runoff is greater than 1.0 million acre-feet (MAF), whereas in the later period (red dots), the system consistently fills in years where runoff is greater than 1.5 MAF. Below these thresholds, the system may still fill depending on carryover conditions. The 1958 through 2008 modeling period contains a larger proportion of years with system runoff greater than 1.5 MAF (52 percent of years) compared to the 1980 through 2008 period (45 percent of years), yet also features the driest year in the dataset (less than 500 thousand acre-feet (KAF) January through July runoff volume).

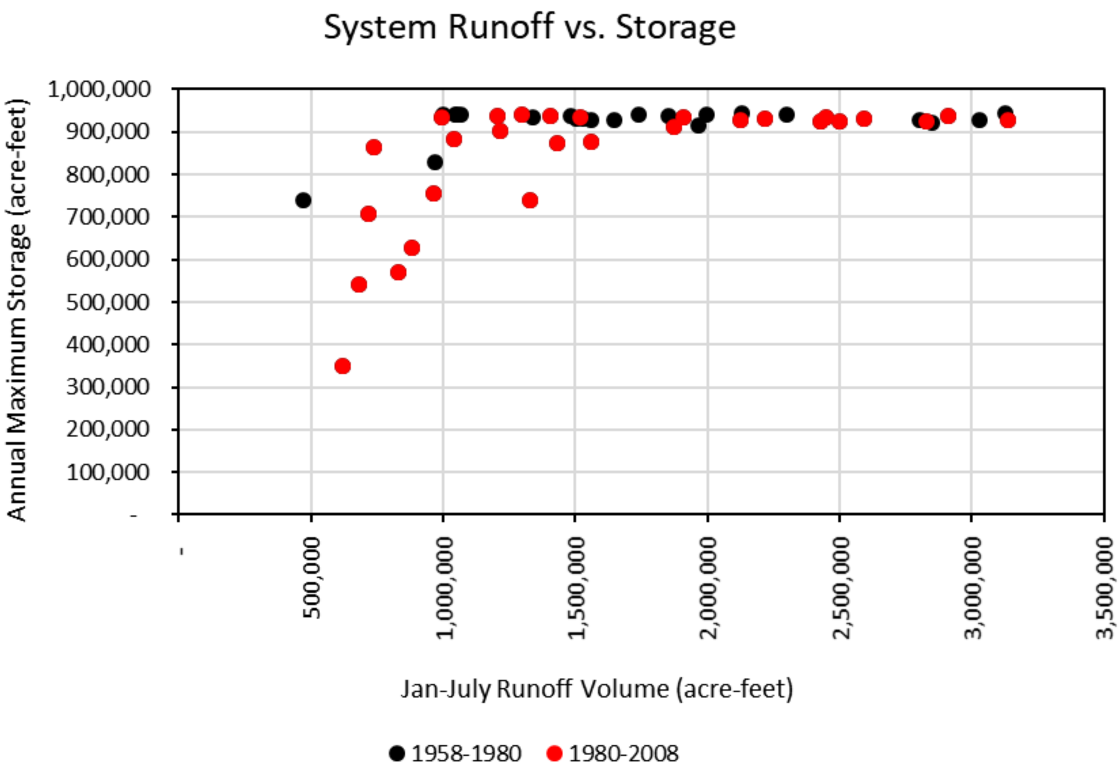

Figure 10. Annual maximum simulated Boise Reservoir System storage vs. January through July runoff volumes above Lucky Peak Dam. Black dots represent the 1958 through 1980 period and red dots represent the 1980 through 2008 period. The full 1958 through 2008 analysis period is therefore represented by the black and red dots combined.

Figure 11 is similar to Figure 10, but shows maximum storage and runoff for Anderson Ranch Reservoir only. As shown in Figure 11, Anderson Ranch Reservoir fills consistently at January through July runoff volumes greater than 350 KAF in the earlier part of the 1958 through 2008 period (black dots). This is in contrast to the later period (red dots), where the reservoir only fills consistently at runoff volumes greater than 600 KAF. In order to better understand how period selection influences model results, Section 3 summarizes key differences in reservoir operations results between the two analysis periods.

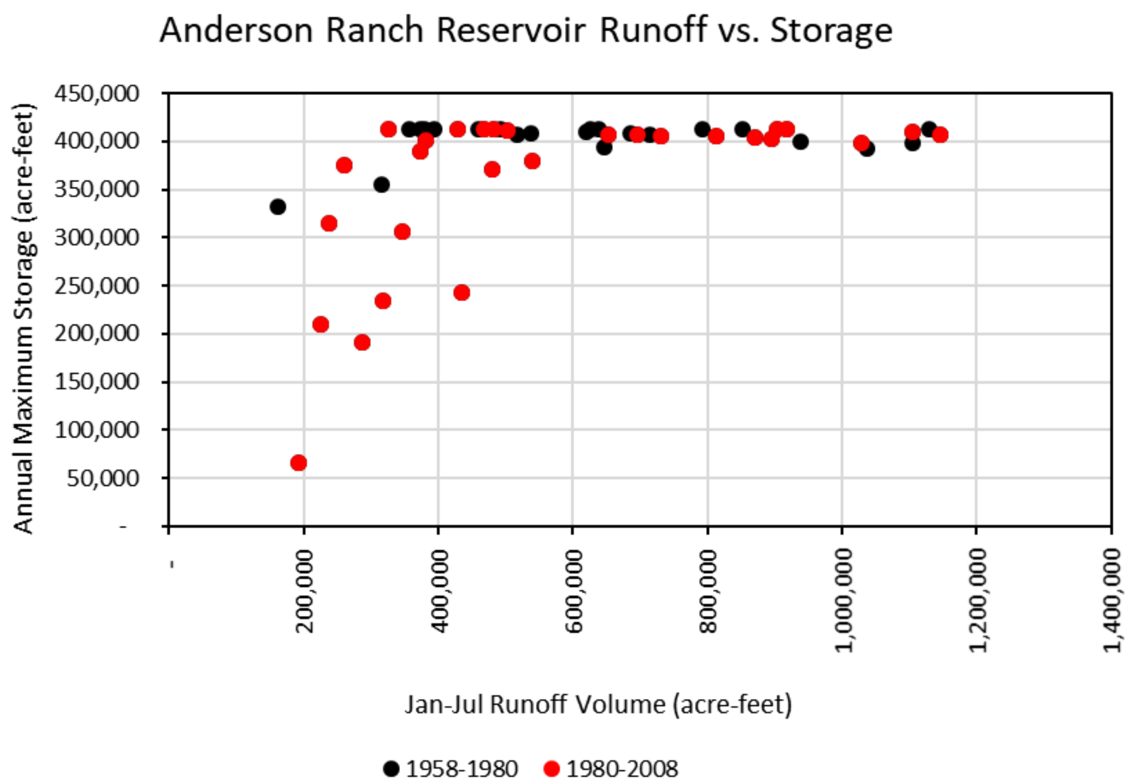

Figure 11. Annual maximum Anderson Ranch Reservoir storage vs. January through July runoff volumes above Anderson Ranch Dam. Black dots represent the 1958 through 1980 period and red dots represent the 1980 through 2008 period. The full 1958 through 2008 analysis period is therefore represented by the black and red dots combined.

The effect of the choice of period is most notable in the Water Availability Analysis (Section 5). Appendix A of this technical memorandum includes plots and discussion of how the analysis period effects the results of the Alternatives.

2.3 Anderson Ranch Reservoir Water Quality Model

The Anderson Ranch Reservoir Water Quality Model consists of a CE-QUAL-W2 (Cole and Wells 2018) model calibrated for the period spanning April 2016 through October 2017. The CE-QUAL-W2 (Version 4.1) model is a two-dimensional, laterally averaged hydrodynamic and water-quality model. Figure 12 illustrates the model segments and spatial extent.

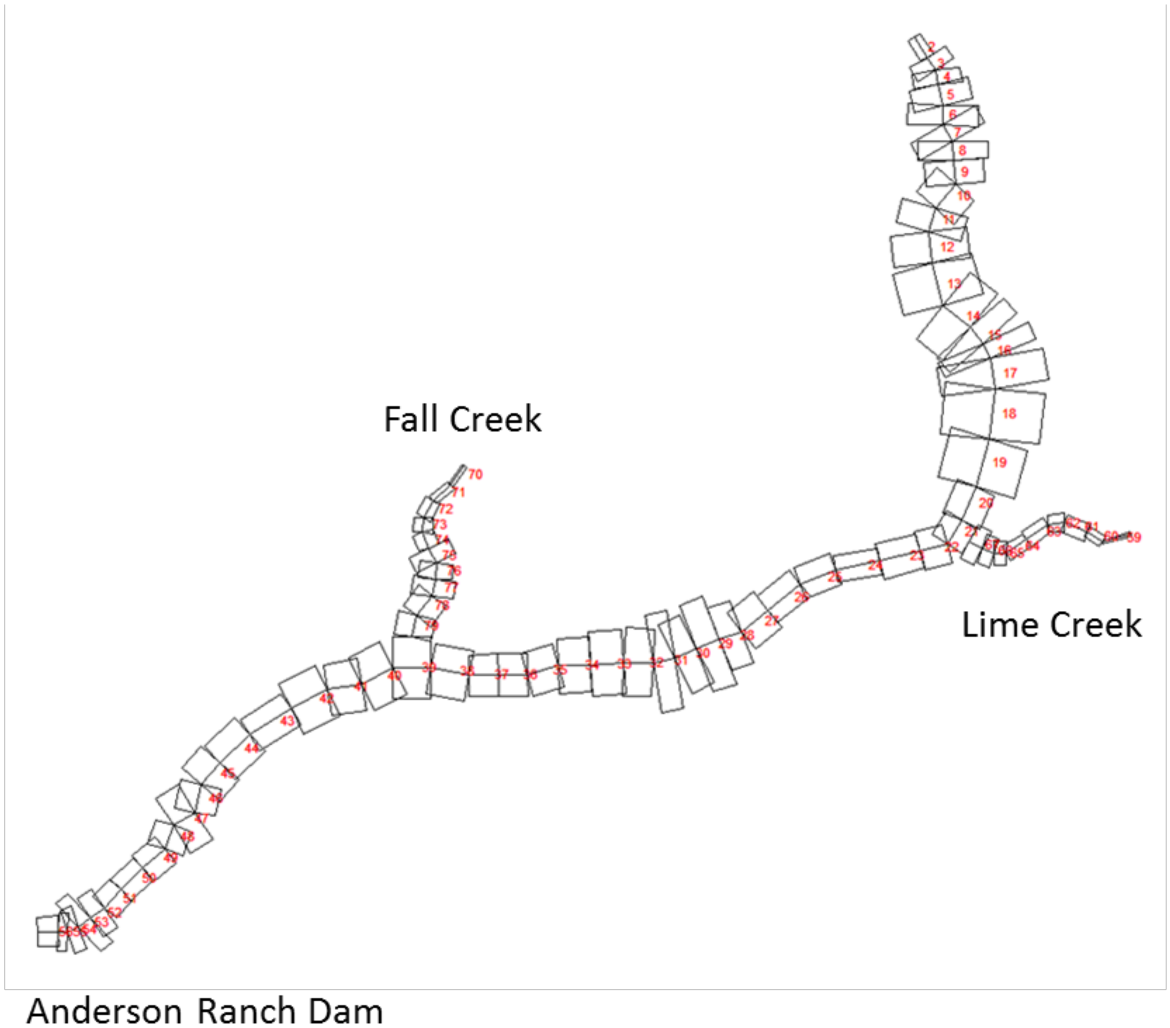

Figure 12. Anderson Ranch Reservoir water quality model segments. The main waterbody extends from the South Fork of the Boise River at Featherville, Idaho to Anderson Ranch Dam. Tributaries represented in the model include Lime Creek and Fall Creek.

Calibration of this preliminary model focused primarily on temperature regimes within the reservoir and in the reservoir outflow. The model has been utilized to confirm baseline water quality conditions in Anderson Ranch Reservoir and to better understand how a 6-foot raise might influence temperature regimes in the South Fork Boise River below Anderson Ranch Dam. Figure 13 illustrates the model simulated temperature (red dotted line) along with the historical observations (black solid line) for the calibration period spanning April 2016 through September 2017. As shown in the figure, the current calibration of the model tends to over-predict outflow temperatures during the warmest parts of the temperature regime and under-predict outflow temperatures during the cooler periods. For this study, these biases are considered in the interpretation of results.

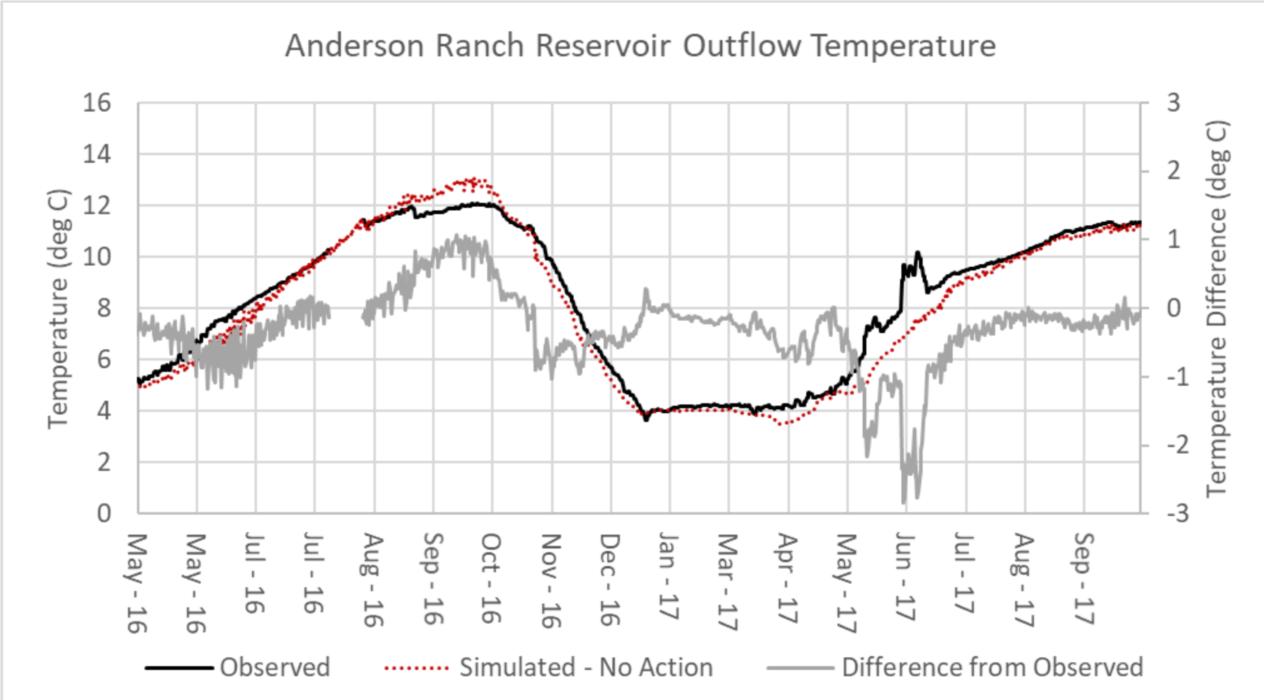

Figure 13. Simulated No Action (red dashed line) and observed (black solid line) outflow temperatures, along with the difference between the two (gray solid line), at Anderson Ranch Dam for the period spanning April 2016 through September 2017.

3 Boise System Operations Analysis

The Boise System Operations Analysis used the Boise Planning model, and the new storage was simulated by increasing the size of Anderson Ranch Reservoir for Alternative B (6-foot Raise) and Alternative C (3-foot Raise). FRM operations remained similar to historical, as the new storage space is not anticipated to be used for FRM. Irrigation delivery operations remained similar to historical with the exception of the additional storage releases from the new space. Any storage in the new space was routed downstream using one of four demand patterns (Table 3). Four patterns were simulated for this analysis because it is uncertain how the new storage water will be used, and there are possible different use patterns that could result in differences in carry-over storage or downstream flows. To evaluate the range of the impacts of the demand patterns for each storage scenario, the results are combined and summarized in the following plots.

Table 3. Demand pattern descriptions.

Number	Name	Description
1	No New Demand	The No New Demand pattern is based on the potential condition where the new space is used to satisfy existing surface water demands in cases where shortage might have otherwise occurred. In this scenario, water users above Glenwood have access to the accrued storage on an as-needed basis.
2	New Early-Season Demand	The New Early-Season Demand pattern is based on the potential condition where water accrued to the new space might be called upon early in the irrigation season. This is similar to the release of storage for flow augmentation (NOAA Fisheries 2008) in the spring and early summer. Use of accrued storage in this scenario is limited by flows at Glenwood[4], where flow augmentation releases occur only when flows at this location are less than 3,000 cfs. As a result of this limitation, water accrued to the new storage account may not be completely exhausted every year.
3	Irrigation Season Demand	The New Irrigation Season Demand pattern is based on the condition where water accrued to the new space is delivered during the irrigation season to users upstream of Glenwood. The water is released at a constant rate from the day the system is full (Day of Allocation) through October 15. Ten percent of the proposed space could be used to provide operational flexibility or for environmental purposes, which could include environmental flows.
4	New M&I Demand	The New M&I Demand pattern is based on the potential condition where water accrued to the new space is delivered for M&I purposes upstream of Glenwood. The water is released at a rate that changes depending on the time of year, similar to current M&I groundwater deliveries (SPF 2016; Table 13) from day the system is full (Day of Allocation) through March 15 of the following year. Ten percent of the proposed space could be used to provide operational flexibility or for environmental purposes, which could include environmental flows.

Plots presented in Section 3 below are shown to summarize the results for the two increased storage Alternatives (6-foot Raise and 3-foot Raise) as compared to No Action (baseline). The plots are shown as summary hydrographs of storage or flow with the daily 50th-percentile (solid lines) and the 10th-percentile to 90th-percentile range (shaded areas). The red solid region in this figure represents the full range of the daily median values associated with the four demand scenarios, while the shaded blue (6-foot Raise) or green (3-foot Raise) region captures the full range of the 10th- to 90th-percentiles. When the 10th percentile and 90th-percentile values of No Action and the Alternatives overlap, the shading becomes darker. When they don't overlap, only the lighter shading appears. The dashed black and blue or green lines represent the absolute maximum and minimum daily values in the Baseline Scenario and the Alternatives.

Although the modeling assumptions may not capture all of the complexities of real-time operations, the model output provides data that allow for the comparison of scenarios (No Action versus the Alternatives).

[4] Similar to real-time operations, the modeling scenarios assumed that if seasonal flow targets during the irrigation season were meet at Glenwood, this would also satisfy irrigation downstream of Glenwood.

3.1 System Storage

Figure 14 depicts the summary hydrograph of the system storage for Alternative B (6-foot Raise) as compared to Alternative A (No Action). The system storage in the 6-foot Raise is up to 29,000 acre-feet larger than No Action. The variation in storage is partly due to the different demand patterns that either use all of the water each year or results in some carryover. It is also partly due to the variability of water available to fill the new space. Generally, the system has more storage year-round due to some carryover of water in the new storage space except for the driest years where it is similar to No Action.

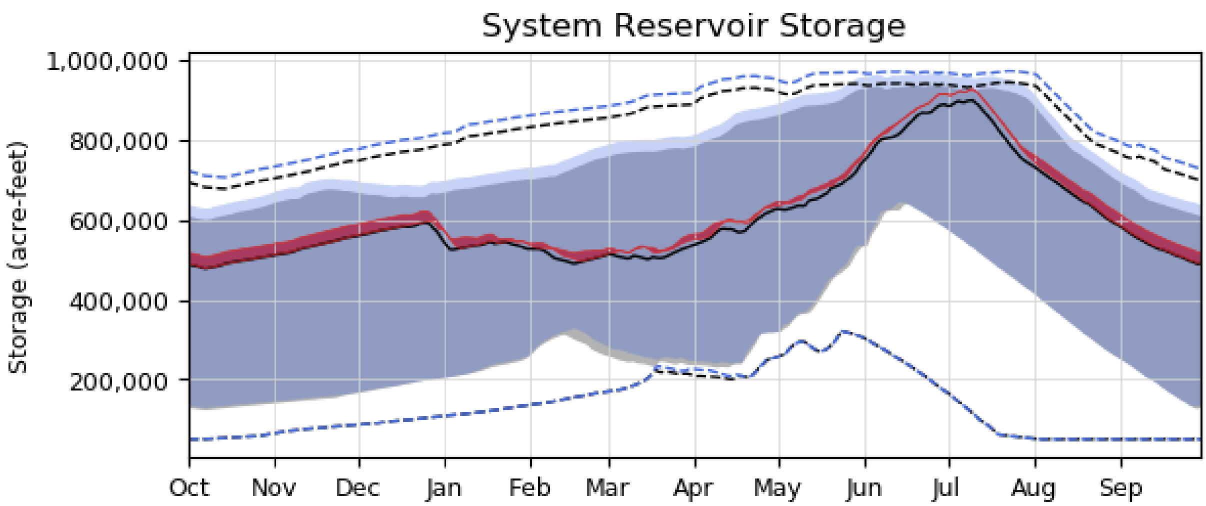

Figure 14. Boise Reservoir System summary storage hydrograph depicting the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. Storage values do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

Figure 15 depicts the summary hydrograph of the system storage for Alternative C (3-foot Raise). This scenario behaves similarly to Alternative B, but the additional storage is only 14,400 acre-feet. As in Alternative B, the system has more storage except for the driest years.

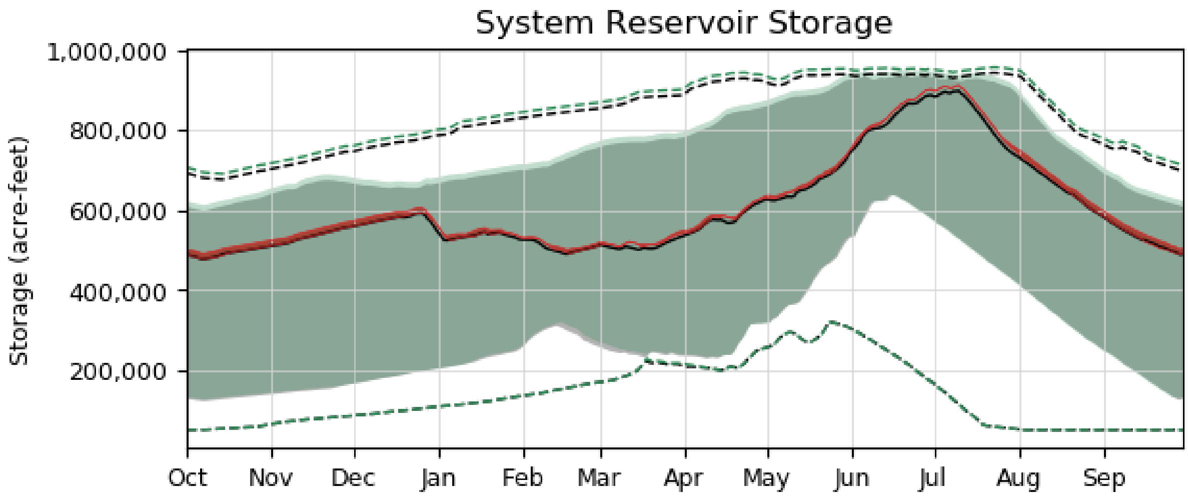

Figure 15. Boise Reservoir System summary storage hydrograph depicting the daily median storage content range for the 3-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. Storage values do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

3.2 Anderson Ranch Reservoir

As shown by the summary hydrograph in Figure 16, Alternative B (6-foot Raise) would result in a year-round increase in daily storage contents at Anderson Ranch Reservoir compared to No Action by as much as 29,000 acre-feet. The system is operated in both Alternatives and No Action to make deliveries out of the lower two reservoirs (Lucky Peak and Arrowrock) while using storage from Anderson Ranch Reservoir to back fill as needed since it is on a tributary with less reliable water supply. In Alternatives B and C, this results in more water being held in Anderson Ranch Reservoir while the additional irrigation demand for the new storage is met with water from the lower system. This results in Anderson Ranch Reservoir having more storage in most years while Lucky Peak Reservoir and Arrowrock Reservoir generally have lower storage.

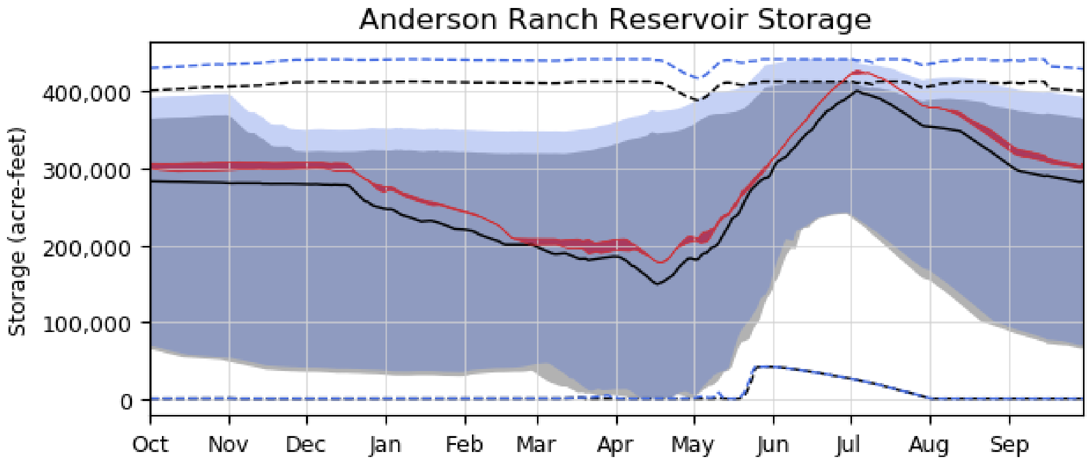

Figure 16. Anderson Ranch Reservoir summary storage hydrograph depicting the daily median storage content range 6-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. The 0 acre-feet storage line corresponds to the minimum storage target of maintaining 62,000 acre-feet of dead and inactive space in the reservoir including 36,956 acre-feet of inactive powerhead space.

Figure 17 shows the summary hydrograph for Alternative C (3-foot Raise) compared to No Action. As with the 6-foot Raise, storage is generally larger than No Action in Anderson Ranch Reservoir except for the driest years.

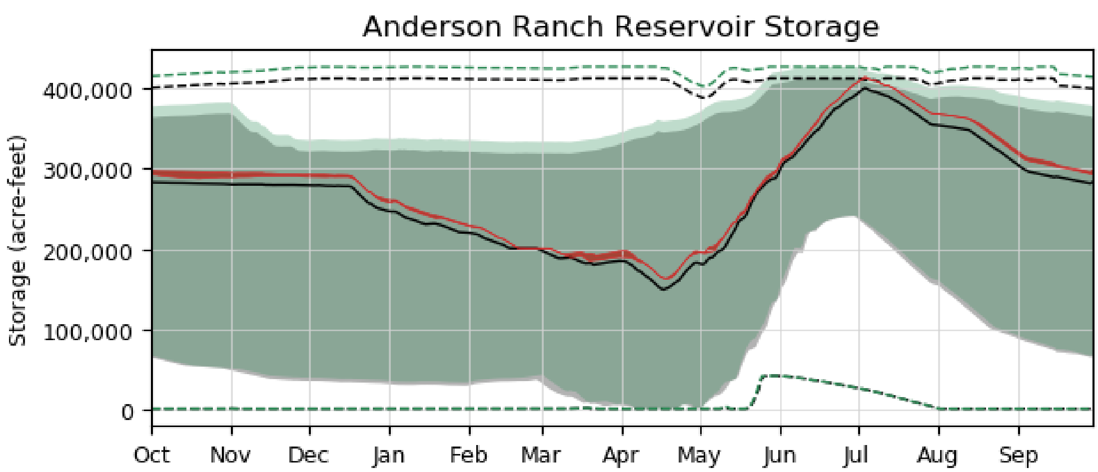

Figure 17. Anderson Ranch Reservoir summary storage hydrograph depicting the daily median storage content range for the 3-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. The 0 acre-feet storage line corresponds to the minimum storage target of maintaining 62,000 acre-feet of dead and inactive space in the reservoir including 36,956 acre-feet of inactive powerhead space.

When pool elevations are greater than 4,174 feet, releases over 11,700 cfs require use of the spillway at Anderson Ranch Dam. Given storage elevations and outflow conditions at Anderson Ranch Reservoir over the 1958 through 2008 analysis period, model results indicate no need for increased use of the spillway.

A stipulation of Reclamation's incidental take permit (USFWS 2005) is for a minimum volume threshold of 62,000 acre-feet in Anderson Ranch Reservoir to be maintained 93 percent of the years. This threshold volume represents the amount of water stored in the dead pool and inactive space, thus corresponding to the top of the inactive power head space and represented by zero-storage in Figure 16 and Figure 17. As shown in the figures, and like No Action, results from the Alternatives indicate the potential for storage contents to approach, but not fall below, this threshold. Median and 90^{th}-percentile daily storage conditions are well above this threshold for the Alternatives.

3.3 Arrowrock Reservoir

Arrowrock Reservoir and Lucky Peak Reservoir are currently operated such that their releases satisfy most of the downstream irrigation demands, with Anderson Ranch Reservoir providing releases to keep Arrowrock Reservoir above its minimum pool constraint. This would remain the case following one of the proposed dam raises at Anderson Ranch Reservoir.

Figure 18 illustrates the Arrowrock Reservoir storage summary hydrograph for No Action and Alternative B (6-foot Raise). The red solid region in this figure represents the full range of the possible daily median values associated with the 6-foot Raise, while the shaded-blue region captures the full range of the 10^{th}- to 90^{th}-percentiles. Due to the way the system operates (as described in Section 3.2), the additional demands are released from the lower system. The additional demands under the 6-foot Raise have the potential to result in reduced storage in Arrowrock Reservoir by the end of the irrigation season compared to No Action. Despite this reduction, Arrowrock Reservoir is shown to refill the additional space by early spring. The 10th- and 90^{th}-percentile storage conditions and the operating range are similar to No Action for the 6-foot Raise Alternative. Figure 19 shows the Arrowrock Reservoir summary pool elevation plot for the 3-foot Raise and for No Action.

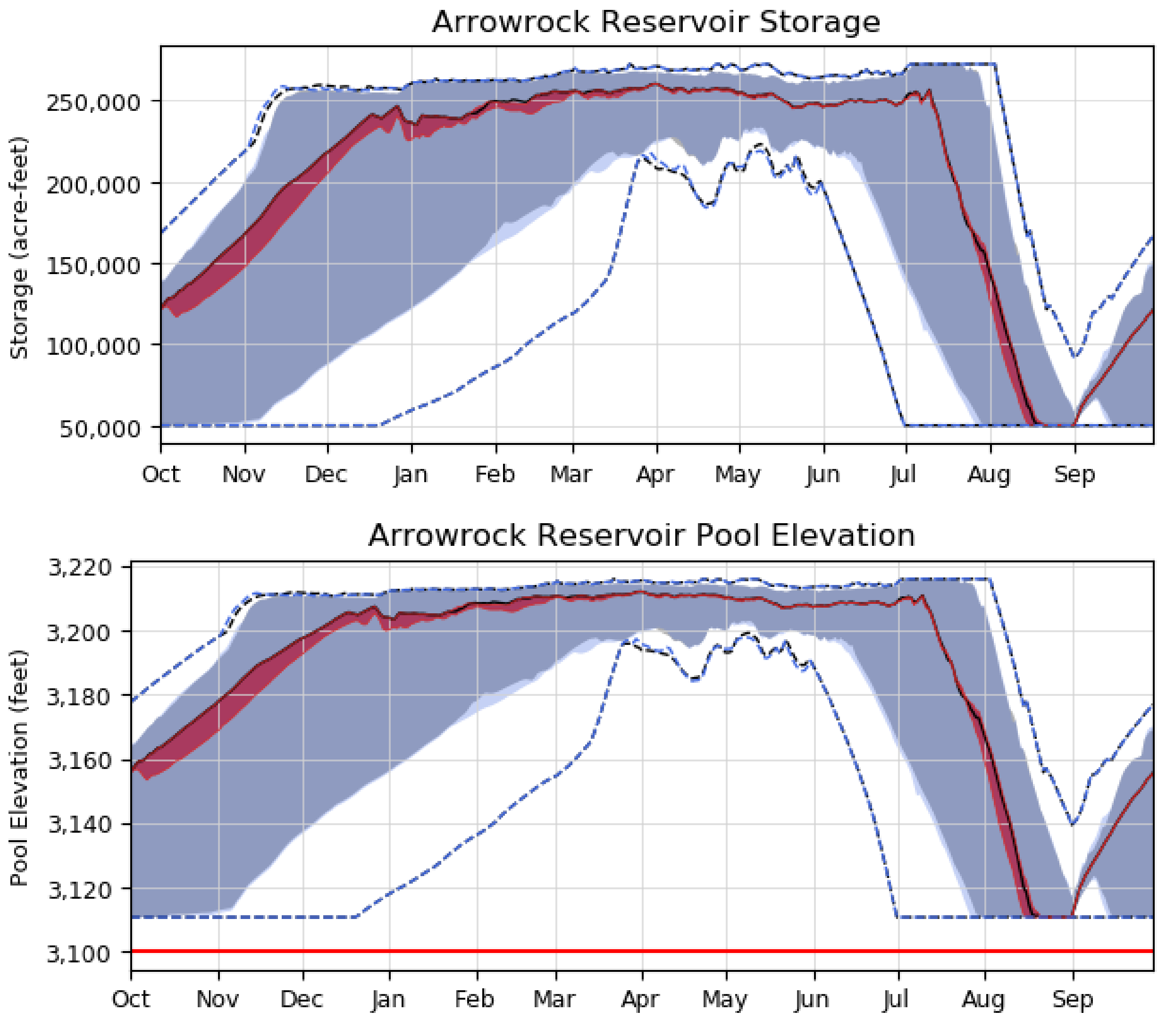

Figure 18. Arrowrock Reservoir summary pool elevation plot depicting the daily median pool elevation range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. The red line represents the minimum pool elevation of 3,100 feet (37,912 acre-feet storage) threshold at which pool elevation conditions may adversely impact bull trout migration.

