BUREAU OF RECLAMATION

Boise River Basin Feasibility Study

Specialist Report: Climate Variability

Boise Project, Idaho

Interior Region 9: Columbia Pacific Northwest

U.S. Department of the Interior

May 2020

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Mission Statements

The Department of the Interior (DOI) 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.

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Acronyms and Abbreviations

Acronym or Abbreviation	Meaning
BCSD	bias corrected spatial disaggregation
CEQ	Council on Environmental Quality
CMIP5	Coupled Model Intercomparison Project 5
EO	Executive Order
GCM	general circulation model
GHCN	Global Historical Climatology Network
MACA	multivariate adaptive constructed analog
RCP	representative concentration pathways
Reclamation	Bureau of Reclamation
RMJOC	River Management Joint Operating Committee
RMJOC-II	Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition
SWE	snow water equivalent
VIC	variable infiltration capacity
WRCC	Western Regional Climate Center
WY	water year

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1. Introduction

The Boise River Basin Feasibility Study is a feasibility study to evaluate increasing water storage opportunities within the Boise River basin by expanding Anderson Ranch Reservoir. The project is located at Anderson Ranch dam and reservoir, the farthest upstream of the three reservoirs within the Boise River system and located 28 miles northeast of the city of Mountain Home in Elmore County, Idaho. Anderson Ranch Dam is a zoned earth fill embankment structure that provides irrigation water, flood control, power generation, and recreation benefits. The reservoir also provides a permanent dead storage pool for silt control and the preservation and propagation of fish and wildlife. Anderson Ranch Dam is operated by the Bureau of Reclamation (Reclamation). Reclamation, in partnership with the Idaho Water Resource Board (IWRB), proposes to raise Anderson Ranch Dam. New water storage would provide the flexibility to capture additional water when available, for later delivery when and where it is needed to meet existing and future demands. The alternatives analyzed in this document include the No-Action Alternative (Alternative A), a 6-foot raise of Anderson Ranch Dam (Alternative B), and a 3-foot raise of Anderson Ranch Dam (Alternative C).

Alternative A provides a basis for comparison with the two action alternatives, Alternative B and Alternative C. Under Alternative A, current baseline conditions would continue, without increasing Anderson Ranch Dam height or constructing associated reservoir rim projects, access roads, or facilities. The expected project duration of Alternative B is approximately 51 months and Alternative C is 44 months. Reclamation would continue existing operations of Anderson Ranch Dam. Alternative B proposes to raise the dam by 6 feet from the present elevation of 4196 feet to 4202 feet to capture and store approximately 29,000 additional acre-feet of water. Alternative B would inundate an estimated 146 acres of additional land around the reservoir above the current full pool elevation of 4196 feet. Alternative C proposes to raise the dam by 3 feet to 4199 feet, allowing for the ability to capture and store approximately 14,400 additional acre-feet of water. Alternative C would inundate an estimated 73 acres of additional land around the reservoir above the current full pool elevation of 4196 feet.

Each of the two action alternatives, Alternative B and Alternative C, includes two separate, but similar, structural construction methods for the dam raise, downstream embankment raise, or mechanically stabilized earth wall raise. Otherwise, the only difference is the dam raise elevations of 6 feet for Alternative B and 3 feet for Alternative C. Project areas and construction durations for each method are nearly identical, except for a 200-foot difference in approach road length at the right abutment and an approximate 1-month difference in construction duration. The longer road length is within the dam footprint on previously disturbed ground. Because these differences are negligible, they are not differentiated within the analysis of each alternative. Alternative analysis assumes the longer road length and construction duration, however, a final construction method will be chosen during later phases of engineering evaluation.

Chapter 1 and Chapter 2 of the Boise River Basin Feasibility Study Environmental Impact Statement (EIS) provide a detailed description of the proposed action, project's purpose and need, project area, and alternatives including design features applicable to the action alternatives. This specialist report supports the analysis of expected impacts on Climate Variability as described in the EIS.

1.1 Regulatory Framework

The regulatory framework associated with the climate variability resources is briefly summarized here. In general, federal and state regulatory agencies provide guidance on analyzing and quantifying environmental impacts to specific resource categories. However, no current federal and state laws or regulations exist relative to climate variability or climate change as a resource category within the environmental impact context.

However, draft federal guidance does exist. Specifically, the Council on Environmental Quality (CEQ) *Draft National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions* (CEQ, 2019). This guidance has not been finalized, and it is not currently a rule or regulation. The draft guidance focuses primarily on greenhouse gas emissions, which are outside the scope of the climate variability resource analysis. The guidance does state that "when relevant, agencies should consider whether the proposed action would be affected by foreseeable changes to the affected environment under a reasonable scenario" (CEQ, 2019).

Multiple federal Executive Orders (EOs) with instructions related to climate variability and greenhouse gas emissions have been revoked, including the following.

- EO 13514, revoked by EO 13693 on March 19, 2015
- EO 13653, revoked by EO 13783 on March 28, 2017
- EO 13690, revoked by Section 6 of EO 13807 on August 15, 2017
- CEQ *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews*, dated August 1, 2016, and withdrawn on April 5, 2017.

Based on available information, no relevant state or local regulations exist relative to climate variability or climate change. The described impacts on the project from climate change recognize that future climate scenarios may impact project construction and operation. Impact criteria associated with climate variability are not defined in the regulatory framework.

2. Affected Environment

This Climate Variability Specialist Report describes the affected environment related to climate variability for the proposed alternatives under the Boise River Basin Feasibility Study. The study area for climate variability analyzed for all Alternatives includes the project area as defined in Chapter 2 of the EIS.

Climate variability is defined as variations in the mean state and other statistics of describing climate on all temporal and spatial scales, beyond individual weather events. The term "climate variability" is often used to denote deviations of climate statistics over a given period when compared to long-term statistics for the same calendar period. Variations may be due to natural or anthropogenic external factors.

Climate variability presents challenges to water management, reservoir management, infrastructure construction, long-term infrastructure operations, and infrastructure maintenance. Historical trends and future climate projections show increasing temperatures, changes in seasonal precipitation patterns and runoff, and the resulting effects on the overall water cycle.

An understanding of site-specific historical climate and future climate projections is an important factor in a project's overall environmental impact. Climate variability can exacerbate or alleviate environmental impacts to other resources, and climate variability can impact the overall construction and operation of a project.

The National Environmental Policy Act-affected environment is the natural, social, and economic environments that might be affected by the proposed action or other alternatives. However, climate variability is unique in that the impact is assessed as both an effect of the action on the resource (the traditional NEPA approach) as well as the effect of the resource (climate variability) on the action. In this case, the overall environmental impact of the action on climate variability is a consequence of both the action itself and the environmental conditions where the project is located. Therefore, the extent that climate variability may influence the baseline as well as projected future conditions should factor into the environmental review process. This assessment incorporates conditions in a projected future climate as relative to conditions in a baseline (existing) climate and describes how the severity of this potential change can impact the proposed action.

This assessment describes the impacts of climate variability on the natural resources, ecosystems, and human environment that could be affected by the action. Also addressed is the potential impact of climate variability on the action itself.

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3. Environmental Consequences

3.1 Methods for Evaluating Impacts

Characterization of baseline (existing) and projected future climate variability for the Anderson Ranch Reservoir area and upstream Anderson Ranch Reservoir watershed was completed using the following methods.

3.1.1 Characterization of Baseline (Existing) Climate Variability

Baseline (existing) climate was characterized using the historical measured data at Anderson Ranch Dam. Because many data records from the Global Historical Climatology Network (GHCN, 2019) Anderson Dam station (network ID USC00100282) were unavailable, the statistical climate summary from Western Regional Climate Center (WRCC, 2019) was used instead. Note that even with the more complete WRCC (2019) record, many records are missing. Analysis was performed using available data. For example, annual precipitation analysis uses only 37 years between 1942 and 1997. While some precipitation data exist beyond 1997, too many days are missing for accurate annual precipitation analysis. The WRCC record includes some data from the GHCN network, and it also fills in missing GHCN data from other climate data networks. The following analyses were performed (wind data are not available at this location).

- Characterization of historical temperature (seasonal, minimum, maximum)
- Characterization of historical precipitation
    - Annual average, seasonal, extreme events, wet years, dry years

In addition, a high-level characterization of the climate over the basin draining to Anderson Ranch Reservoir was summarized using 30-year normals from the PRISM Climate Group (2019). This characterization included analysis of monthly patterns of 1981 to 2010 normals for minimum temperature, maximum temperature, and precipitation averaged over the basin.

3.1.2 Characterization of Future Climate Variability

Projected future climate variability was analyzed and characterized and included the following.

- Future climate variability of annual, seasonal, and monthly average temperature, precipitation, and snow water equivalent (SWE) was projected for the Anderson Ranch Reservoir watershed. Characterization of future climate variability of annual, seasonal, and monthly average temperature and precipitation used projected future climate as represented by Coupled Model Intercomparison Project 5 (also called CMIP5) downscaled Climate and Hydrology Datasets for River Management Joint Operating Committee [RMJOC] Long-Term Planning Studies: Second Edition (RMJOC-II) gridded datasets (Bonneville Power Administration, U.S. Army Corps of

Engineers, Bureau of Reclamation [BPA et al.], 2018). Characterization of future climate focused on the modeled change between modeled baseline and modeled future (as opposed to absolute future climate values).

- Characterization of future climate variability for average temperature, precipitation, and snow water equivalent for future simulations was based on two climate model projections selected Reclamation for the Boise River (Reclamation, 2020), representing two representative concentration pathways (RCPs): RCP 4.5 and RCP 8.5. The subset of the two climate model projections was selected from 172 projections developed for the Columbia River Basin (BPA et al., 2018). The subset of the two climate model projections from 172 projections was selected by Reclamation based on criteria specific to the South Fork Boise River basin for water resource modeling. [Projected changes in future climate contain significant uncertainties. Uncertainties exist with respect to understanding and modeling of the earth systems, future development and RCPs, and to simulating changes at the local scale. Individual climate models are subject to uncertainties and anomalous results for specific points in space or time. To overcome this, many future climate analyses use an ensemble method, where results from multiple climate models are aggregated. By aggregating from multiple models, anomalous results are typically excluded, and uncertainty is quantified and communicated. The two model simulations used for this analysis were selected from the 172 RMJOC-II climate model projections (consisting of RCP 4.5 and RCP 8.5 projections) using the objective subset selection method described in BPA et al. (2018). Future climate results shown in this analysis may be subject to unique configuration of the underlying discrete climate models.] The following 2060s climate change scenarios were selected by Reclamation to capture the 10th- and 90th-percentile changes in future water year volumes and winter/spring volume ratios. These two metrics were identified as being important to water supply and the Boise reservoir system operations (Reclamation, 2020).
- Projected seasonal changes to stream flows at the South Fork Boise River at Anderson Ranch Dam are based on stream flows developed using the variable infiltration capacity (VIC) hydrologic model driven by bias corrected spatial disaggregation (BCSD) and multivariate adaptive constructed analog (MACA) downscaled climate projections and routed to the South Fork Boise River at Anderson Ranch Dam (Table 1). BCSD downscaling approach is a quantile mapping technique operated on a monthly and location-specific basis (Wood et al., 2002). The MACA downscaling method uses a catalog of past meteorological sequences and looks for weather pattern commonality in the general circulation model (GCM) outputs themselves (Abatzoglou and Brown, 2012). Projected changes to flows at the South Fork Boise River are based on the two climate model projections selected by Reclamation based on criteria specific to the South Fork Boise River basin.
- The VIC model (Liang et al., 1994; Liang et al., 1996) is a spatially distributed hydrologic model that simulates land surface-atmosphere exchanges of moisture and energy at each model grid cell. The VIC model incorporates spatially distributed parameters describing topography, soils, land use, and vegetation classes. The model accepts input meteorological data directly from global or national gridded databases

or from GCM projections. To compensate for the coarseness of the discretization VIC incorporates subgrid variability to describe variations in the land parameters as well as precipitation distribution.

- Because watershed spatially averaged precipitation, temperature, and SWE projections were not available in the BPA et al. (2019) dataset, BCSD data from Reclamation (2013; 2014a; 2014b) were used for this analysis. This dataset was prepared by Reclamation and other partners.

Table 1. Climate Change Scenarios, Models, Emissions Scenarios, Downscaling Methods and Hydrologic Models Selected by Reclamation

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

3.1.3 Assumptions

The climate variability resource projects future changes to annual, seasonal, and monthly climate. It does not quantify changes to probable maximum storm or probable maximum flood, nor does it assess impacts of climate variability on spillway sizing or reservoir operations. While included in some of the modeling (such as VIC modeling), the climate variability resource analysis does not specifically quantify changes in evaporation from a larger lake surface area, more water for irrigation, and more transpiration from the crops.

Routed stream flows, associated downscaled precipitation and temperature data, and modeled stream flows were obtained from RMJOC-II (BPA et al., 2019). These are based on two climate model projections selected from 172 projections developed for the Columbia River Basin (BPA et al., 2018). The subset of the 172 projections was selected by Reclamation based on criteria specific to the South Fork Boise River basin.

The climate variability resource does not include atmospheric drivers to increased climate variability, such as changes to greenhouse gas emissions caused by the project. Greenhouse gas emissions associated with the project are described in the Air Quality Specialist Report (Appendix B). The climate variability resource does not assess water quality or sedimentation.

The climate variability resource projects future changes to catchment hydrology, but it does not assess baseline hydrology. Baseline hydrology and water operations is included in the No Action Alternative discussion in Chapter 2 of the EIS.

3.1.4 Impact Indicators and Significance Criteria

Within the context of the climate variability resource, *impacts* refers to the impact of climate variability on the project *as well as* exacerbation of project impacts on other resources due to climate variability. The following criteria were used to determine whether an impact would qualify as a significant impact:

- Projected future climate variability makes the project inoperable. Significance of impact is not a discrete value, rather it is relative to the baseline climate condition.
- Projected future climate variability, such as changes to timing and magnitude of reservoir inflows, reduce the effectiveness of the project. Significance of impact is not a discrete value, rather it is relative to the baseline climate condition.
- Projected future climate variability exacerbate project impacts on other resources such that the impact severity changes from one intensity category to another (for example, impact on biological resources is increased from minor to moderate, or from moderate to major impact).

In coordination with the water operations and hydrology resources, impact indicators of the climate variability on hydrology were analyzed, including summary plots of inflows to Anderson Ranch Reservoir based on historical and future climate projections (Table 2). Impacts of climate variability on the project and on resources other than water operations and hydrology were qualitatively described.

Table 2. Impact Indicators and Significance Criteria

Impact Indicators	Significance Criteria
Project becomes inoperable	Relative to baseline climate
Reduced project effectiveness	Relative to baseline climate
Other resource impacts exacerbated	Other resource impact intensity category changes

3.2 Direct, Indirect, and Cumulative Impacts

3.2.1 Alternative A – No Action

In the No-Action Alterative, projected future climate variability may increase (high scenario) or decrease (low scenario). This will impact the timing and volume of flows entering Anderson Ranch Reservoir. Associated impacts on downstream hydrology incorporating current reservoir operations under baseline and future climate conditions are described in Reclamation (2020).

The following discussion summarizes baseline and future climate characterization. This discussion applies to Alternative B and Alternative C, in addition to Alternative A.

3.2.1.1 Baseline Climate Characterization - Anderson Ranch Dam Station

Historical climate at Anderson Ranch Dam is summarized in Figure 1 through Figure 13. This analysis is based on observed climate at Anderson Ranch Dam, station 100282 (WRCC

(2019) station 100282 is named “Anderson Dam,” but is referred to in this document as “Anderson Ranch Dam” for consistency with the rest of the document), as recorded and summarized by WRCC (WRCC, 2019). The Anderson Ranch Dam station record starts in 1942 and ends in 2017, but data are missing. The precipitation record since 2000 is incomplete, and temperature records between 1983 and 2006 are incomplete. The following analysis is based on months with no more than 5 days of missing data and on years where all months have no more than 5 missing days.

Minimum Temperature

Average monthly minimum temperatures at Anderson Ranch Dam range from 19°F in January to 56°F in July (Figure 1). The historical highest monthly minimum temperature in the winter is 30°F, indicating that even the warmest years drop below freezing in the winter. Extreme low minimum temperatures drop below 0°F, with a record low of -21°F on January 4, 1966 (Figure 2). Winter months have the largest range of extreme minimum temperature variability (Figure 3).