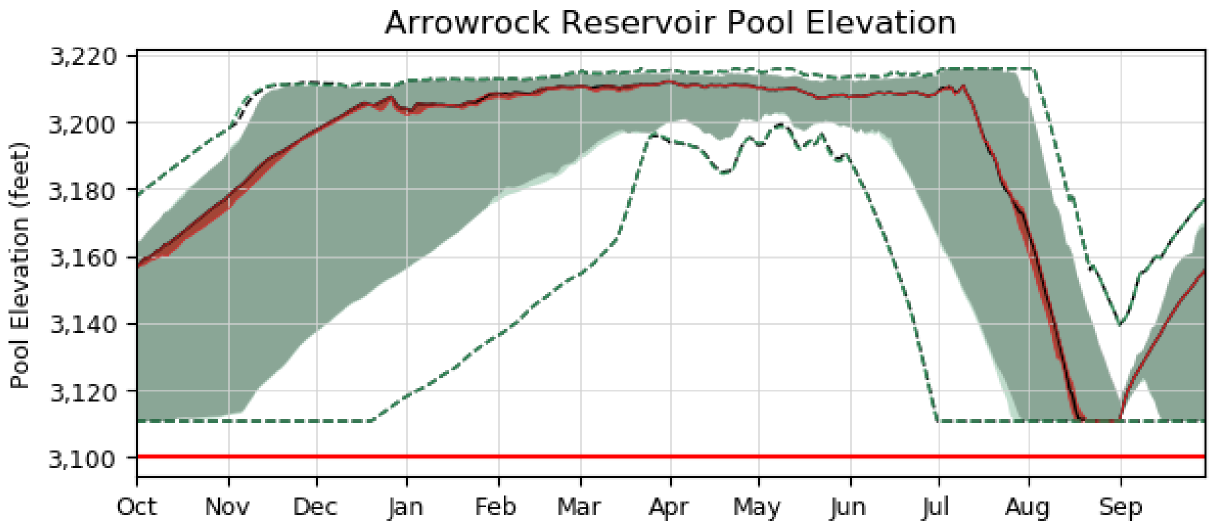

Figure 19. Arrowrock Reservoir summary pool elevation plot depicting the daily median pool elevation range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. The red line represents the minimum pool elevation of 3,100 feet (37,912 acre-feet storage) threshold at which pool elevation conditions may adversely impact bull trout migration.

3.4 Lucky Peak Reservoir

Storage in Lucky Peak Reservoir associated with Alternative B (6-foot Raise) and Alternative C (3-foot Raise) changed relatively little from No Action, with the most notable changes (as seen in Figure 20 and Figure 21) occurring at the end of the irrigation season and the start of refill. The red solid region in these figures represents the full range of the daily median values associated with the raise Alternatives, while the shaded blue region captures the full range of the 10th- to 90th-percentiles. Increased demands under Alternatives B and C resulted in drafting Lucky Peak Reservoir down to the "elk pool" operational objective up to 5 days earlier when compared to No Action. From there, storage volumes are similar between No Action and the Alternatives through the winter until refill begins in February and March.

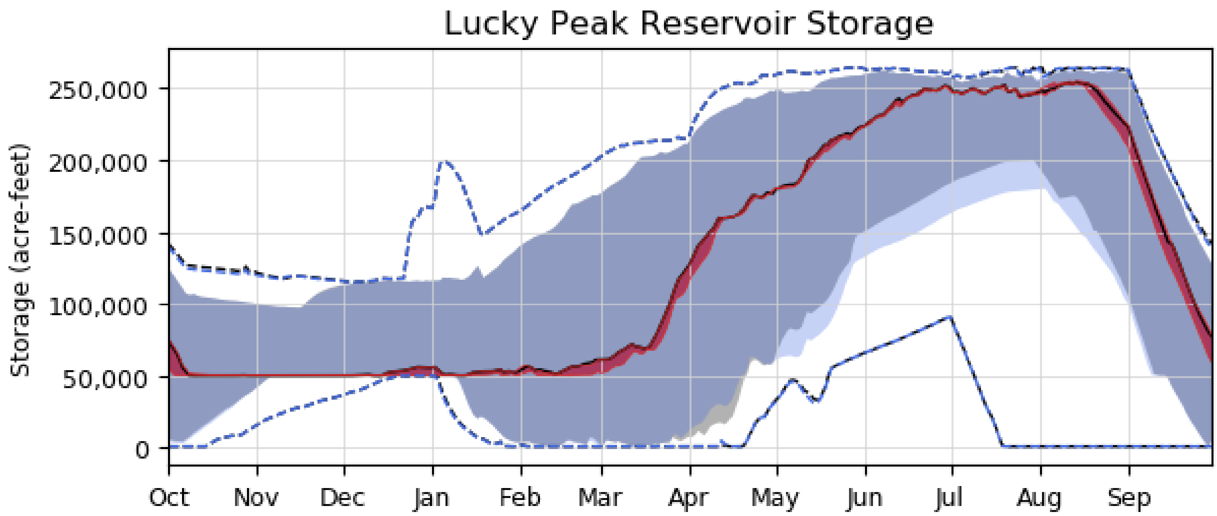

Figure 20. Lucky Peak Reservoir summary storage hydrograph depicting the daily median storage content range for the 6-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values.

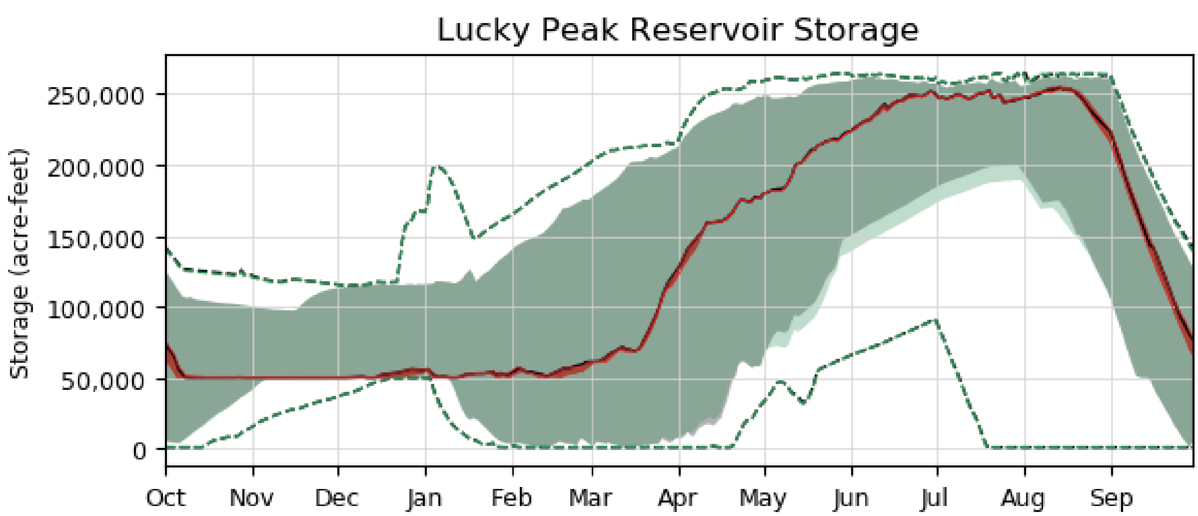

Figure 21. Lucky Peak Reservoir summary storage hydrograph depicting the daily median storage content range for the 3-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values.

3.5 South Fork Boise River below Anderson Ranch Dam

Except under the most/least-frequent flow conditions, streamflow below Anderson Ranch Dam associated with Alternative B (6-foot Raise) and Alternative C (3-foot Raise) changed very little from the No Action condition. Figure 22 and Figure 23 illustrate the daily summary hydrograph for the 6-foot Raise and the 3-foot Raise Alternatives relative to No-Action. The largest differences between the Alternatives and No Action occurs in the early-spring in the maximum flow condition (where the model is balancing the system differently than may occur in real-time FRM operations) and in the late-spring in the maximum and 90th-percentile flow conditions (where the Alternatives result in an earlier recession as the new space refills). The median region in Figure 22 and Figure 23 show an increase in flow in mid-August with a slight difference in the timing of the increase between demand patterns. In the model, this increase in flow coincides with the point in time where releases from Anderson Ranch Dam are needed to keep Arrowrock Reservoir above a model target minimum content of 50,000 acre-feet (actual minimum pool is 3,100 feet or 37,912 acre-feet of storage). These releases are made at Anderson Ranch Dam powerplant capacity (approximately 1,600 cfs but can be as high as 1,800 cfs depending on forebay elevation/head). The daily streamflow exceedance plot in Figure 24 through Figure 29 illustrate similar findings with very little difference observed between the demand scenarios and the baseline condition.

In real-time operations, flows out of Anderson Ranch Reservoir to backfill Arrowrock Reservoir would likely begin earlier and result in a more constant flow through the end of the summer. The duration of these flows will depend upon on the required release volume. For example, a release of the full 6-foot Raise new-storage volume (29,000 acre-feet) would equate to 9.1 days of flow at 1,600 cfs and 4.5 days for the 3-foot Raise.

Minimum flow targets and ramping rates (the rate at which outflows can be increased or decreased) have been established for the South Fork Boise River below Anderson Ranch Dam for the purpose of maintaining fisheries habitat. These minimum flow targets are depicted by red lines in Figure 26, Figure 27, Figure 28, and Figure 29; 300 cfs from September 15 through March 31 and 600 cfs from April 1 through September 15. Modeling results indicate no changes to the potential of Anderson Ranch Dam outflows continuing to meet these minimum flow targets and ramping rates as compared to the No-Action.

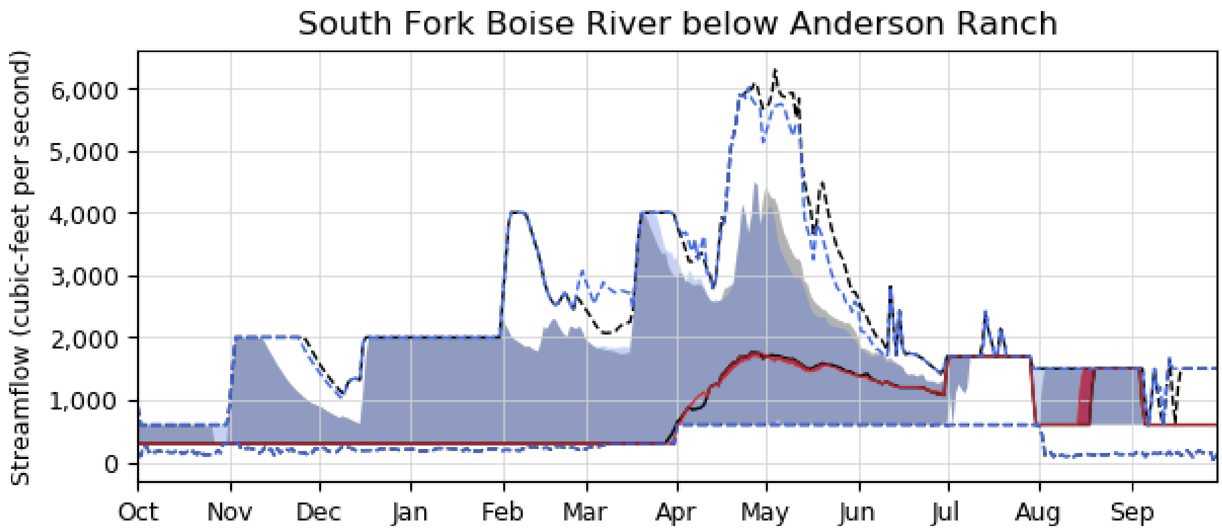

Figure 22. South Fork Boise River below Anderson Ranch Dam summary streamflow hydrograph depicting the daily median streamflow range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values.

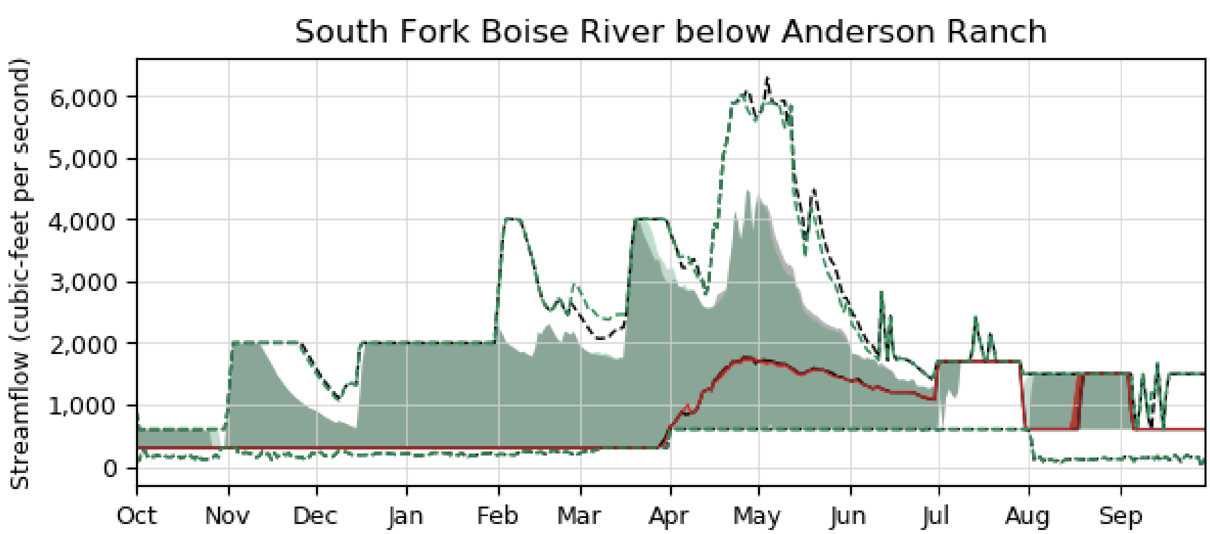

Figure 23. South Fork Boise River below Anderson Ranch Dam summary streamflow hydrograph depicting the daily median streamflow range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values.

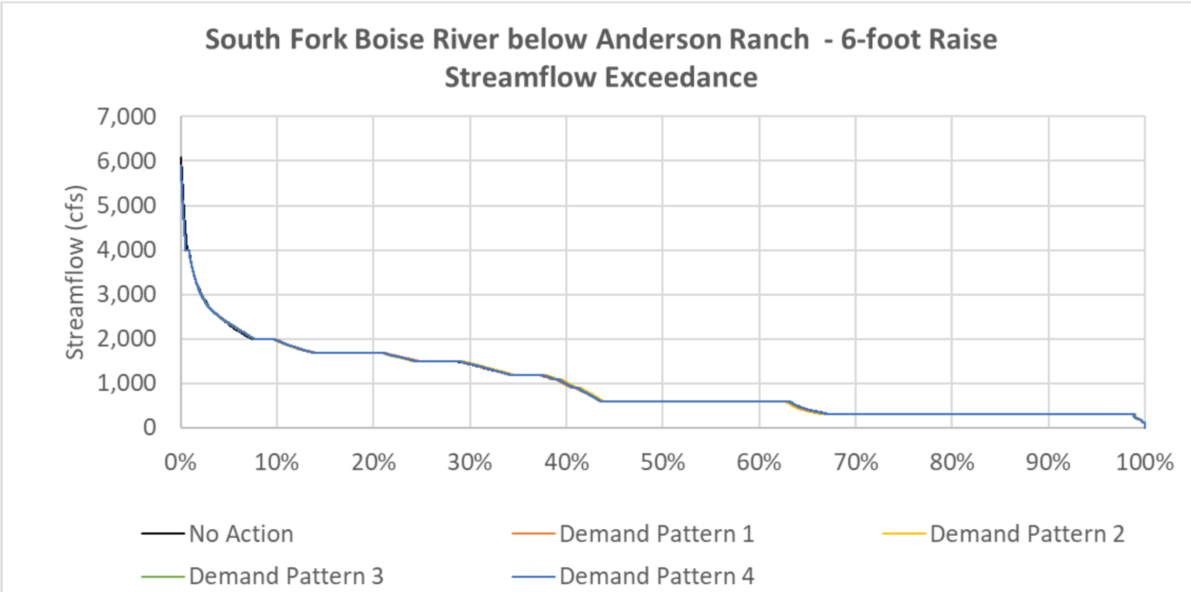

Figure 24. South Fork Boise River below Anderson Ranch Dam streamflow exceedance plot for the 6-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount.

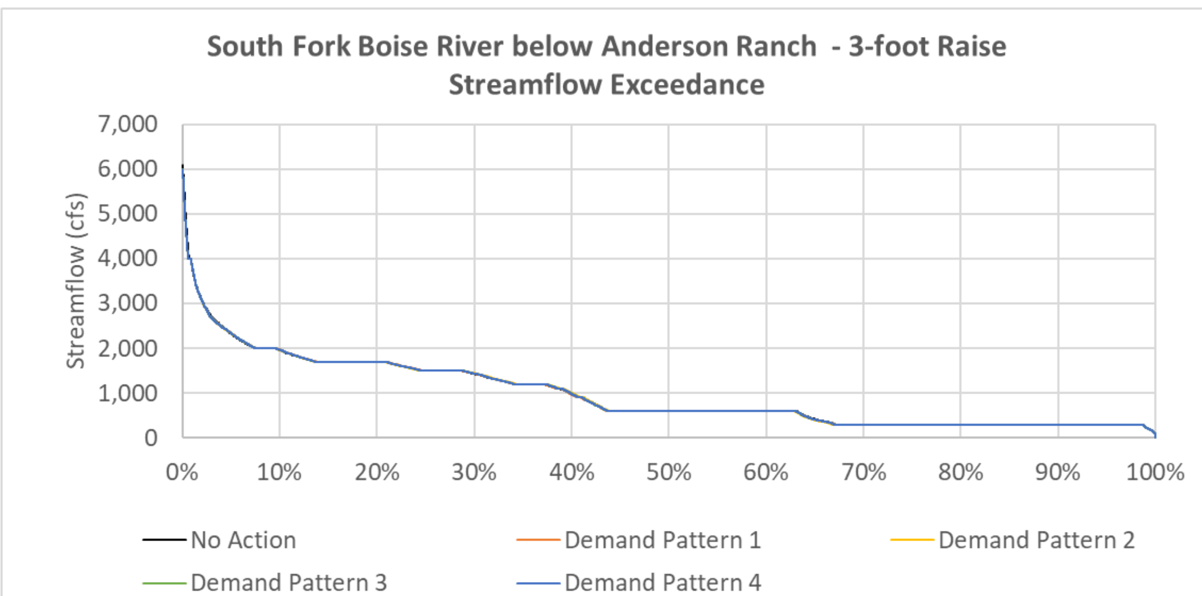

Figure 25. South Fork Boise River below Anderson Ranch Dam streamflow exceedance plot for the 3-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount.

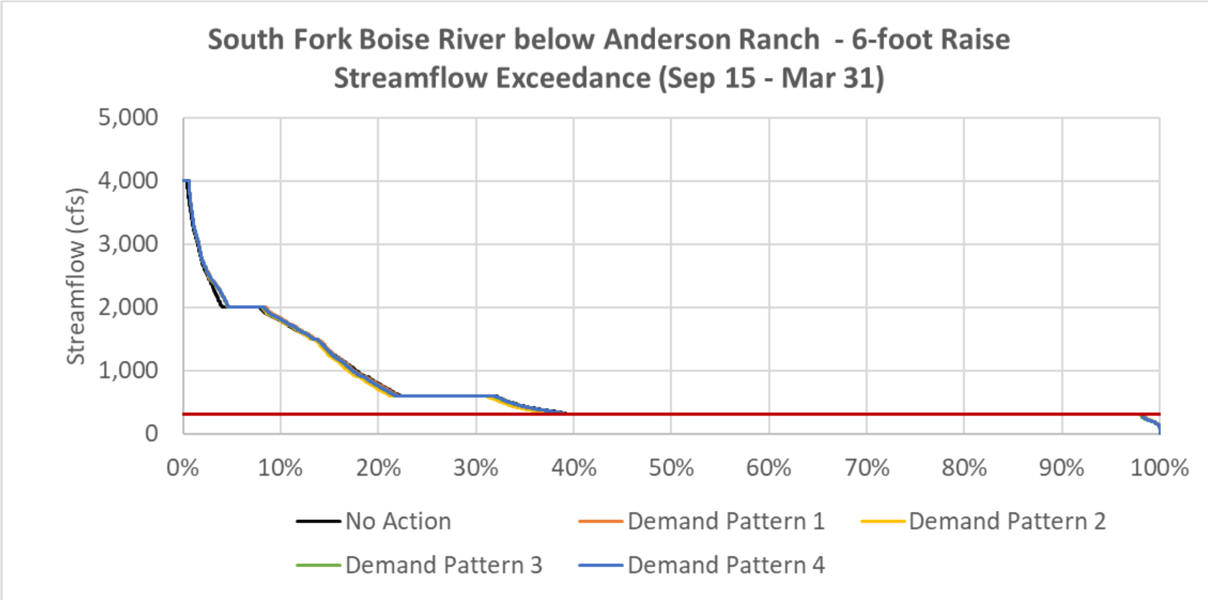

Figure 26. South Fork Boise River below Anderson Ranch Dam winter streamflow exceedance plot during the months of September 15 through March 31 for the 6-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount. Red line represents 300 cfs threshold.

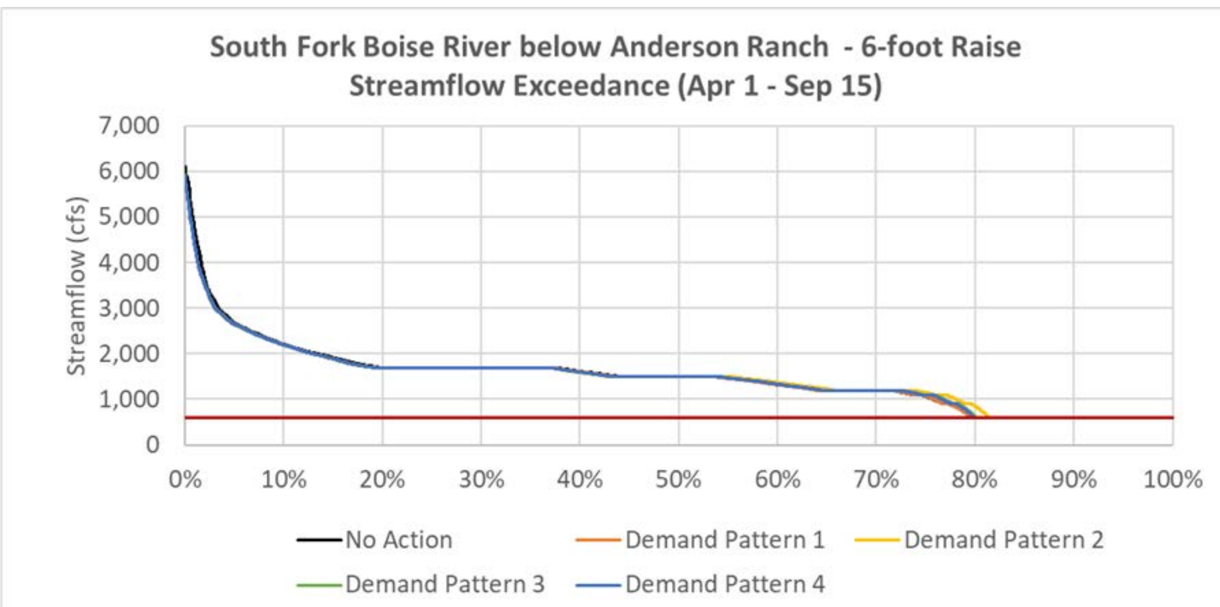

Figure 27. South Fork Boise River below Anderson Ranch Dam winter streamflow exceedance plot during the months of April 1 through Sept 15 for the 6-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount. Red line represents 600 cfs threshold.

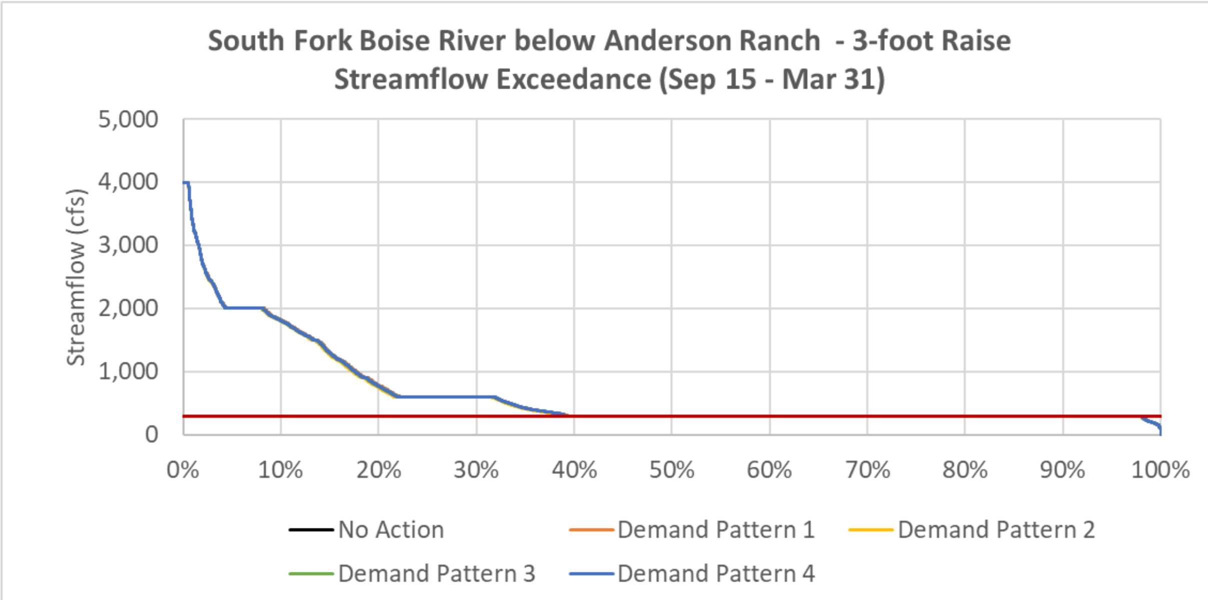

Figure 28. South Fork Boise River below Anderson Ranch Dam winter streamflow exceedance plot during the months of September 15 through March 31 for the 3-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount. Red line represents 300 cfs threshold.

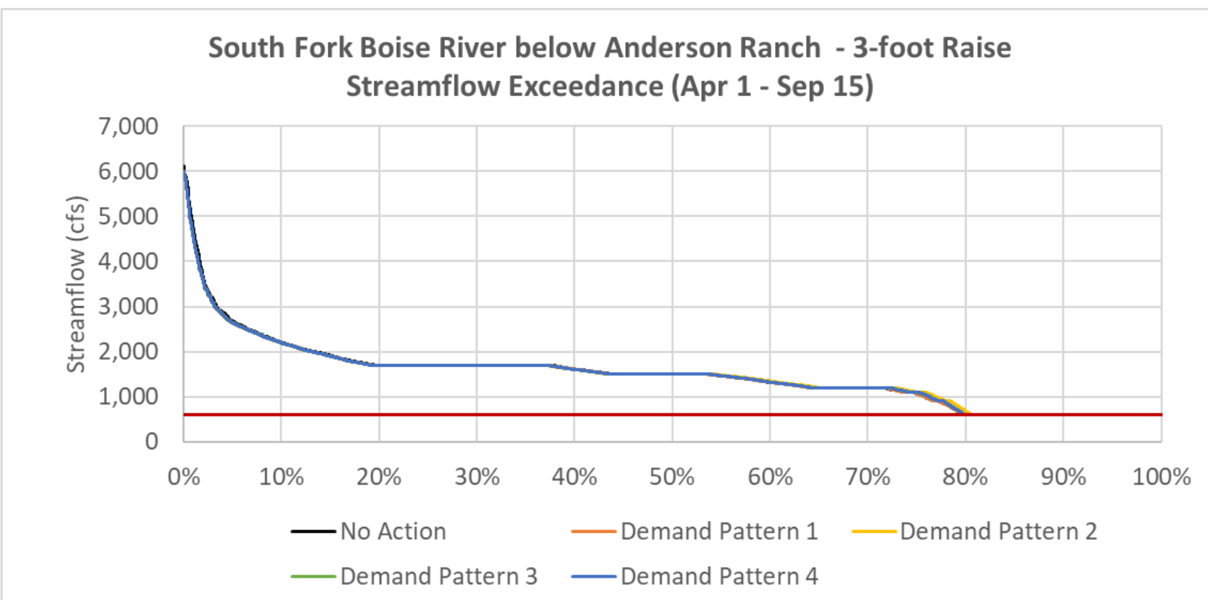

Figure 29. South Fork Boise River below Anderson Ranch Dam spring streamflow exceedance plot during the months of April 1 through September 15 for the 3-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount. Red line represents 600 cfs threshold.

Temperature regimes in the South Fork Boise River below Anderson Ranch Dam are important for supporting trout habitat. Based on operations modeling that suggested the potential for increased year-round storage in Anderson Ranch Reservoir, the Anderson Ranch Reservoir Water Quality Model was run assuming a 6-foot and a 3-foot increased pool depth across the entire 2016 and 2017 calibration period. All other model parameters and input data remained the same as the No Action condition. As illustrated in Figure 30, results for the 6-foot pool depth increase suggest some potential for decreased temperatures during the times of year when water temperatures are typically the highest. Results also show temperatures remaining between 2 degrees C and 15 degrees C (the suitable temperature range for trout) over the analysis period. Figure 31 shows the results for the 3-foot pool depth increase simulation. These results indicate temperatures similar to No Action.