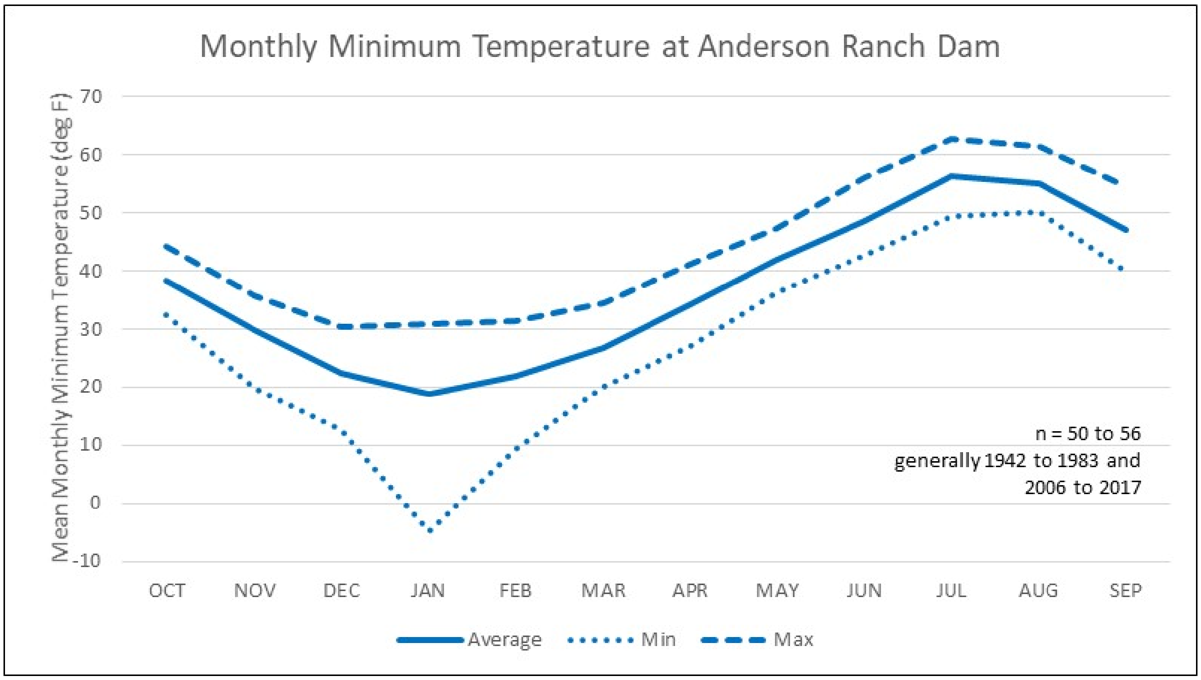

Figure 1. Monthly minimum temperature at Anderson Ranch Dam

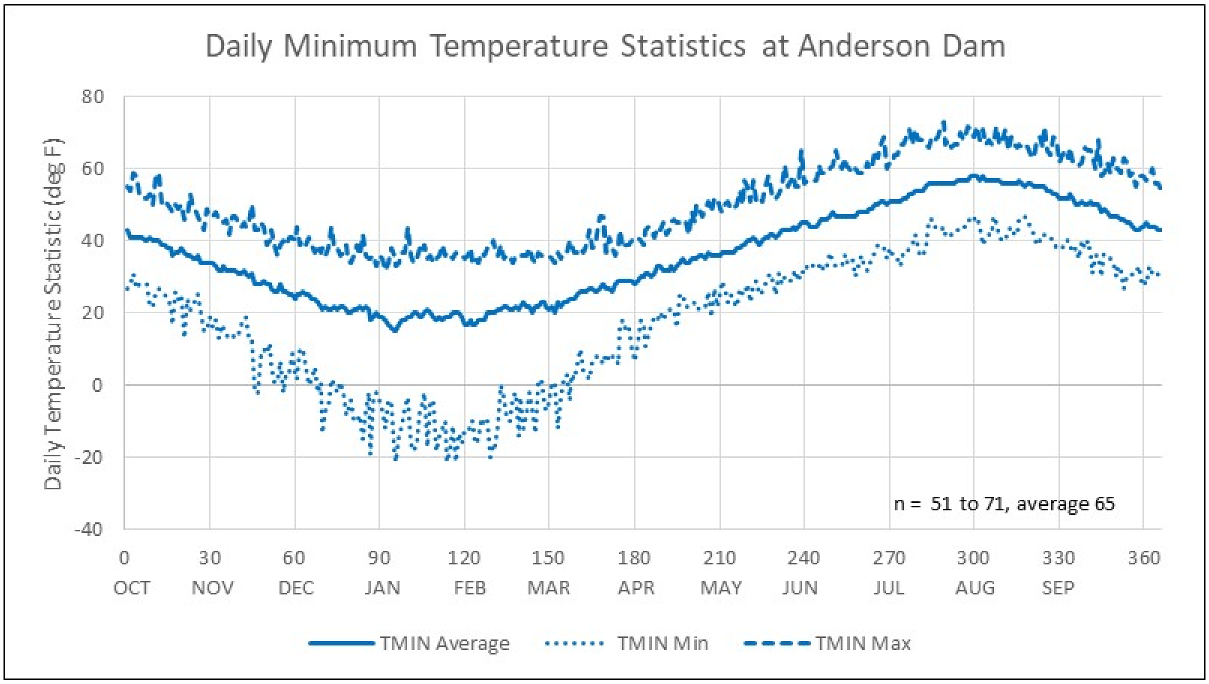

Figure 2. Daily minimum temperature statistics at Anderson Ranch Dam

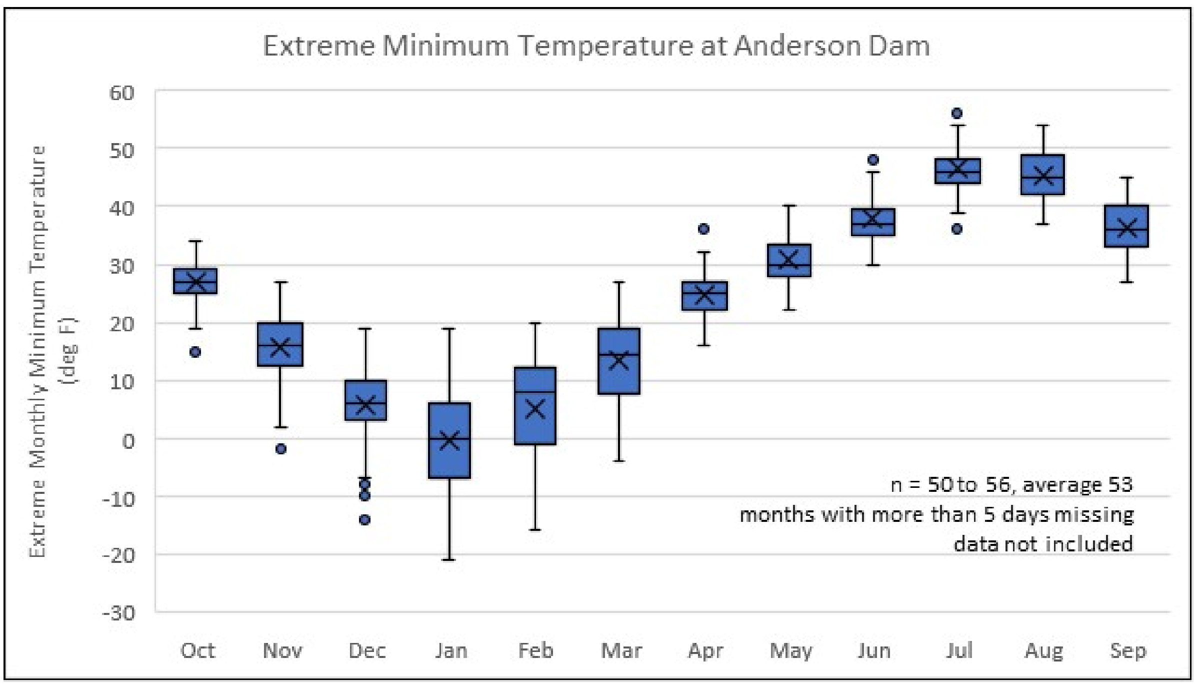

Figure 3. Extreme minimum temperature at Anderson Ranch Dam

Maximum Temperature

Average monthly maximum temperatures at Anderson Ranch Dam range from 35°F in January to 91°F in July (Figure 4). The historical lowest monthly maximum temperature in the winter drops below 20°F, indicative of long duration deep freeze conditions. Extreme high monthly maximum temperatures exceed 95°F for July and August, with extreme high daily maximum temperatures exceeding 100°F for much of July and August (Figure 5 and Figure 6), and a record high temperature of 111°F on July 13, 2000.

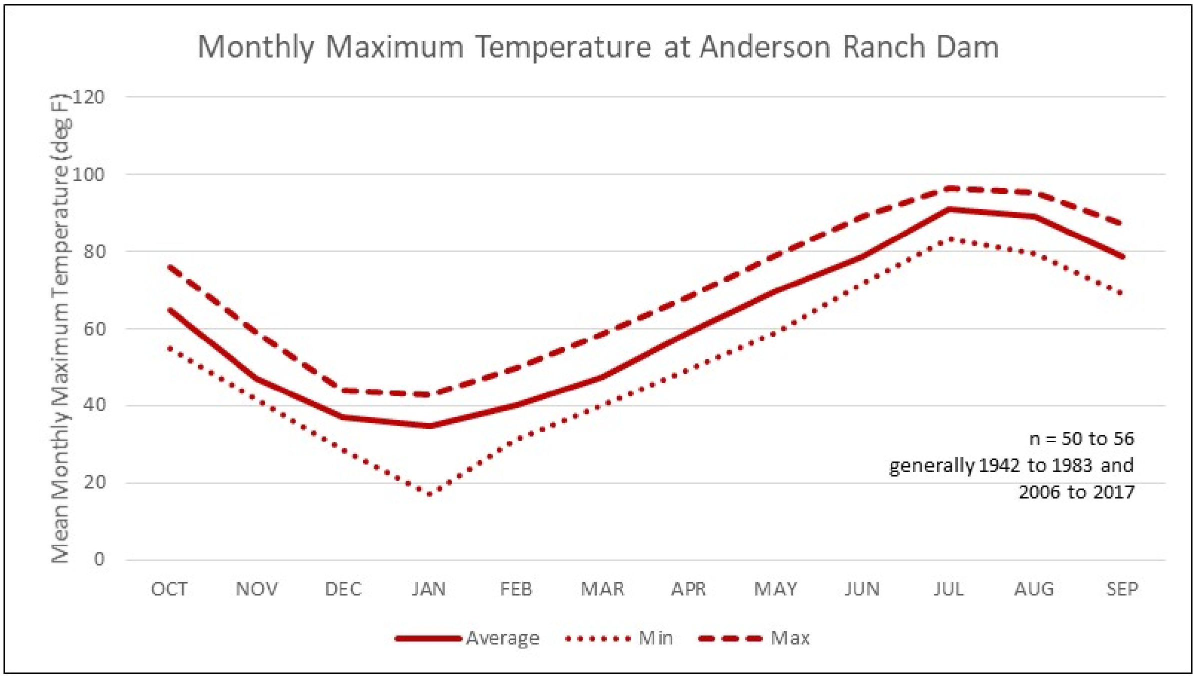

Figure 4. Extreme minimum temperature at Anderson Ranch Dam

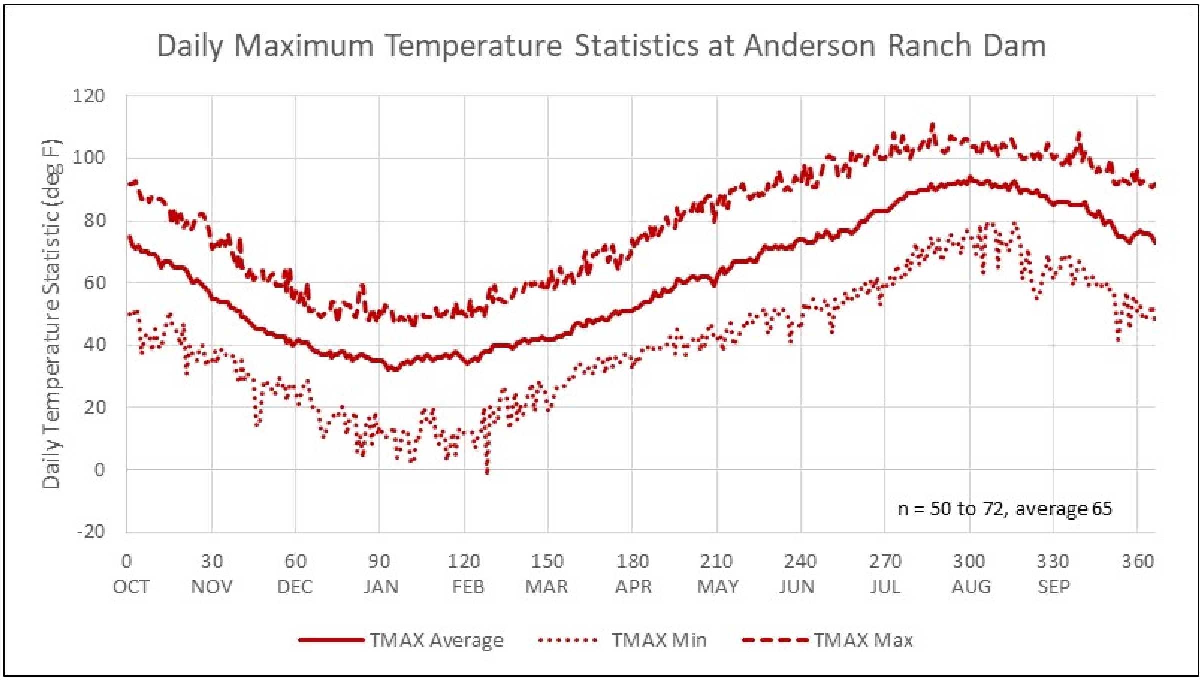

Figure 5. Daily maximum temperature at Anderson Ranch Dam

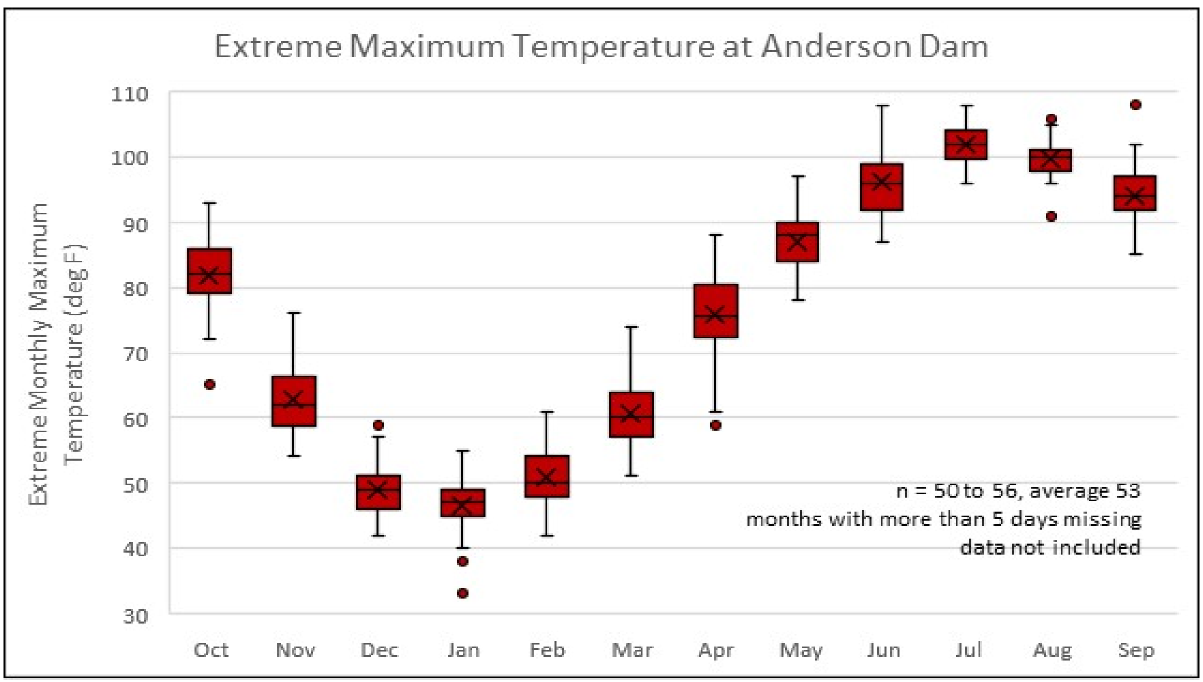

Figure 6. Extreme maximum temperature at Anderson Ranch Dam

Precipitation

Mean annual precipitation at Anderson Ranch Dam during 37 years between 1942 and 1997 is 19.8 inches. During this time, annual precipitation has varied between a high of 35.5 inches in 1970 to a low of 12.8 inches in 1949 (Figure 7). Seven of 37 years have received less than 15 inches of rain. Most of this precipitation falls in the late fall and winter; more than 50% of the annual precipitation occurs between November and February, which all receive more than 2 inches per month on average (Figure 8).

The wettest recorded months are December and January. December 1942 received 10.4 inches, and December 1964 and 1996 both received more than 9.0 inches. January 1970 received 11.1 inches, and January 2006 received 8.2 inches. The driest recorded months are July, August, and September, which all receive less than 1 inch per month on average; July and August both receive 0.4 inch per month on average. All months have a historical record of potentially being very dry (less than 0.1 inch).

Average daily precipitation generally follows the monthly precipitation pattern (Figure 9). Maximum daily precipitation is generally between 0.25 inch and 1.5 inches, with some occasions of daily precipitation exceeding 2 inches (Figure 10). Extreme precipitation statistics also generally follow the monthly precipitation pattern, with the wettest extreme precipitation days occurring in December and January. However, some very wet days are caused by convective thunderstorms during the otherwise dry months of August and September.