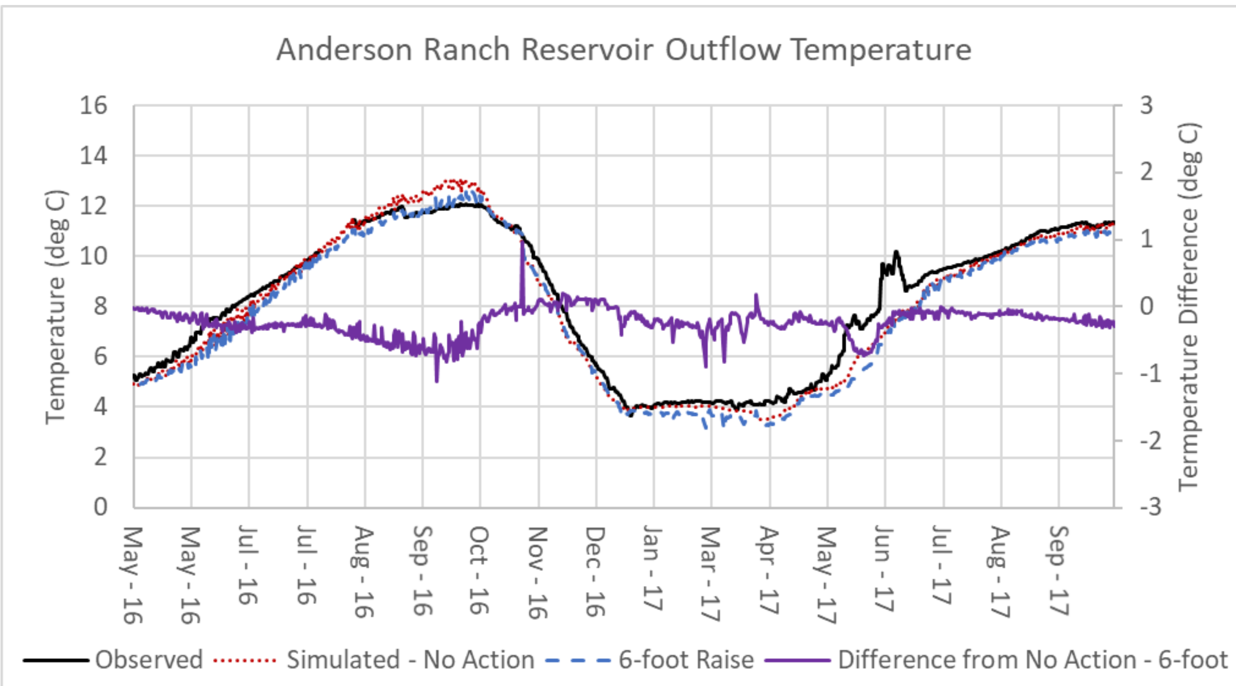

Figure 30. Simulated Anderson Ranch Dam outflow temperatures for the baseline condition and a theoretical sensitivity analysis scenario involving a year-round 6-foot deeper pool elevation. Temperature timeseries were generated using CE-QUAL-W2.

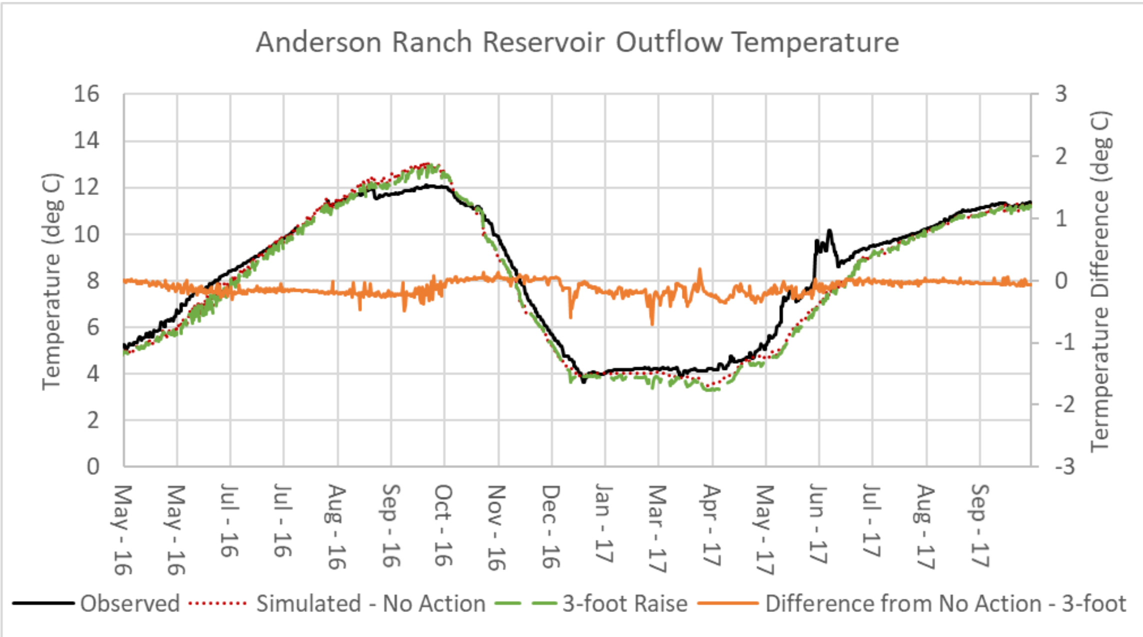

Figure 31. Simulated Anderson Ranch Dam outflow temperatures for the baseline condition and a theoretical sensitivity analysis scenario involving a year-round 3-foot deeper pool elevation. Temperature timeseries were generated using CE-QUAL-W2.

3.6 Boise River at Glenwood

The Boise System Reservoirs (Anderson, Arrowrock, and Lucky Peak) are collectively operated to provide FRM operations and limit flows when possible to 6,500 cfs or less at the Boise River at Glenwood Bridge location. During real-time operations, beginning on January 1st and generally continuing each month through July, the U.S. Army Corps of Engineers' Walla Walla District and Reclamation's Columbia Pacific Northwest Region water management groups generate and coordinate seasonal runoff volume forecasts for the Boise River basin. These forecasts are used to determine the system reservoir space requirements to meet downstream FRM objectives. Minimum streamflow objectives are met for all Alternatives at this location.

Unlike real-time operations, the Boise Planning Model utilizes a "perfect forecast" where the runoff volume is already known because it is the sum of inflows to the reservoirs, which is a model input. This can cause observed flows at Glenwood to increase or decrease more often than indicated by model results. This is important to keep in mind when interpreting the model results, as flows during the modeled period are mostly limited to 6,500 cfs while historical operations have resulted in higher flows in some years.

Figure 32 and Figure 33 illustrate the 10th-, 50th-, and 90th-percentile streamflows in the Boise River at Glenwood for the 6-foot Raise and 3-foot Raise Alternatives, respectively. Figure 34 and Figure 35 depict the daily exceedance values for No Action and Alternative B (6-foot Raise) and Alternative C (3-foot Raise) with the four demand patterns. As shown in these figures, streamflow conditions at Glenwood are similar across all Alternatives and demand patterns. The most notable difference is seen in late July, where additional flow augmentation releases associated with Scenario 2 result in streamflow remaining around 3,000 cfs through the end of July.

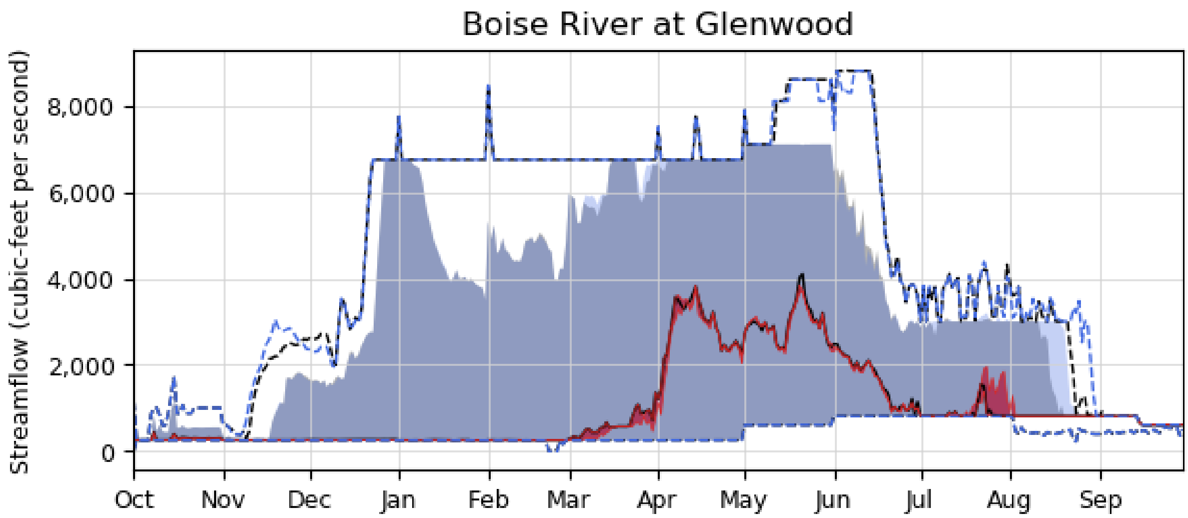

Figure 32. Boise River at Glenwood summary streamflow hydrograph depicting the daily median streamflow range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values.

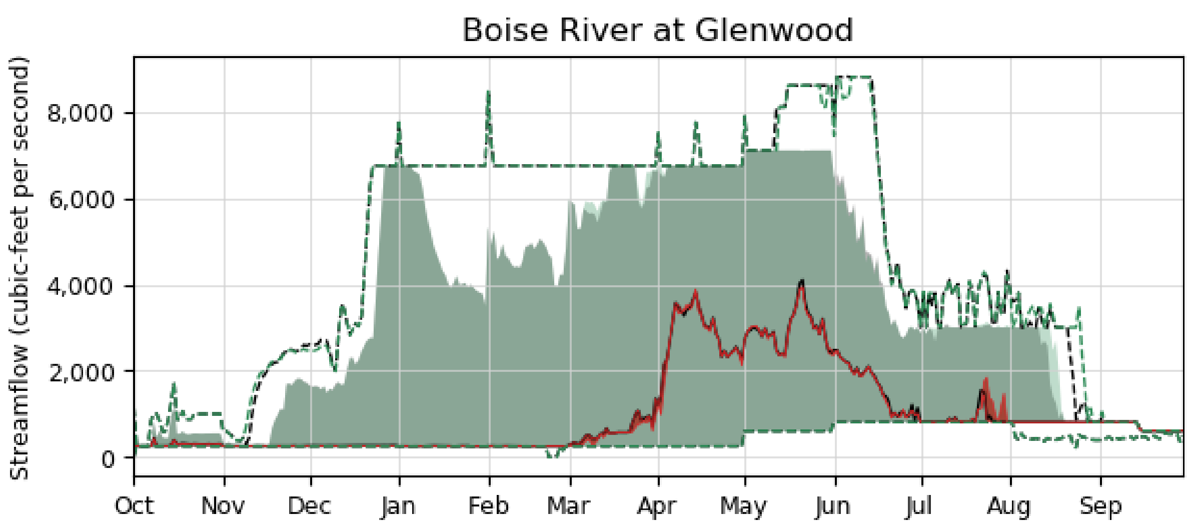

Figure 33. Boise River at Glenwood summary streamflow hydrograph depicting the daily median streamflow range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values.

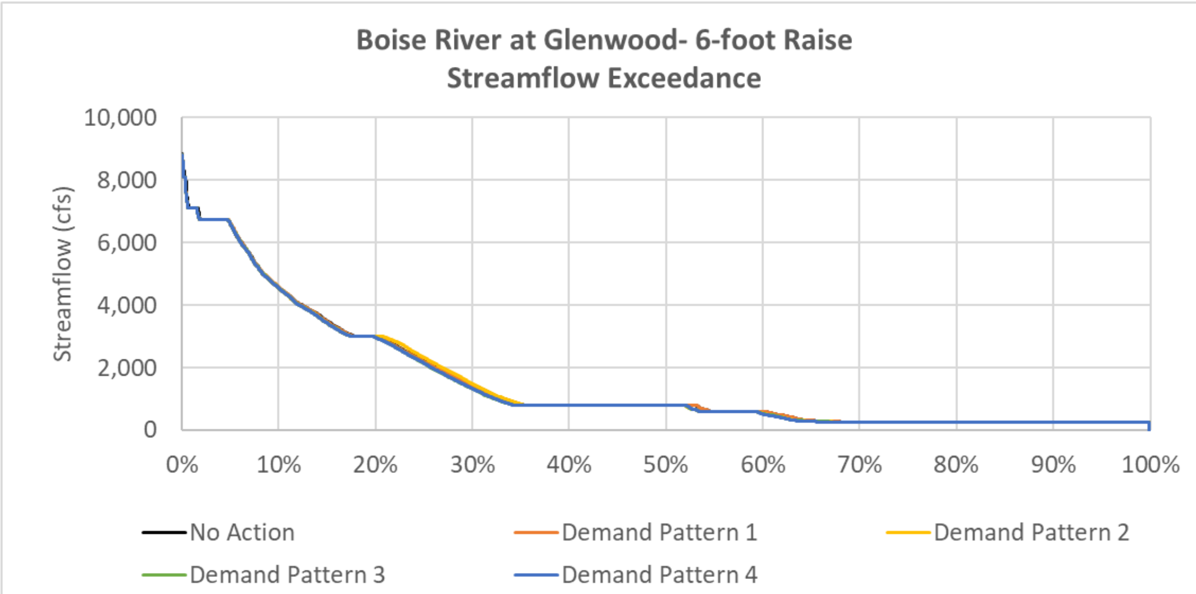

Figure 34. Boise River at Glenwood streamflow exceedance plot for the 6-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount.

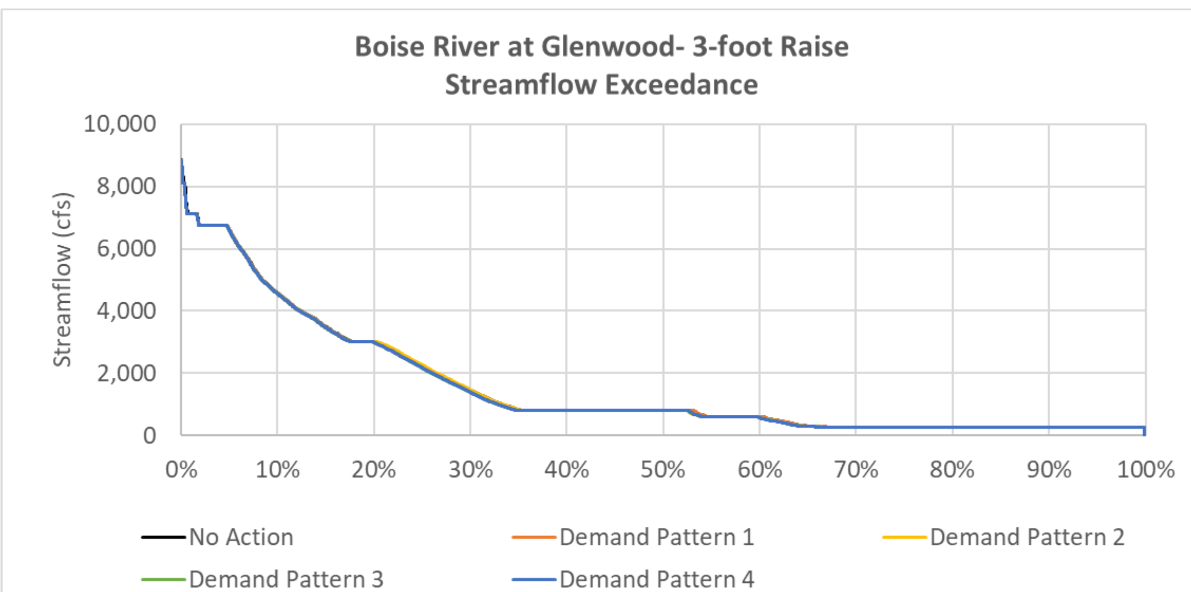

Figure 35. Boise River at Glenwood streamflow exceedance plot for the 3-foot Raise Alternative. The exceedance percentile represents the percent of days in the analysis period that streamflow was greater than or equal to a given streamflow amount.

3.7 Climate Change

Evaluation of the Alternatives at Anderson Ranch Dam included analysis of storage availability and streamflow impacts under a range of potential future conditions as characterized by the recent RMJOC-II Climate Change Study (RMJOC-II 2018). The RMJOC-II climate change stud developed a set of 160 natural streamflow projections using output from ten Global Climate Models, two downscaling techniques, two emission scenarios, and four versions of hydrologic models. See the RMJOC-II Climate Change Study documentation for more detail on the development of this dataset (RMJOC-II 2018).

The RMJOC-II Climate Change Study notes overall trends of increased fall and winter streamflow, earlier and higher spring peak runoff, and earlier streamflow recession. The study also suggests the potential for increased rain-on-snowpack events during the winter and spring and annual flow peaks shifting several weeks earlier compared to historical conditions.

3.7.1 2060s Streamflow Projections

A subset of the 160 RMJOC-II projections (consisting of Representative Concentration Pathways (RCP) 4.5 and RCP 8.5 projections) was selected using the objective subset selection method described in the current draft RMJOC-II Report Part 1, Section 8.2.2 (RMJOC-II 2018). This method was applied to the 2060s (2050 to 2079), using the Lucky Peak Reservoir and Anderson Ranch Reservoir locations, and used water year volume and winter/spring volume ratio as selection metrics. The resulting subset consisted of two future projections that, taken together, capture the 10^{th}- and 90^{th}-percentile future water year volumes and winter/spring volume ratios. These two metrics were identified as being important to water supply and Boise Reservoir System operations. These projections, labeled 2060s High and 2060s Low, are listed in Table 4. More information about the development of the projections can be found in Part I of the RMJOC-II Climate Change Study report (RMJOC-II 2018).

The RMJOC-II Climate Change Study streamflows were generated by running a calibrated VIC hydrologic model with forcing files associated with each climate change scenario as well as the Livneh baseline scenario. While RMJOC-II projections are transient projections spanning 1950 through 2099, this study considered discrete slices of the full record to represent the historical period (1958 through 2008) and the future 2060s period (2050 through 2079). The Livneh dataset, which served as the baseline forcing file in the VIC model calibration, provides an important reference point in interpreting changes associated with future climate change projections.

Figure 36 and Figure 37 depict comparisons of observed and simulated historical gains for each of the climate change projections for the historical period spanning 1980 through 2008. The Livneh projection and the CanESM2 projection show the closest agreement to historical observations in terms of flow magnitude and timing, while the historical CSIRO-Mk3-6-0 projection shows a lower and later runoff pattern and much higher summer flow compared to the other models. Despite the relatively poor historical fit of the CSIRO-Mk3-6-0 projection, this dataset was selected using the objective subset selection method described in the current draft RMJOC-II Report Part 1, Section 8.2.2 and serves to capture a wide range of runoff conditions.

Table 4. 2060s climate change scenarios selected to capture the 10th- and 90th-percentile changes in future water year volumes and winter/spring volume ratios.

Climate Scenario	Global Climate Model	Emissions Scenario	Downscaling Method	Hydrologic Model
2060s High	CanESM2	RCP 8.5	MACA	VIC
2060s Low	CSIRO-Mk3-6-0	RCP 4.5	BCSD	VIC

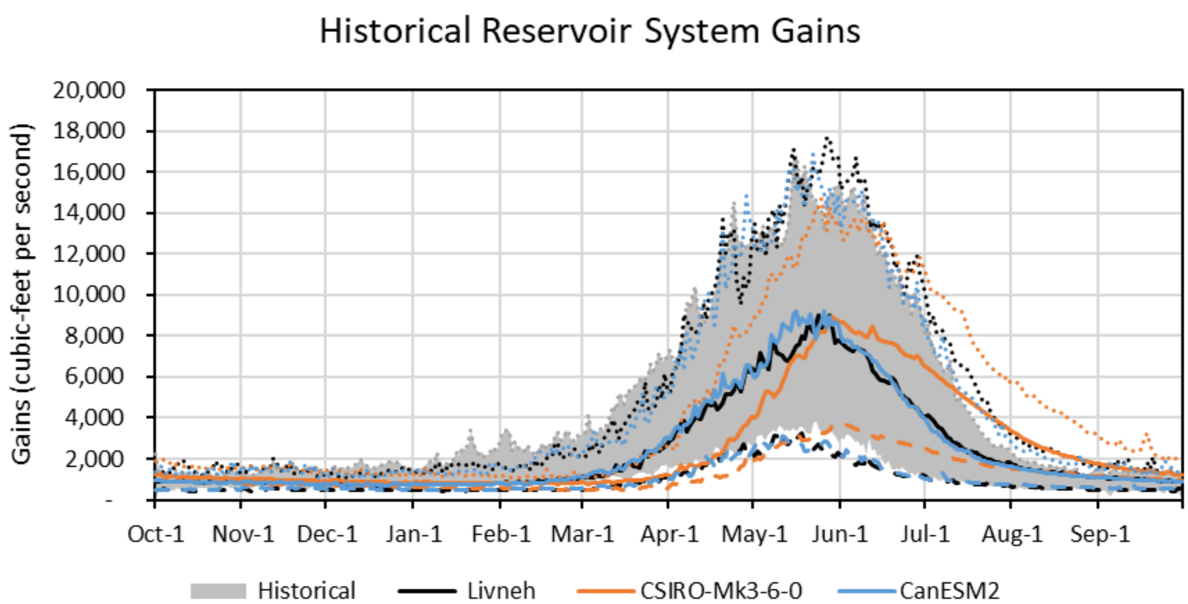

Figure 36. Comparison of observed and simulated gain (inflow) projections for the period spanning 1958 through 2008. The shaded area represents the 10th- to 90th-percentile daily observed gains during this period. The black set of lines represent the 10th-, 50th-, and 90th-percentile daily simulated gains associated with the historical Livneh dataset, while the orange and blue lines represent the simulated gains associated with the GCMs that were selected to represent the 2060s Low (CSIRO-Mk3-6-0) and 2060s High (CanESM2) climate change conditions.

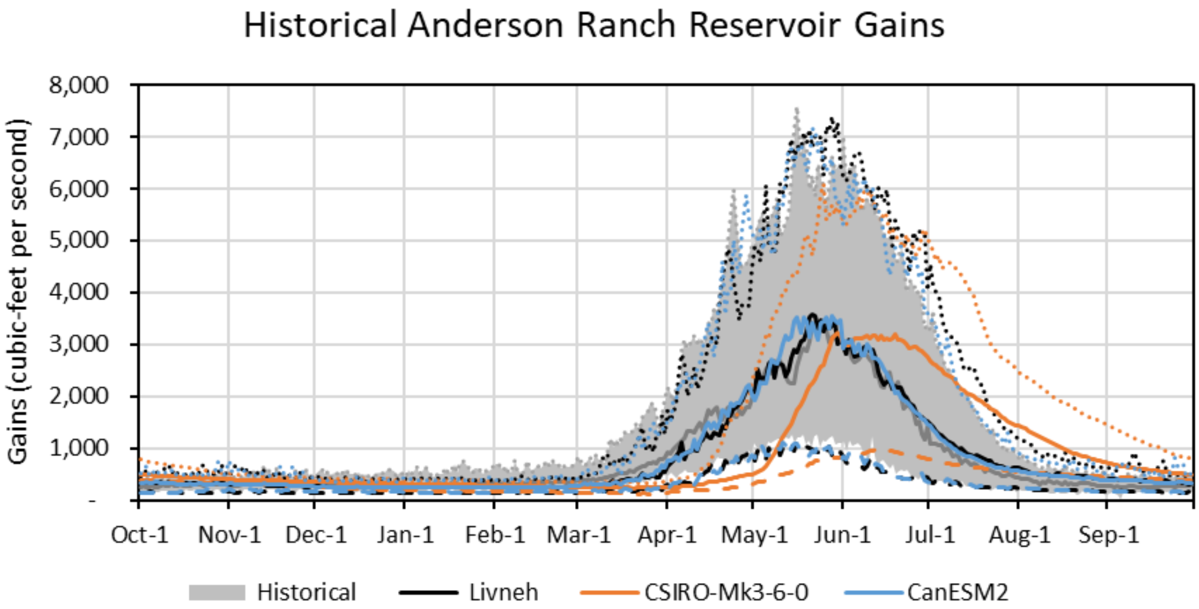

Figure 37. Comparison of observed and simulated gain (inflow) projections for the period spanning 1958 through 2008. The shaded area represents the 10th- to 90th-percentile daily observed gains during this period. The black set of lines represent the 10th-, 50th-, and 90th-percentile daily simulated gains associated with the historical Livneh dataset, while the orange and blue lines represent the simulated gains associated with the GCMs that were selected to represent the 2060s Low (CSIRO-Mk3-6-0) and 2060s High (CanESM2) climate change conditions.

Figure 38 and Figure 39 illustrate the future 2060s (2050 through 2079) projected gains associated with each climate change projection (CSIRO-Mk3-6-0 and CanESM2) relative to the observed historical period. As shown in these figures, the CSIRO-Mk3-6-0 projection exhibits similar median peak flow magnitude and timing to the historical period, but a much smaller 90th-percentile peak flow magnitude, longer peak runoff recession, and higher summer flows. The CanESM2 projection shows the most change from historical with large increases in runoff during the late-fall and winter months and peak runoff occurring approximately one month earlier.

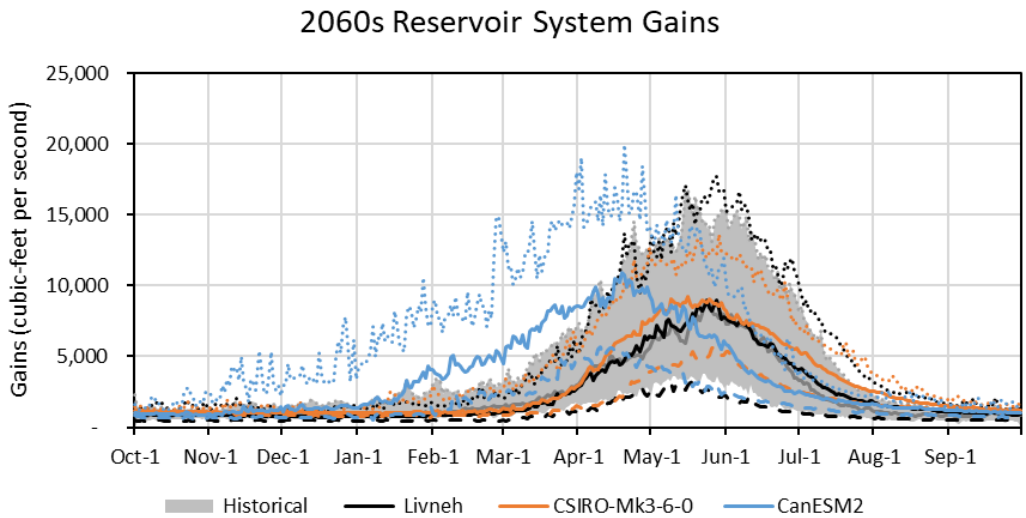

Figure 38. Comparison of historical observed gains and historical simulated gains (Livneh) to future simulated gain projections for the 2060s (CSIRO-Mk3-6-0 and CanESM2). The gray area and darker gray line represent, respectively, the 10th- through 90th-percentile and the 50th-percentile daily observed gains above Lucky Peak Dam over the historical 1958 through 2008 period. The black lines represent the simulated Livneh gains for the same historical period. The orange and blue lines represent the future (2050 through 2079) 10th-, 50th-, and 90th-percentile daily simulated gains for the 2060s Low (CSIRO-Mk3-6-0) and 2060s High (CanESM2) climate change conditions.

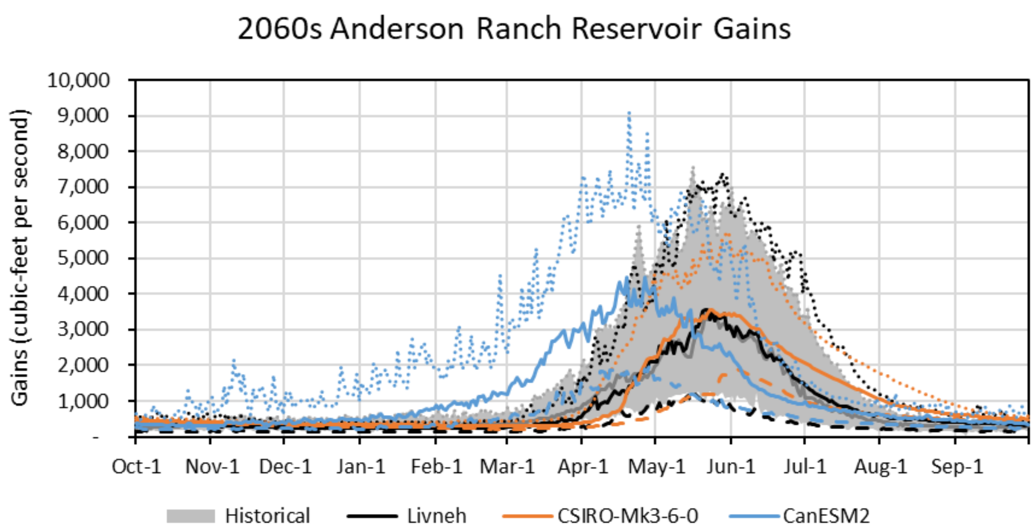

Figure 39. Comparison of historical observed gains and historical simulated gains (Livneh) to future simulated gain projections for the 2060s (CSIRO-Mk3-6-0 and CanESM2). The gray area and darker gray line represent, respectively, the 10th- through 90th-percentile and the 50th-percentile daily observed gains to Anderson Ranch Reservoir over the historical 1958 through 2008 period. The black lines represent the simulated Livneh gains for the same historical period. The orange and blue lines represent the future (2050 through 2079) 10th-, 50th-, and 90th-percentile daily simulated gains for the 2060s Low (CSIRO-Mk3-6-0) and 2060s High (CanESM2) climate change conditions.

3.7.2 2060s System Operations

Boise Reservoir System operations for No Action and for the two Alternatives were modeled under each climate scenario (simulated historical Livneh, 2060s Low, and 2060s High) for the purpose of evaluating how the system might perform under a wide range of potential future hydrologic conditions. The four demand patterns were modeled for each Alternative with each climate scenario and are summarized in the figures presented in this section. Figure 40 and Figure 41 illustrate the daily median and the daily 10th- to 90th-percentile range in system storage associated with the 6-foot Raise and 3-foot Raise Alternatives, respectively, and with No Action, for each hydrologic dataset. As shown by these figures, median daily storage volumes in the 2060s Low scenario exhibit conditions (magnitude and timing) similar to the Livneh modeled historical hydrology scenario (second panel), but with increased 10th- and 50th-percentile storage through the summer, fall and winter months. While the 2060s High scenario shows a similar maximum volume of fill for the 50th- and 90th-percentile, the timing of maximum fill occurs a month earlier. Compared to the Livneh scenario, this scenario also exhibits lower system carryover, similar winter storage, and earlier spring refill for these percentiles. Storage conditions for the 10th-percentile exhibit a year-round increase in the 2060s High scenario compared to the Livneh scenario. In the 2060s Low scenario, less-frequent high inflow volumes result in more years with smaller flood space requirements and therefore more years with smaller FRM drafts compared to historical period. In contrast, in the 2060s High scenario, much larger inflow volumes create conditions where the system is releasing as much water as possible to keep up with FRM objectives while also trying to keep flows downstream below flood stage.

Figure 42 and Figure 43 illustrate the daily median and the daily 10th- to 90th-percentile range in Anderson Ranch Reservoir storage associated with the 6-foot Raise and 3-foot Raise Alternatives, respectively, and with No Action, for each hydrologic dataset. Storage regimes between the dam raise scenarios are similar to one another with the dam raise scenarios exhibiting increased storage relative to the baseline condition in both climate change scenarios. As shown in this figure, the 2060s Low scenario exhibits year-round increase in median daily storage compared to the Livneh scenario, while the 2060s High scenario shows median storage conditions that are similar to Livneh during the summer and fall months and increased storage through the winter and spring. Increased summer gains in the 2060s Low scenario result in more frequent high carryover conditions compared to the historical period, while increased winter flows in the 2060s High scenario result in more years with high winter storage conditions.

Downstream of Anderson Ranch Dam, simulated streamflow in the South Fork of the Boise River shows an increase during the winter and spring under the 2060s High scenario compared to the Livneh scenario. The 2060s Low scenario also shows increased flows during the spring relative to the Livneh scenario, but no increase from mid-December through February. Both 2060s scenarios show increased median flows in the fall resulting from the model making FRM releases to meet winter flood space requirements. In the 2060s Low scenario, the fall FRM release is larger, corresponding to a larger October 1 carryover volume associated with increased summer gains under this hydrologic scenario. Streamflow differences between the 6-foot Raise and 3-foot Raise Alternatives are small and consist primarily of slight shifts in flow timing. These trends are exhibited in Figure 44 and Figure 45.

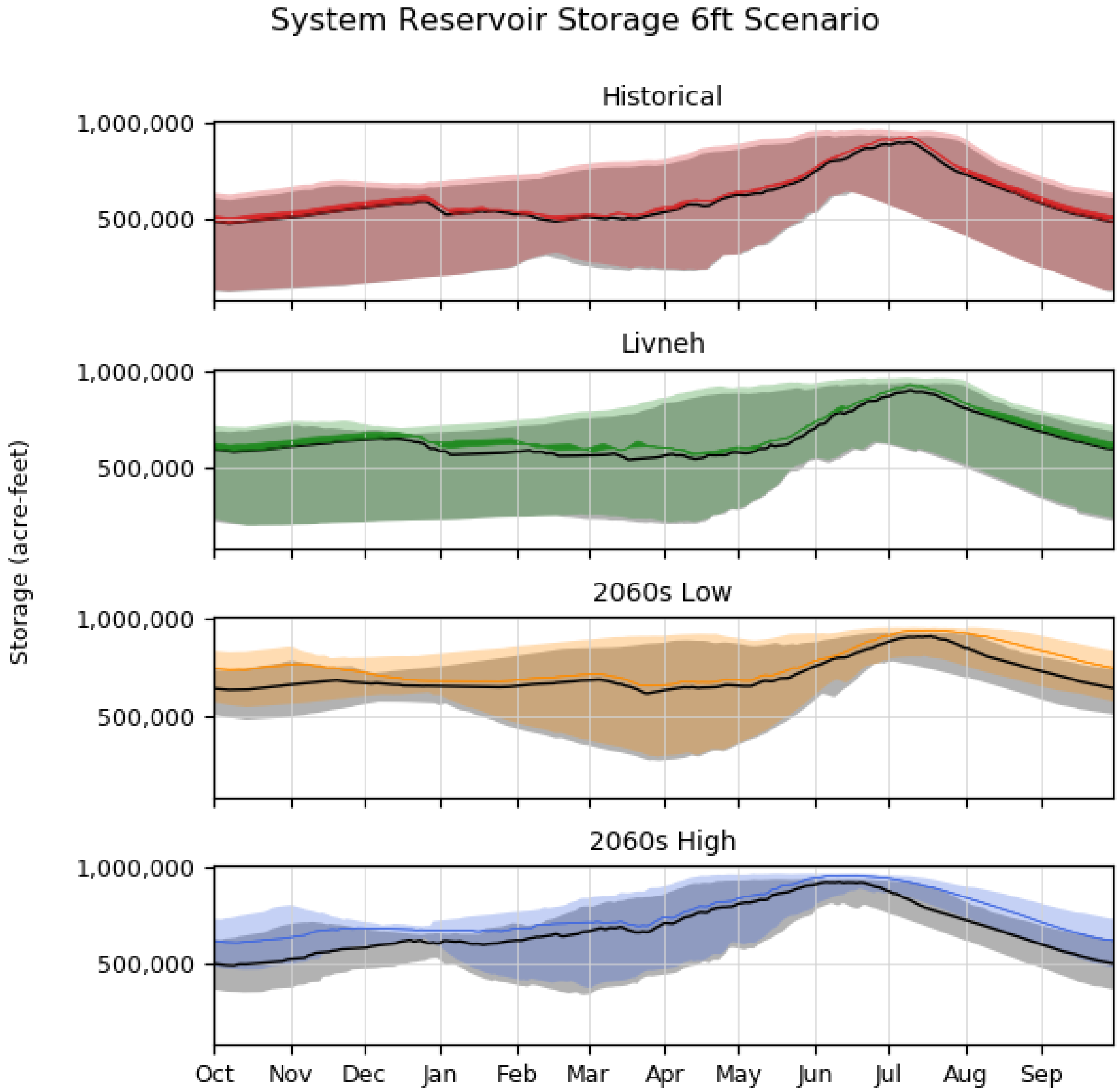

Figure 40. Boise Reservoir System historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 6-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection. Storage values depicted represent total system storage, excluding 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

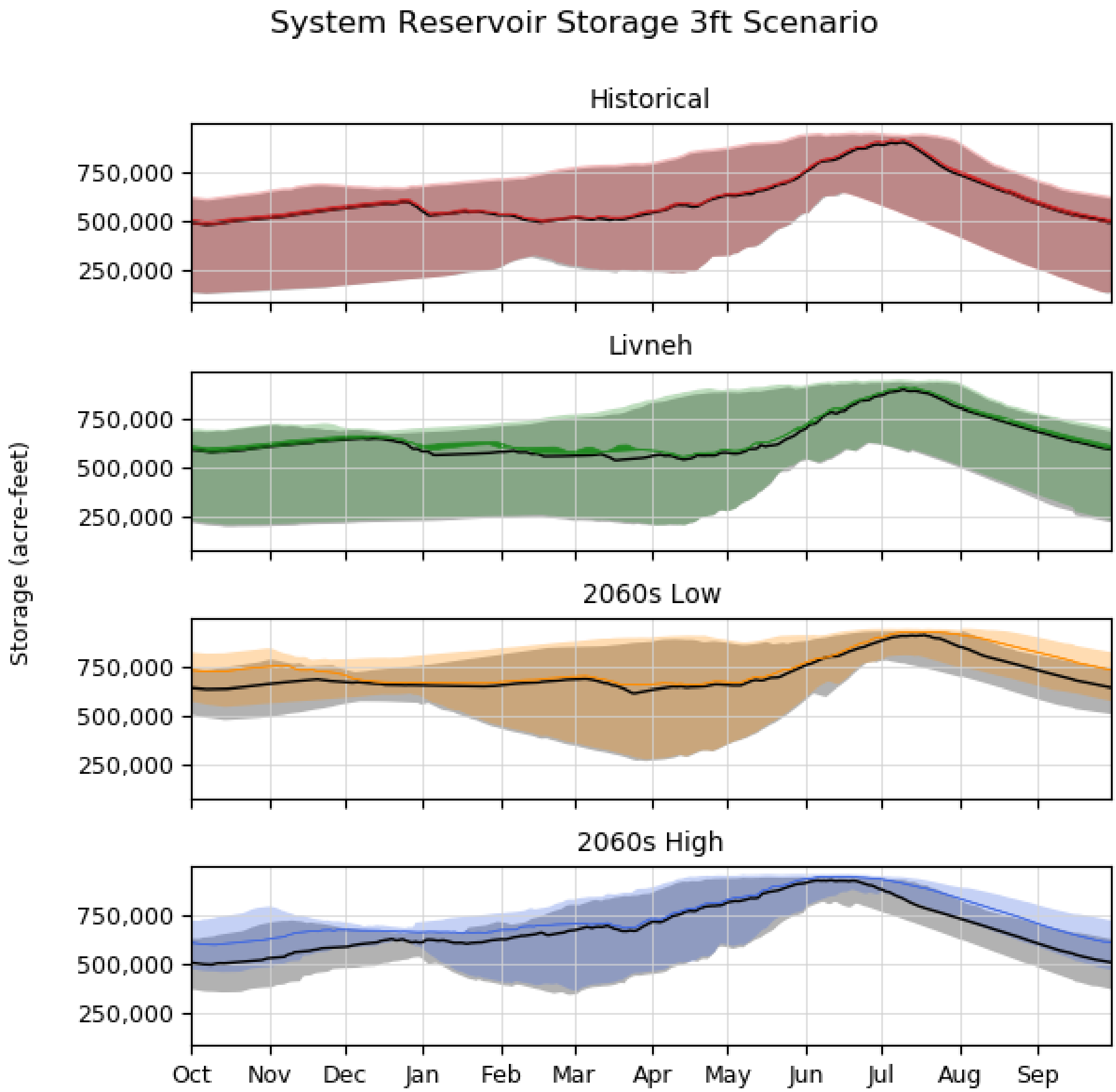

Figure 41. Boise Reservoir System historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 3-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection. Storage values depicted represent total system storage, excluding 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

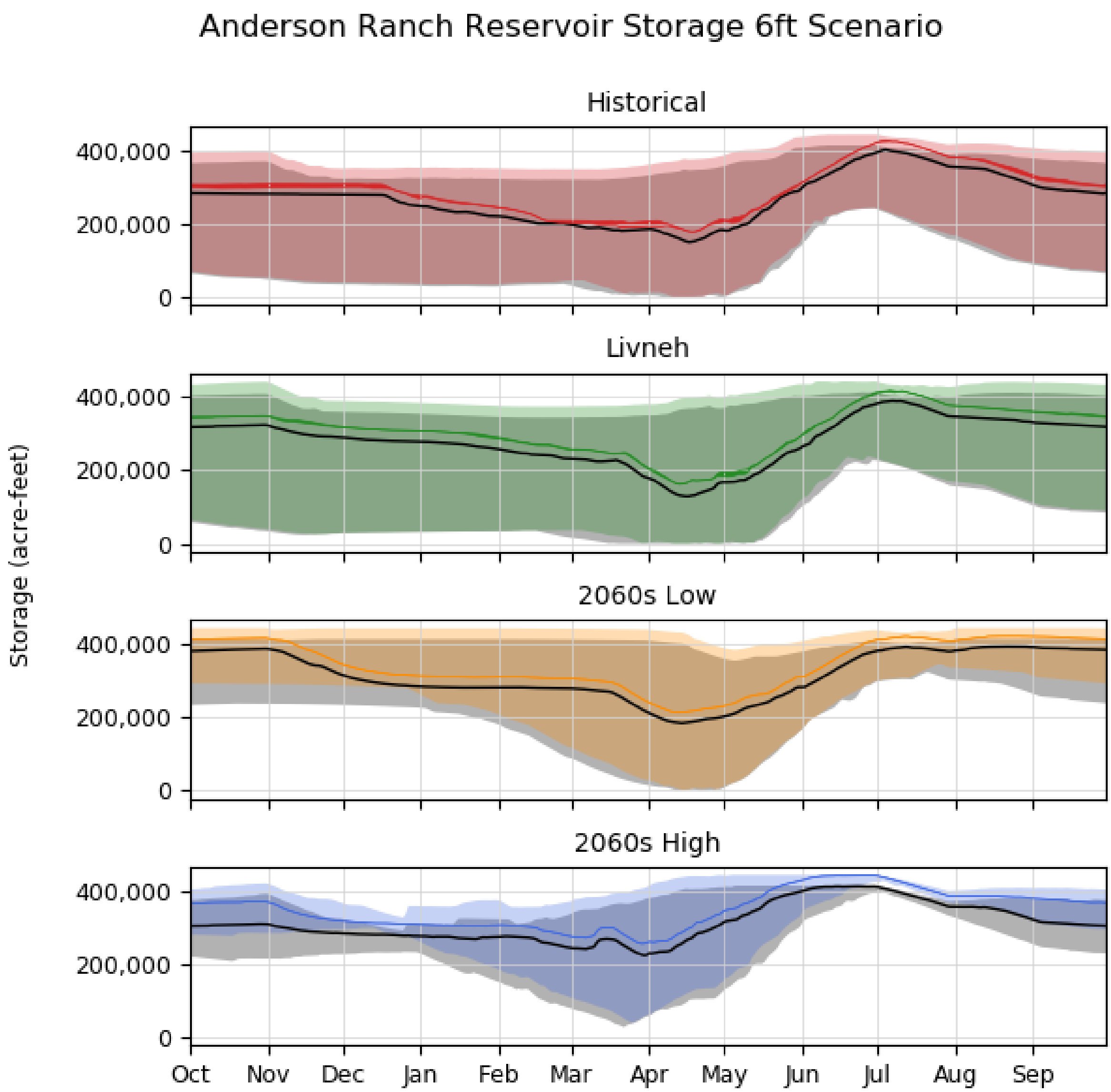

Figure 42. Anderson Ranch Reservoir historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 6-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection. Storage values depicted do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

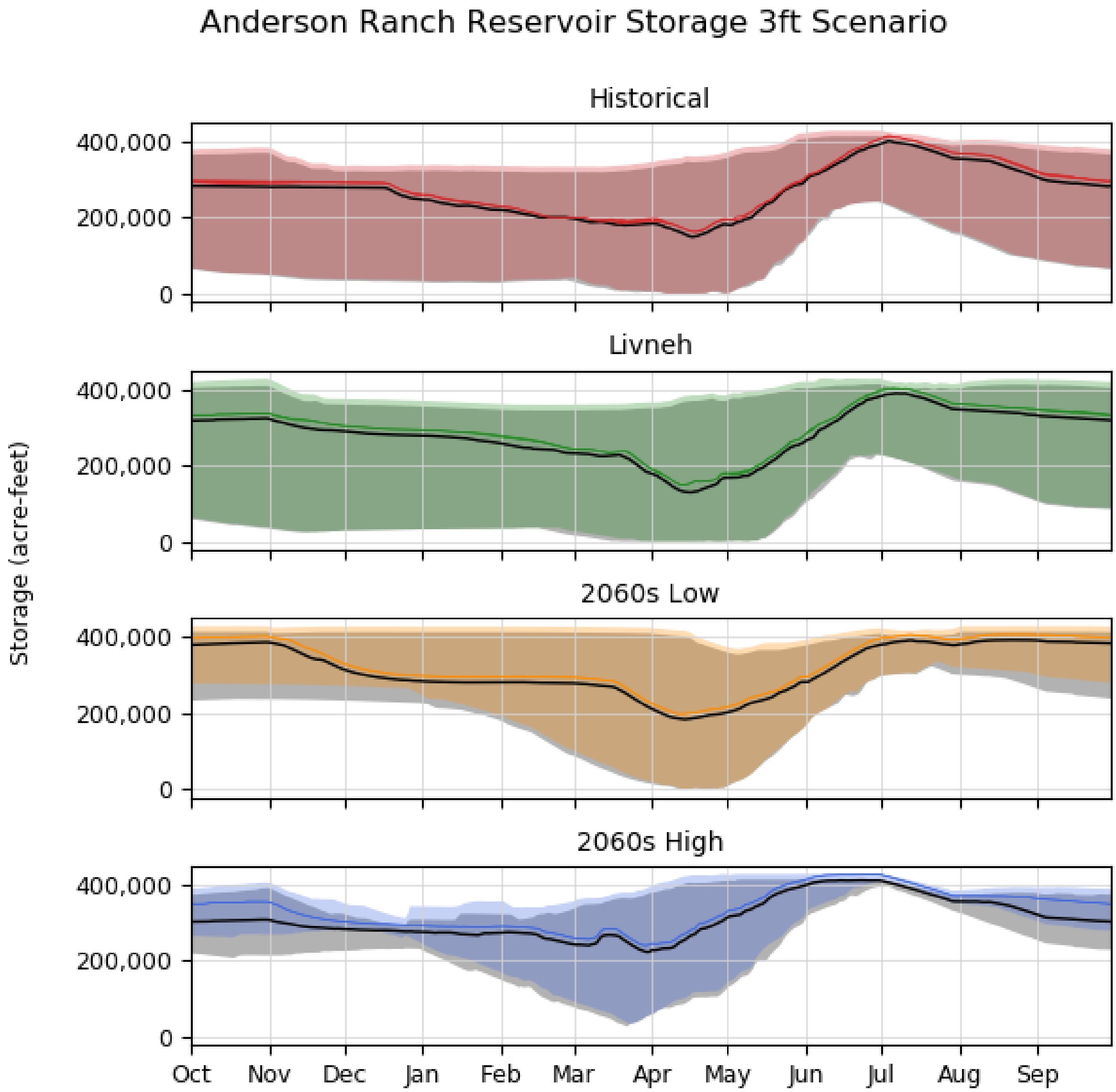

Figure 43. Anderson Ranch Reservoir historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 3-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection. Storage values depicted do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

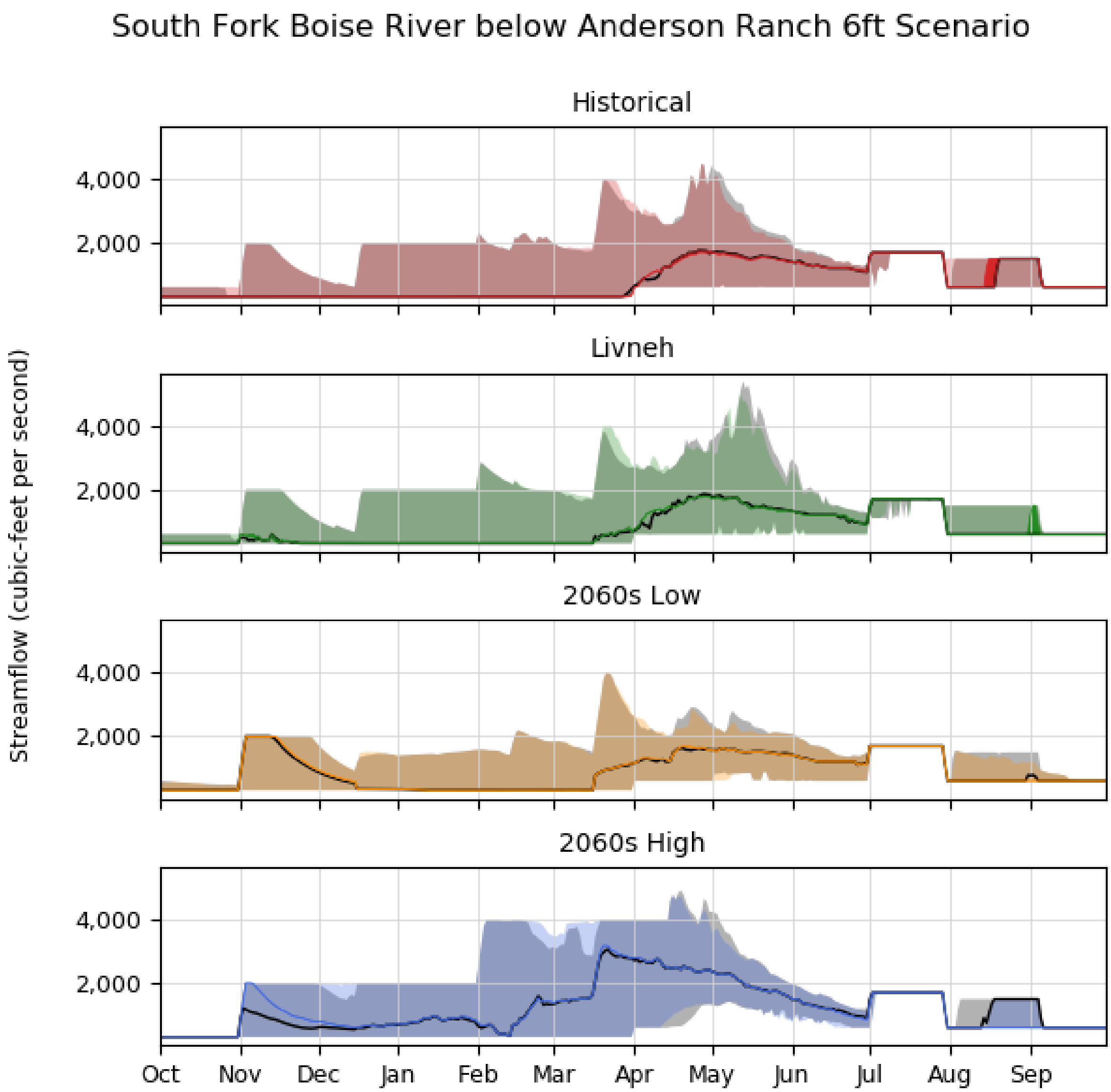

Figure 44. South Fork Boise River below Anderson Ranch historical and 2060s summary hydrographs depicting the daily median streamflow range for the 6-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

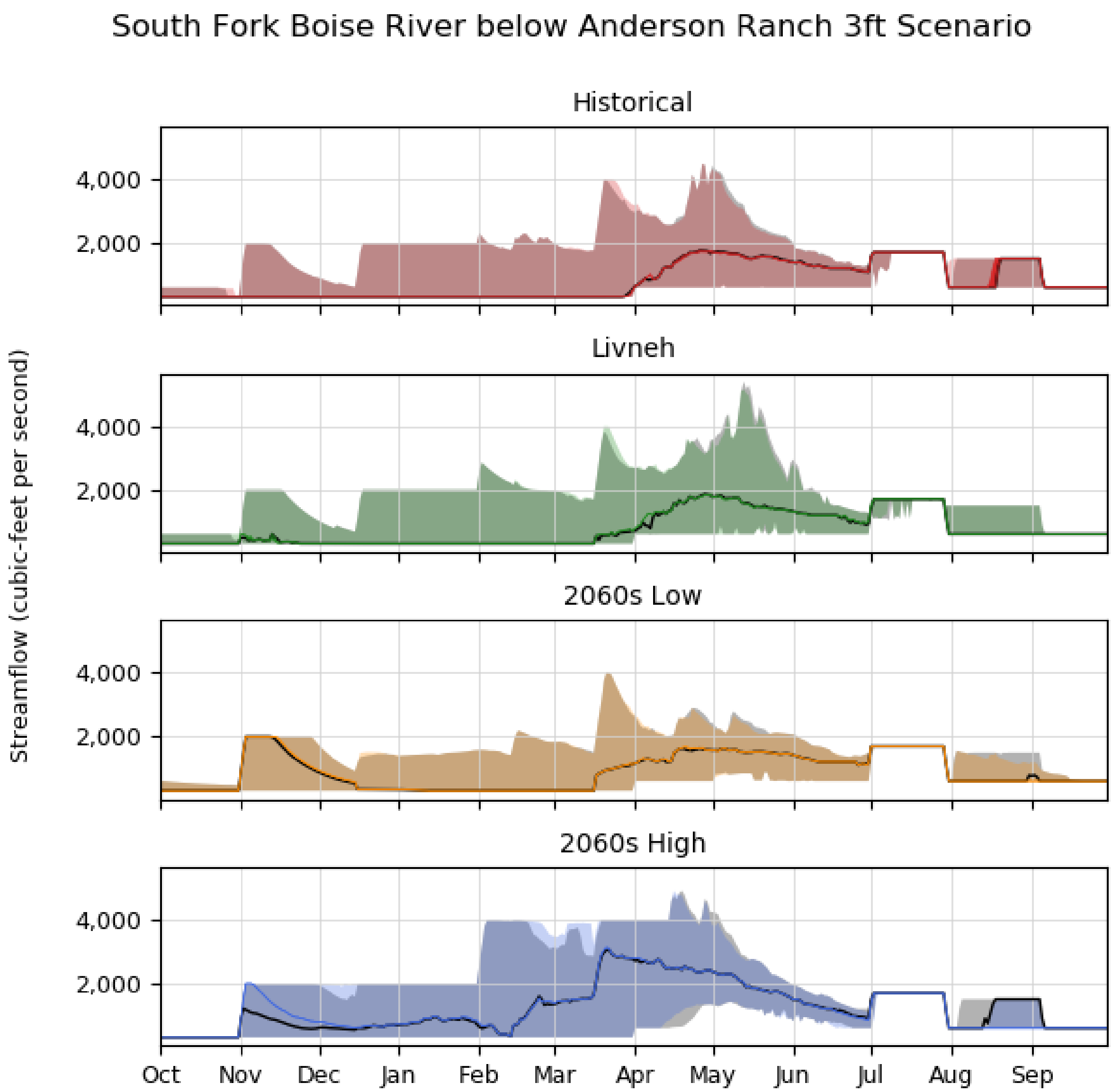

Figure 45. South Fork Boise River below Anderson Ranch historical and 2060s summary hydrographs depicting the daily median streamflow range for the 3-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

Arrowrock Reservoir and Lucky Peak Reservoir storage volumes are similar across all scenarios but show some key differences. In Arrowrock Reservoir, the most notable difference between the 2060s Low scenario and the Livneh scenario occurs in the 10th-percentile storage condition, where storage is consistently higher throughout the year in the 2060s Low scenario. The 2060s High scenario also shows higher 10th-percentile Arrowrock Reservoir storage conditions relative to the Livneh scenario, but a trend towards later refill and earlier recession compared to the 2060s Low and the Livneh scenarios. This change in timing is also seen in the daily median storage condition. As shown in Figure 46 and Figure 48 for the 6-foot Raise (Figure 47 and Figure 49 for the 3-foot Raise), the most notable changes in Lucky Peak Reservoir include lower carryover in 2060s High scenario, higher median storage through the winter months in the 2060s Low scenario, and earlier refill in the 2060s High scenario.

In Lucky Peak Reservoir, future hydrologic conditions shorten the period that the reservoir is able to maintain the 60,000-acre-foot storage content for the elk pool. In both future scenarios, storage content begins to increase in early winter, with maximum fill occurring several months earlier (April, instead of July) in the 2060s High scenario than in during the historical period. Timing of maximum fill in the 2060s Low scenario is similar to the historical condition.

In terms of differences between the Alternatives and No Action, the largest differences in median values are seen in Arrowrock Reservoir towards the end of the irrigation season where the solid colored regions show a wider range. The differences between the scenarios are less pronounced in Lucky Peak Reservoir, with the scenarios exhibiting a narrow range in median regimes under future hydrologic conditions.

Simulated streamflow in the Boise River at Glenwood show noticeable differences between hydrologic conditions (particularly through winter and spring months) and little to no difference between the Alternatives and the Baseline Scenario. As shown in Figure 50 and Figure 51, median winter streamflow is higher under both future hydrologic conditions. Daily median streamflow climbs steadily in the 2060s High condition from December through the winter until they reach a maximum of approximately 6,500 cfs in March. The 2060s Low condition results in elevated median streamflow during the winter months and spring runoff beginning a few weeks earlier than in the Livneh scenario.

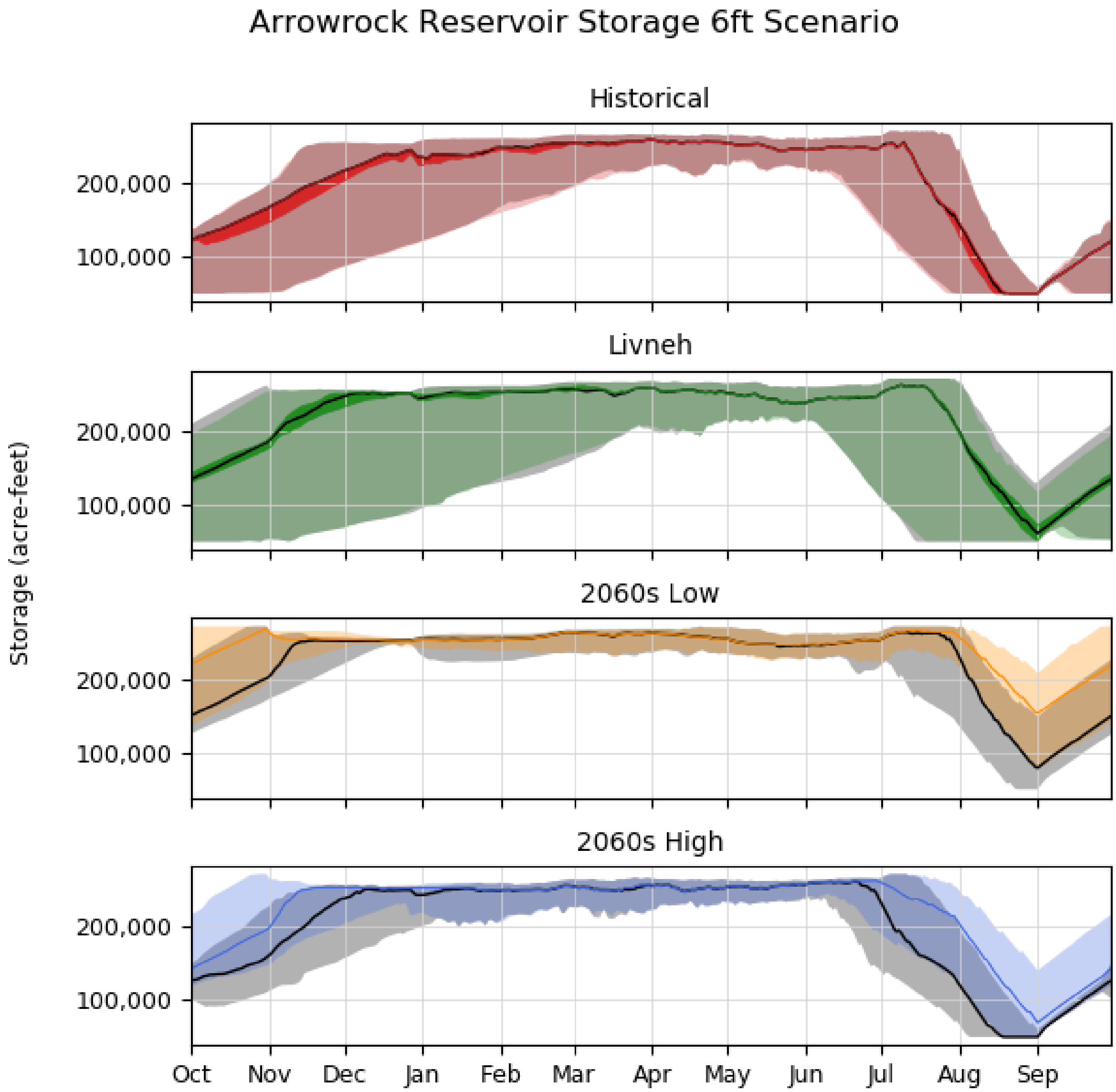

Figure 46. Arrowrock Reservoir historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 6-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

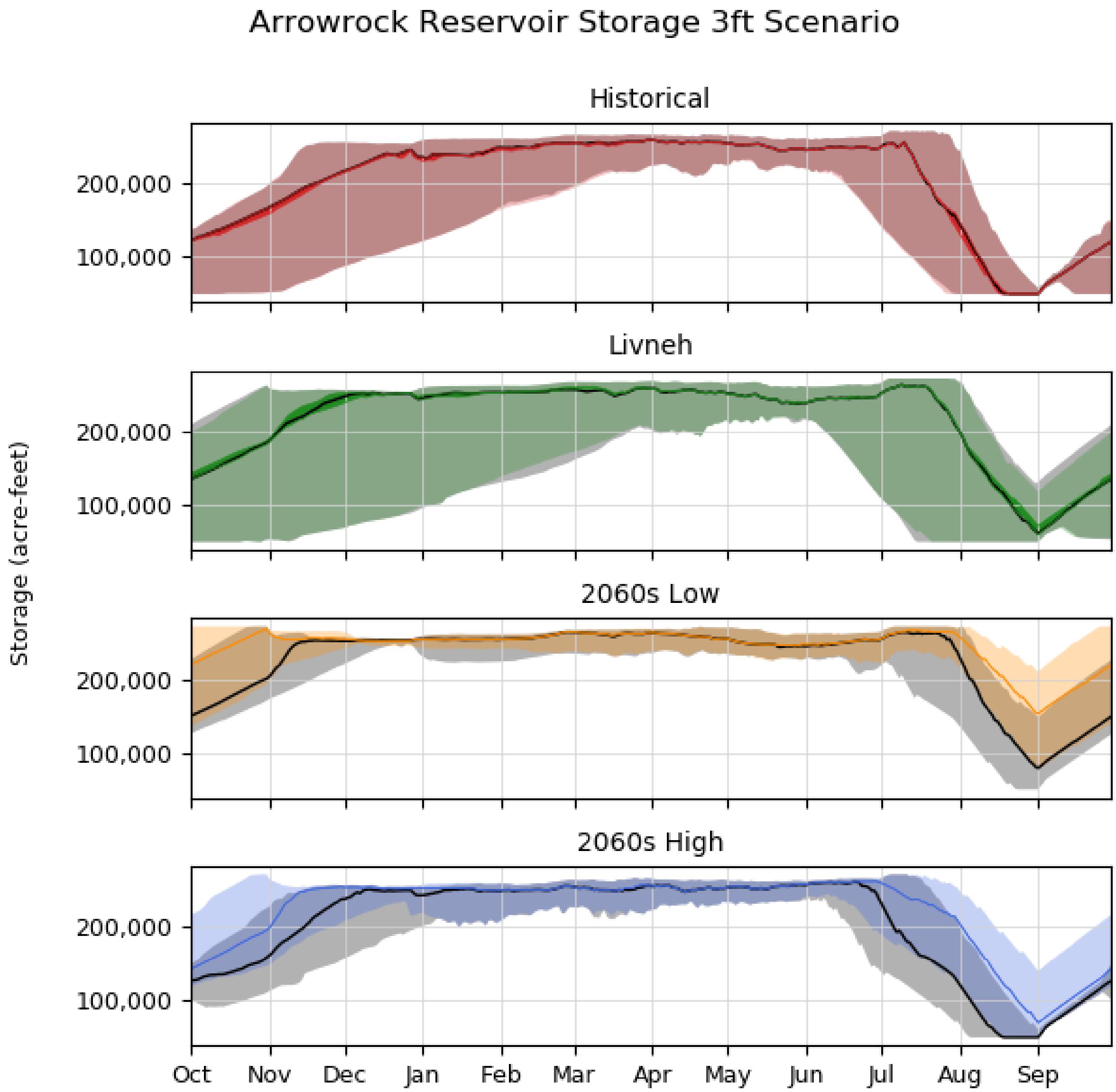

Figure 47. Arrowrock Reservoir historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 3-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