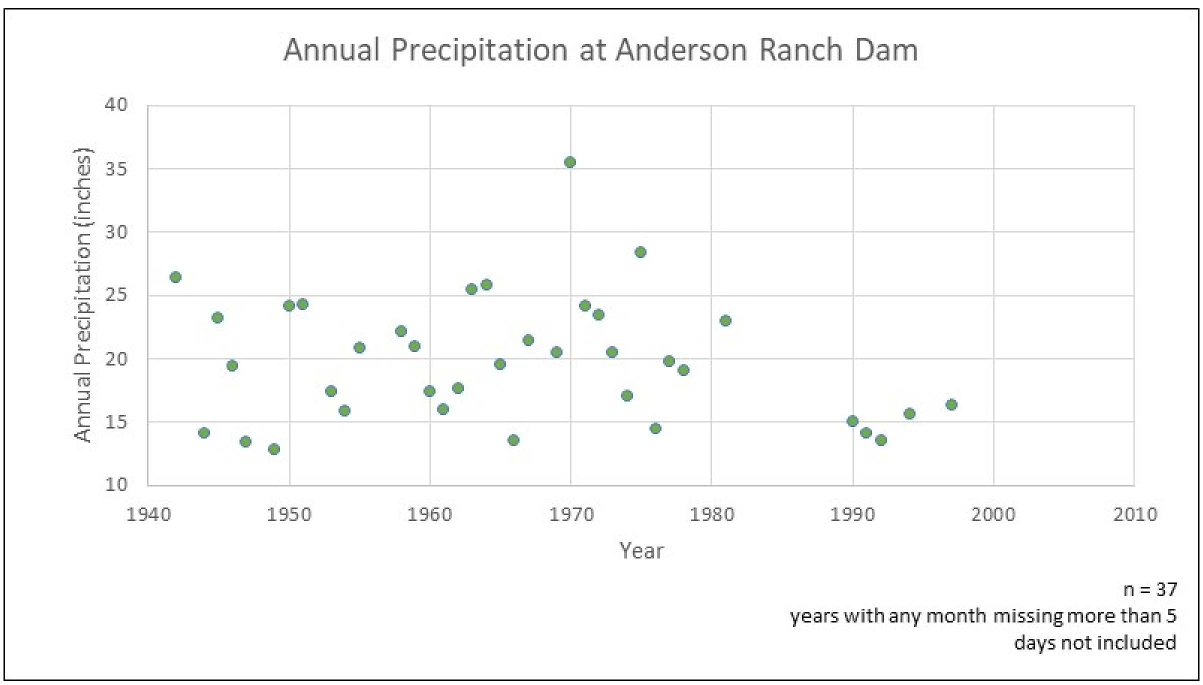

Figure 7. Annual precipitation at Anderson Ranch Dam

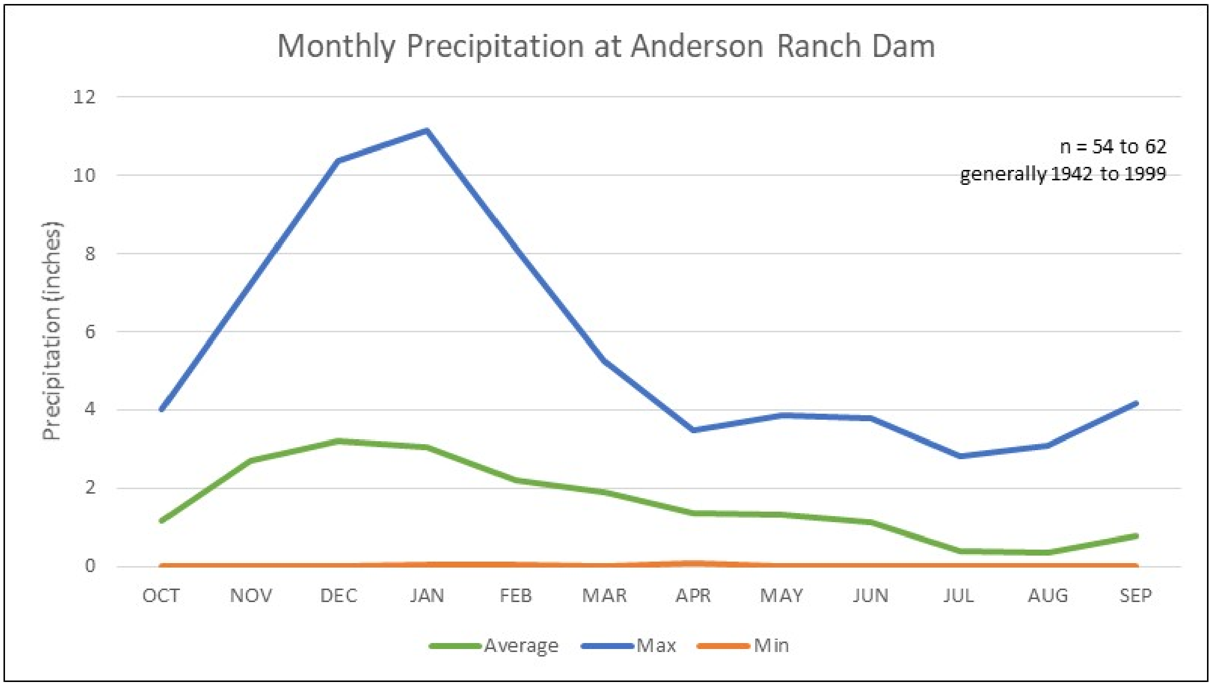

Figure 8. Monthly precipitation at Anderson Ranch Dam

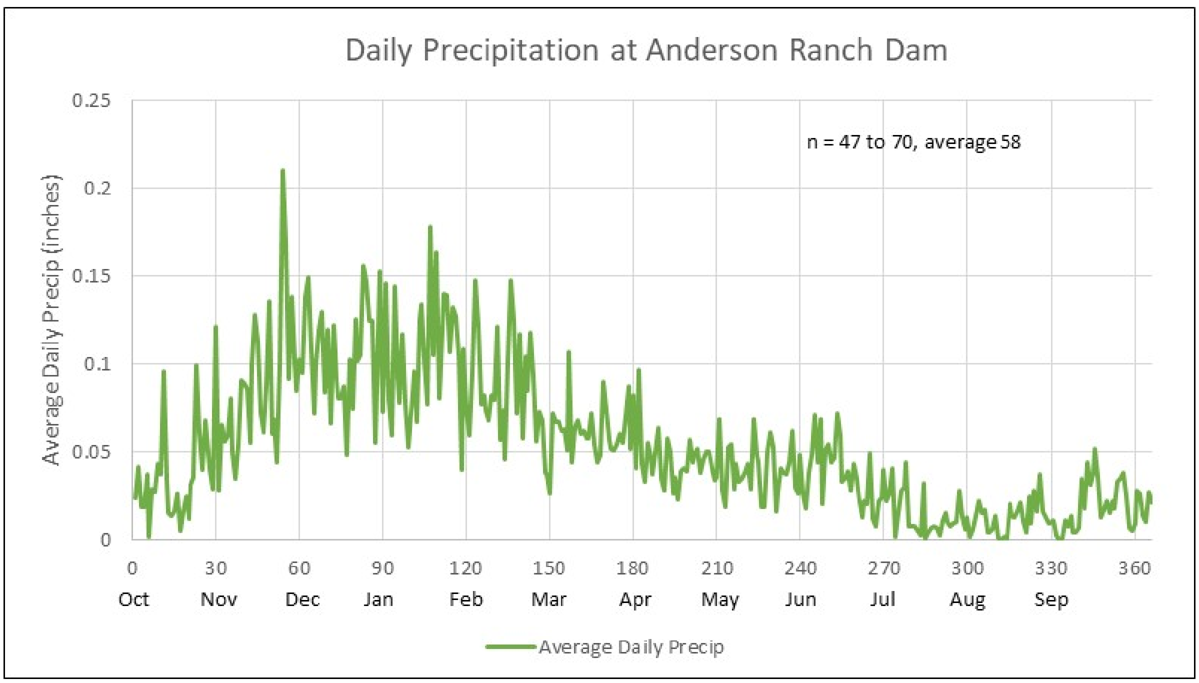

Figure 9. Daily precipitation at Anderson Ranch Dam

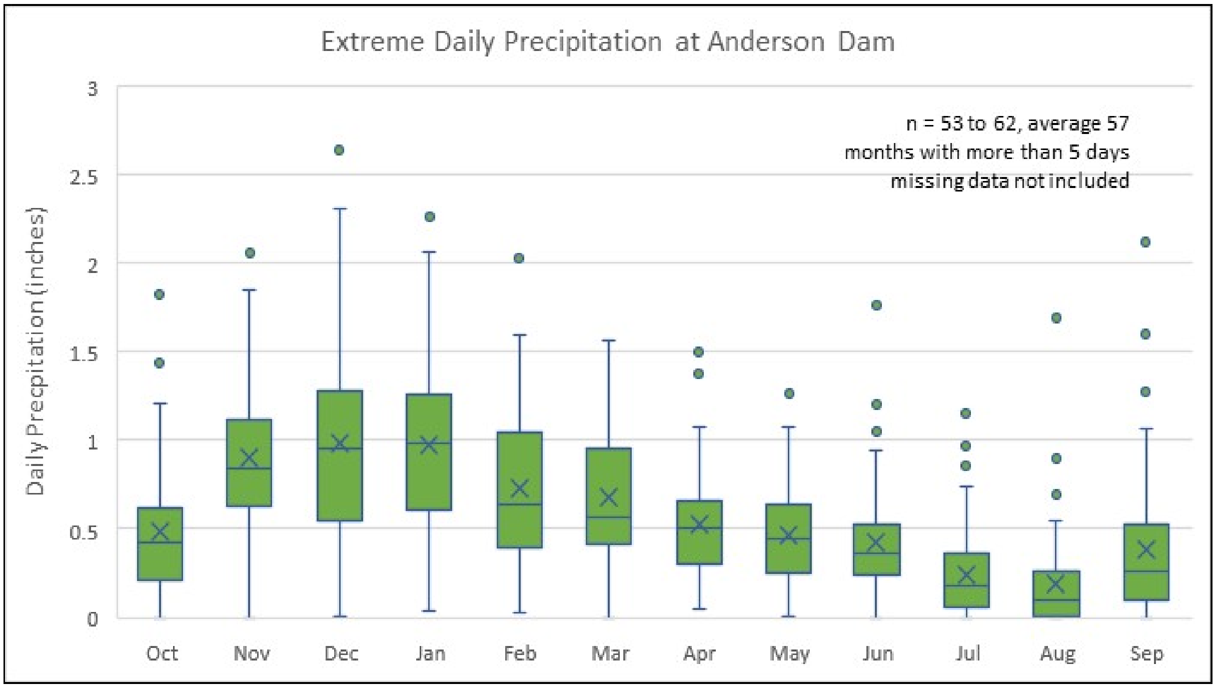

Figure 10. Extreme daily precipitation at Anderson Ranch Dam

Snow

Average annual snowfall at Anderson Ranch Dam is 55 inches (Figure 11). More than half of this falls in December and January. Maximum daily snowfall for a given day frequently exceeds 10 inches, with at least eight instances of daily snowfall exceeding 20 inches (Figure 12). Average total snow depth on March 1 at Anderson Ranch Dam is about 10 inches, with a record high snow depth of 54 inches occurring in 1952 (Figure 13).

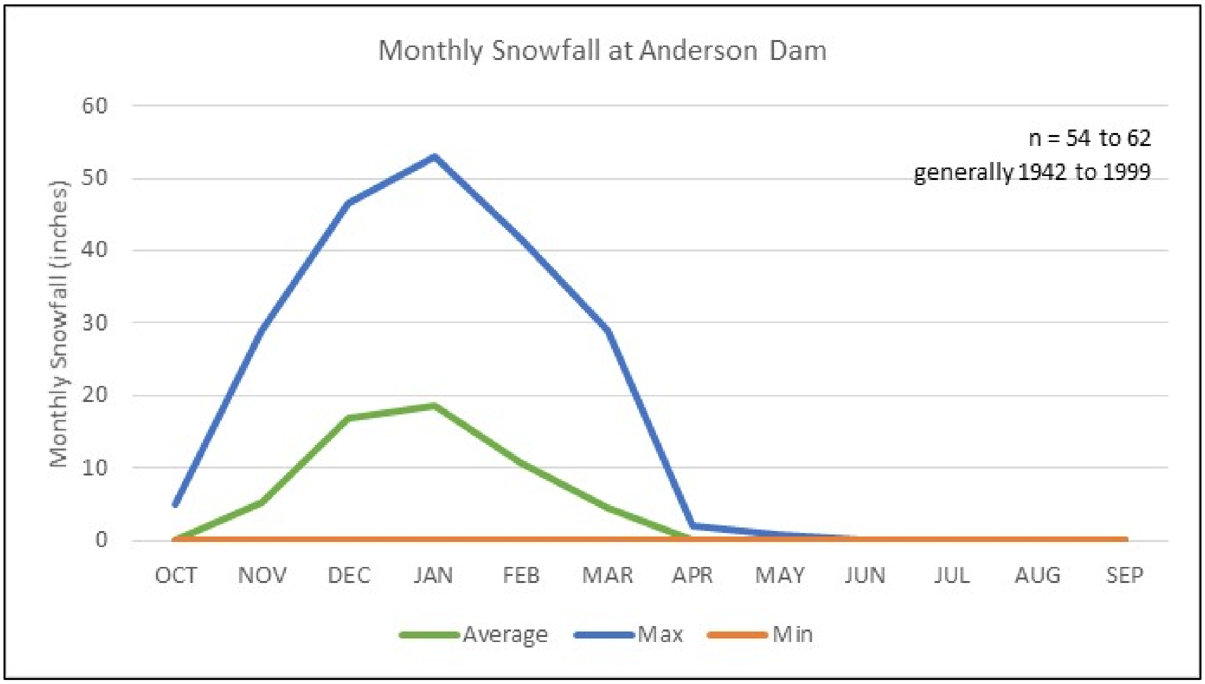

Figure 11. Monthly snowfall at Anderson Ranch Dam

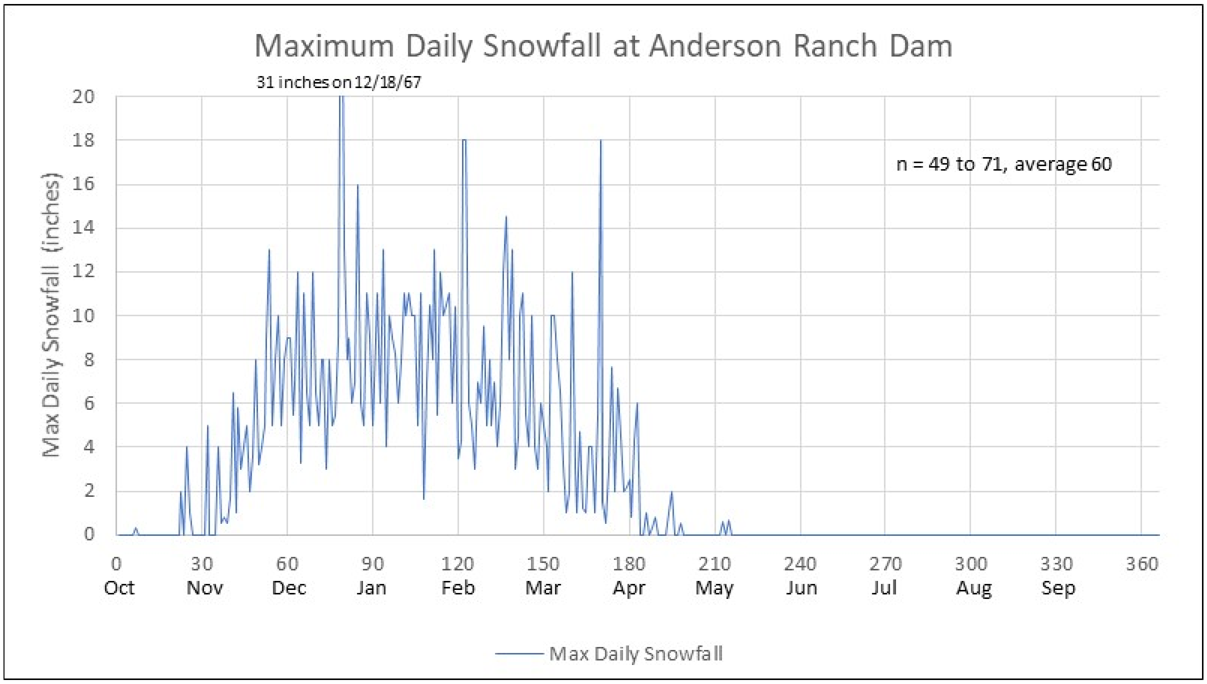

Figure 12. Daily snowfall at Anderson Ranch Dam

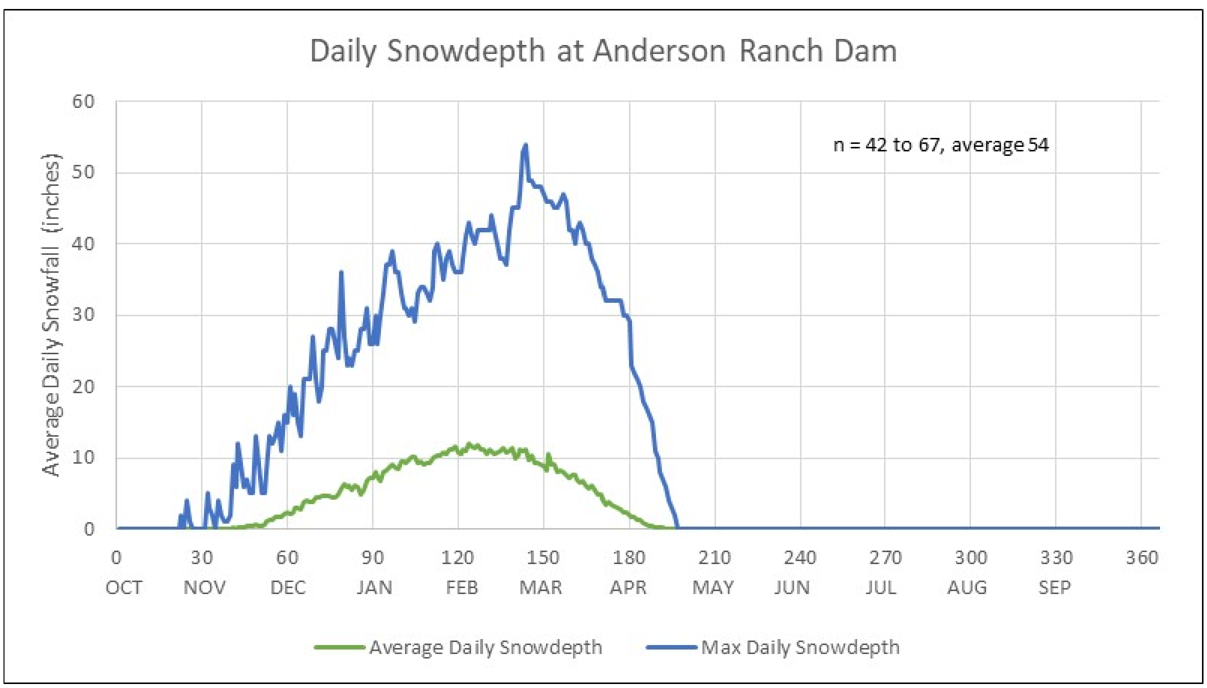

Figure 13. Daily snow depth at Anderson Ranch Dam

3.2.1.2 Baseline Climate Characterization - Watershed

Figure 14 through Figure 18 summarize the monthly climate temperature and precipitation normals in the Anderson Ranch Reservoir watershed. The normals are derived from the PRISM spatial climate model for the period 1981 to 2010 (PRISM, 2019). These normals do not represent the temporal range or extremes. Temporal range, variability, and extremes are evaluated for the Anderson Ranch Dam station in the preceding section.

In each watershed climate figure, the black line represents the spatial average across the Anderson Ranch Reservoir watershed. The watershed is 980 square miles, with elevation ranging from 4200 feet at Anderson Ranch Dam to 10,337 feet at the highest point in the watershed, an unnamed peak about 1 mile south of Bromaghin Peak, on the Blaine-Camas county line. For minimum temperature, maximum temperature, and precipitation, the corresponding average value at Anderson Ranch Dam station is plotted in comparison to the full watershed. Note that the time period over which Anderson Ranch Dam station averages are calculated differ from the PRISM 1981 to 2010 and is subject to data availability as described in the analysis of Anderson Ranch Dam station data above.

Minimum Temperature

The range of the highest minimum temperature in Anderson Ranch Reservoir watershed and the lowest minimum temperature in the watershed is relatively consistent, approximately 13°F for all months (Figure 19). Extreme low minimum temperature of 5.7°F occurs in January in the higher elevation valleys, where cold air sinks at night. The monthly average minimum temperature averaged over the watershed ranges from 13.8°F in December to 48.0°F in July (Figure 14). The Anderson Ranch Dam station minimum temperatures represent the highest minimum temperatures across the watershed.

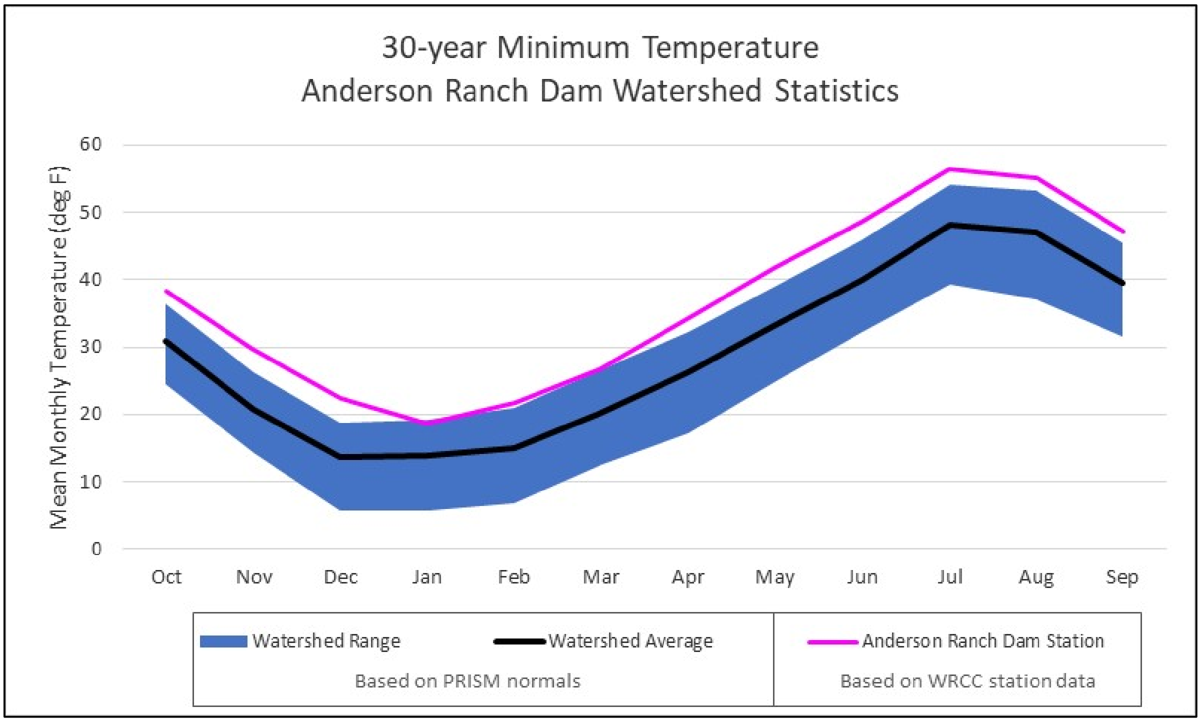

Figure 14. 30-year minimum temperature – Anderson Ranch Reservoir watershed statistics

Maximum Temperature

Average maximum temperatures vary more than minimum temperatures across the watershed, with watershed July average maximum temperature range of about 23°F (65°F to 88°F; Figure 15), and January average maximum temperature with a range of only 11°F (24°F to 35°F). Similar to minimum temperatures, the highest maximum temperatures are generally found near Anderson Ranch Dam itself, the lowest elevation in the watershed. The lowest maximum temperatures occur at the highest elevations, near the watershed crest. Extreme high maximum temperature of 88°F occurs in July near Anderson Ranch Reservoir. The monthly average minimum temperature averaged over the watershed ranges from 30.5°F in December to 78.1°F in July (Figure 16). The Anderson Ranch Dam station maximum temperatures represent the highest maximum temperatures across the watershed.

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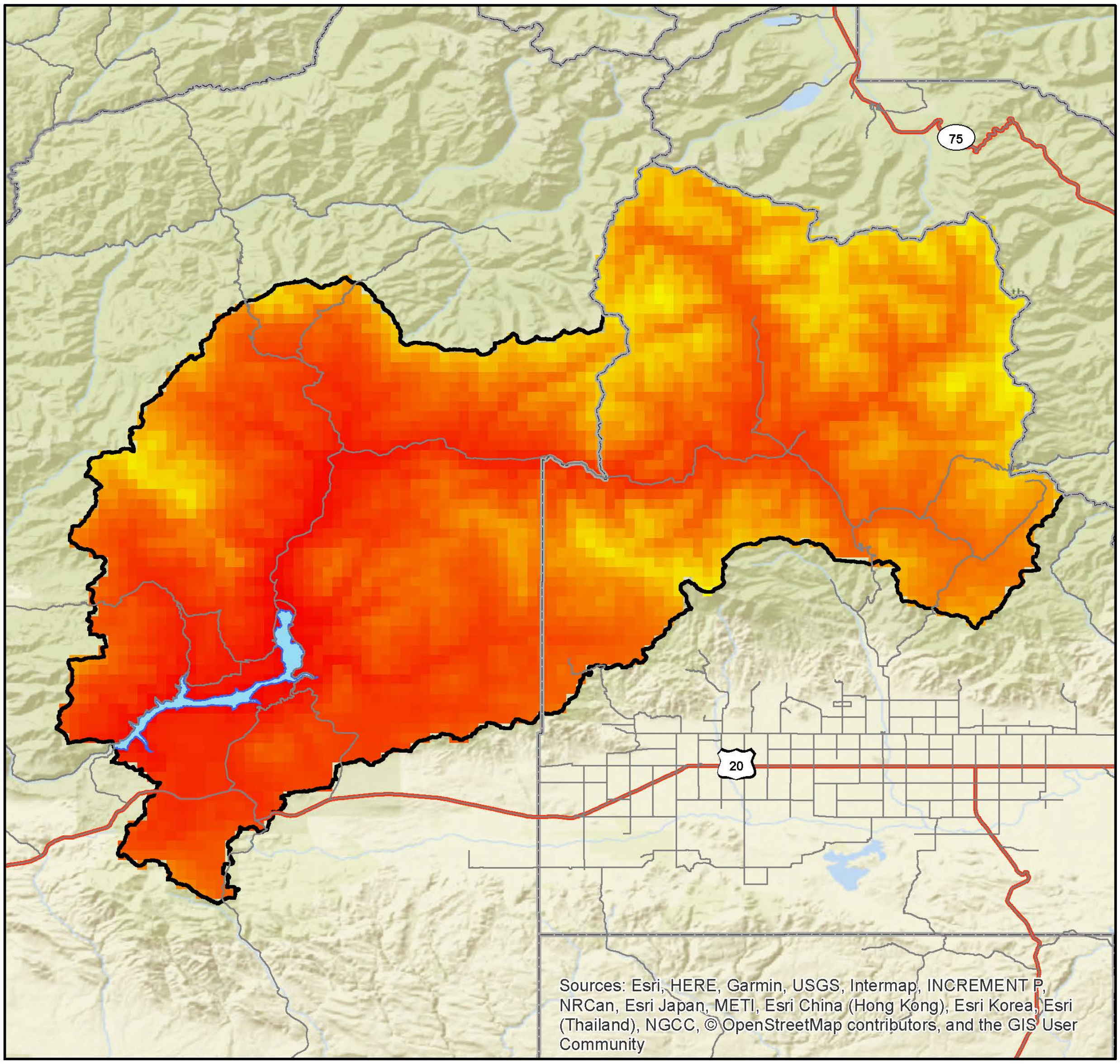

LEGEND

- **Roads**
- **Highways**
- **County Boundaries**
- **Anderson Ranch Reservoir**
- **Anderson Ranch Reservoir Watershed**

Temperature (F)

High : 87.9

Low : 65.2

N

0 1 2 4 6 8

Miles

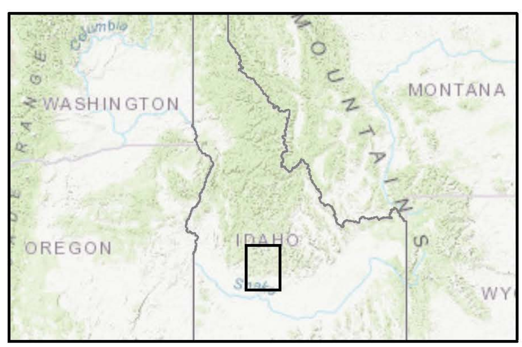

Figure 15: July Maximum Temperature Boise Project - Arrowrock Division

Boise River Basin Feasibility Study

Notes:

1. This map is provided as-is and may contain representations of property boundaries. It is intended for general references only. None of the parties involved in preparing this map or data contained herein warrant or represent information to be complete and accurate and cannot be held responsible for errors or omissions.
2. Climate data from PRISM Climate Group (2019).

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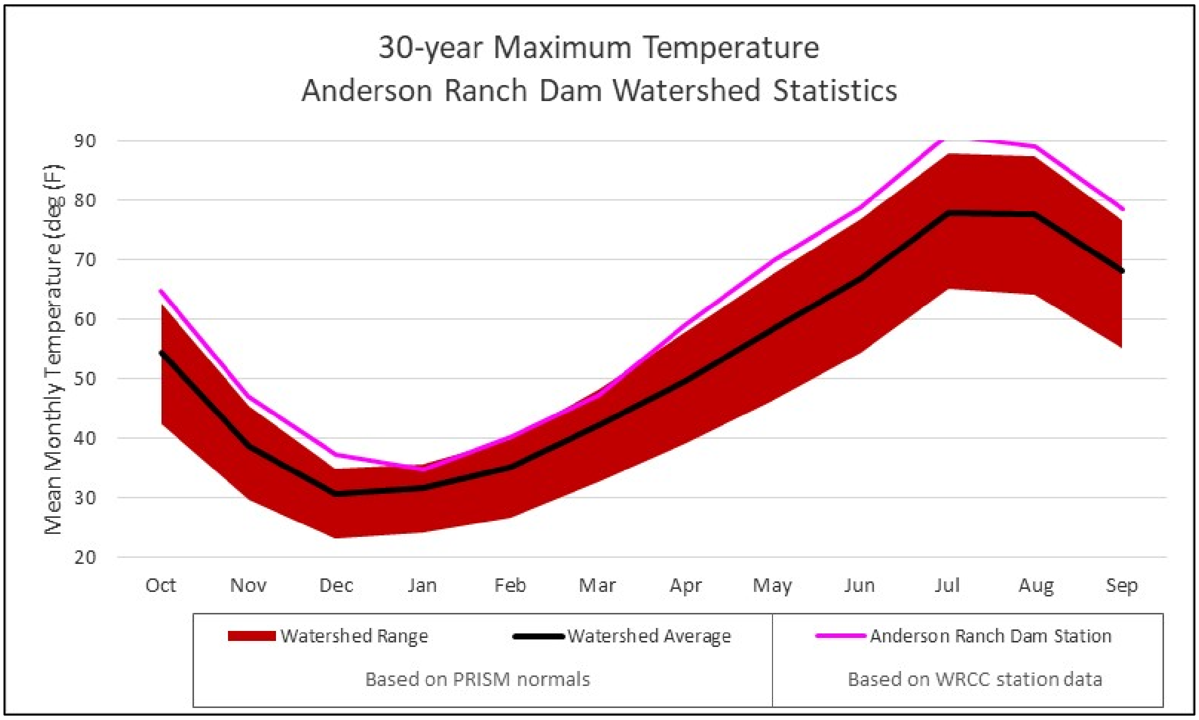

Figure 16. 30-year maximum temperature – Anderson Ranch Reservoir watershed statistics

Precipitation

Average precipitation across the Anderson Ranch Reservoir watershed varies widely, from 18.6 inches per year around Anderson Ranch Reservoir and the southwestern portion of the watershed to 54.3 inches per year at the northern watershed boundary (Figure 17). The basin average annual precipitation is 31.1 inches. The Anderson Ranch Dam station annual and monthly precipitation is near the minimum for the watershed (Figure 18). The interannual distribution of precipitation in the watershed is similar to that at Anderson Ranch Dam, with the highest precipitation in December and January and the lowest in July and August. Basin average December precipitation is 4.9 inches, and average July precipitation is 0.7 inch. Precipitation variability across the watershed is greatest in the winter; December precipitation ranges from 3.1 inches to 8.9 inches, a 5.8-inch range, and July precipitation ranges from 0.3 inch to 1.4 inches, a 1.1-inch range.

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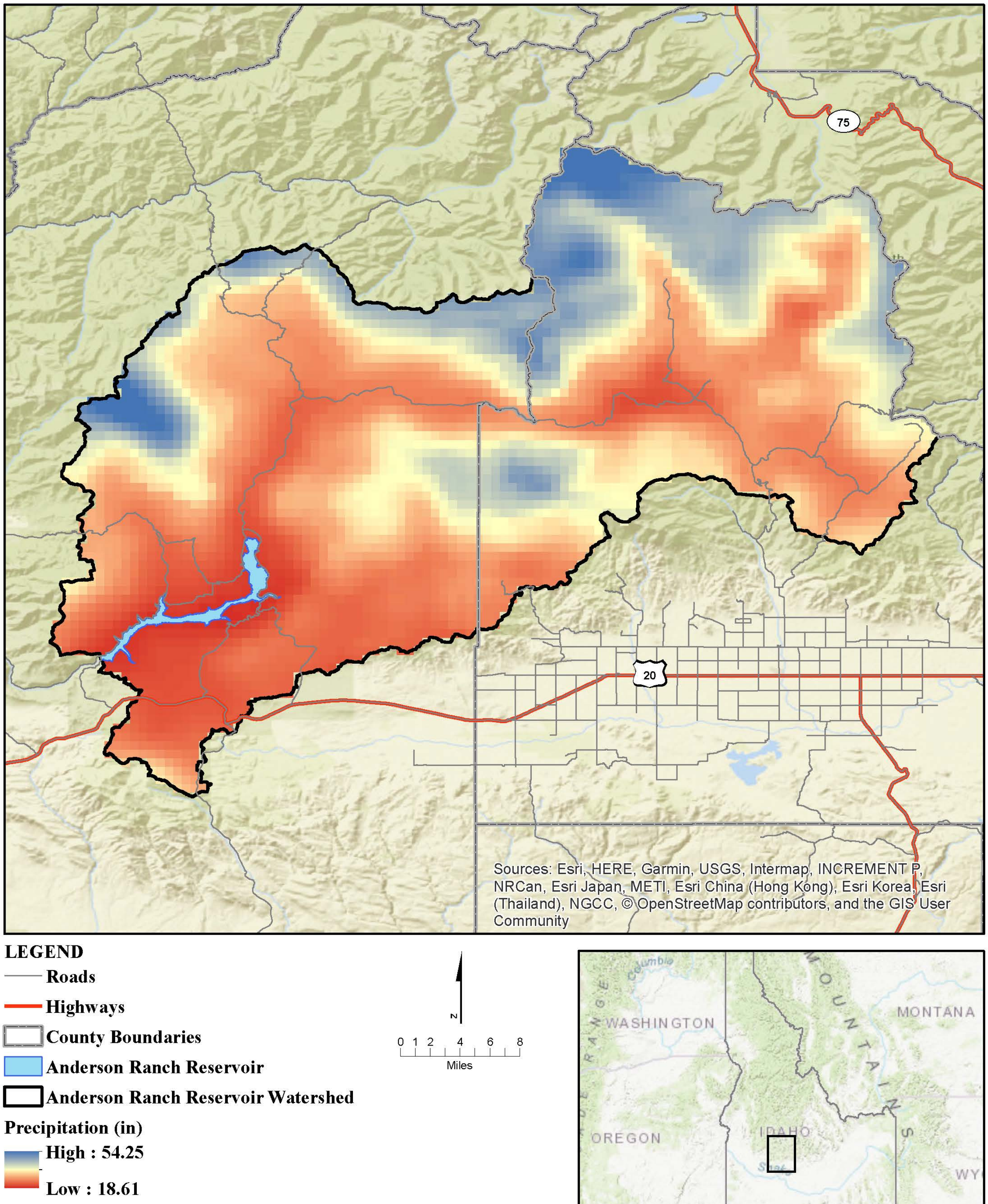

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Figure 17. Mean Annual Precipitation Boise Project - Arrowrock Division
Boise River Basin Feasibility Study

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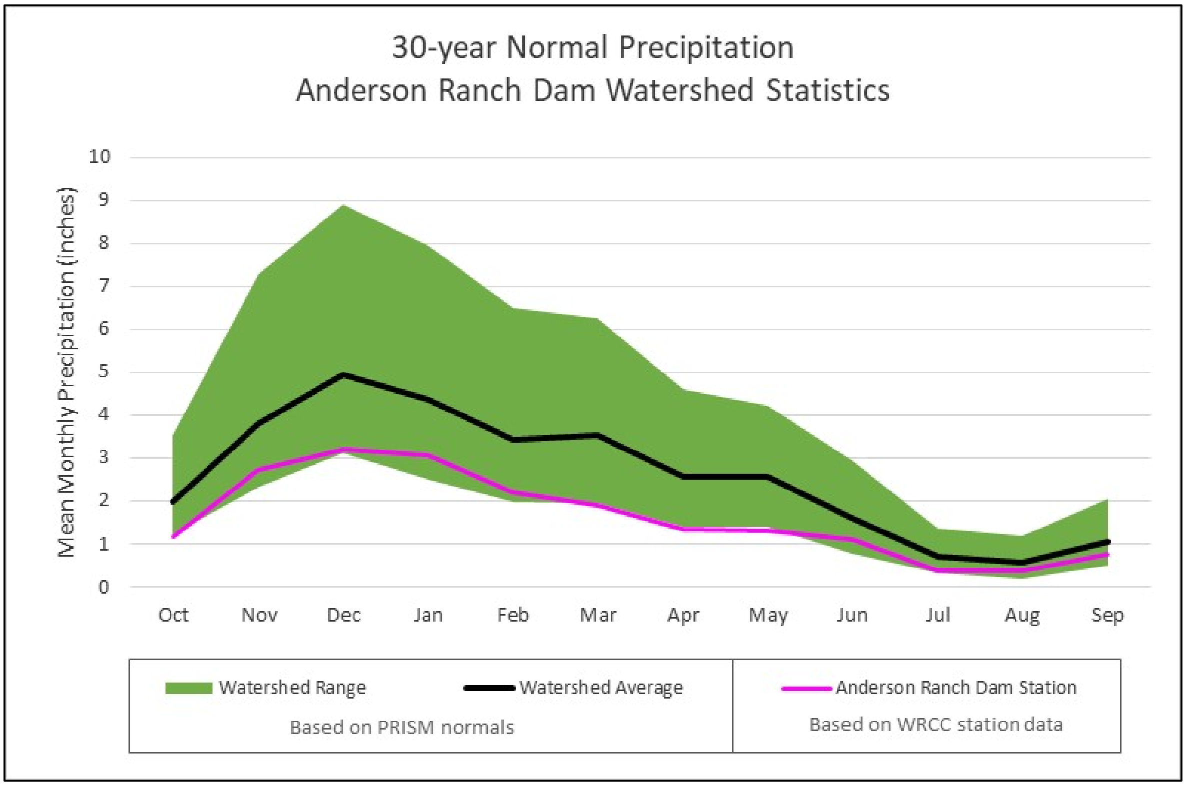

Figure 18. 30-year normal precipitation – Anderson Ranch Reservoir watershed statistics

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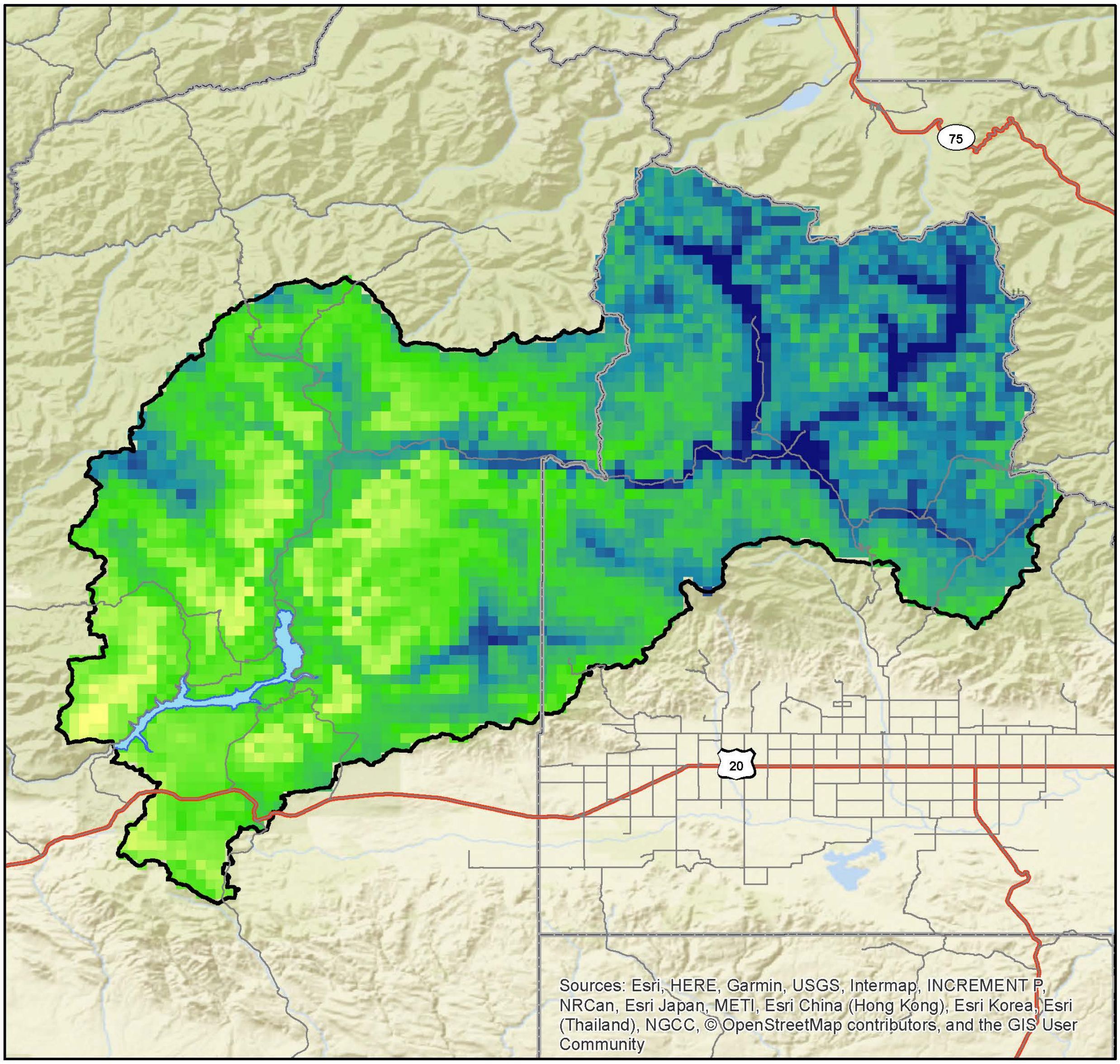


LEGEND

Roads

Highways

County Boundaries

Anderson Ranch Reservoir

Anderson Ranch Reservoir Watershed

Temperature (F)

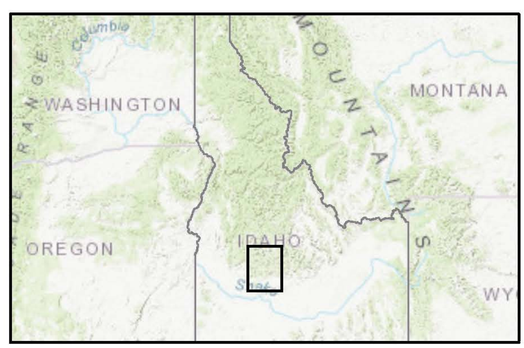
High : 19.2

Low : 5.6

N

0 1 2 4 6 8

Miles



Notes:
1. This map is provided as-is and may contain representations of property boundaries. It is intended for general references only. None of the parties involved in preparing this map or data contained herein warrant or represent information to be complete and accurate and cannot be held responsible for errors or omissions.
2. Climate data from PRISM Climate Group (2019).