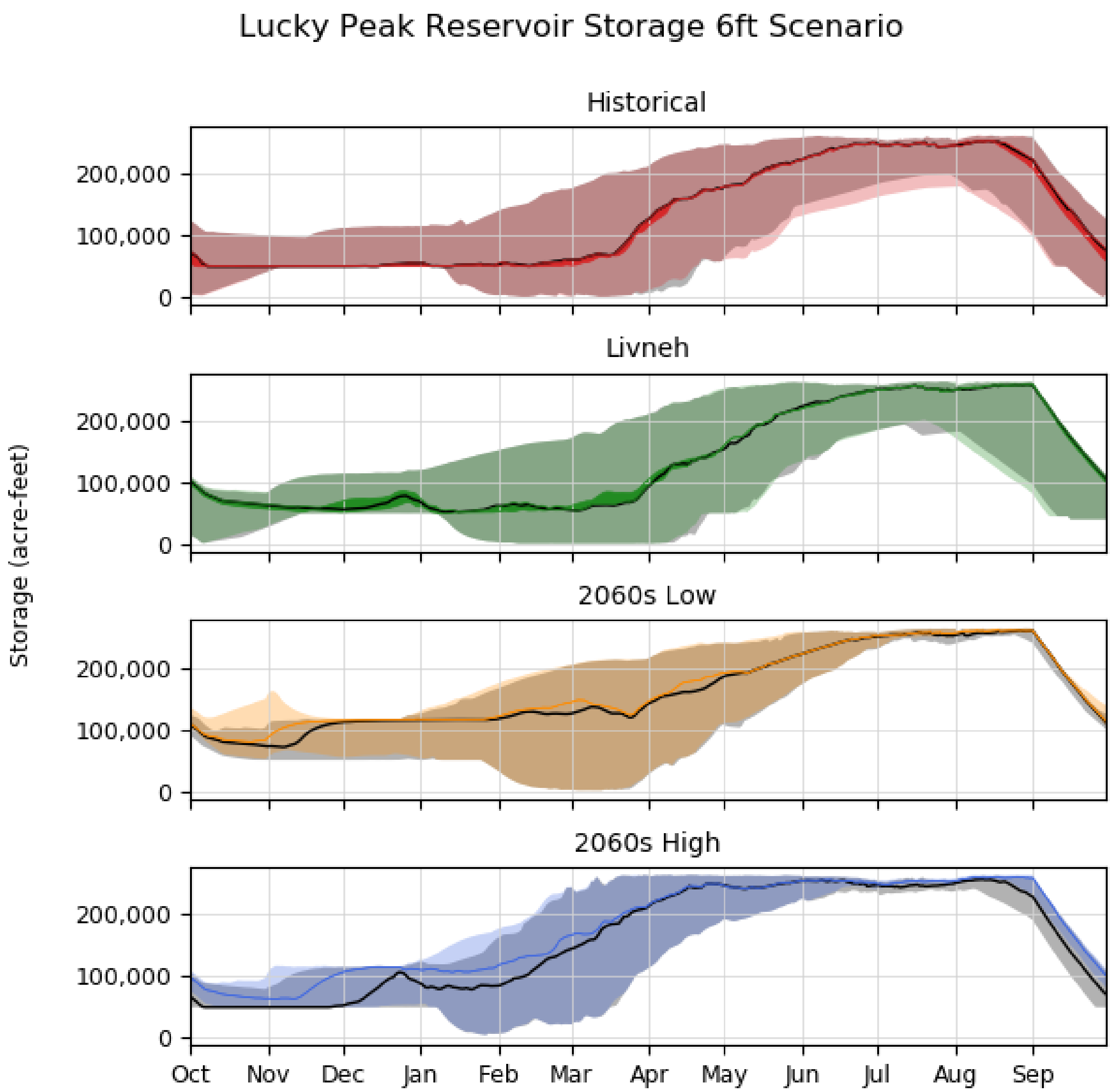

Figure 48. Lucky Peak Reservoir historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 6-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

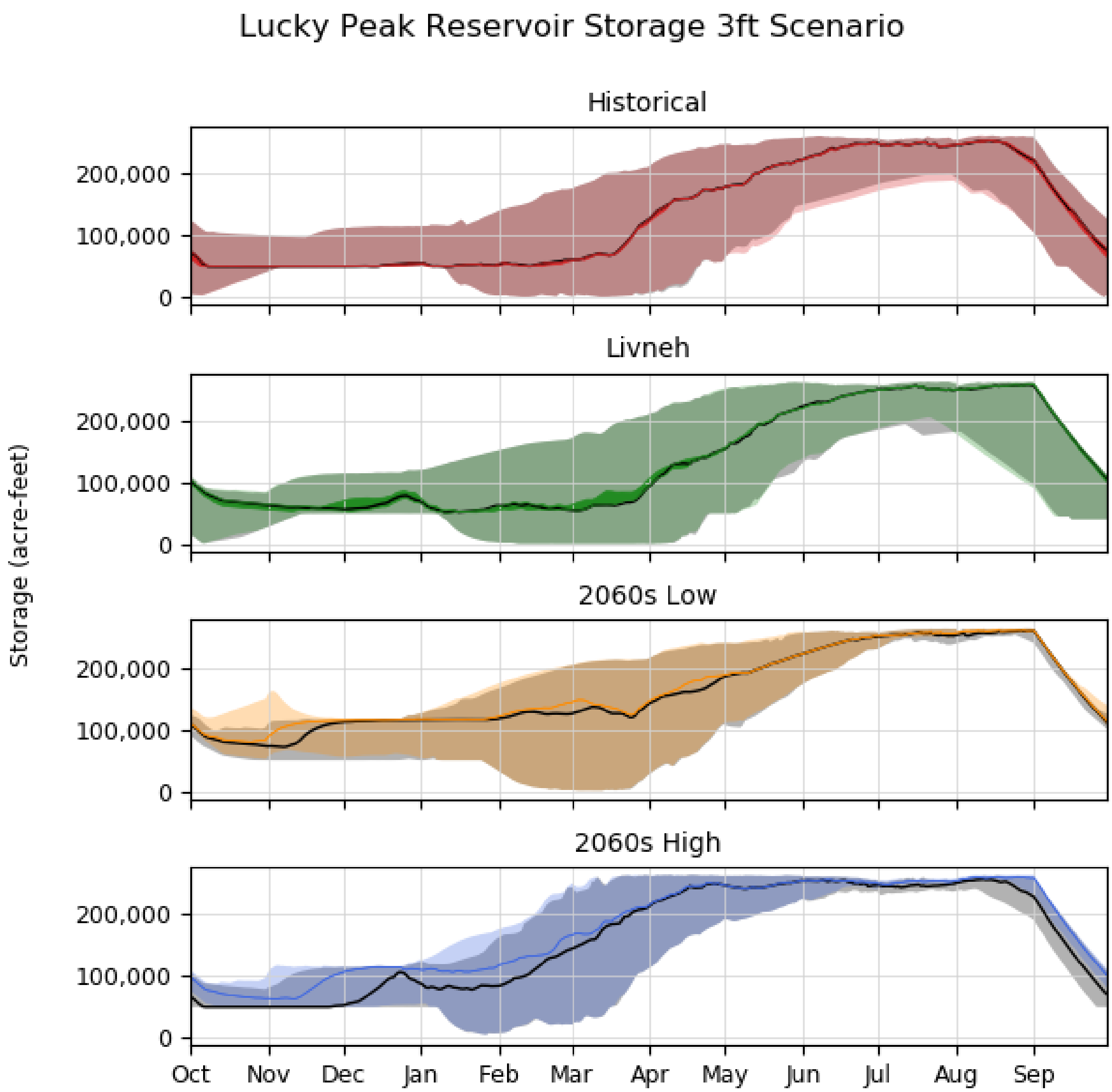

Figure 49. Lucky Peak Reservoir historical and 2060s summary storage hydrographs depicting the daily median storage content range for the 3-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

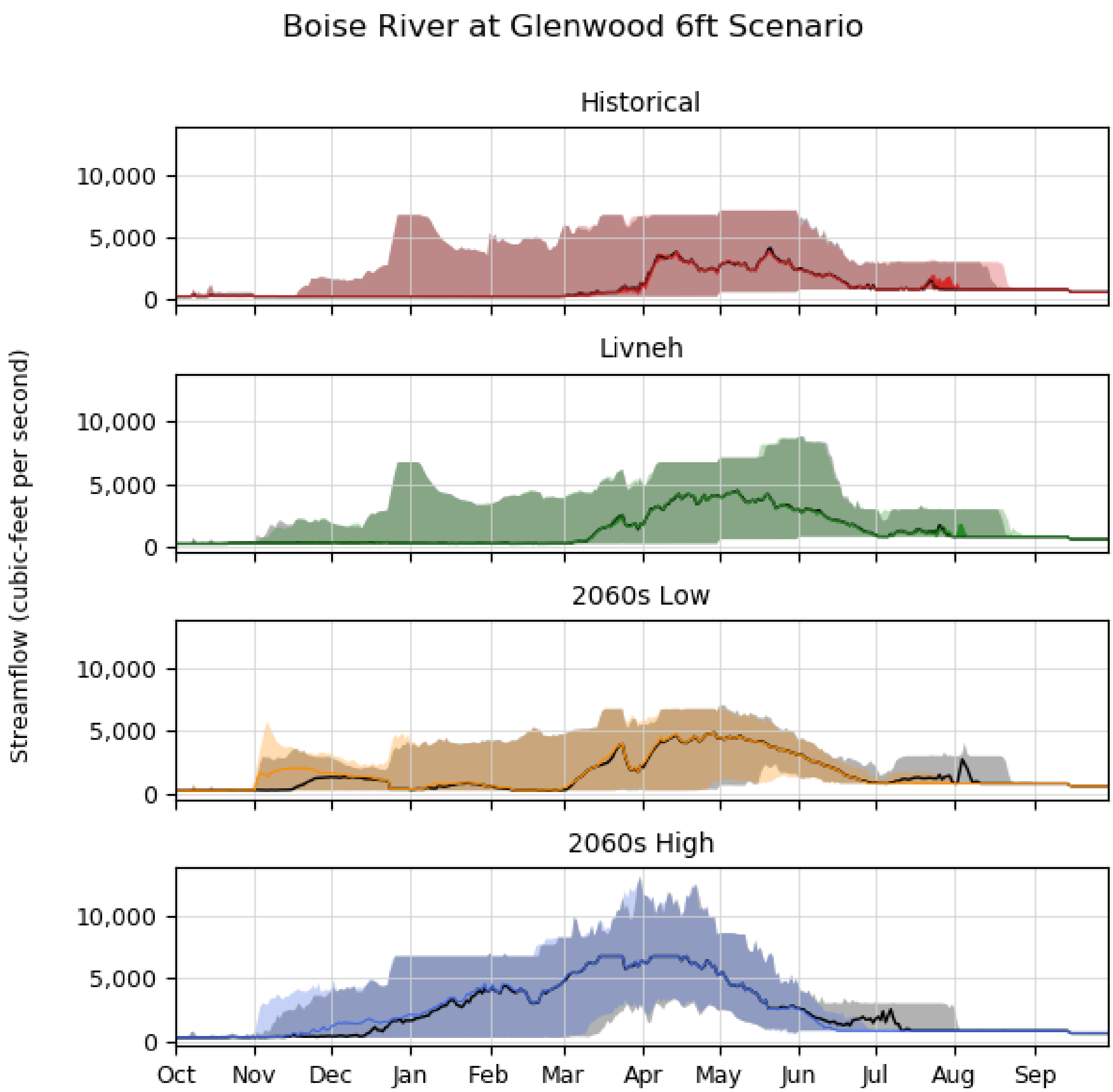

Figure 50. Boise River at Glenwood historical and 2060s summary hydrographs depicting the daily median streamflow range for the 6-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

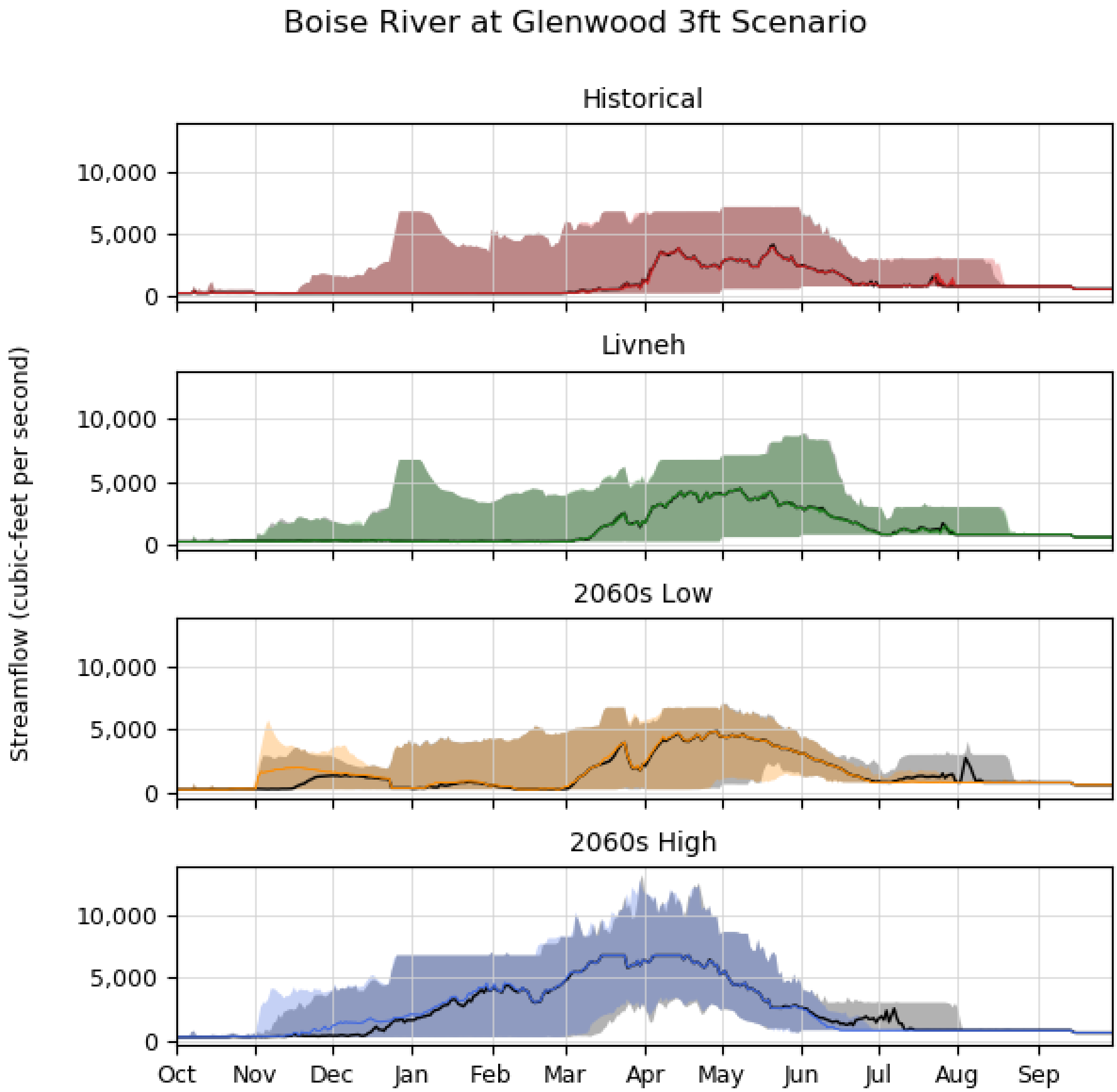

Figure 51. Boise River at Glenwood historical and 2060s summary hydrographs depicting the daily median streamflow range for the3-foot Raise (narrow solid colored regions) and daily median for No Action (black lines). The shaded colored regions and the underlying shaded gray regions represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Each panel and color represent a different hydrologic condition. The top (red) panel represents the historical condition, the second (green) panel represents the Livneh historical hydrology, the third (orange) panel represents the 2060s Low climate change projection, and the fourth (blue) panel represents the 2060s High climate change projection.

The climate change conditions simulated in this study demonstrated a stronger influence on operations compared to the proposed increase in storage at Anderson Ranch Reservoir. Both climate change scenarios showed a trend towards wetter conditions (higher streamflow and storage contents) during the winter and spring months compared to streamflow and storage conditions associated with the Livneh historical hydrology. That said, all hydrologic conditions showed the potential for increased storage under the Alternatives relative to the baseline condition. This suggests that the storage benefit associated with the dam raise may still be realized under future hydrologic conditions. Once again, it must be noted that these simulations utilize perfect forecasts and current operational objectives. This study does not consider forecast uncertainty, nor how that uncertainty may change going into the future as changing weather conditions influence the proportion of precipitation that falls as rain as opposed to accumulating as snowpack.

4 Potential Downstream Effects

On May 5, 2008, the National Oceanic and Atmospheric Administration (NOAA) Fisheries released a new biological opinion (2008 Upper Snake BiOp; NOAA Fisheries 2008) for the continued operations and maintenance of Reclamation projects in the Snake River Basin above Brownlee Reservoir. The Operations and Maintenance of the Boise River System is part of the larger Upper Snake River basin and covered by the Incidental Take Statement in the 2008 Upper Snake BiOp. As described in the proposed action in the 2008 NOAA BiOp, and as mandated by the 2004 Snake River Water Rights Act of 2004, Reclamation is required to provide water for downstream ecological needs, known as “Flow Augmentation Water.” Flow augmentation water is defined as water released at targeted times and places to increase streamflows to benefit migrating salmon and steelhead. The flow augmentation water is provided from multiple sources including: Reclamation’s uncontracted, powerhead reservoir space, annual storage rentals, acquired natural flow water rights, and leased natural flow water rights. The minimum volume target for flow augmentation is 427,000 acre-feet (though there may not be enough water to meet this target in dry years) and can be as much as 487,000 acre-feet from the entire Upper Snake River basin, depending on annual basin conditions. Reservoir space, including both uncontracted and contracted space, used to meet flow augmentation requirements would fill prior to any new reservoir space, including that created by a raise at Anderson Ranch Dam.

Separate from flow augmentation requirements as previously noted, through interagency coordination, Reclamation works with NOAA Fisheries and the Columbia River Technical Management Team (TMT) to coordinate Upper Snake flow augmentation releases. Upper Snake flow augmentation is intended to enhance flows in the lower Snake and Columbia rivers for federally protected out-migrating juvenile salmon and steelhead. Flow objectives and actual flows at Lower Granite Dam during the spring migration period are used to help determine flow augmentation release timing. The flow objectives at Lower Granite Dam vary between 85,000 cfs and 100,000 cfs (depending on water supply forecasts) during the spring (April 3 - June 20). It is important to note that Lower Granite Dam flow objectives are guidelines and often difficult to meet throughout the entire fish migration period, especially in dry years.

As part of this analysis, Reclamation assessed potential changes to flow at Lower Granite Dam on the Lower Snake River for Alternative B (6-foot Raise) and Alternative C (3-foot Raise). Figure 52 through Figure 55 show the monthly volume for each year from 1958 through 2008 at Lower Granite Dam for No Action and Alternatives B and C, respectively. In addition, the gray lines indicate the percent difference in flow which range from -1.3 percent to 0.7 percent for Alternative B and -0.4 percent to 0 percent for Alternative C for some years. Generally, there is a slight decrease in flows at Lower Granite as more water is being stored in the Boise System. However, there would be no change in the ability to anticipated flow augmentation volume from the No Action alternative due to the storage fill priority (see Section 5). Note that the largest percent change in flow was -1.3 percent in 1985 for Alternative B where there is a shift in timing in the delivery from June to July as the system filled earlier and released flow augmentation earlier.

Section 5 describes the total delivery of flow augmentation water out of the Boise System for the different Alternatives.

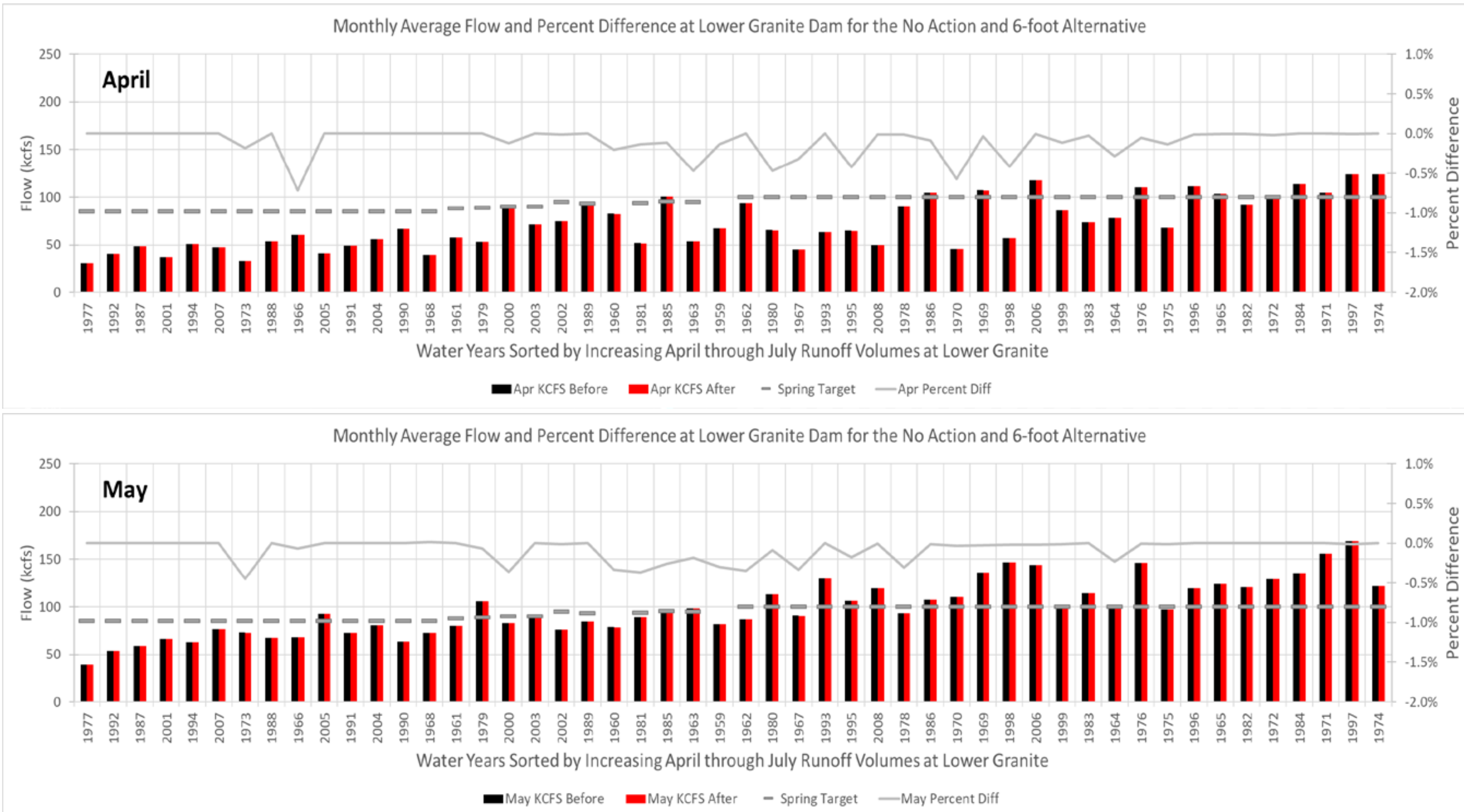

Figure 52. Flow at Lower Granite Dam for No Action (black bar), the 6-foot Raise Alternative (red bar), and the flow objective (gray dash) for April (top) and May (bottom). The percent change in flow is shown with the gray line.

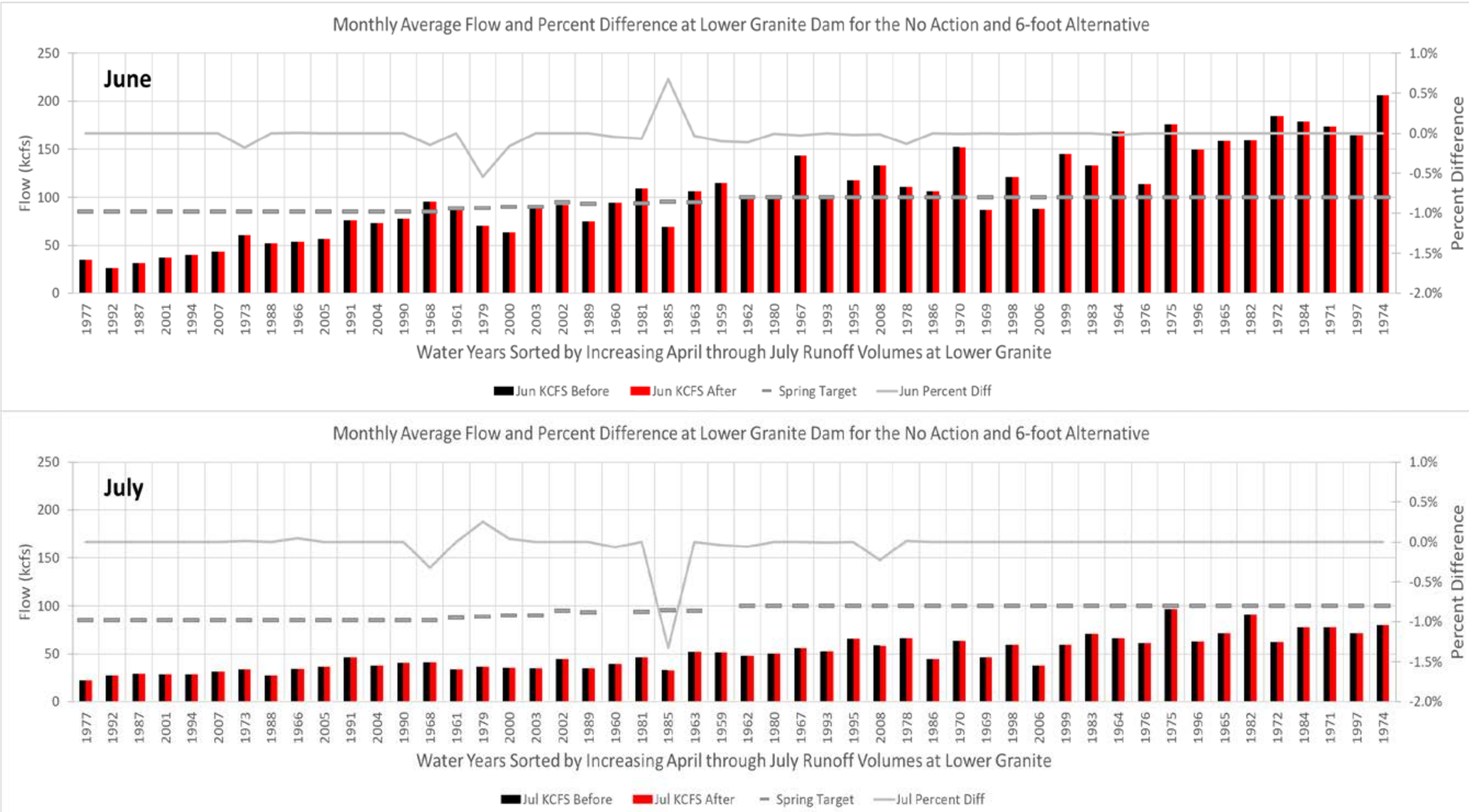

Figure 53. Flow at Lower Granite Dam for No Action (black bar), the 6-foot Raise Alternative (red bar), and the flow objective (gray dash) for June (top) and July (bottom). The percent change in flow is shown with the gray line.

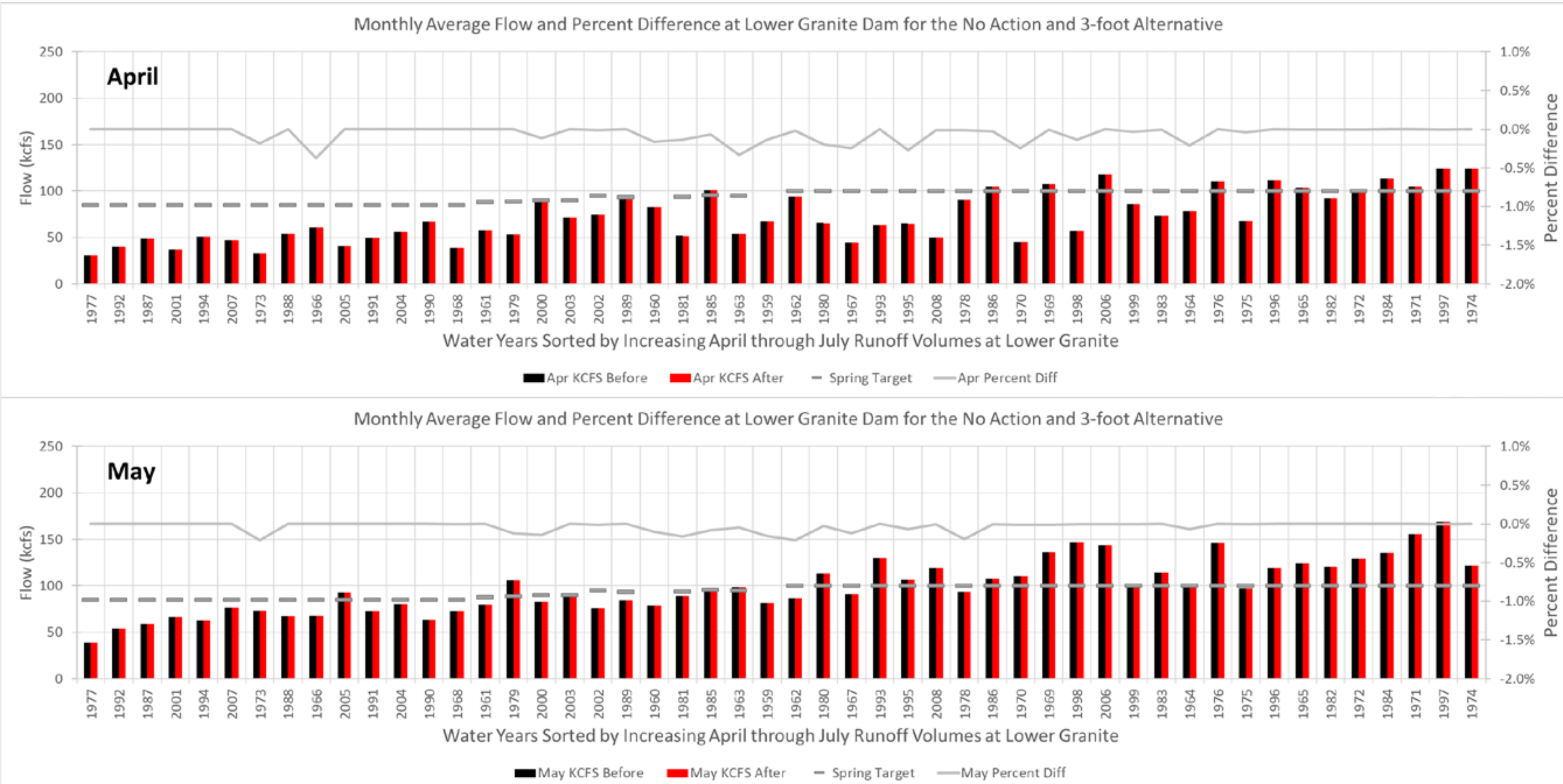

Figure 54. Flow at Lower Granite Dam for No Action (black bar), the 3-foot Raise Alternative (red bar), and the flow objective (gray dash) for April (top) and May (bottom). The percent change in flow is shown with the gray line.