Figure 19: January Min. Temperature Boise Project - Arrowrock Division

Boise River Basin Feasibility Study

BUREAU OF RECLAMATION

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Snow

Watershed averaged snow data were not evaluated. The Anderson Ranch Reservoir watershed is higher than Anderson Ranch Dam and generally receives more winter precipitation, so it is assumed that the Anderson Ranch Dam station snowfall analyzed in the preceding section is a low boundary on total watershed snow. SWE, which drives much of the South Fork Boise River hydrology, is described for both historical and projected future in Section 3.2.1.3.

3.2.1.3 Future Climate Characterization – Watershed

This section summarizes projected future climate and hydrologic variability trends at Anderson Ranch Reservoir watershed. These trends are based on projection of 2060s climate for both low (CSIRO-Mk3-6-0, RCP 4.5) and high (CanESM2, RCP 8.5) future climate scenarios.

In general, compared to the baseline climate characterization described in the sections above, projected future climate variability is expected to increase, with higher temperatures, a greater range between dry and wet years, and more frequent extreme climate events (hot, wet, or dry).

Projected Temperature

Substantial uncertainty exists relative to understanding and modeling of earth systems, future development and emission scenarios, and simulations of changes at the local scale. However, wide agreement exists across the scientific community and among climate models that the projected temperature increase signal is strong and temporally consistent. Figure 20 shows annual average temperature for Anderson Ranch Reservoir watershed from water year 1951 through 2079 for two climate model projections from CSIRO-Mk3-6-0 (low) and CanESM2 (high). Table 3 summarizes the modeled climate values over the historical (1980 through 2009) and future (2050 through 2079) periods. The annual average temperatures are spatially averaged over Anderson Ranch Reservoir watershed. Annual average temperature is projected to steadily increase from the modeled baseline period (1980–2009) to modeled future period (2050–2079) by approximately 5°F (low) and 9°F (high). The variability in annual temperature, measured as the standard deviation over a 30-year period, increases for the high future climate scenario, but decreases for the low future climate scenario.

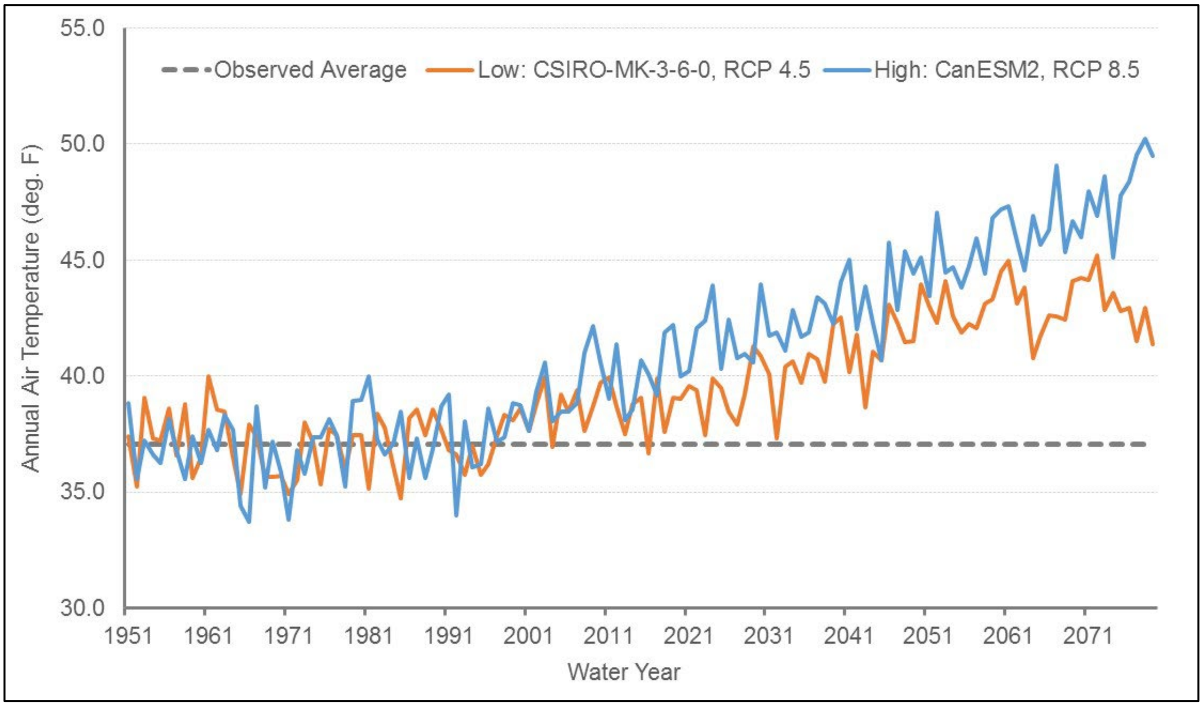

Figure 20. Historical (dotted line, average over 1951–1999) and modeled annual average temperature for Anderson Ranch Reservoir watershed

Table 3. Historical and future average annual temperature for Anderson Ranch Reservoir watershed

	Low: CSIRO-Mk3-6-0, RCP 4.5		High: CanESM2, RCP 8.5	
Mean Annual Temperature	**Mean Value**	**Std Dev.**	**Mean Value**	**Std Dev.**
Historical (1980-2009) (°F)	38	1.3	38	1.6
Future (2050-2079) (°F)	43	1.1	47	1.8
Difference (°F)	5	-0.2	9	0.3

Long-term monthly mean temperature for the model-simulated historical period from water year (WY) 1980 to 2008 and future projections from WY 2050 to 2079 for low- and high-climate model projections are shown in Figure 21. Figure 22 shows the projected changes in monthly mean temperature over the future period water year 2050 through 2079 with respect to model simulated historical period (The model-simulated historical data were used to compute future changes instead of observed data to account for climate model simulation biases over both the historical and future simulated periods) over WY 1980 through 2008. In these simulations, every month experiences an increase between approximately 4°F and 12°F, in the most extreme case (high climate model projection for March). Winter and spring seasons have the highest increase in average temperature.

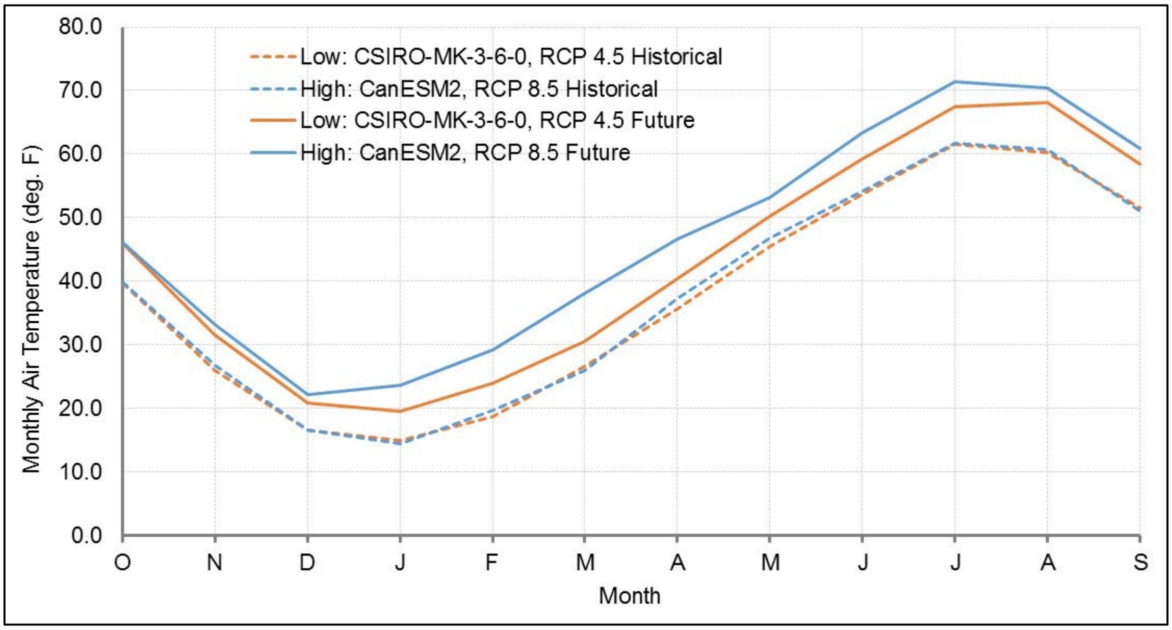

Figure 21. Projected future monthly average temperature for Anderson Ranch Reservoir watershed

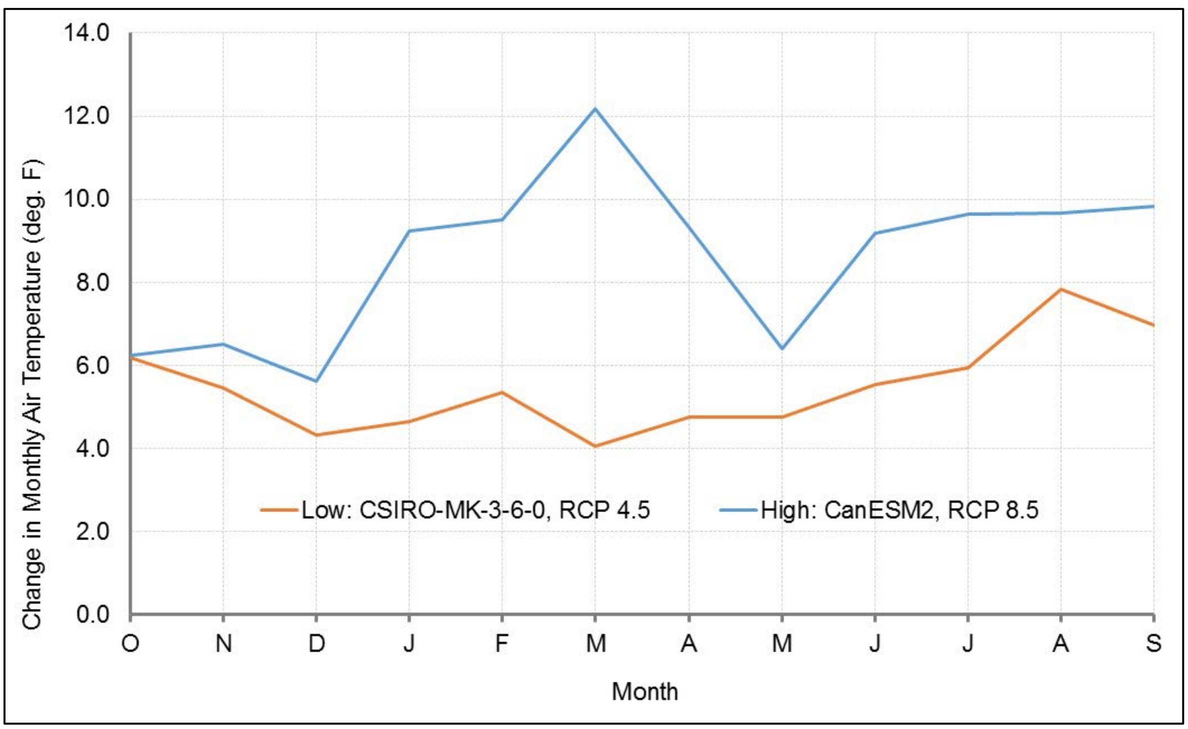

Figure 22. Change in monthly average temperature for Anderson Ranch Reservoir watershed from modeled baseline to projected future

Projected Precipitation

This section focuses on projected changes to longer duration (monthly and annual) precipitation. While extreme precipitation was not explicitly analyzed for the Anderson Ranch Reservoir watershed, climate models generally agree that future extreme precipitation will be more intense and occur more frequently than it has historically (Intergovernmental Panel on Climate Change, 2014).

Projected changes in annual precipitation for the future climate models vary widely. Some projections suggest wetter future conditions, and others suggest slightly drier future conditions. The strong natural precipitation variability over multiple decades complicates the determination of wet-dry trends. As shown in Figure 23 and summarized for the modeled historical and future periods in Table 4, the climate model projections indicate a 9% (low) to 37% (high) increase in annual watershed precipitation from the modeled baseline period (1980–2009) to modeled future period (2050–2079). The high future climate model also indicates an increase in annual precipitation variability, measured as standard deviation, and the low model shows a decrease in annual variability.

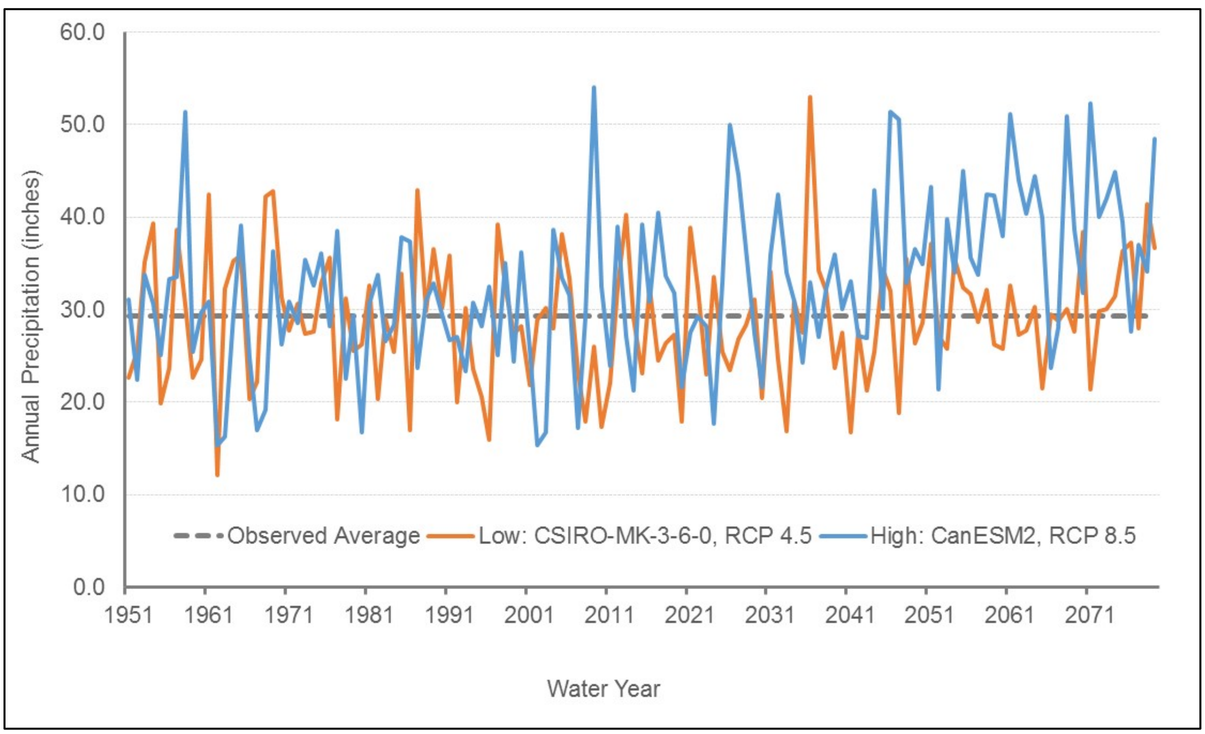

Figure 23. Historical (dotted line, average over 1951 to 1999) and projected annual precipitation for Anderson Ranch Reservoir watershed

Table 4 . Historical and future average annual precipitation for Anderson Ranch Reservoir watershed

	Low: CSIRO-Mk3-6-0, RCP 4.5		High: CanESM2, RCP 8.5	
Mean Annual Precipitation	**Mean Value**	**Std Dev.**	**Mean Value**	**Std Dev.**
Historical (1980–2009) (inches)	28	6.9	29	6.4
Future (2050–2079) (inches)	31	4.8	39	7.6
Difference (inches)	3	-2.2	10	1.2
Relative Difference (%)	9%	-31%	37%	19%

The changes in precipitation are more apparent as long-term monthly precipitation averages over the future period compared to annual averages or the model simulated historical period of annual average precipitation (Figure 24 and Figure 25). Winter and spring precipitation increase from 0.5 inch (12%, Jan.) to 0.8 inch (30%, March) for low climate model projection and from 0.9 inch (30%, March) to 1.8 inches (40%, Jan.) for the high climate model projection. Late summer precipitation increases substantially, especially in August under the high climate model projection (2.4 inches increase, approximately 265%) and in September under the low climate model projection (0.8-inch increase, approximately 68%).