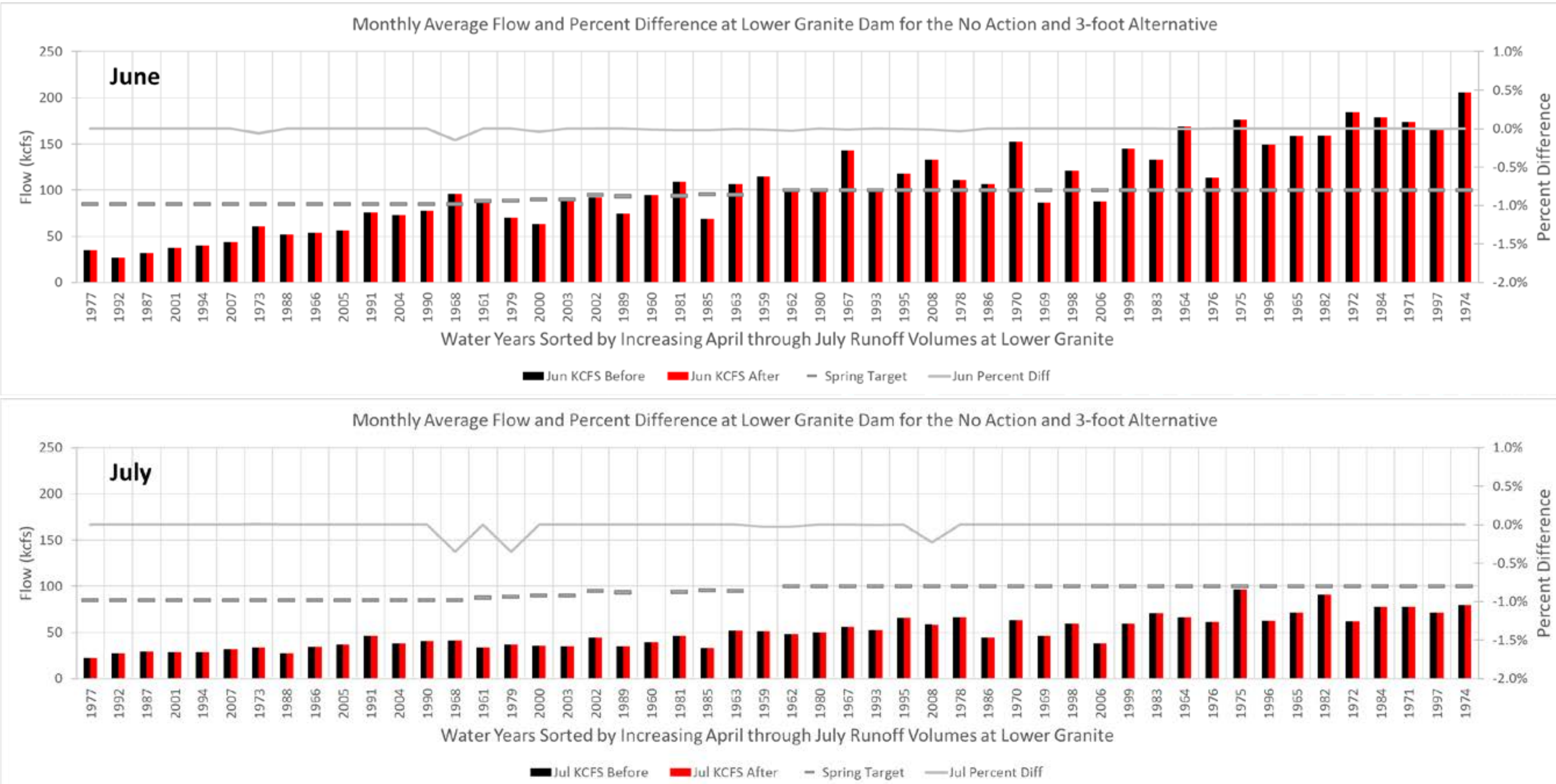

Figure 55. Flow at Lower Granite Dam for No Action (black bar), the 3-foot Raise Alternative (red bar), and the flow objective (gray dash) for June (top) and July (bottom). The percent change in flow is shown with the gray line.

5 Water Availability and Refill Probability

At the time of this study, multiple proposals of new water rights for diversion from – and storage in – Anderson Ranch Reservoir were being considered. Given the uncertainty around if and when these new proposals would be implemented, a range of scenarios was analyzed. The Director of the Idaho Department of Water Resources administers natural flow and storage water rights in priority using the water right accounting program. The sequential priority of water right administration is such that the space for water delivered in the previous water year for "flow augmentation" (water that is released out of basin to support ecosystems in the Columbia River) will accrue storage before any new junior storage or natural flow water rights established on the Boise River. Accordingly, those accounts, often previously known as "last to fill," are being modeled as filling before the new accounts or diversions, as this is anticipated how the system would operate in real time.

The analysis utilized a version of the Boise Planning Model to estimate the amount of water available to the potential new water rights at or near Anderson Ranch Reservoir. Both new storage and potential diversions were treated as diversions from Anderson Ranch Reservoir in the model versus in the System Operations model version that treated the new storage as space in the reservoir. Because of this, the timing of storage and use of the new Anderson Ranch Reservoir space could be different in real-time operations; however, the annual volume allocated to that space would be representative of what would be stored in real-time.

Table 5 lists the potential new water rights that were evaluated as part of this analysis along with their associated maximum diversion rate and annual volume limit. These three potential water rights were assumed to only be in priority when:

- There is a minimum of 800 cfs below Anderson Ranch Dam;
- There is a minimum of 240 cfs below New York Canal[5] June 16th through February 29th;
- There is a minimum of 1,100 cfs below New York Canal March 1st through May 31st; and
- The system is making releases for FRM.

[5] The New York Canal is the largest diversion from the Boise River. See Section 7 for more information.

Table 5. Potential new water rights considered in this analysis.

Entity	Diversion Rate Limit	Diversion Volume Limit
Anderson Ranch New Storage (#63-34753)	No limit	29,000 acre-feet
Elmore County (#63-34348)	200 cfs	10,000 acre-feet
	100 cfs	No limit
Cat Creek Energy (#63-34652)	3,000 cfs	30,000 acre-feet[6]

This modeling analysis assumed a flow augmentation target and space volume of 99,768 acre-feet of existing storage space (this does not include the new 6-foot or 3-foot storage space). This is comprised of 40,932 acre-feet of uncontracted space in Lucky Peak Reservoir, 21,880 acre-feet of rentals (representing the maximum volume of rentals provided from the Boise Reservoir System in 2017), and 36,956 acre-feet of Anderson powerhead space. Any physical accrual of storage above 849,901 acre-feet (representing the 949,669 -acre-foot maximum system capacity minus 99,768 acre-feet of last to fill space) was released for flow augmentation in each simulated year.

Considering the potential for analysis period selection to influence refill probability, the results of this analysis are presented for both the full 50-year simulation period and the shorter 28-year period used in the Preliminary Hydrologic Evaluation (Reclamation 2017).

Three different diversion configurations of the potential new accounts result in a total of six scenarios considered in this analysis. These scenarios include the following (with entities listed in the priority order in which they were modeled):

1. Anderson Ranch New Storage Six feet;
2. Elmore County > Anderson Ranch New Storage Six feet > Subordinated Cat Creek Energy;
3. Elmore County > Cat Creek Energy > Anderson Ranch New Storage Six feet;
4. Anderson Ranch New Storage Three feet;
5. Elmore County > Anderson Ranch New Storage Three feet > Subordinated Cat Creek Energy; and
6. Elmore County > Cat Creek Energy > Anderson Ranch New Storage Three feet.

[6] This is the consumptive use portion of this water right. When CCE makes its initial fill, it will divert up to 100,000 acre-feet at a rate of 9996 cfs. That is not considered in this modeling assessment.

5.1 Historical Results

Figure 56 and Figure 57 depict the exceedance curves of annual water availability for new storage in Anderson Ranch Reservoir for the October 1958 through September 2008 and the October 1980 through September 2008 analysis periods, respectively, for Alternative B (6-foot Raise). As shown in these figures, refill probability of 29,000 acre-feet of new storage ranges from 29 percent to 62 percent depending on scenario and analysis period. The highest refill probability was associated with the Anderson Ranch New Storage-only scenario for the 50-year period, while the lowest refill probability was associated with the scenario where Anderson Ranch fills last behind flow augmentation, Elmore County, and Cat Creek Energy (CCE) for the 28-year period.

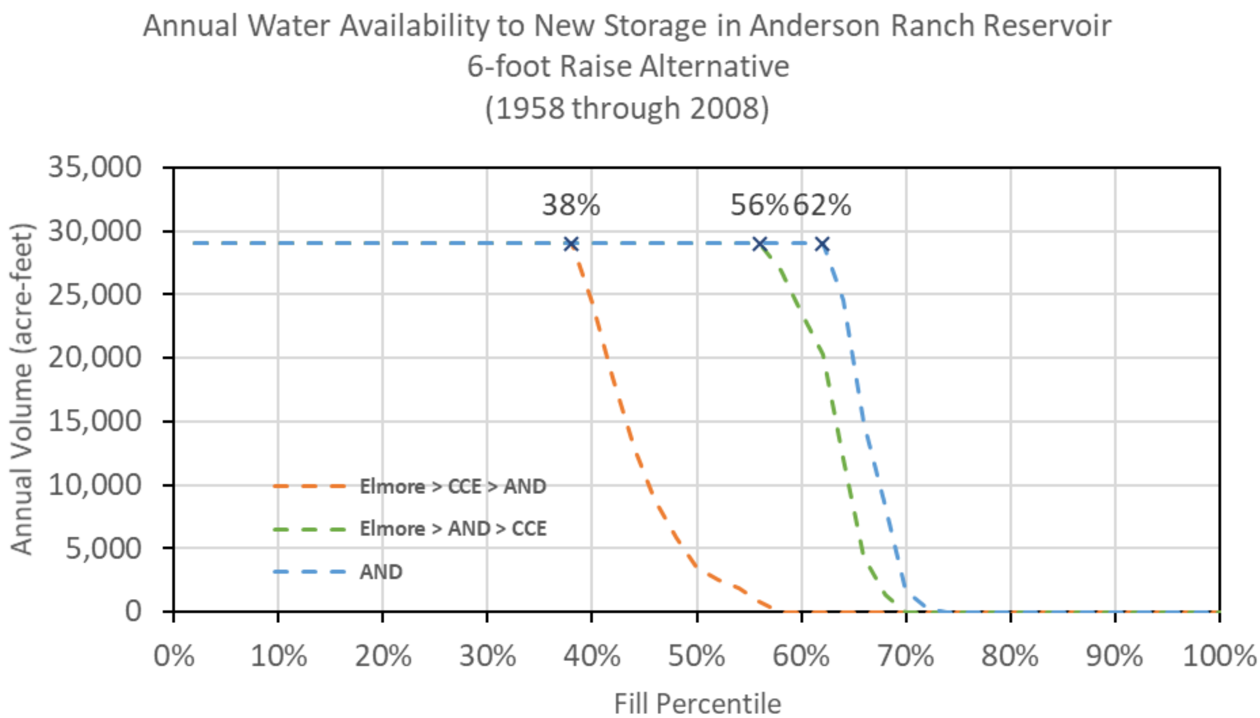

Figure 56. Refill probability for the 6-foot Raise Alternative (29,000 acre-feet of new storage in Anderson Ranch Reservoir) for the 50-year period spanning October 1958 through September 2008. The three scenarios shown represent varying orders of seniority for the Elmore County and Cat Creek Energy water right permits. The legend shows the priority order for each scenario, with entities listed in order from most senior to most junior.

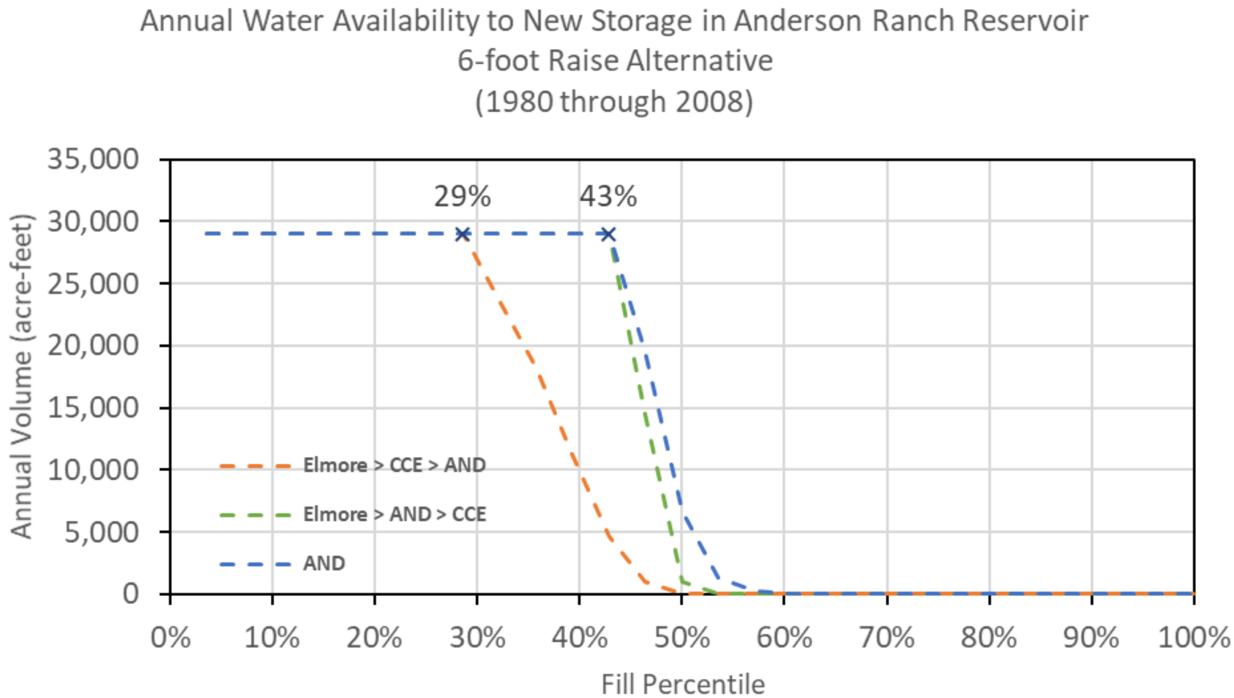

Figure 57. Refill probability for the 6-foot Raise Alternative (29,000 acre-feet of new storage in Anderson Ranch Reservoir) for the 28-year period spanning October 1980 through September 2008. The three scenarios shown represent varying orders of seniority for the Elmore County and Cat Creek Energy water right permits. The legend shows the priority order for each scenario, with entities listed in order from most senior to most junior.

Figure 58 and Figure 59 depict the exceedance curves of annual water availability for new storage in Anderson Ranch Reservoir for the October 1958 through September 2008 and the October 1980 through September 2008 analysis periods, respectively, for the 3-foot Raise Alternative. As shown in these figures, refill probability of 14,400 acre-feet of new storage ranges from 36 percent to 64 percent depending on scenario and analysis period. The 3-foot Raise scenarios have a generally higher refill probability because there is less space to fill. The highest refill probability was associated with the Anderson Ranch New Storage-only scenario for the 50-year period, while the lowest refill probability was associated with the scenario where Anderson Ranch fills last behind flow augmentation, Elmore County, and Cat Creek Energy for the 28-year period.

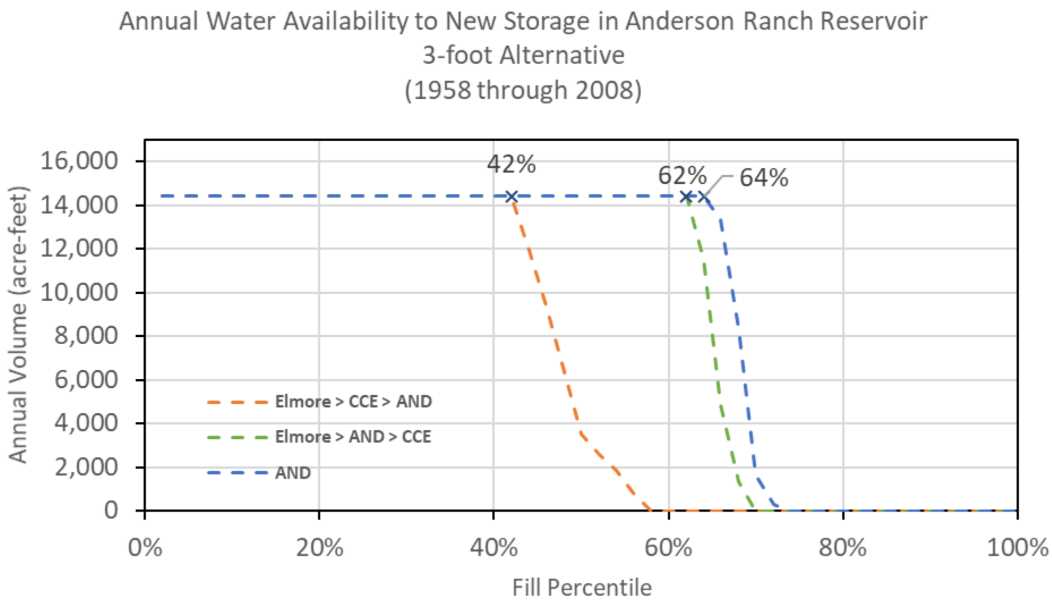

Figure 58. Refill probability for the 3-foot Raise Alternative (14,400 acre-feet of new storage in Anderson Ranch Reservoir) for the 50-year period spanning October 1958 through September 2008. The three scenarios shown represent varying orders of seniority for the Elmore County and Cat Creek Energy water right permits. The legend shows the priority order for each scenario, with entities listed in order from most senior to most junior.

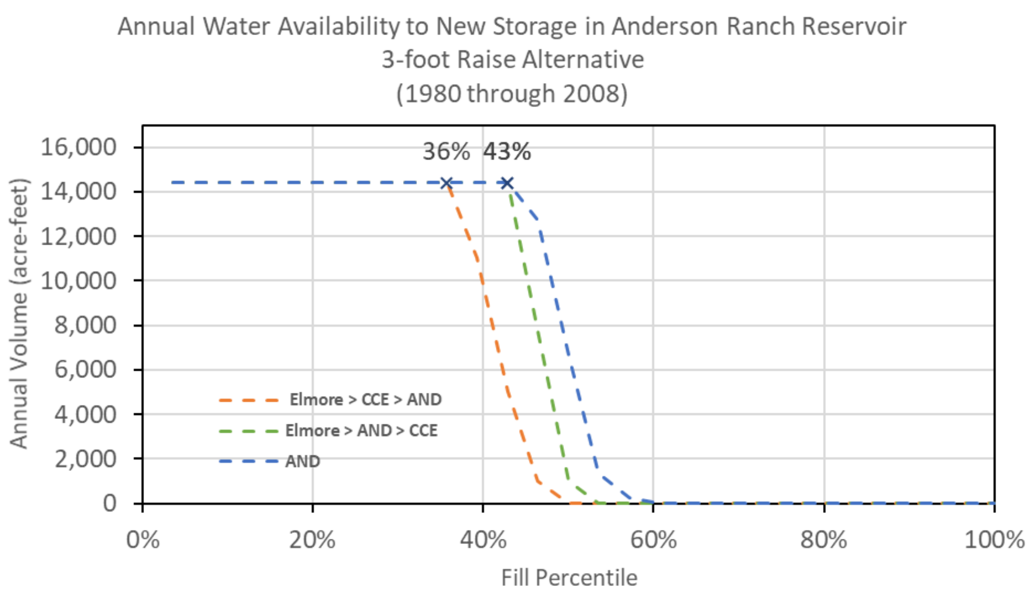

Figure 59. Refill probability for the 3-foot Raise Alternative (14,400 acre-feet of new storage in Anderson Ranch Reservoir) for the 28-year period spanning October 1980 through September 2008. The three scenarios shown represent varying orders of seniority for the Elmore County and Cat Creek Energy water right permits. The legend shows the priority order for each scenario, with entities listed in order from most senior to most junior.

Table 6 summarizes the estimated probability of completely filling 29,000 acre-feet of new storage in Anderson Ranch Reservoir for each of the scenarios and historical periods considered in this analysis. The top scenario, Elmore County > CCE > Anderson Ranch, is the most likely to occur given current water right applications based on publicly available information. The other two are shown for comparison purposes. The results for the 28-year period are similar to those reported by the 2017 Preliminary Hydrologic Evaluation which estimated the new storage would refill in 43 percent to 46 percent of years.

Table 6. Refill probability for the 6-foot Raise (29,000 acre-feet) and 3-foot Raise (14,400 acre-feet) Alternatives given two analysis periods and two new water right permits for Elmore County and Cat Creek Energy (CCE). The scenario column depicts the priority order for each scenario, with entities listed in order from most senior to most junior.

Scenario	6-foot Raise (29,000 acre-feet)		3-foot Raise (14,400 acre-feet)	
	50 Year	28 Year	50 Year	28 Year
Elmore County > CCE > Anderson Ranch	38%	29%	42%	36%
Elmore County > Anderson Ranch > CCE	56%	43%	62%	43%
Anderson Ranch Only	62%	43%	64%	43%

5.2 Climate Change

The water availability scenarios were run using the climate change scenarios described in Section 3.7. These 30-year scenarios include the Livneh Simulated Historical (1980 through 2009)[7] and two 2060s scenarios (2050 through 2079) capturing a range of future conditions. As shown in Table 7, both climate change scenarios exhibit higher refill probabilities compared to the Livneh Simulated Historical dataset. This can be attributed to the year-round increase in streamflow in both of the 2060s climate change conditions relative to the Livneh Simulated Historical conditions. Tables of refill probabilities for new storage in Anderson, as well as for the Elmore County and Cat Creek Energy diversions, are included in the Appendix.

[7] The full Livneh Simulated Historical dataset extends from 1950 through 2010. Similar to the historical results described in Section 4.1.1, evaluation of refill probability using the full period results in different refill probabilities compared to using the more recent 30-year period.

Table 7. Refill probability for the 6-foot Raise (29,000 acre-feet) and 3-foot Raise (14,400 acre-feet) Alternatives given two future climate change scenarios and two new water right permits for Elmore County and Cat Creek Energy (CCE). The simulated historical Livneh Baseline dataset is provided for reference. The scenario column depicts the priority order for each scenario, with entities listed in order from most senior to most junior.

Scenario	Livneh (1980-2009)		2060s Low		2060s High	
	6-foot Raise	3-foot Raise	6-foot Raise	3-foot Raise	6-foot Raise	3-foot Raise
Elmore County > CCE > Anderson Ranch	50%	56%	57%	63%	92%	92%
Elmore County > Anderson Ranch > CCE	56%	66%	78%	90%	92%	92%
Anderson Ranch Only	67%	73%	87%	92%	92%	95%

6 Construction Phase

Construction activities associated with the 6-foot Raise will necessitate drawdown of Anderson Ranch Reservoir and the installation of a coffer dam (Reclamation 2019). Two different pool elevation restrictions have been proposed (4,174 feet and 4,184 feet) based on findings of the flood routing study performed by the Denver Technical Services Center. These restrictions serve the purpose of protecting against flood overtopping failure modes to an acceptable level of risk as determined by Reclamation. The proposed construction schedule calls for Anderson Ranch Reservoir volume to be reduced to the restricted pool elevation at construction commencement for approximately 3.5 years.

6.1 Description of Operations

Depending on the hydrologic conditions, normal outflows for downstream water demand may be sufficient to reduce the pool elevation in Anderson Ranch Reservoir to below the designated restriction elevation (4,174 feet or 4,184 feet) by the end of August 2022. If this is not the case, summer releases will be adjusted accordingly to meet the restricted elevation requirement. For purposes of the EIS, a pool restriction of elevation 4,174 feet was analyzed due to this being the most restrictive with regards to possible impacts to streamflow, reservoir conditions, and FRM operations. Analyzing the lower restriction elevation of 4,174 feet also bounds lesser impacts that would be experienced from a higher restriction elevation of 4,184 feet (or higher). After installation of the coffer dam, operations for FRM and water supply will continue as normal under the restricted pool elevation, resulting in deeper drafts of Anderson Ranch Reservoir than would have occurred without the pool elevation restriction. Deeper drafts will be limited by the powerhead elevation of 4,036 feet. As pool elevations in Anderson Ranch Reservoir approach this lower limit, operations may need to be adjusted to maintain pool elevations above 4,036 feet while still meeting downstream targets including minimum flows in the South Fork Boise River and minimum pool elevation in Arrowrock Reservoir. The analysis on Boise System FRM operations during the pool restriction is summarized in the EIS.

6.2 Potential Storage Shortfall

Drawdown of Anderson Ranch Reservoir during the construction period for both Alternatives has the potential to result in reduced fill to reservoir storage accounts. The amount of shortfall will be dependent on runoff conditions. Only in the driest of years does Anderson Ranch pool elevation remain below the pool elevation limits associated with the construction operations. In other years, the volume of shortfall can be defined as the fill amount the reservoir could have achieved under normal operations, minus the amount of fill achieved under the pool restrictions.

This analysis focusses on the maximum potential shortfall, representing a condition where the reservoir could have filled completely but pool elevation restrictions limited the amount of fill. This analysis also assumes that the ability to fill downstream reservoirs would not be impacted by the restriction. Figure 60 illustrates the storage-elevation curve for Anderson Ranch Reservoir, as well as the storage volumes associated with a full pool (approximately 413,000 acre-feet) and two different restriction elevations (approximately 358,000 acre-feet for a 4,184 foot restriction and approximately 317,000 acre-feet for a 4,174 foot restriction). The maximum volume of shortfall per year under each restriction is then calculated as the full-pool volume minus the restricted-pool volume, resulting in a shortfall of approximately 55,000 acre-feet per year for a 4,184 foot restriction and a shortfall of approximately 97,000 acre-feet per year for a 4,174 foot restriction.

Assuming the shortfall volume would be shared proportionally among current Anderson Ranch spaceholders, the maximum shortfall volume for each spaceholder is calculated as the total shortfall volume multiplied by the percent of total space owned. Table 8 depicts the amount of space owned, the percent of space owned, and the shortfall volume per year under two different restriction elevations for each Anderson Ranch spaceholder.

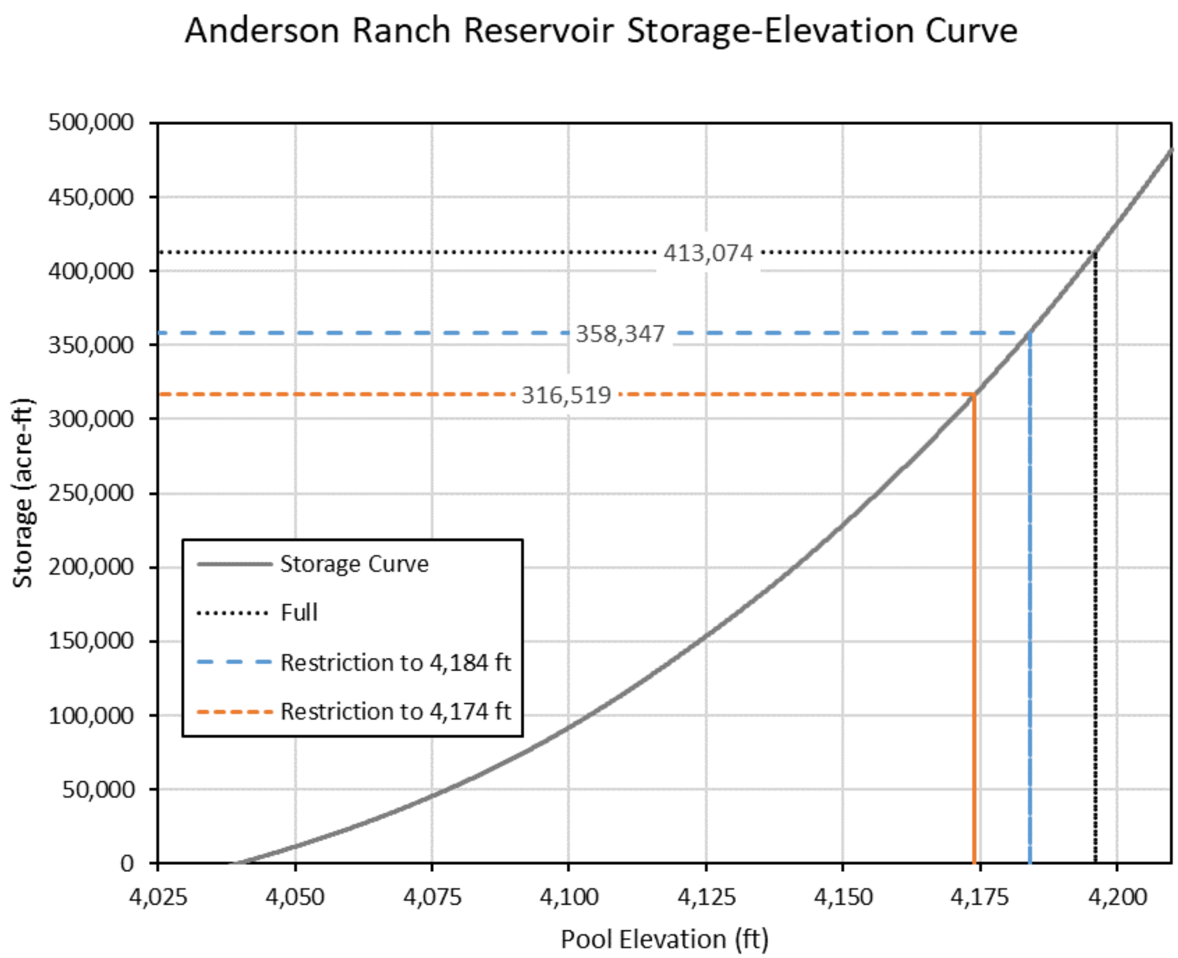

Figure 60. Storage/elevation curve for Anderson Ranch Reservoir with lines depicting storage at full pool (black dotted) and two different pool elevation restrictions associated with the proposed construction activities: 4,184 feet (blue dashed), and 4,174 feet (orange dashed).

Table 8. Anderson Ranch Reservoir spaceholders and the amount of space owned, percent of space owned (excluding power head), and the potential maximum shortfall volumes under two different pool elevation restrictions.

Spaceholder	Space Owned (acre-feet)	Percent of Total Space	Shortfall Volume for 4,184-foot Restriction (acre-feet/year)	Shortfall Volume for 4,174-foot Restriction (acre-feet/year)
Trinity Springs	800	0.19%	105.99	187.00
New York	351,554	85.11%	46,576.39	82,174.86
Surprise Valley/Micron	3,000	0.73%	397.46	701.24
Ridenbaugh	14,785	3.58%	1,958.82	34,55.96
Bubb	531	0.13%	70.35	124.12
Suez Water	1,000	0.24%	132.49	233.75
Settlers	5,675	1.37%	751.86	1,326.52
Farmers Union	5,593	1.35%	741.00	1,307.35
Boise Valley	939	0.23%	124.41	219.49
Capitol View	449	0.11%	59.49	104.95
New Dry Creek	1,266	0.31%	167.73	295.92
Ballentyne	367	0.09%	48.62	85.79
Phyllis	24,986	6.05%	3,310.32	5,840.41
Little Pioneer	2,123	0.51%	281.27	496.25
Uncontracted	6	0.00%	0.79	1.40
TOTAL	413,074	100%	54,727	96,555

7 Evaluation of Canal Lining

During the study, an alternative to line portions of the New York Canal and Mora Canal was briefly considered but eliminated after a cursory evaluation showed that it would not meet the planning objectives of providing additional water supply in the Boise River Basin. The New York Canal distributes water for the Boise Project Board of Control. It diverts water from the Boise River at Diversion Dam and delivers it at approximately 2,300 cfs during the peak of the irrigation season. Since its construction, water has seeped from the canal into the shallow aquifer. Each year, this seeped water returns to the Boise River and provides water supply to diverters in the lower reaches of the Boise River.

The cursory evaluation considered reducing seepage from the New York canal that would be accomplished by lining the canal. By reducing seepage by about 8 percent, it was assumed that

50,000 acre-feet of water could be left in reservoir storage and allocated for new uses. However, reducing seepage would also reduce the amount of return flow to the lower reaches of the Boise River. Downstream diverters would then either call on their storage more frequently or it was assumed they would rent water to make up their shortfall. The cursory evaluation concluded this alternative would result in a net zero benefit of providing additional water supply in the Boise River Basin.

8 Conclusions

This study evaluated the storage, streamflow, and temperature changes that may occur at key locations as a result of the proposed increased storage capacity at Anderson Ranch Reservoir for two Alternatives: a 6-foot Raise at Anderson Ranch Dam, and a 3-foot Raise at Anderson Ranch Dam. The primary conclusions of this study are listed below.

- Model results suggest no change to the ability of the Boise System to continue to meet the operating and ecological objectives in both Alternatives.

- Conditions under the Alternatives would not result in increased use of the spillway at Anderson Ranch Dam.

- There is potential for increased flows below Anderson Ranch Dam in the late summer when releases from Anderson Ranch Reservoir are called upon for irrigation demand and to backfill Arrowrock Reservoir. In these cases, it is presumed that releases will be made at the rate of power plant capacity, approximately 1,600 cfs. The duration of these flows depends on the new volume to be released. A release of the full 6-foot Raise volume (29,000 acre-feet) would equate to 9.1 days of flow at 1,600 cfs or 4.5 days for the 3-foot Raise volume (14,400 acre-feet).

- Results for the 6-foot Raise Alternative and 3-foot Raise Alternative showed a slight decrease in water temperatures during the times of year when water temperatures are typically the highest. Results show temperatures remaining between 2 degrees C and 15 degrees C (the suitable temperature range for fish) over the two-year water quality analysis period.

- Water availability analysis results indicate the 6-foot Raise Alternative account was able to fill completely in 38 percent of years in the 1958 through 2008 analysis period. For the 3-foot Raise Alternative, the account was able to fill completely in 42 percent of years in the 1958 through 2008 analysis period.