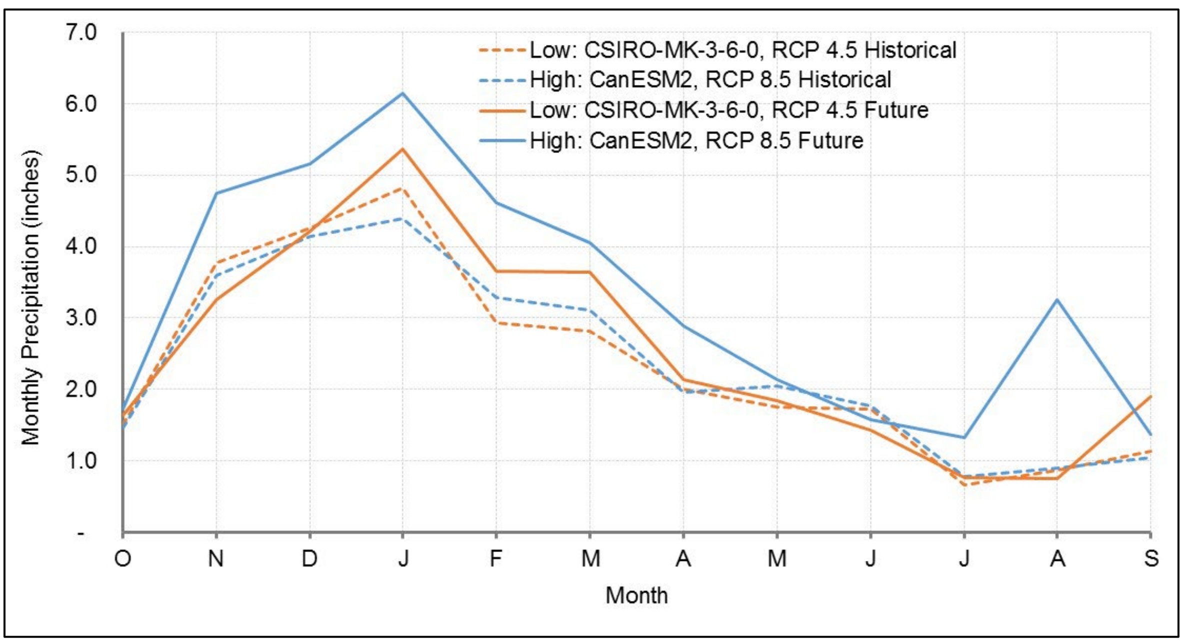

Figure 24. Projected monthly precipitation for Anderson Ranch Reservoir watershed

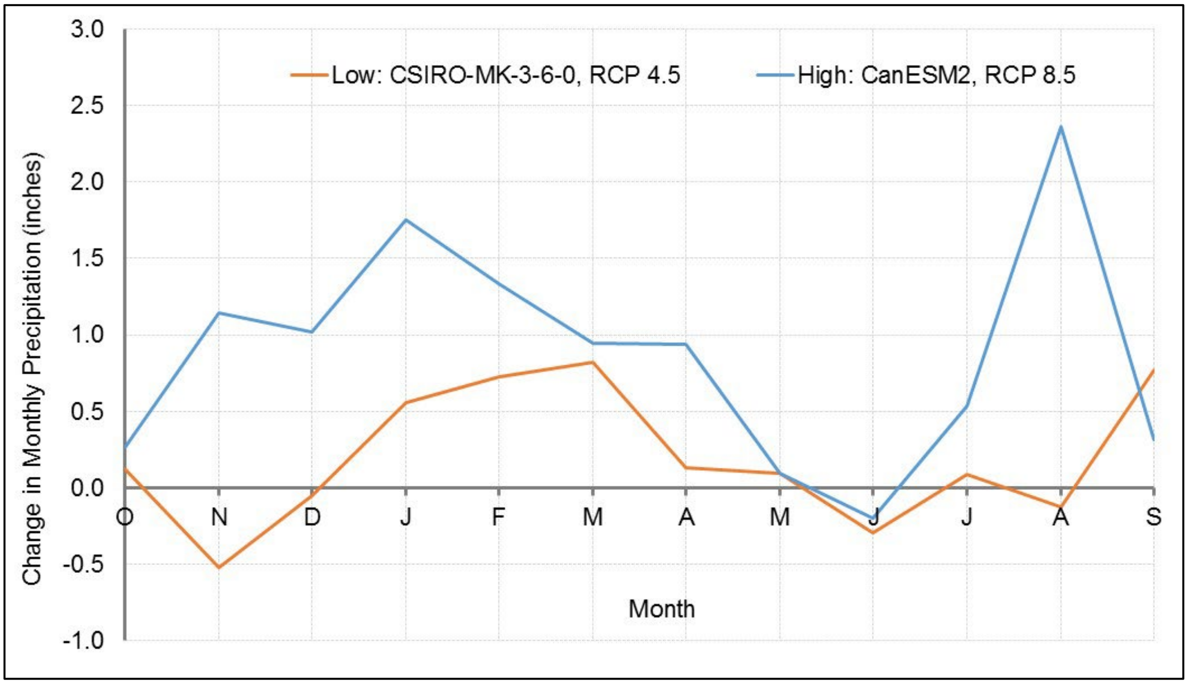

Figure 25. Projected changes in monthly precipitation for Anderson Ranch Reservoir watershed: absolute change

Projected Snow Water Equivalent

Figure 26 and Figure 27 present VIC hydrological model simulated mean monthly SWE averaged over the Anderson Ranch Reservoir watershed. Projected changes in monthly SWE are shown in Figure 27. The combination of climate and hydrologic models indicates that the overall amount of snowpack will be substantially reduced compared to model-simulated historical period under both climate projections. March, April, and May are projected to have the largest reduction in SWE, with the maximum value up to about 8 inches (April). In terms of relative changes, May is projected to have between 50% and 100% reduction in SWE in both climate model projections.

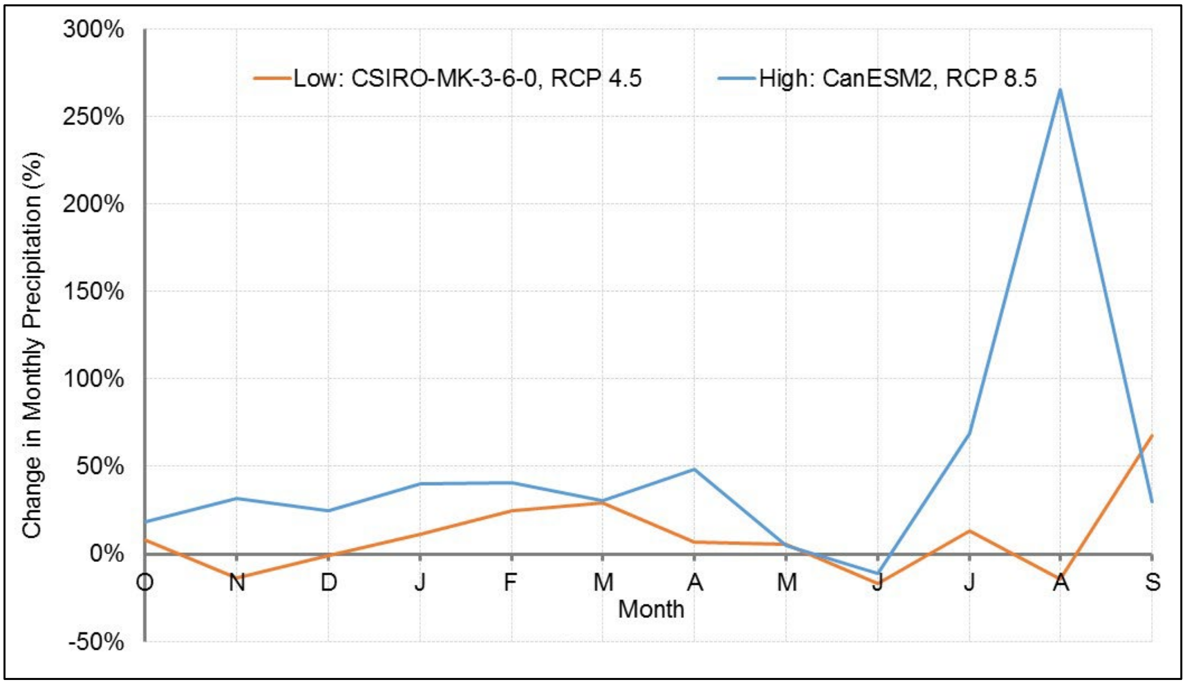

Figure 26. Projected changes in monthly precipitation for Anderson Ranch Reservoir watershed: relative change

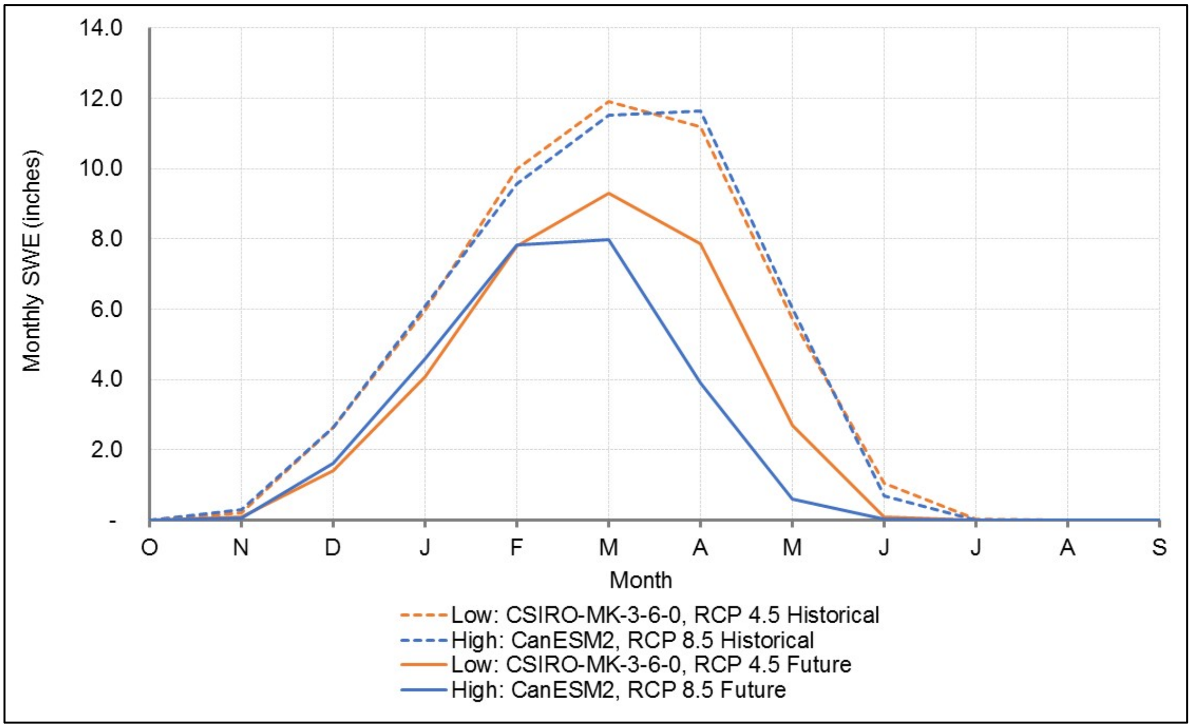

Figure 27. Projected monthly Snow Water Equivalent for Anderson Ranch Reservoir watershed

Figure 28 and Figure 29 illustrate the ratios between future and historical annual SWE in the beginning of each month from February to June simulated by two climate model projections. These values are summarized for April SWE in Table 5, which shows a 30% and 67% reduction in April 1 SWE for the low and high future climate, respectively. While substantial annual variability exists, an overall pattern of reduced future snowpack emerges for all months. In general, results from the low-climate model projections show smaller changes from the historical period than those produced by the high climate model projection. In addition, the ratios between future and historical SWE are projected to get substantially smaller (especially under the high-climate model projection) from February to May toward the end of this century as a result of large reductions in snowpack in spring and summer

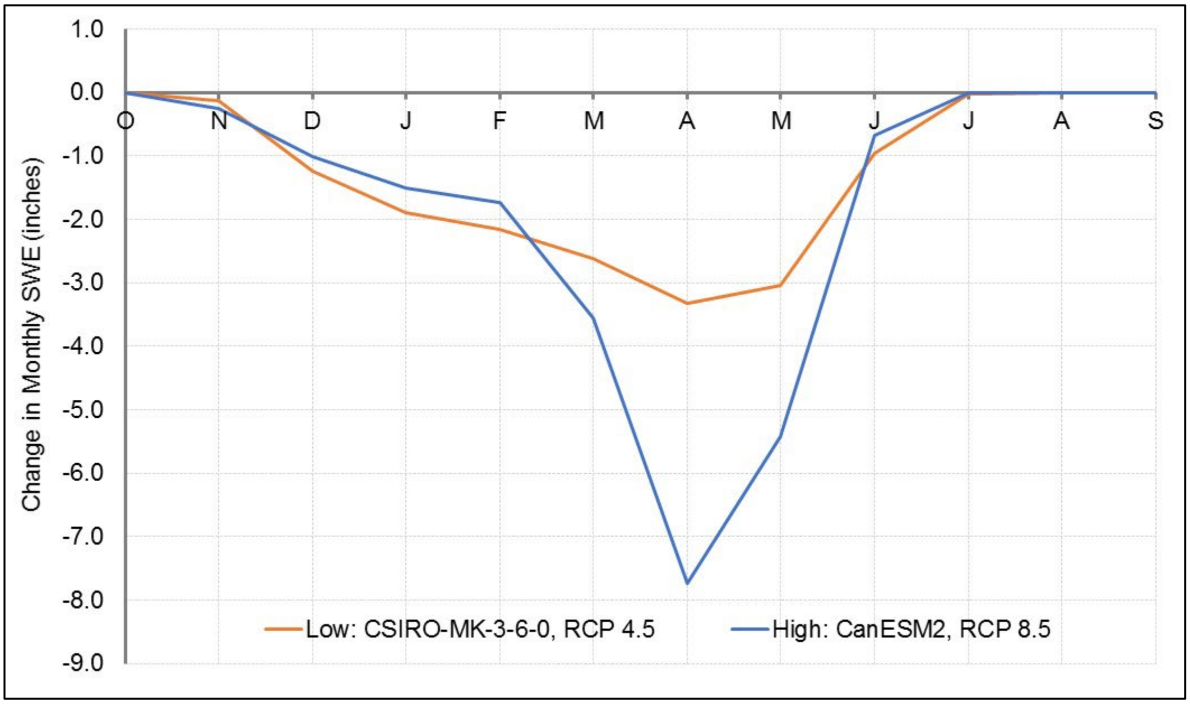

Figure 28. Projected changes in monthly Snow Water Equivalent for Anderson Ranch Reservoir watershed: absolute change

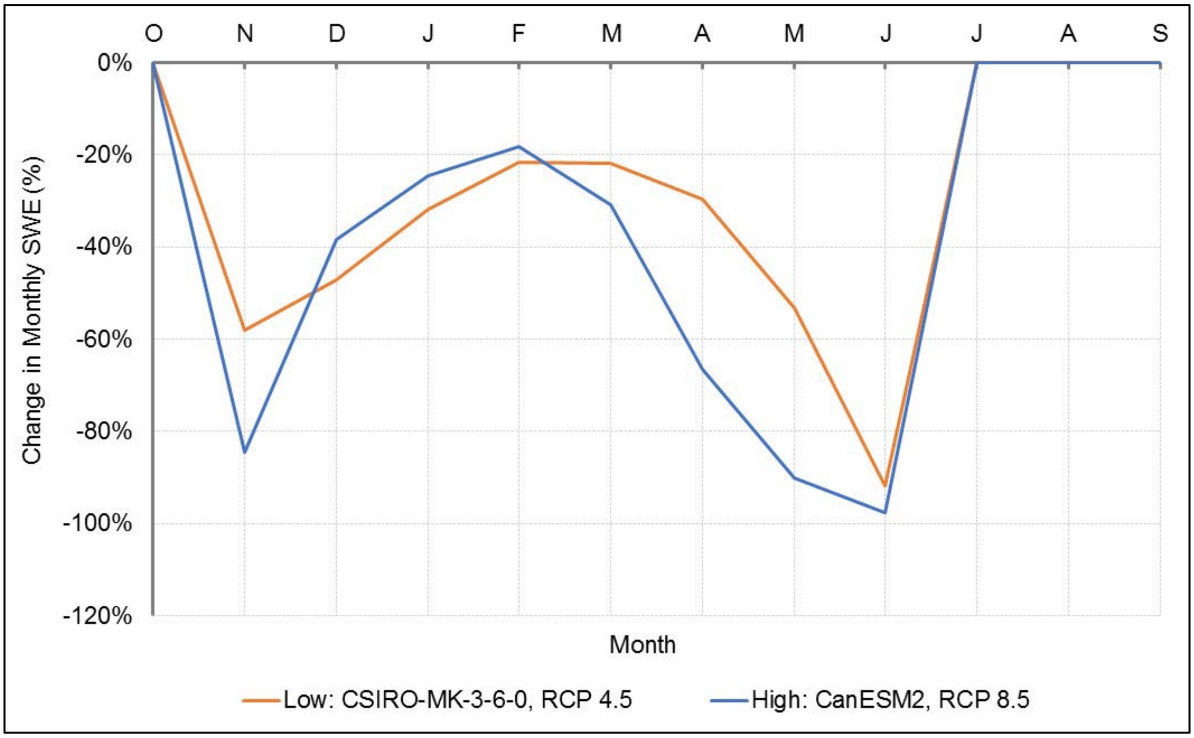

Figure 29. Projected changes in monthly Snow Water Equivalent for Anderson Ranch Reservoir watershed: relative change

Table 5. Historical and future average April 1 SWE for Anderson Ranch Reservoir watershed

	Low: CSIRO-Mk3-6-0, RCP 4.5		High: CanESM2, RCP 8.5	
Future April 1 SWE over Historical Mean Ratio	**Mean Value**	**Std Dev.**	**Mean Value**	**Std Dev.**
Historical (1980–2009)	1.0	0.4	1.0	0.5
Future (2050–2079)	0.7	0.3	0.3	0.3
Difference	-0.3	-0.1	-0.7	-0.2
Relative Difference (%)	-30%	-21%	-67%	-41%

Projected Stream Flows

Future changes in climate variability and trends are expected to affect streamflow to the South Fork Boise River at Anderson Ranch Dam. Figure 30 and Table 6 display annual simulated streamflow at the South Fork Boise River at Anderson Ranch Dam over WY 1951 to 2079 for both climate model projections. Streamflow was simulated using VIC hydrological model and does not include effects of Anderson Ranch Reservoir operation.

Future average annual simulated streamflow as driven by climate model projections is projected to increase by 12% (low) to 47% (high) as compared to the model-simulated historical period. The high-climate model projection indicates an increase in annual streamflow variability, measured as standard deviation, and the low climate model shows a decrease in annual variability.

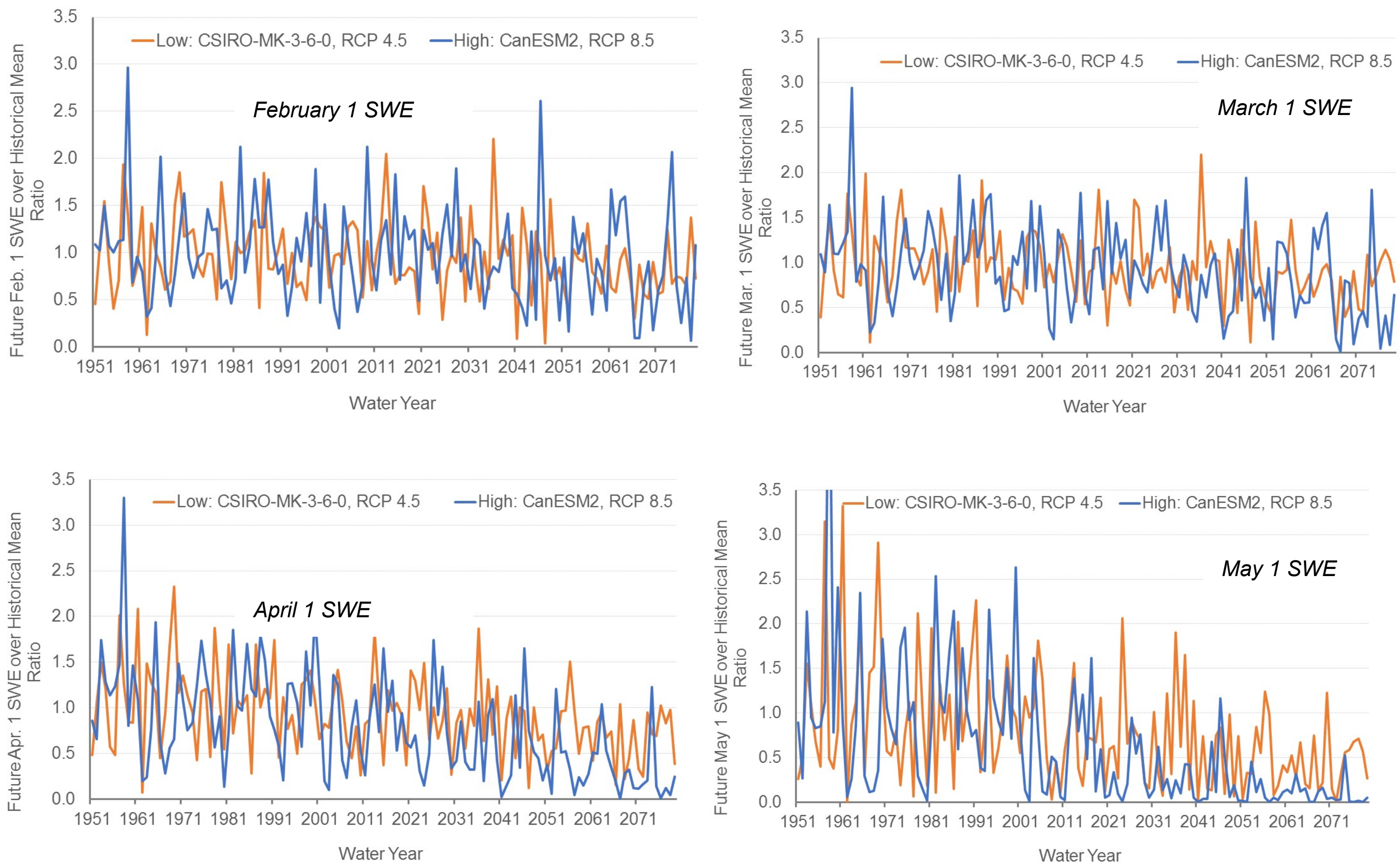

Figure 30. Fractional changes in simulated Snow Water Equivalent for Anderson Ranch Reservoir watershed (relative to 1980 through 2008 average)

Table 6. Historical and future average annual stream flows

	Low: CSIRO-Mk-3-6-0, RCP 4.5		High: CanESM2, RCP 8.5	
Mean Annual Streamflow	**Mean Value**	**Std Dev.**	**Mean Value**	**Std Dev.**
Historical (1980–2009) (cfs)	920	350	940	350
Future (2050–2079) (cfs)	1040	260	1380	460
Difference (cfs)	120	-90	440	110
Relative Difference (%)	12%	-27%	47%	29%

cfs = cubic feet per second

While the climate models project moderate changes to average annual streamflow, the largest change in stream flow is observed as a shift in the timing of the hydrograph. Figure 31 shows low-future-climate and high-future-climate mean monthly streamflow simulation for both historical (1980 to 2008) and future (2050 to 2079) periods.