- 2060s climate change hydrologic conditions showed the potential for increased storage for the 6-foot Raise Alternative and 3-foot Raise Alternative compared to No-Action.

However, it must be noted that these simulations utilize perfect forecasts and current operational objectives. This study does not consider forecast uncertainty, nor how that uncertainty may change going into the future as warming conditions influence the proportion of precipitation that falls as rain rather than accumulating as snowpack.

- Drawdown of Anderson Ranch Reservoir during the construction phase of a dam-raise project has the potential to result in a shortfall of volume of 55,000 acre-feet per year of drawdown for a 4,184 foot restriction and a shortfall of volume of 97,000 acre-feet per year for a 4,174 foot restriction.

Literature Cited

Parenthetical Reference	Bibliographic Citation
Cole and Wells 2018	Cole, T. and S. Wells. 2018. *CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 4.1*. Department of Civil and Environmental Engineering, Portland State University, Portland, Oregon.
NOAA Fisheries 2008	National Oceanic and Atmospheric Administration (NOAA) Fisheries. 2008. *Upper Snake Biological Opinion, Consultation for the Operation and Maintenance of 10 Bureau of Reclamation Projects and 2 Related Actions in the Upper Snake River above Brownlee Reservoir*. Department of Commerce, NOAA Fisheries.
Reclamation 2017	Bureau of Reclamation. 2017. *Boise Feasibility Study Preliminary Hydrologic Evaluation Technical Memorandum*. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. February 2017.
Reclamation 2019	Bureau of Reclamation. 2019. *Feasibility Design Report – Anderson Ranch Dam 6-Foot Reservoir Raise*. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. May 2019.
RiverWare® 7.5	University of Colorado. *RiverWare® 7.5*. Published by the Regents of the University of Colorado, 4845 Pearl East Circle, Suite 200, Boulder, Colorado 80301.
RMJOC-II 2018	River Management Joint Operating Committee. 2018. *Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition (RMJOC-II): Part I – Hydroclimate Projections and Analyses*. June 2018. https://www.bpa.gov/p/Generation/Hydro/hydro/cc/RMJOC-II-Report-Part-I.pdf.
SPF 2016	SPF Water Engineering. 2016. *Treasure Valley DCMI Water-Demand Projections (2015-2065)*. Prepared for the Idaho Water Resources Board and Idaho Department of Water Resources. August 2016.
USFWS 2005	U.S. Fish and Wildlife Service. 2005. *Biological Opinion for Bureau of Reclamation Operations and Maintenance in the Snake River Basin Above Brownlee Reservoir*. Department of the Interior, U.S. Fish and Wildlife Service, Snake River Fish and Wildlife Office, Boise, Idaho. March 2005.

This page intentionally left blank.

Appendix A

Analysis Period Sensitivity

The analysis period sensitivity is most notable in the Water Availability Analysis and is shown in Section 5. The information provided in this appendix is additional detail that may provide more context for each Alternative.

A.1 Reservoir Conditions

A comparison of results under two different analysis periods was conducted to better understand the sensitivity of the study results to period selection. As discussed in Section 2.2, increased occurrence of low runoff years, combined with earlier runoff recession, results in increased years with low refill in the 1980 through 2008 period when compared to the 1958 through 2008 period.

A.1.1 Alternative B – 6-foot Raise (Preferred)

Figure A-1 through Figure A-10 depict the daily 10th-, 50th-, and 90th-percentile storage values for the 6-foot Raise Alternative, along with the daily minimum and maximum values. All figures exhibit a trend of lower carryover and lower storage volumes through the winter months in the shorter 1980 through 2008 period compared to the 1958 through 2008 period, but similar peak refill volumes. As in the longer 1958 through 2008 period, 1980 through 2008 operations under the scenarios fall within the historical range. Differences in system storage between this Alternative and No Action are similar in magnitude for both analysis periods. For storage at individual reservoirs, differences between this Alternative and No Action are larger in the longer 50-year period than in the shorter 28-year period.

As shown in Figure A-2, the 1980 through 2008 period shows lower median system carryover volume at the end of the irrigation season compared to the longer 1958 through 2008 period shown in Figure A-1, but the two periods show the system reaching similar median peak fill volumes by the end of June. Differences between the scenarios and the baseline condition are similar in magnitude in both periods.

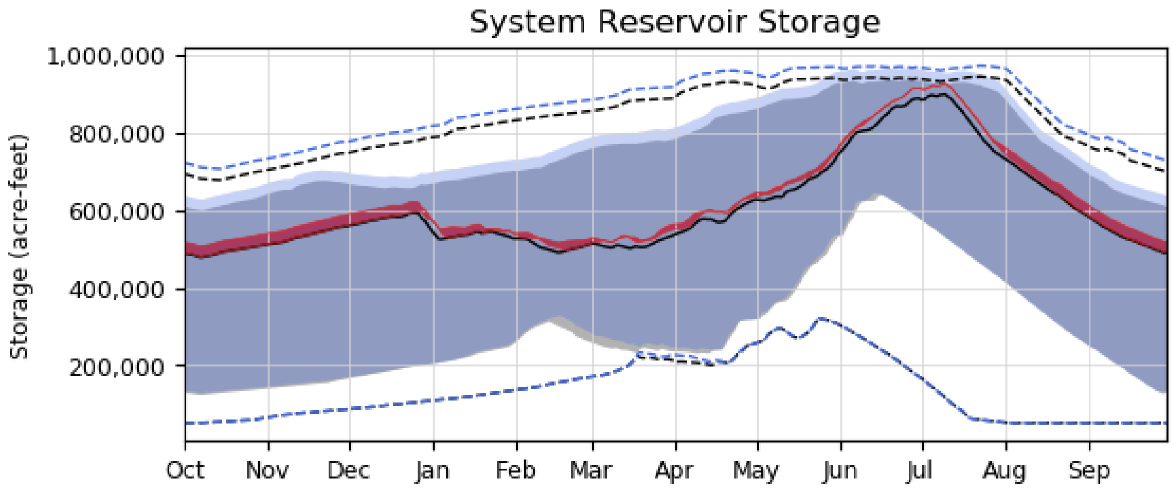

Figure A-1. Boise Reservoir System storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. Storage values do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

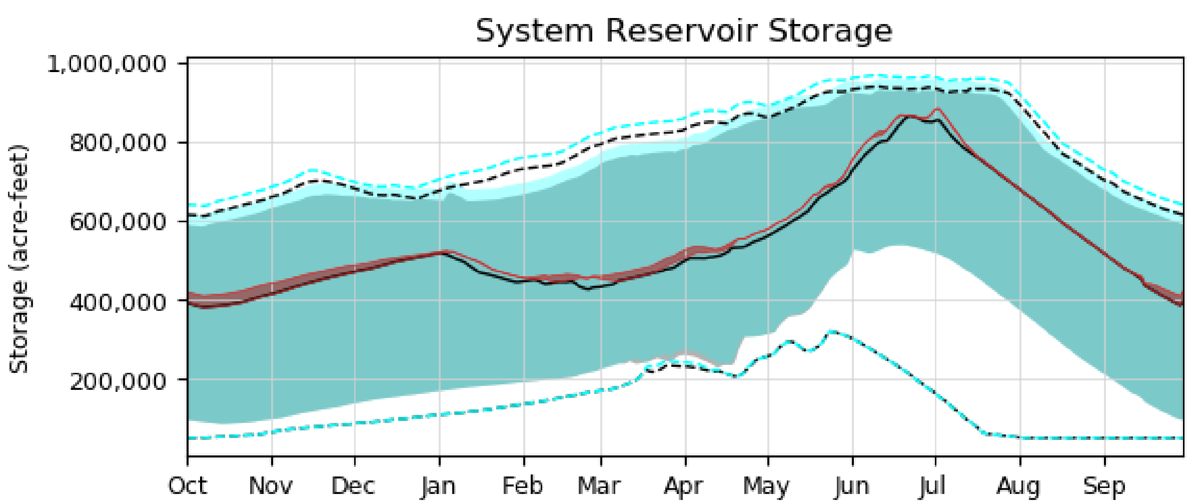

Figure A-2. Boise Reservoir System storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values. Storage values do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

Similar to the differences shown for system storage volume, storage volume at Anderson Ranch Reservoir also exhibits lower carryover conditions, but similar refill potential in both analysis periods (Figure A-4). The 1980 through 2008 period results in conditions where the scenario storage volume range is closer to the baseline condition from the end of the irrigation season through mid-February.

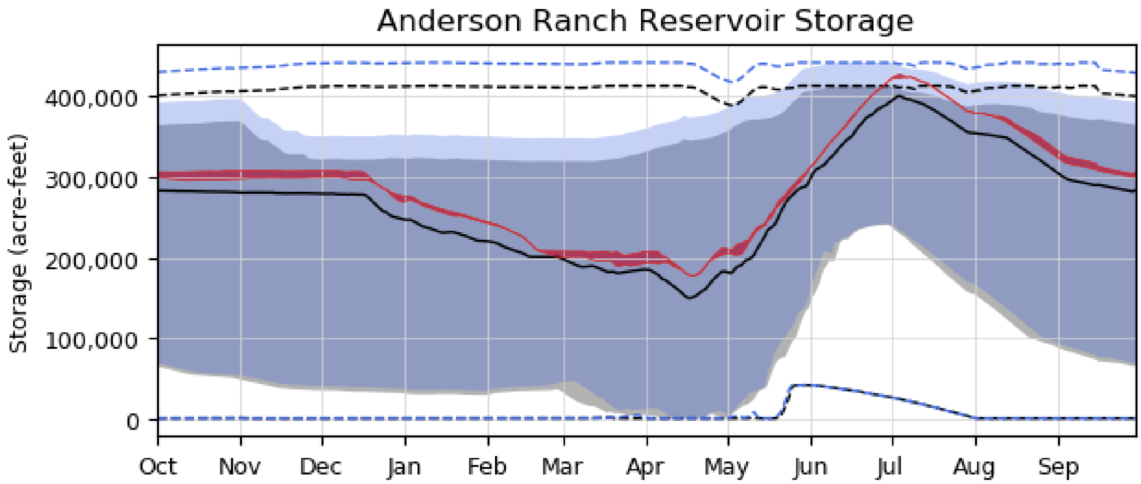

Figure A-3. Anderson Ranch Reservoir storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. Storage values shown do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

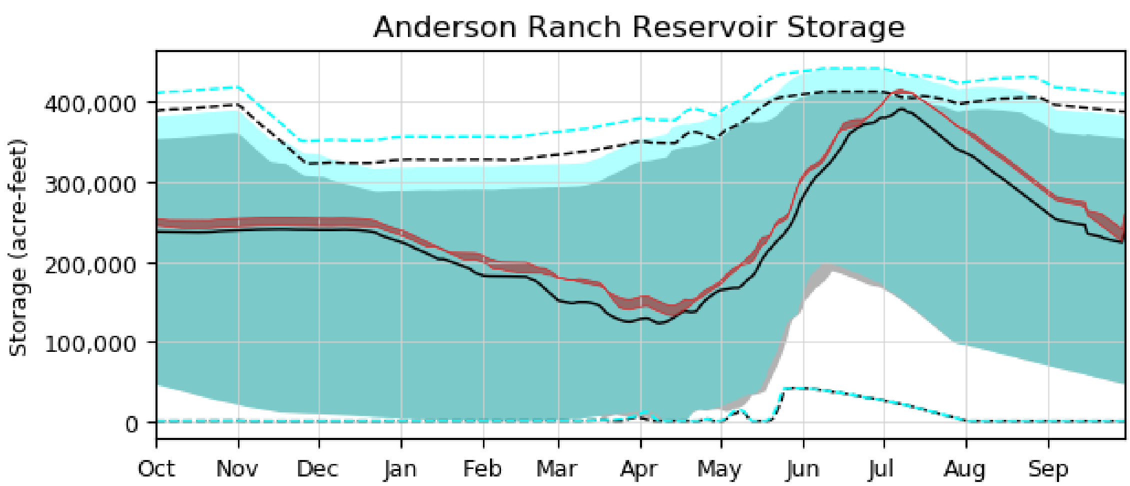

Figure A-4. Anderson Ranch Reservoir storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values. Storage values shown do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

At Arrowrock Reservoir, an increased number of low runoff volume years in the shorter analysis period result in lower storage volumes and pool elevations through the winter compared to the longer analysis period. This is illustrated in Figure A-5 through Figure A-8. In both analysis periods, Arrowrock Reservoir is drawn down more deeply by the end of the irrigation season as it is used to satisfy downstream irrigation demands and to backfill Lucky Peak Reservoir.

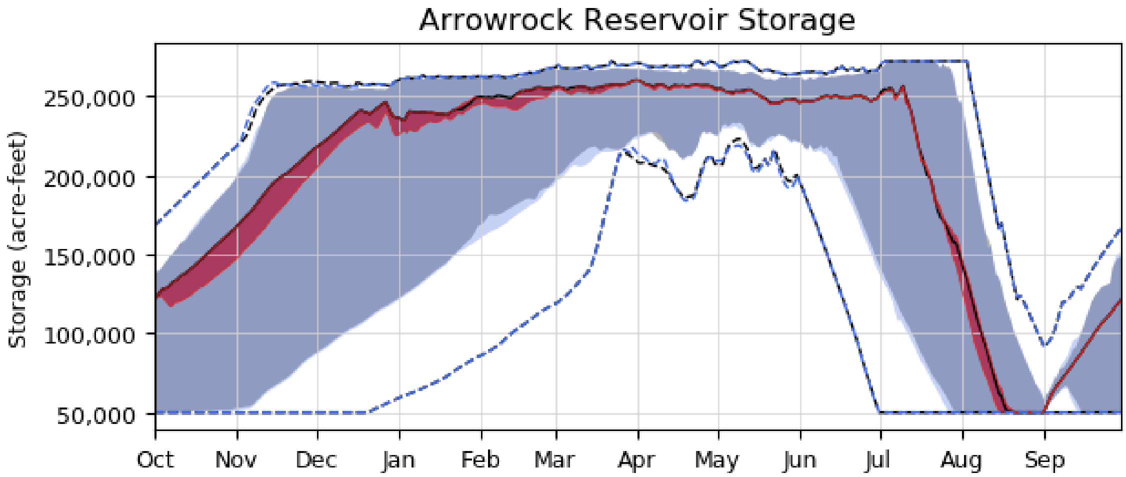

Figure A-5. Arrowrock Reservoir storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values.

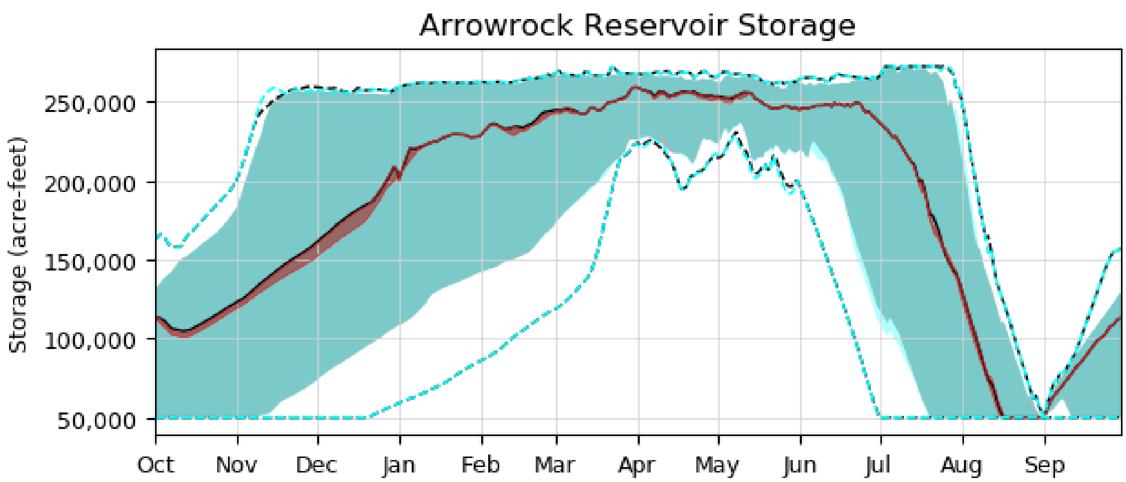

Figure A-6. Arrowrock Reservoir storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values.

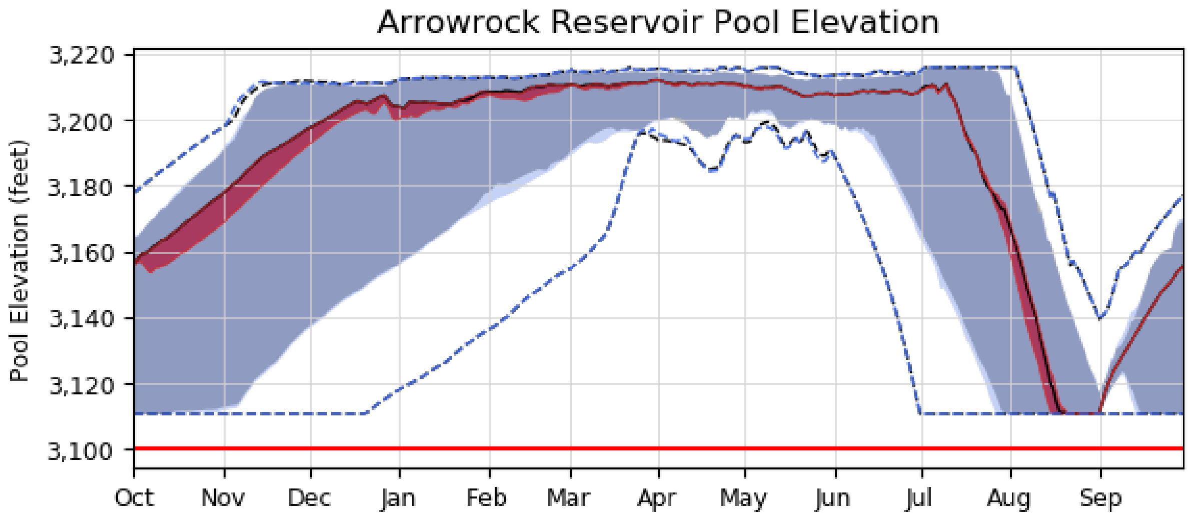

Figure A-7. Arrowrock Reservoir pool elevation for the 50-year analysis period (1958 through 2008). This figure depicts the daily median pool elevation range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. The red line represents the threshold at which pool elevation conditions may adversely impact bull trout migration.

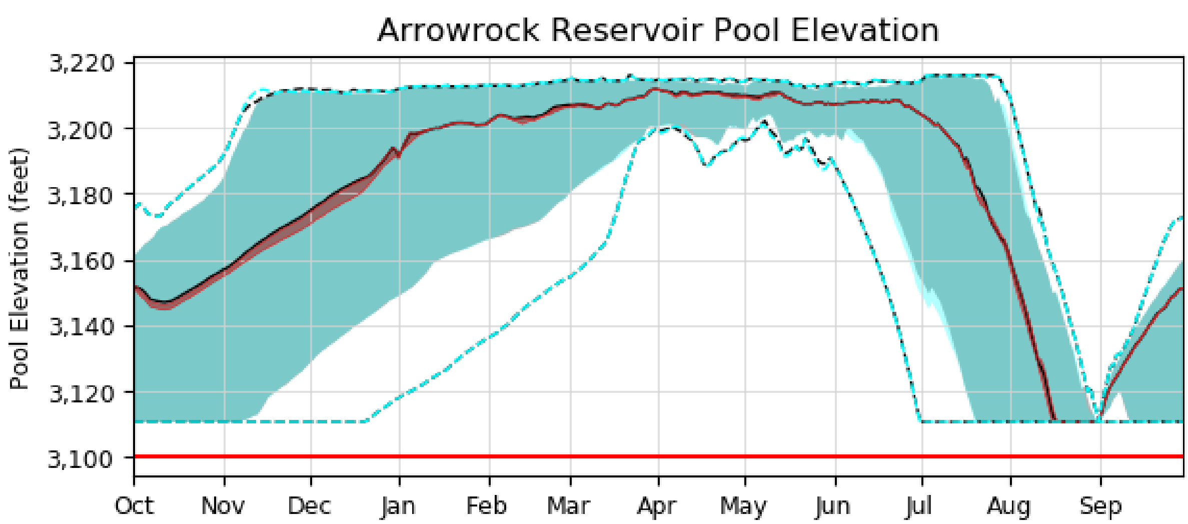

Figure A-8. Arrowrock Reservoir pool elevation for the 28-year analysis period (1980 through 2008). This figure depicts the daily median pool elevation range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values. The red line represents the threshold at which pool elevation conditions may adversely impact bull trout migration.

As shown in Figure A-9 and Figure A-10, Lucky Peak Reservoir storage is similar between both analysis periods, particularly in the 50th-percentile. The increased number of dry years in the shorter analysis period has the effect of reduced 90th-percentile storage during the fall months and reduced 10th-percentile storage during the summer months.

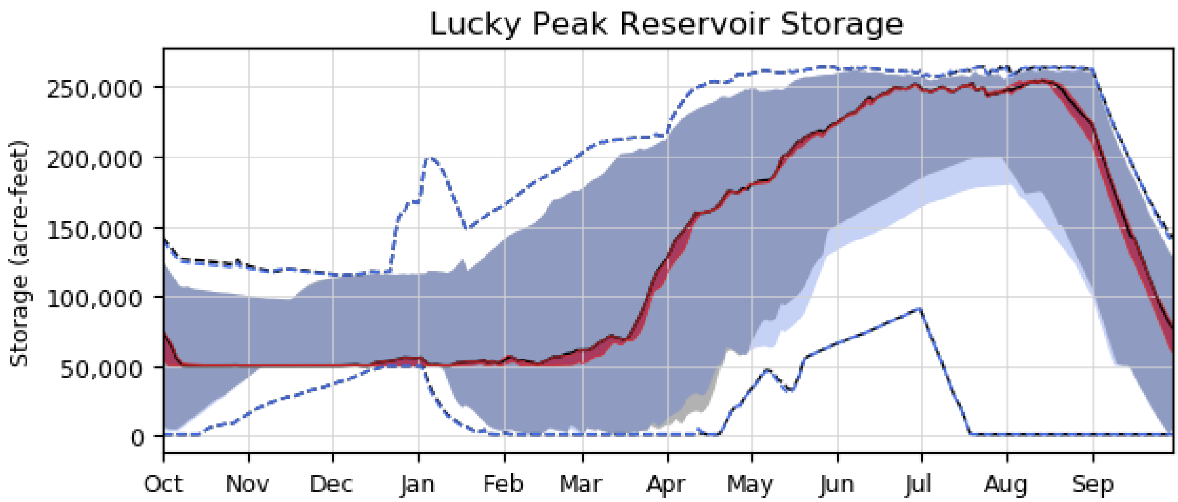

Figure A-9. Lucky Peak Reservoir storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values.

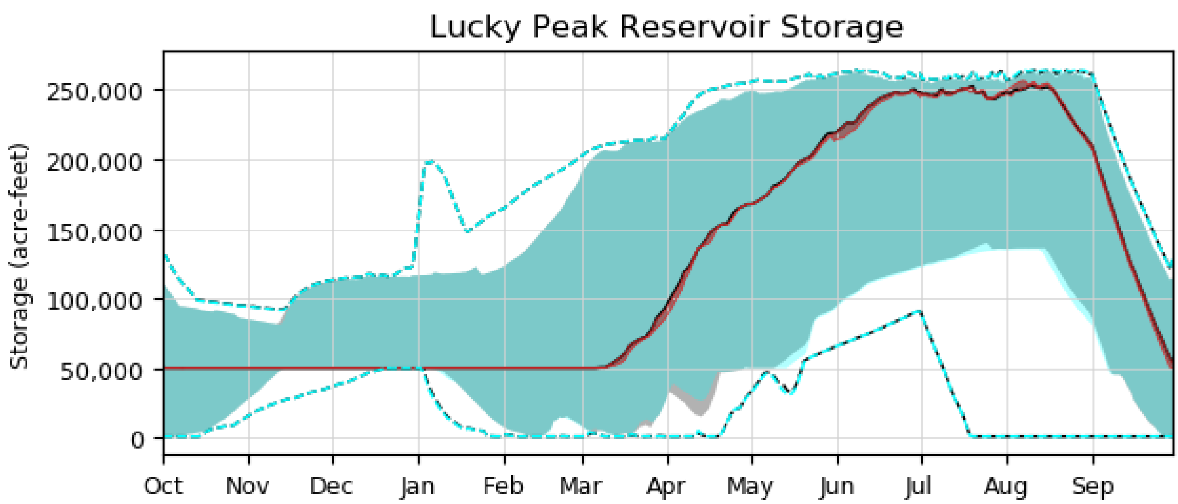

Figure A-10. Lucky Peak Reservoir storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values.

A.1.2 Alternative C – 3-foot Raise

Figure A-11 through Figure A-20 depict the daily 10th-, 50th-, and 90th-percentile storage values for the 3-foot Raise Alternative, along with the daily minimum and maximum values. All figures exhibit a trend of lower carryover and lower storage volumes through the winter months in the shorter 1980 through 2008 period compared to the 1958 through 2008 period, but similar peak refill volumes. As in the longer 1958 through 2008 period, 1980 through 2008 operations under the scenarios fall within the historical range. Differences in system storage between this Alternative and No Action are similar in magnitude for both analysis periods. For storage at individual reservoirs, differences between this Alternative and No Action are larger in the longer 50-year period than in the shorter 28-year period.

As shown in Figure A-12, the 1980 through 2008 period shows lower median system carryover volume at the end of the irrigation season compared to the longer 1958 through 2008 period shown in Figure A-11, but the two periods show the system reaching similar median peak fill volumes by the end of June. Differences between the scenarios and the baseline condition are similar in magnitude in both periods and are generally less than then 6-foot Raise.

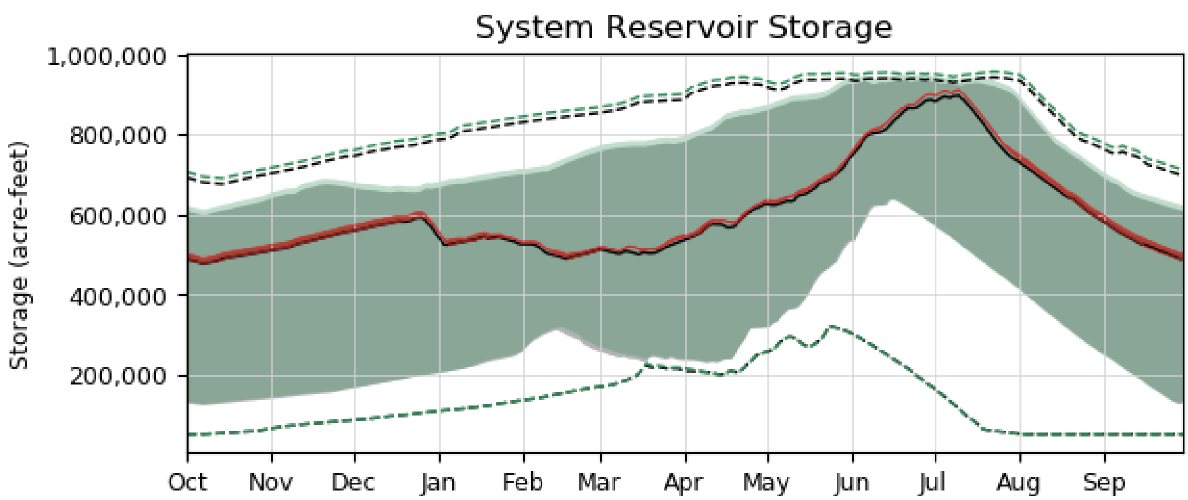

Figure A-11. Boise Reservoir System storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise Alternative (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values. Storage values do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

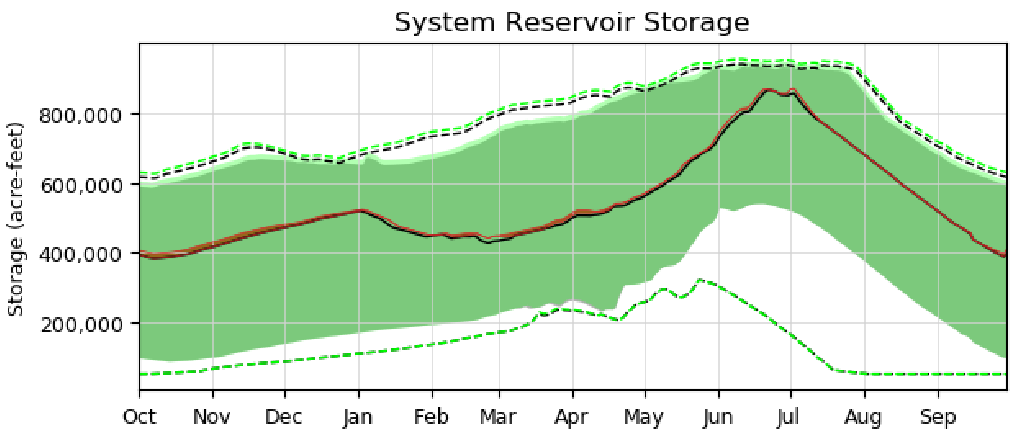

Figure A-12. Boise Reservoir System storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. Storage values do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

Similar to the differences shown for system storage volume, storage volume at Anderson Ranch Reservoir also exhibits lower carryover conditions, but similar refill potential in both analysis periods (Figure A-14). The 1980 through 2008 period results in conditions where the scenario storage volume range is closer to the baseline condition from the end of the irrigation season through mid-February.

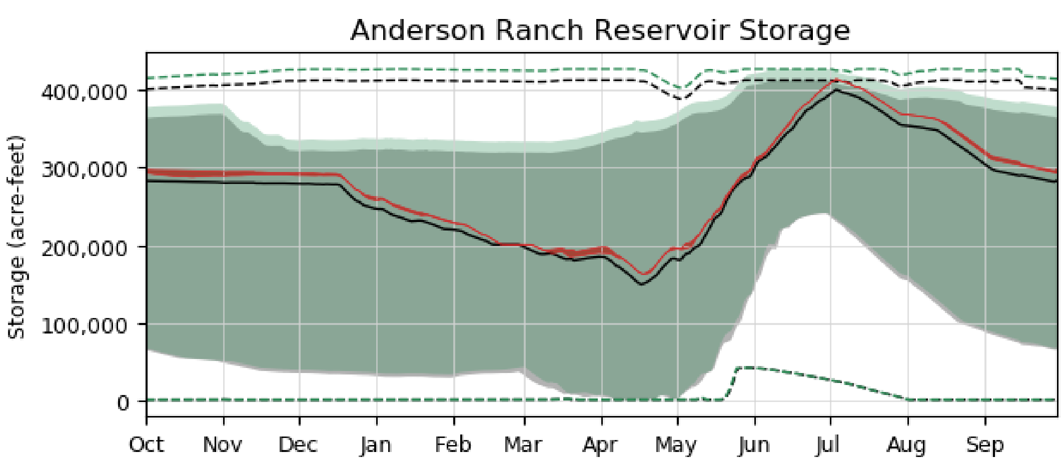

Figure A-13. Anderson Ranch Reservoir storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values. Storage values shown do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

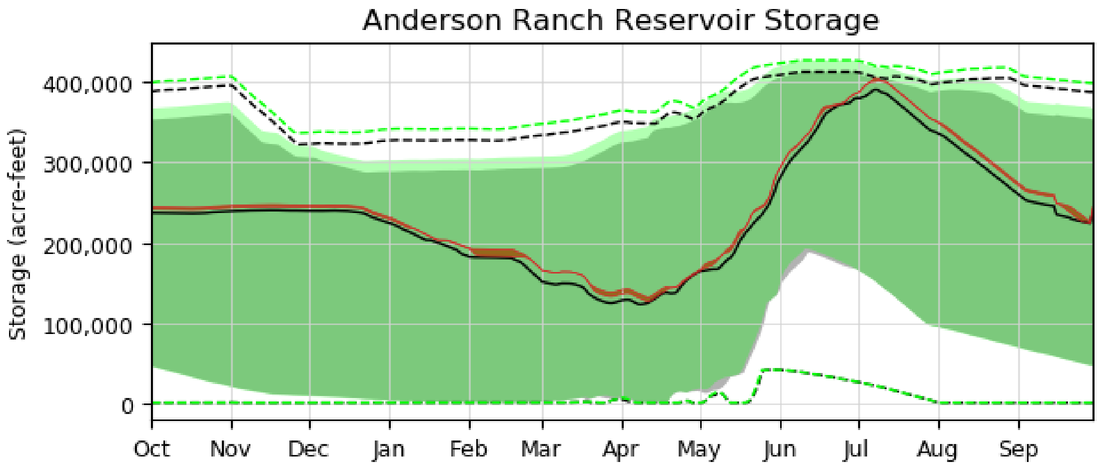

Figure A-14. Anderson Ranch Reservoir storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. Storage values shown do not include 36,956 acre-feet of inactive powerhead space in Anderson Ranch Reservoir.