The timing of stream flow is projected to shift in a future climate. The spring runoff is projected to occur earlier, with the peak of the hydrograph shifting approximately one month earlier (high-climate model projection). Wintertime runoff is also projected to increase due to higher temperatures, more precipitation falling as rain rather than snow, and earlier snowmelt. Consequently, less water is projected to store in snowpack. This together with the increase in evapotranspiration due to elevated temperature will lead to the decrease in summer runoff, especially in June and July.

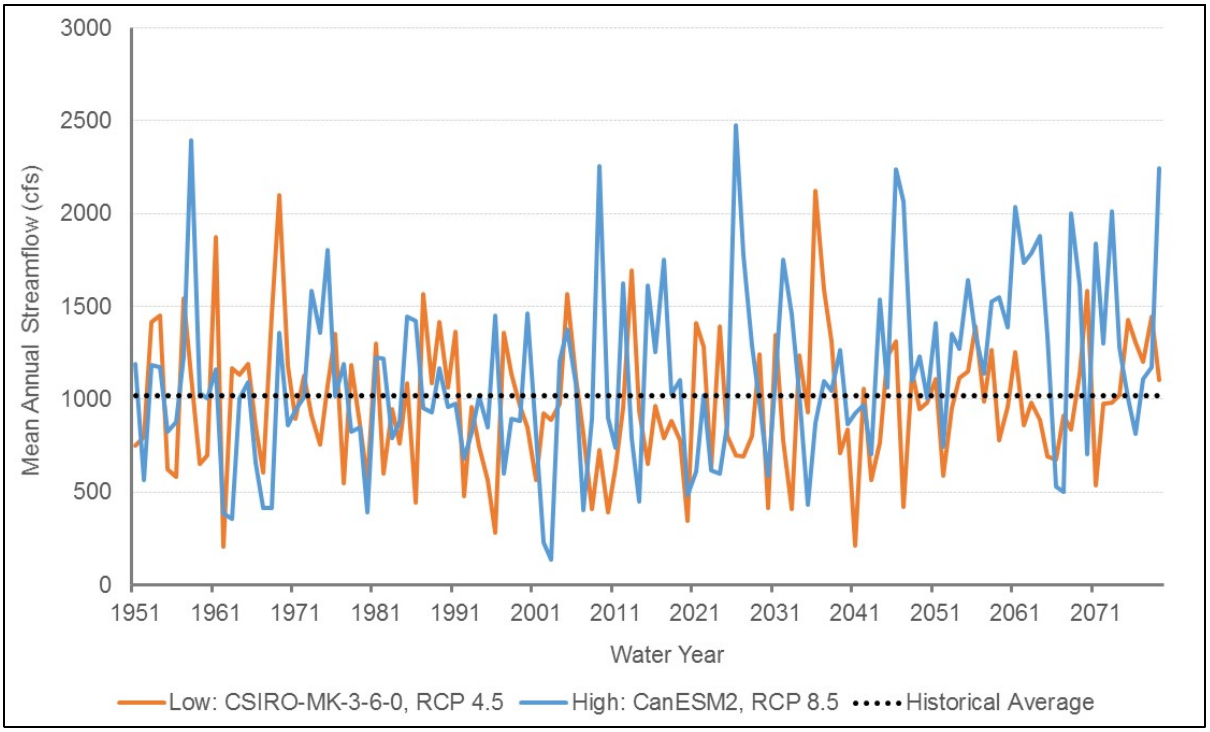

Figure 31. Historical (dotted line, average over 1951–1999) and projected simulated annual stream flows in the South Fork Boise River at Anderson Ranch Dam

Figures 32 through 34 illustrate the changes in monthly mean streamflow between future- and model-simulated historical periods from climate model projections. The biggest changes in monthly streamflow are projected to occur in spring. January to April runoff increases by 50% to 100% in the low-climate model projections and by 100% to 400% in the high-climate model projections. Projected future summer flow decreases with June experiencing the largest reduction (-36% in low-climate model projection and -38% in high-climate model projection). Notably, late summer runoff is projected to increase (up to approximate 25% in August in high-climate model projection) due to the increase in summer precipitation.

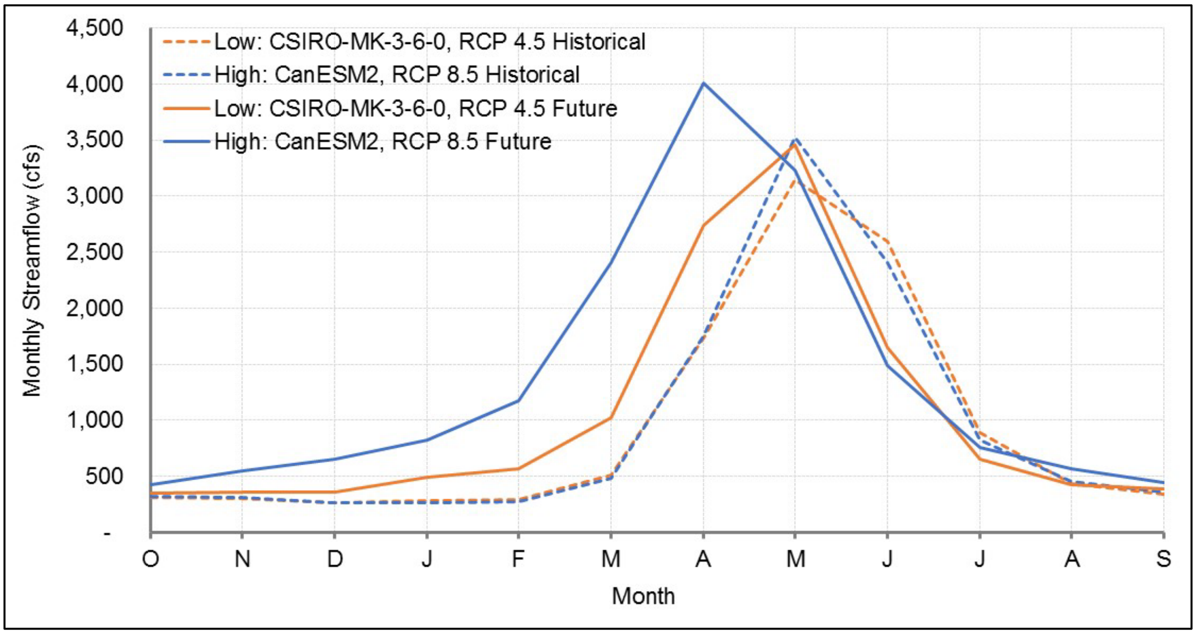

Figure 32. Projected monthly simulated stream flows in the South Fork Boise River at Anderson Ranch Dam

Figure 35 shows the projected future stream flows for climate change projections compared to the observed historical period, highlighting the annual variability of both observed and projected future stream flows. The low projection shows similar median peak flow magnitude and timing as the historical period, but a much smaller 90th-percentile peak flow magnitude. The low climate projection has higher summer flows as well as longer summer recession. The high climate projection, on the other hand, shows large increases in runoff in late fall and winter months. The peak of the hydrograph also occurs approximately 1 month earlier than the historical period.

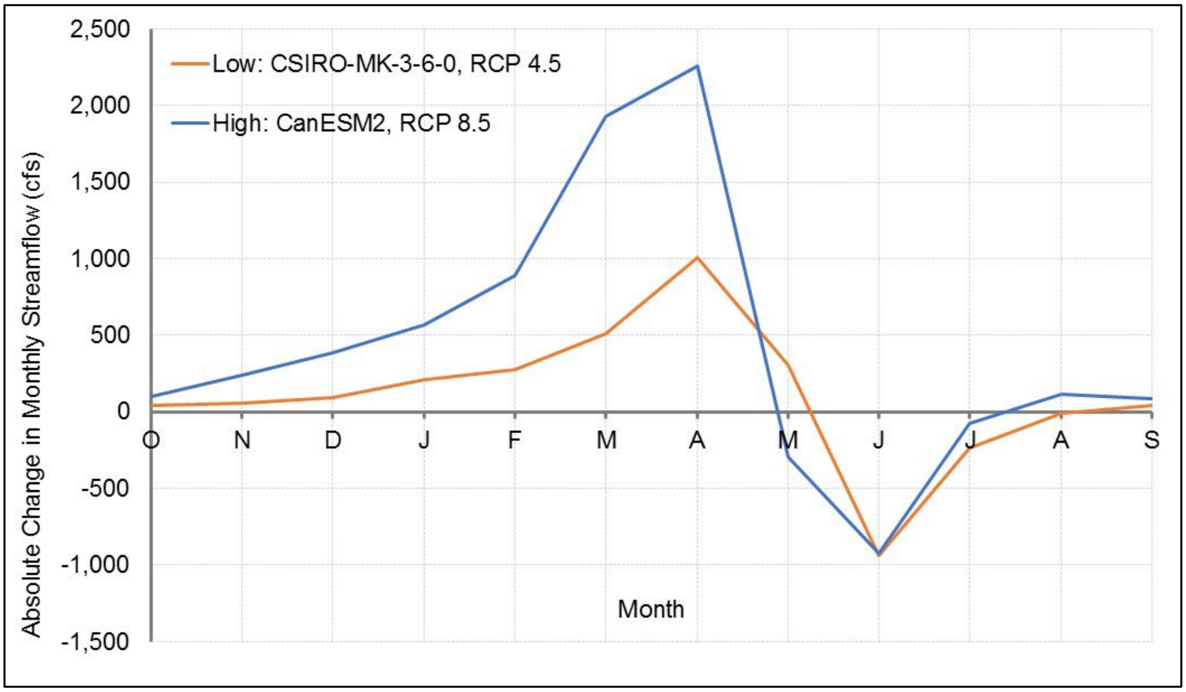

Figure 33. Projected changes in monthly simulated stream flows in the South Fork Boise River at Anderson Ranch Dam: absolute change

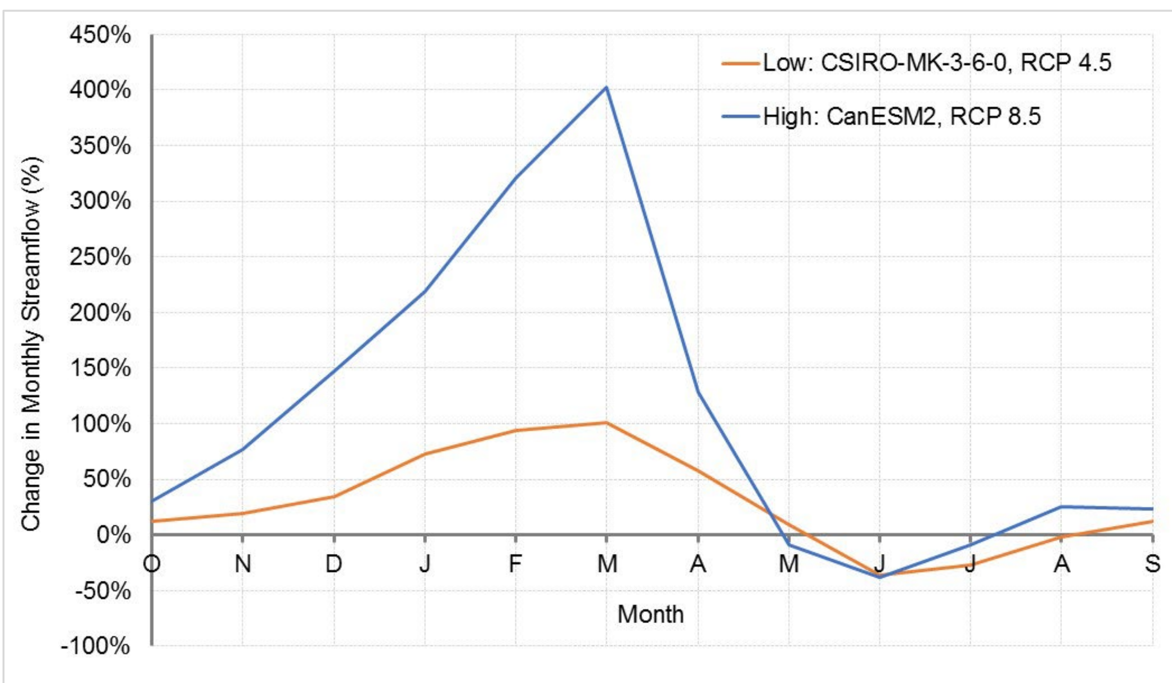

Figure 34. Projected changes in monthly simulated stream flows in the South Fork Boise River at Anderson Ranch Dam: relative change

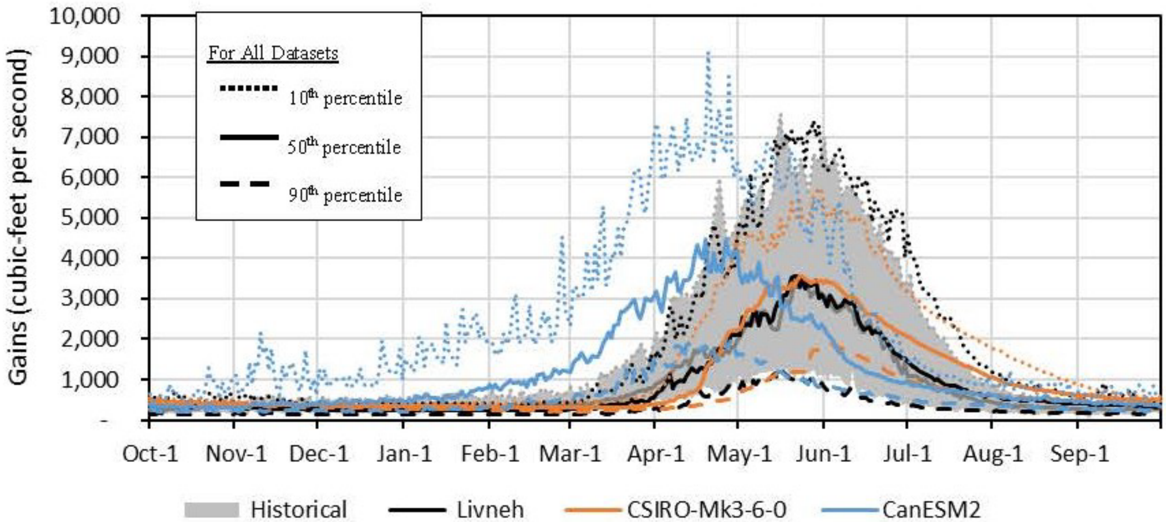

Figure 35. Comparison of historical observed stream flows (gains) and historical simulated gains (Livneh et al.) to future simulated streamflow projections simulated by Low: CSIRO-MK-3-6-0, RCP 4.5 and High: CanESM2, RCP 8.5 at the Anderson Ranch Reservoir

Source: Boise River Basin Feasibility Study – Water Operations Technical Memorandum, April 2020

3.2.2 Alternative B – Anderson Ranch Dam Six-Foot Raise

Impacts of Alternative B to the climate variability resource are described here relative to the description of Alternative A baseline and future climate characterization in Section 3.2.1.

Future climate variability is not expected to make the project inoperable, and may instead make the project more effective than in baseline climate conditions.

Future climate timing and magnitude of inflows showed the potential for increased storage for Alternative B compared to Alternative A (Reclamation, 2020), a minor, indirect and long-term beneficial impact to project operability.

While future climate variability may exacerbate project impacts to other resources, as described below, it is not expected to change other resource impact severity from one category to another.

Baseline Climate Characterization

Baseline climate characterization for Alternative B is identical to that for Alternative A described in Section 3.2.1.

Future Climate Characterization

Future climate characterization for Alternative B is similar to that described for Alternative A in Section 3.2.1. This section focuses on aspects of future climate that uniquely affect or are affected by Alternative B.

Changes in precipitation patterns are projected to cause changes in annual and seasonal stream flows. Wetter winters and increased frequency of extreme precipitation events may increase future flooding. Increased frequency of extreme precipitation events may increase local stormwater runoff and cause increased erosion affecting infrastructure and ecosystems.

Changes in temperature are projected to cause changes in the magnitude and timing of snowmelt, evapotranspiration, and stream flow patterns. Increased temperatures and more frequent freeze/thaw cycles may impact infrastructure strength and reliability, requiring more frequent maintenance. Increased temperatures will likely increase evapotranspiration rates and potentially agricultural water needs and overall energy demands.

Changes in annual and seasonal snowmelt patterns and shifts to the streamflow hydrographs are projected due to increases in temperature. Among other effects, changes to streamflow magnitude and timing may impact stream ecosystems, reservoir operations, and recreational use of water resources.

In addition to impacts of climate variability on the project, increased climate variability is expected to exacerbate impacts of the project on other resources. Resource impacts most susceptible to exacerbation by climate variability include the following.

- Increased long-term erosion potential (Soils and Geology Specialist Report, Appendix B) caused by increased precipitation depths and intensity during some seasons
- Increased long-term water temperature (Water Resources Specialist Report, Appendix B) both in the reservoir and river, caused by increased atmospheric temperature
- Adverse impacts to vegetation (Vegetation Specialist Report, Appendix B) may be exacerbated by increased atmospheric temperatures, changing precipitation patterns, and changing snowmelt patterns
- Increased water temperature caused by increased atmospheric temperature may adversely affect fish and aquatic species (Fisheries Specialist Report, Appendix B)
- Changes to atmospheric temperature, amount and timing of precipitation and their associated effects on natural ecosystems may exacerbate impacts to wildlife (Wildlife Specialist Report, Appendix B)

Future Climate Hydrology

Hydrologic analyses of Alternative B, including future climate reservoir conditions, are described in detail in Reclamation (2020). Figure 36 shows that total 2060s system storage (both low and high climate scenarios) are higher for Alternative B (shaded colored regions) than for Alternative A (shaded grey regions). In addition, 2060s system storage is as high and higher than the baseline climate scenario (2060s panels compared to Livneh panel). Figure 37 shows similar patterns for Anderson Ranch Reservoir storage.

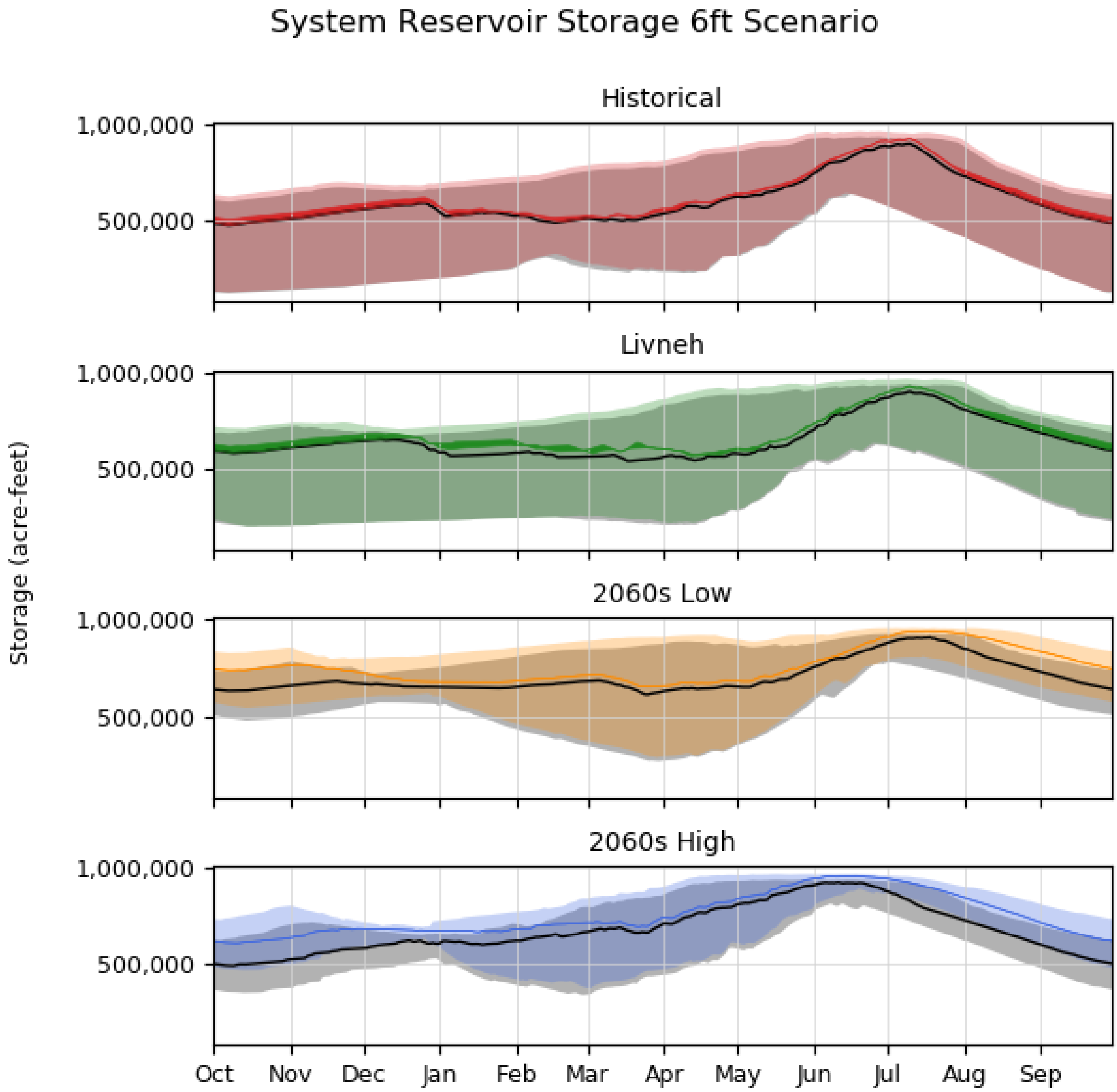

Figure 36. Alternative B, Boise Reservoir System historical and 2060s summary storage hydrographs

Charts depict the daily median storage content range for the 6-foot Raise (narrow solid colored regions) and daily median for the 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 the 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.

Source: Boise River Basin Feasibility Study – Water Operations Technical Memorandum, April 2020

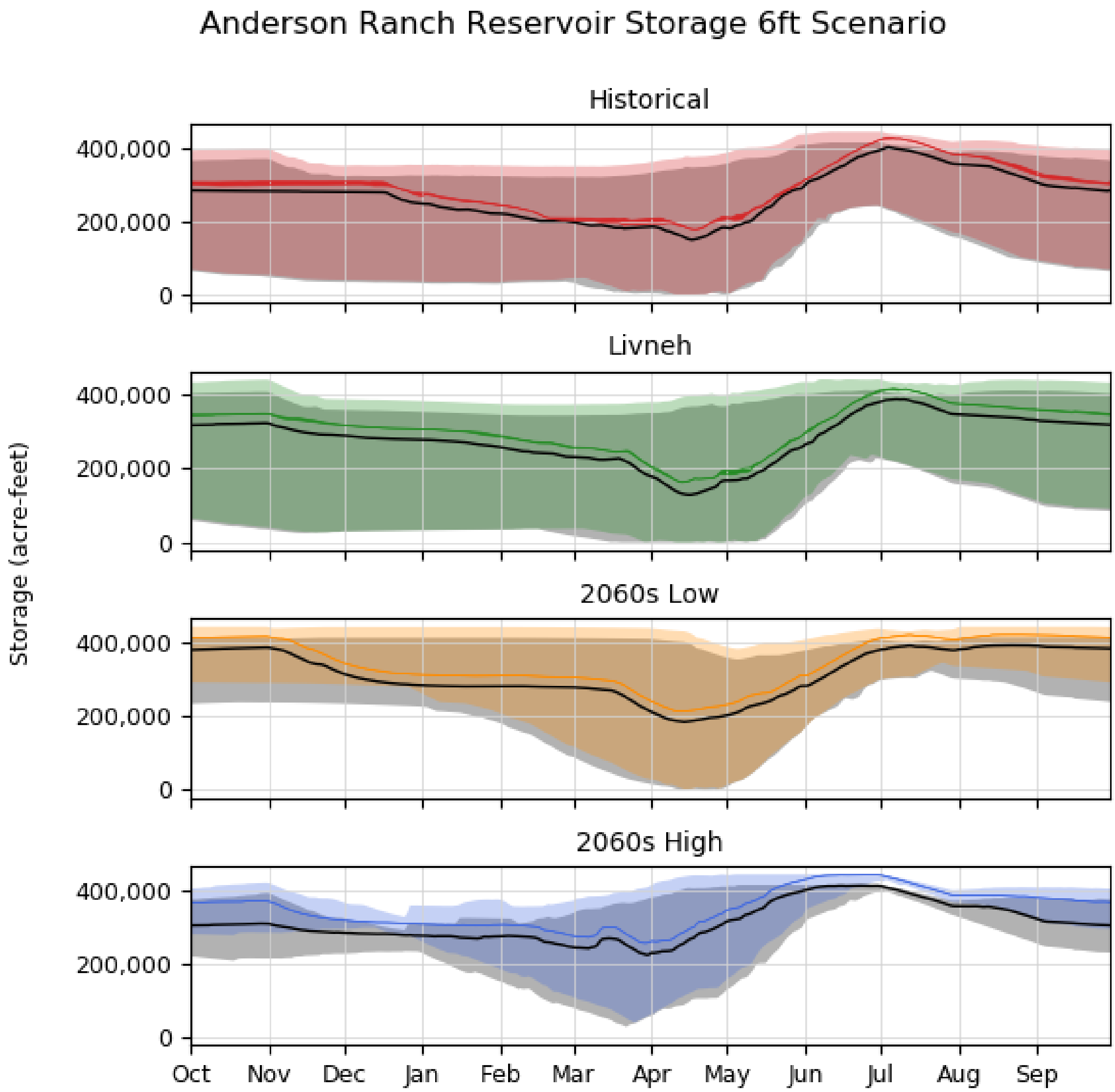

Figure 37. Alternative B, Anderson Ranch Reservoir historical and 2060s summary storage hydrographs

Charts depict the daily median storage content range for the 6-foot Raise (narrow solid colored regions) and daily median for the 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 the 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.

Source: Boise River Basin Feasibility Study – Water Operations Technical Memorandum, April 2020

3.2.3 Alternative C – Anderson Ranch Three-Foot Raise

Future climate variability is not expected to make the project inoperable, and may instead make the project more effective than in baseline climate conditions.

Future climate timing and magnitude of inflows showed the potential for increased storage for Alternative C compared to Alternative A (Reclamation, 2020), a minor, indirect and long-term beneficial impact to project operability.

To the extent that increased climate variability is expected to exacerbate impacts of the project on other resources, impacts associated with those other resources may differ between Alternative B and Alternative C.

Future Climate Hydrology

Hydrologic analyses of Alternative C, including future climate reservoir conditions, are described in detail in Reclamation (2020). Figure 38 shows that total 2060s system storage (both low and high climate scenarios) are higher for Alternative C (shaded colored regions) than for Alternative A (shaded grey regions). In addition, 2060s system storage is as high and higher than the baseline climate scenario (2060s panels compared to Livneh panel). Figure 39 shows similar patterns for Anderson Ranch Reservoir storage.

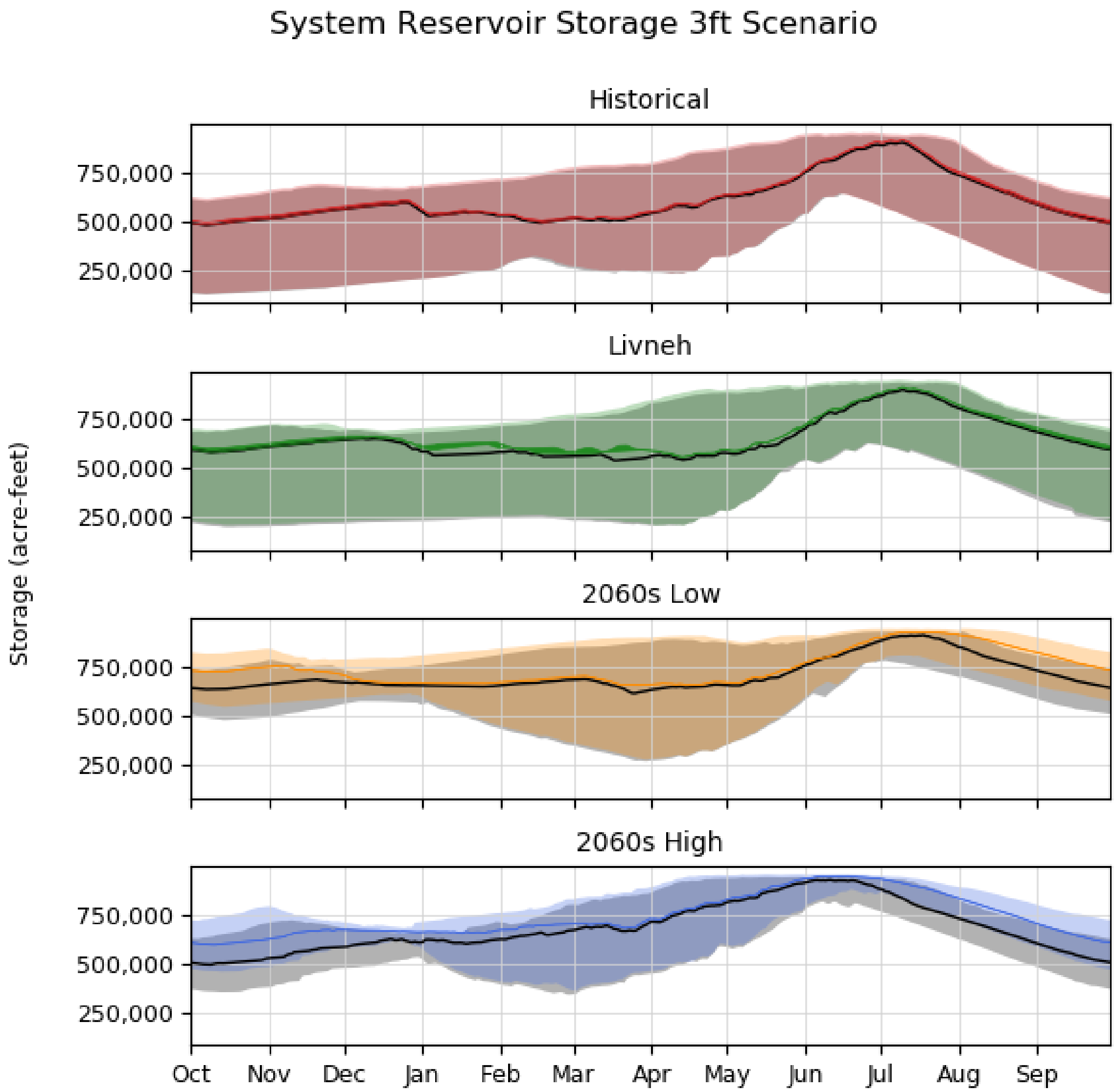

Figure 38. Alternative C, Boise Reservoir System historical and 2060s summary storage hydrographs

Charts depict the daily median storage content range for the 3-foot Raise (narrow solid colored regions) and daily median for the 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 the 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.

Source: Boise River Basin Feasibility Study – Water Operations Technical Memorandum, April 2020

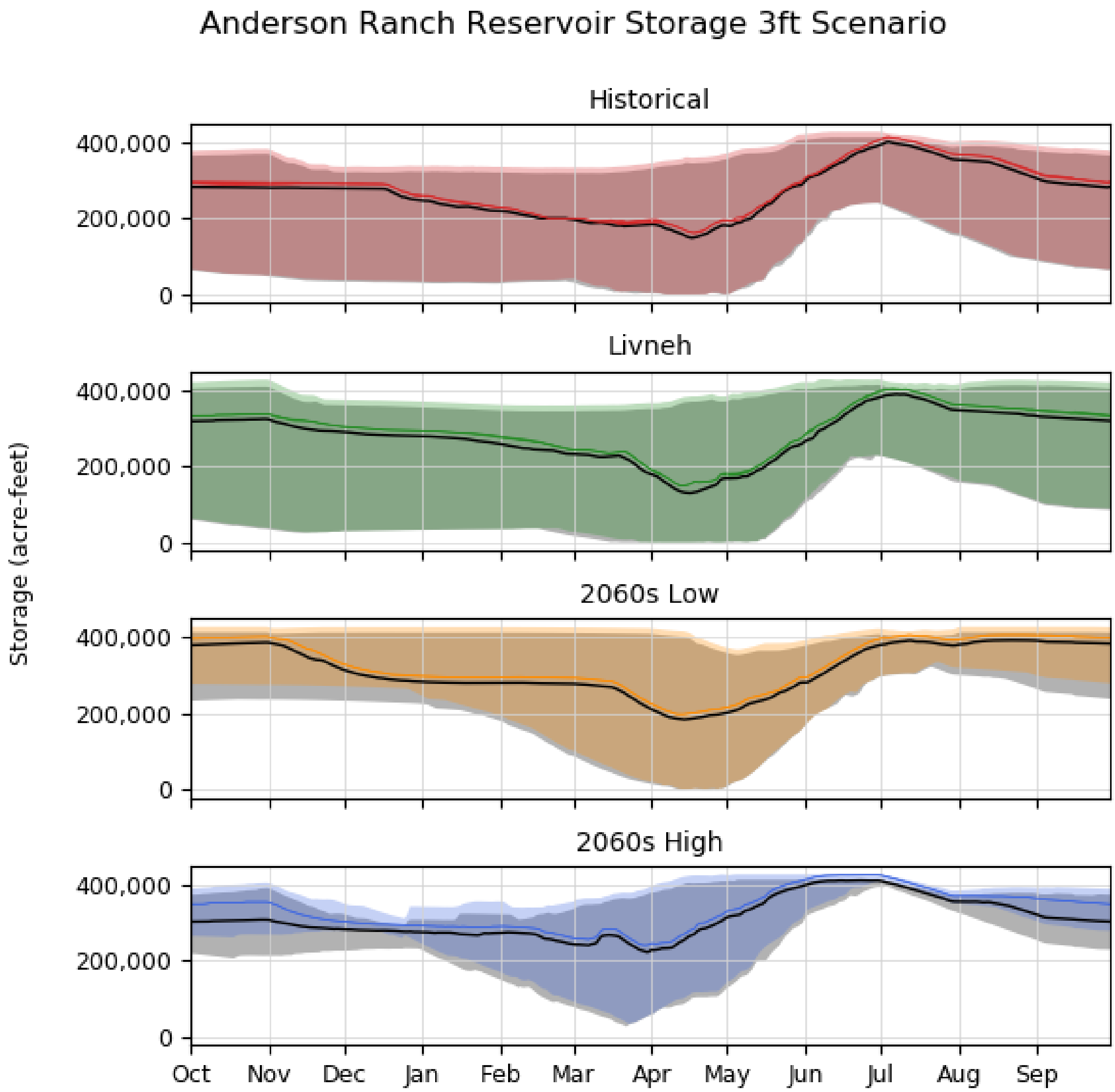

Figure 39. Alternative C, Anderson Ranch Reservoir historical and 2060s summary storage hydrographs

Charts depict the daily median storage content range for the 3-foot Raise (narrow solid colored regions) and daily median for the 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 the 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.

Source: Boise River Basin Feasibility Study – Water Operations Technical Memorandum, April 2020

3.2.4 Cumulative Impacts

Cumulative effects are analyzed for Alternative B and Alternative C. Cumulative effects are those that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. The cumulative effects analysis considers projects, programs, and policies that are not speculative and are based on known or reasonably foreseeable long-range plans, regulations, operating agreements, or other information that establishes them as reasonably foreseeable. Reclamation has identified two past projects: Pine Bridge replacement and the Anderson Ranch Dam crest raise for security enhancement. Reclamation has also identified two potential future projects to be considered for the cumulative impact analysis: Cat Creek Energy Project and South Fork Boise River Diversion Project. Additional project proposal information for these, as known by Reclamation to date, is provided in Chapter 2 of the EIS.

No direct or indirect impacts to climate variability as a result of the past or proposed construction at Pine Bridge or the dam crest are identified, therefore no cumulative impacts for past actions are identified.

The Cat Creek Energy Project and South Fork Boise River Diversion Project both propose to draft water from the reservoir with separate pump stations located along the reservoir rim. Analysis of these projects in Reclamation (2020) using both baseline (Livneh) and future climate scenarios shows that, while the addition of these two projects reduces the refill probability compared to Anderson Only, the increased storage (Alternatives B and C) has a 38% probability of being filled with all three projects. Also, that refill probability increases in both future climate scenarios (Table 7).

Table 7. Refill Probability for Alternatives B and C for Future Climate Scenarios

Scenario	Livneh (1980-2009)		2060s Low		2060s High	
	Alt. B	Alt C.	Alt. B	Alt C.	Alt. B	Alt C.
SFBRDP > CCE > Anderson	50%	56%	57%	63%	92%	92%
SFBRDP > Anderson > CCE	56%	66%	78%	90%	92%	92%
Anderson Only	67%	73%	87%	92%	92%	95%

SFBRDP = South Fork Boise River Diversion Project

CCE = Cat Creek Energy project

Refill probability for the 6-foot (29,000 acre-feet) and 3-foot (14,400 acre-feet) Raise Alternatives given two future climate change scenarios and two new water right permits for SFBRDP and 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.

Source: Boise River Basin Feasibility Study – Water Operations Technical Memorandum, April 2020

3.2.5 Mitigation

Because only negligible or beneficial impacts are associated with the climate variability resource, mitigation is not required and not proposed. Note that the term “mitigation” is often used in climate documents to refer to mitigation of greenhouse gas emissions. Analysis and discussion of greenhouse gas emissions and emissions mitigation are described in the Air Quality Specialist Report (Appendix B).

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4. References

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