At Arrowrock Reservoir, an increased number of low runoff volume years in the shorter analysis period result in lower storage volumes and pool elevations through the winter compared to the longer analysis period. This is illustrated in Figure A-15 through Figure A-18. In both analysis periods, Arrowrock Reservoir is drawn down more deeply by the end of the irrigation season as it is used to satisfy downstream irrigation demands and to backfill Lucky Peak Reservoir.

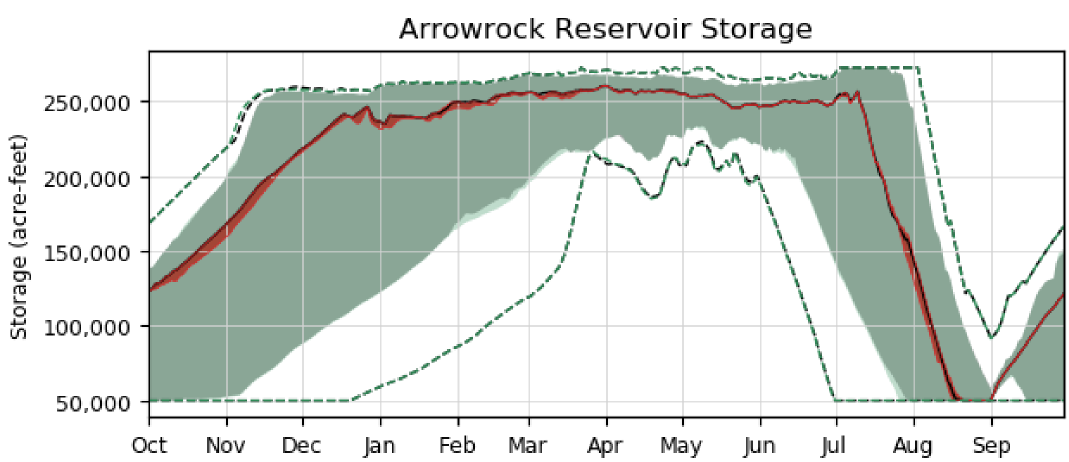

Figure A-15. Arrowrock Reservoir storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values.

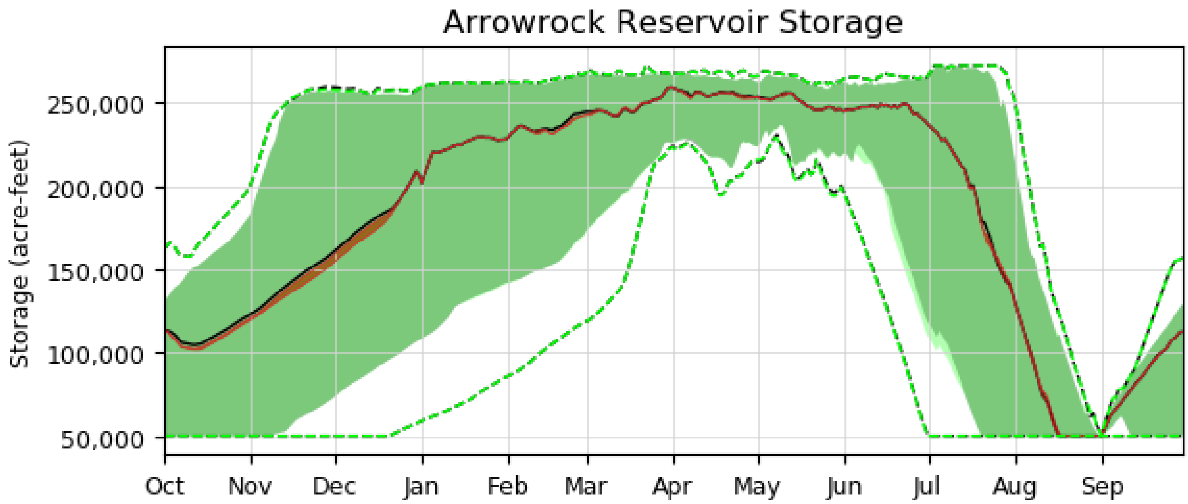

Figure A-16. Arrowrock Reservoir storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values.

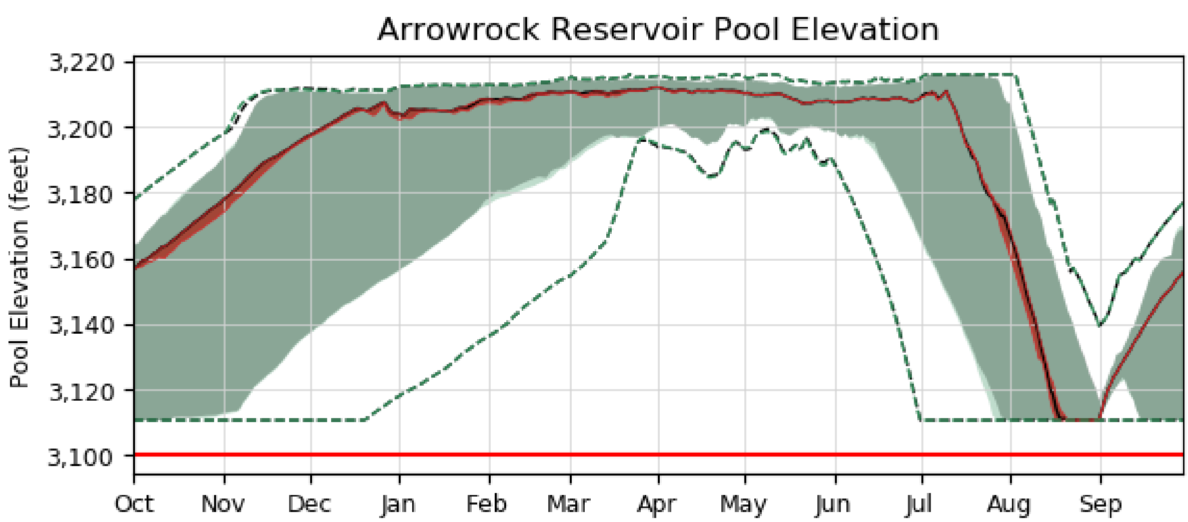

Figure A-17. Arrowrock Reservoir pool elevation for the 50-year analysis period (1958 through 2008). This figure depicts the daily median pool elevation range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values. The red line represents the threshold at which pool elevation conditions may adversely impact bull trout migration.

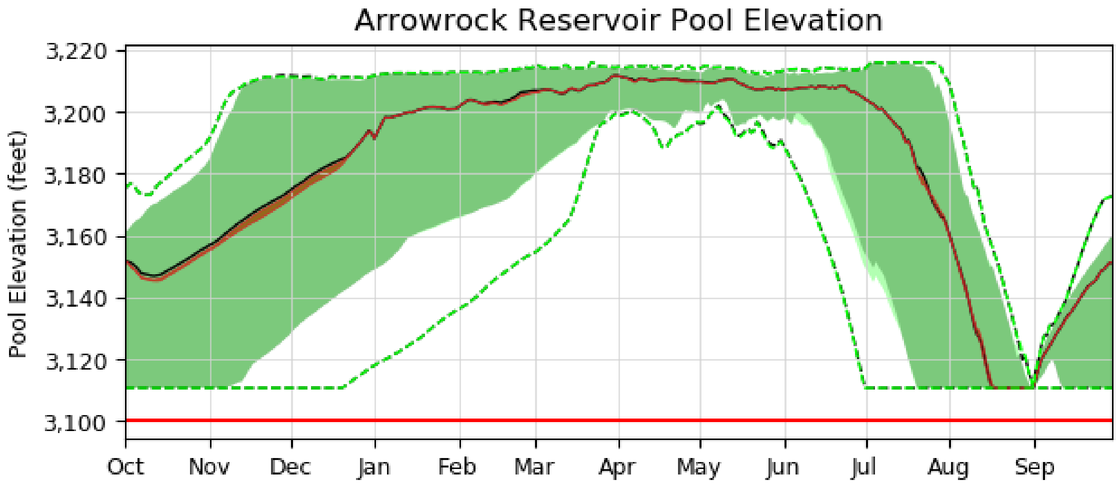

Figure A-18. Arrowrock Reservoir pool elevation for the 28-year analysis period (1980 through 2008). This figure depicts the daily median pool elevation range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. The red line represents the threshold at which pool elevation conditions may adversely impact bull trout migration.

As shown in Figure A-19 and Figure A-20, Lucky Peak Reservoir storage is similar between both analysis periods, particularly in the 50th-percentile. The increased number of dry years in the shorter analysis period has the effect of reduced 90th-percentile storage during the fall months and reduced 10th-percentile storage during the summer months.

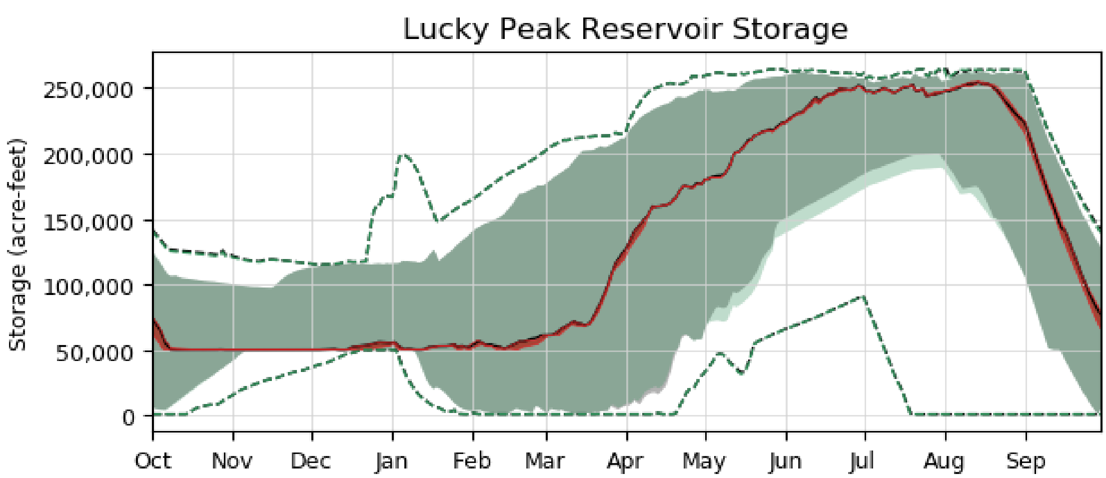

Figure A-19. Lucky Peak Reservoir storage for the 50-year analysis period (1958 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values.

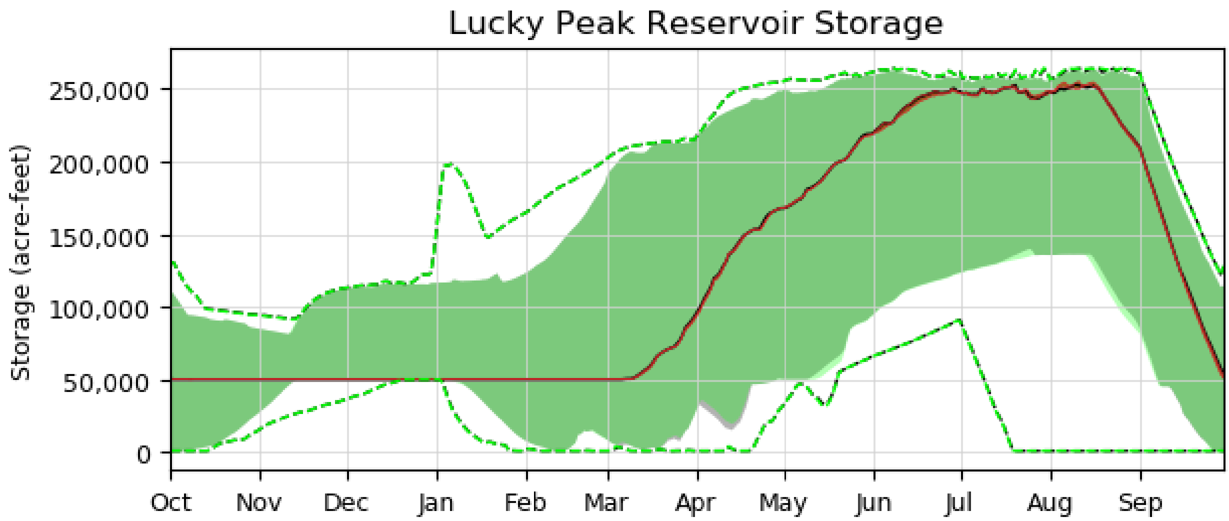

Figure A-20. Lucky Peak Reservoir storage for the 28-year analysis period (1980 through 2008). This figure depicts the daily median storage content range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values.

A.2 Streamflow Conditions

A.2.1 Alternative B – 6-foot Raise (Preferred)

Differences in streamflow between the two periods are shown in Figure A-21 through Figure A-24 for the 6-foot Raise. Streamflow below Anderson Ranch Dam (Figure A-21 and Figure A-22) are similar between both periods, with the largest difference occurring in the spring. During this time of year, the 1980 through 2008 analysis period results in lower 50th-percentile streamflow compared to the 1958 through 2008 analysis period. Both periods show similar differences between this Alternative and No Action.

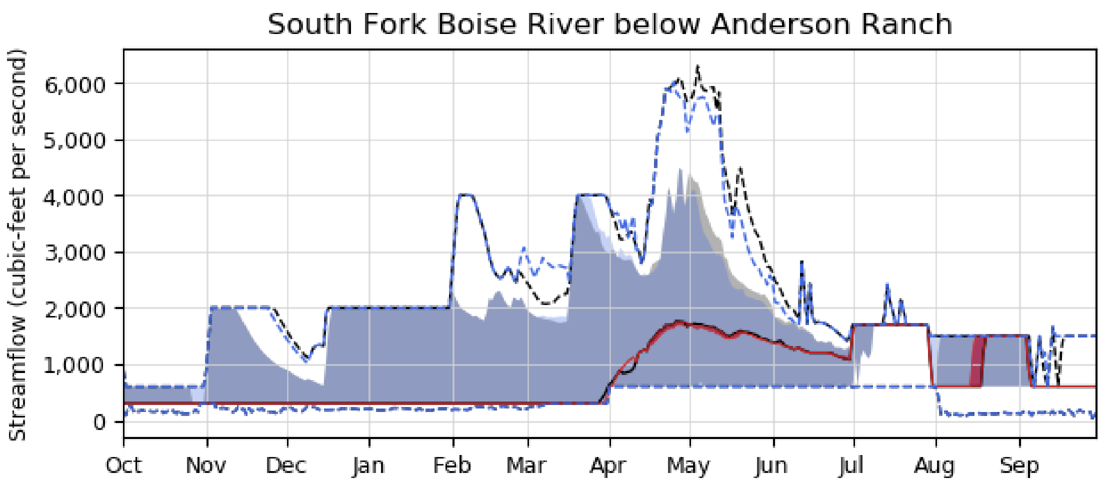

Figure A-21. South Fork Boise River below Anderson Ranch streamflow for the 50-year analysis period (1958 through 2008). This figure depicts the daily median streamflow range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values.

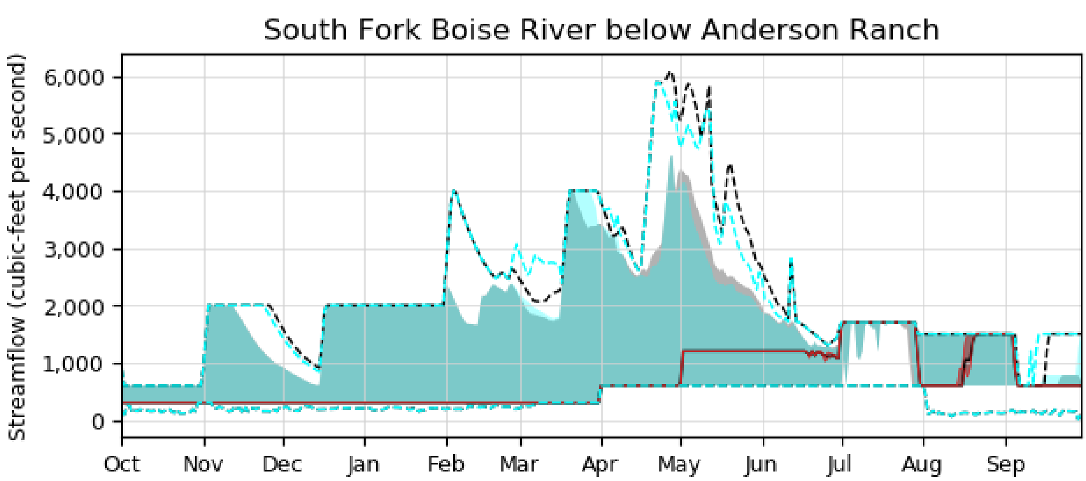

Figure A-22. South Fork Boise River below Anderson Ranch streamflow for the 28-year analysis period (1980 through 2008). This figure depicts the daily median streamflow range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values.

Boise River at Glenwood streamflow shows relatively little difference between the two analysis periods. Summary hydrographs for this location are shown in Figure A-23 and Figure A-24. As shown in these figures, the most notable difference between the two periods is the reduced occurrence of flows over 7,000 cfs and lower median July flows in the shorter 1980 through 2008 period. The increased number of low runoff years in the 1980 through 2008 period creates less need for high flood releases while also creating conditions where storage accounts used for July flow augmentation releases do not fill completely (resulting in lower flows in July).

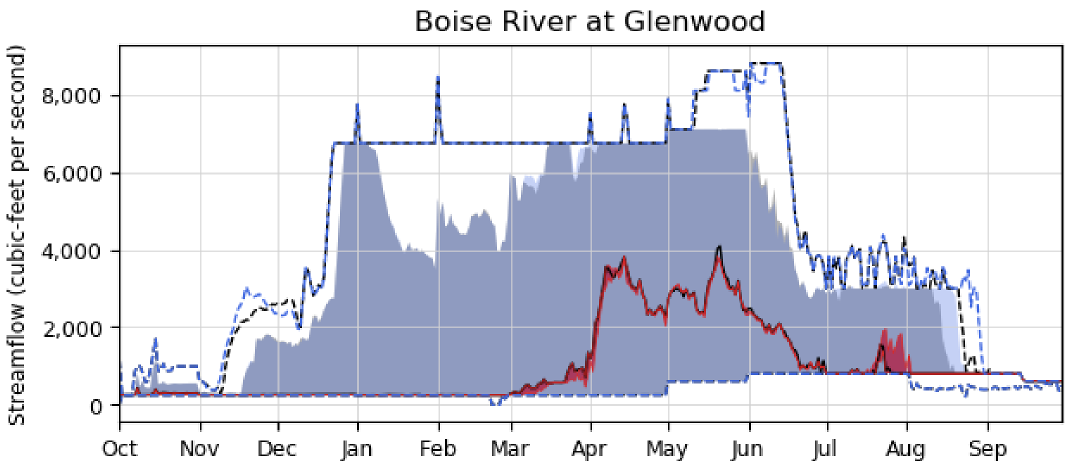

Figure A-23. Boise River at Glenwood streamflow for the 50-year analysis period (1958 through 2008). This figure depicts the daily median streamflow range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded blue region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot Raise and No Action, respectively. Dashed blue and black lines represent the daily minimum and maximum values. The negative values shown in late-February correspond to an anomaly in the gains at Glenwood. The increase in flows in late-July and early-August in this Alternative median condition (red) is associated with the potential for the new storage to be used for additional flow augmentation releases (see note, Page A-16).

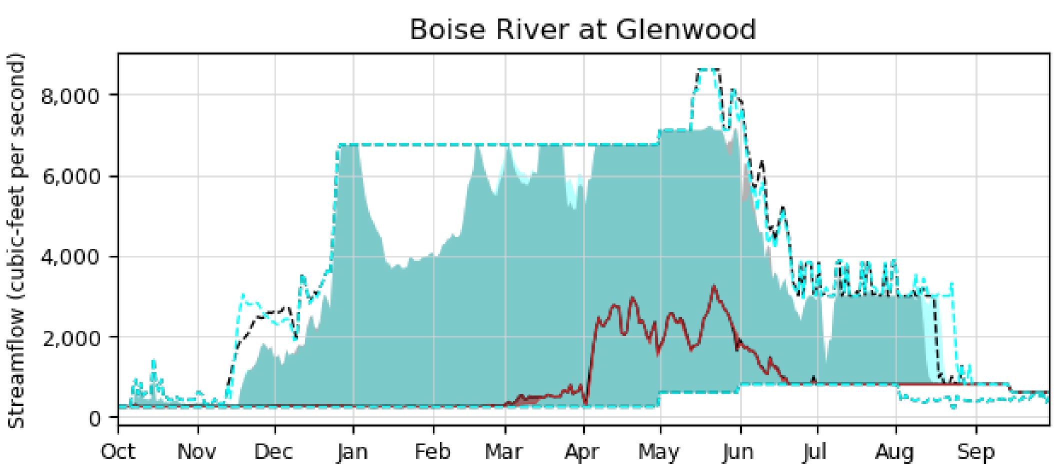

Figure A-24. Boise River at Glenwood for the 28-year analysis period (1980 through 2008). This figure depicts the daily median streamflow range for the 6-foot Raise (red region) and daily median for No Action (black line). The shaded turquoise region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 6-foot and No Action, respectively. Dashed turquoise and black lines represent the daily minimum and maximum values. The February and July anomalies are absent in the shorter time period, likely due to more reliable inflow datasets.

A.2.2 Alternative C – 3-foot Raise

Differences in streamflow between the two periods are shown in Figure A-25 through Figure A-28 for the 3-foot Raise. Streamflow below Anderson Ranch Dam (Figure A-25 and Figure A-26) are similar between both periods, with the largest difference occurring in the spring. During this time of year, the 1980 through 2008 analysis period results in lower 50th-percentile streamflow compared to the 1958 through 2008 analysis period. Both periods show similar differences between this Alternative and No Action.

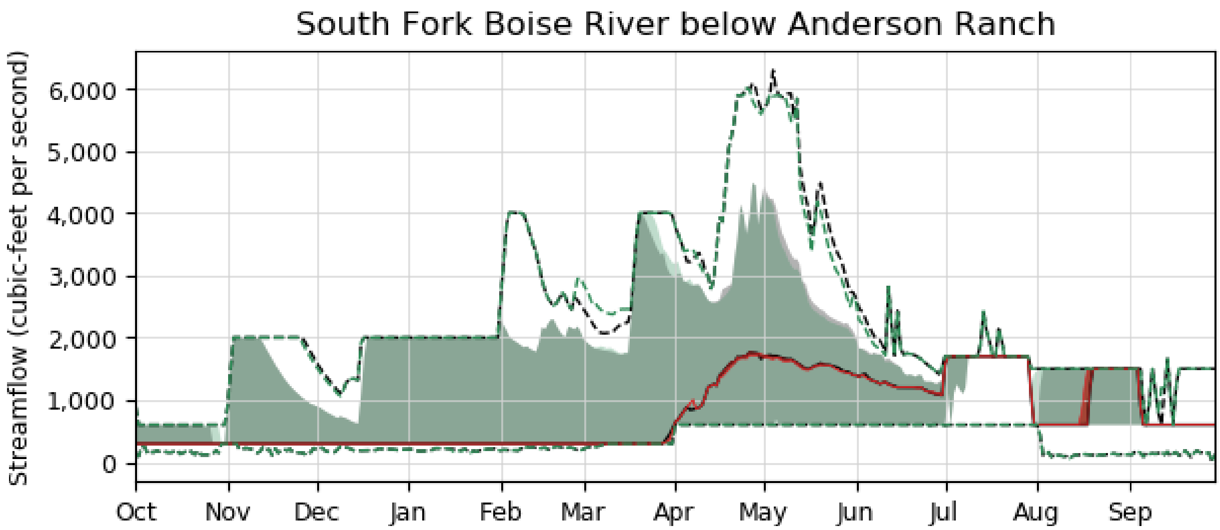

Figure A-25. South Fork Boise River below Anderson Ranch streamflow for the 50-year analysis period (1958 through 2008). This figure depicts the daily median streamflow range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values.

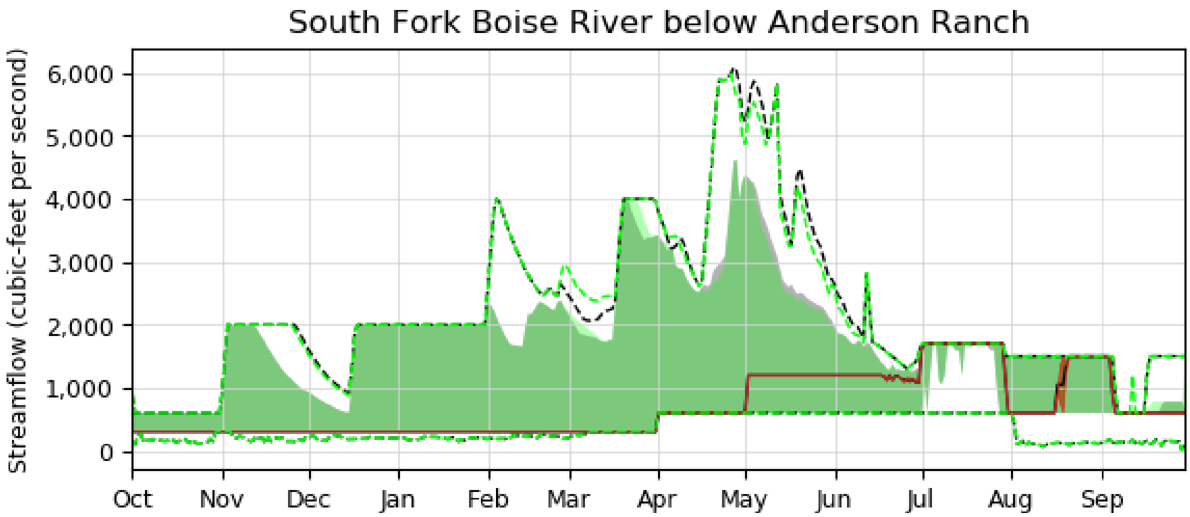

Figure A-26. South Fork Boise River below Anderson Ranch streamflow for the 28-year analysis period (1980 through 2008). This figure depicts the daily median streamflow range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10^{th}-percentile to 90^{th}-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values.

Boise River at Glenwood streamflow shows relatively little difference between the two analysis periods. Summary hydrographs for this location are shown in Figure A-27 and Figure A-28. As shown in these figures, the most notable difference between the two periods is the reduced occurrence of flows over 7,000 cfs and lower median July flows in the shorter 1980 through 2008 period. The increased number of low runoff years in the 1980 through 2008 period creates less need for high flood releases while also creating conditions where storage accounts used for July flow augmentation releases do not fill completely (resulting in lower flows in July).

Note: Since it is unknown at this time how the new storage will be allocated, four demand patterns were explored as a sensitivity analysis of how the new water could be used. The sensitivity analysis presented here in Appendix A was conducted per initial consideration of using the reserved space for flow augmentation. It was subsequently concluded that the reserved space was not to include flow augmentation as a federal purpose in this Study. This conclusion was developed in coordination with the Solicitor's Office, consistent with the goal of ensuring that a federal decision does not negatively affect an established federal action or decision. While the text of the Technical Memorandum reflects the results of that coordination, schedules did not allow for the Appendix A sensitivity analysis to be re-run. It is likely the results of a refined sensitivity analysis would not be significantly different from those for the existing sensitivity analysis.

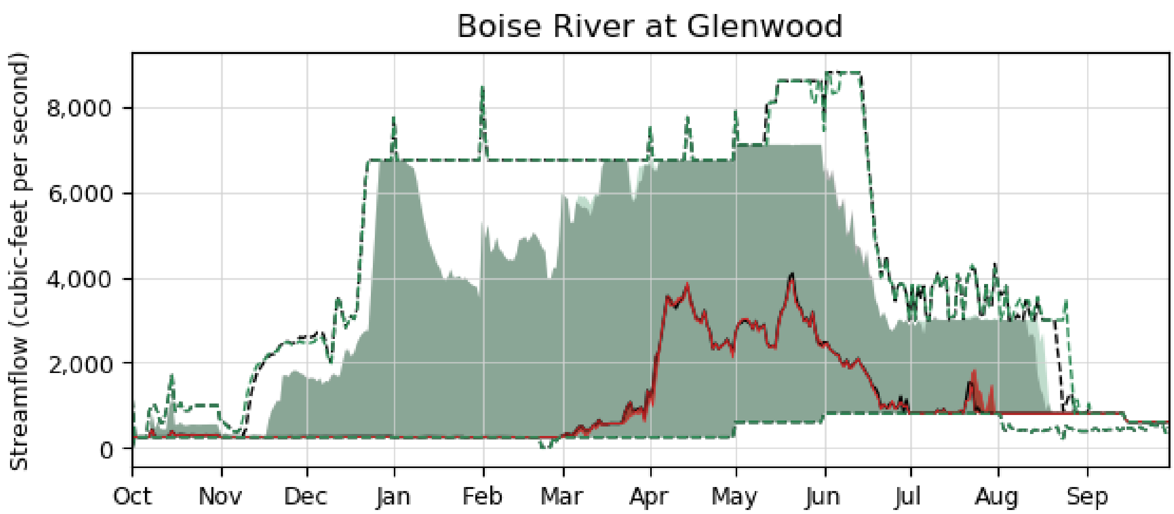

Figure A-27. Boise River at Glenwood streamflow for the 50-year analysis period (1958 through 2008). This figure depicts the daily median streamflow range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green-gray region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green-gray and black lines represent the daily minimum and maximum values. The negative values shown in late-February correspond to an anomaly in the gains at Glenwood. The increase in flows in late-July and early-August in the 3-foot Raise median condition (red) is associated with the potential for the new storage to be used for additional flow augmentation releases (see note, Page A-16).

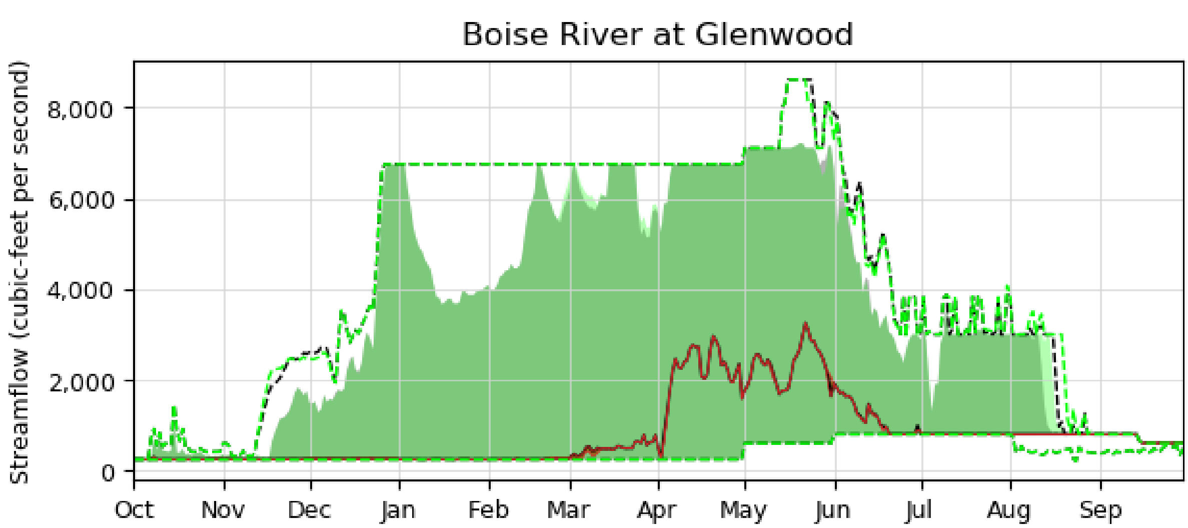

Figure A-28. Boise River at Glenwood for the 28-year analysis period (1980 through 2008). This figure depicts the daily median streamflow range for the 3-foot Raise (red region) and daily median for No Action (black line). The shaded green region and shaded gray region represent the 10th-percentile to 90th-percentile range captured by the 3-foot Raise and No Action, respectively. Dashed green and black lines represent the daily minimum and maximum values. The February and July anomalies are absent in the shorter time period, likely due to more reliable inflow datasets.