CHAPTER 4 - CLIMATE

This chapter provides an overview of projected changes in future regional climate and assesses how these changes may affect resources and the effectiveness of the alternatives of this environmental impact statement (EIS). The first part of this chapter discusses changes in regional trends for air temperature, precipitation, snowpack, streamflow, and water temperature based on recent regional climate change studies. The second part of this chapter assesses the effects of these projected climate changes on the resources included for analysis for each of the alternatives.

4.1 CLIMATE CHANGE IN THE COLUMBIA RIVER BASIN

The environmental consequences on the physical, biological, economic, social, and cultural resources discussed in Chapter 3 reflect modeling and analyses based on observed climate in the region over the 80-year period of 1929 to 2008. Temperatures have increased during and after that time period and are expected to continue to increase (U.S. Global Change Research Program [USGCRP] 2017; River Management Joint Operating Committee [RMJOC] 2018). As a result of these rising temperatures, other aspects of the environment are changing as well, such as receding glaciers, diminishing snow cover, shrinking sea ice, rising sea levels, and increasing atmospheric water vapor (USGCRP 2017). According to the Fourth National Climate Assessment Volume I (USGCRP 2017), annual trends of earlier spring snow melt and reduced snowpack are already affecting water resources in the western United States, and these trends are expected to continue. Numerous studies have projected that as warming continues, snowpack in the Columbia River Basin is likely to decline, winter streamflows will tend to increase, peak seasonal snowmelt season will tend to occur earlier in the spring, and summer flows will likely decrease (RMJOC 2018).

The basis for climate assessment in this EIS includes projected regional temperature, precipitation, snowpack, and streamflow changes from the first part of the second RMJOC long-term planning study, commonly referred to as the RMJOC-II study. Part 1 of this study presents the results of a 4-year research project completed by the University of Washington and Oregon State University, with resource support and technical expertise provided by the RMJOC[1] agencies and regional stakeholders (RMJOC 2018). This study presents the most recent and best available scientific information on the future hydroclimate for the Columbia River Basin. The RMJOC-II report (2018) found the following for the 2020 to 2049 time period (referred to as the 2030s):

- Temperatures in the region have warmed about 1.5 degrees Fahrenheit (0.8 degrees Celsius) since the 1970s. They are expected to warm another 1 to 4 degrees Fahrenheit (0.6 to 2.2 degrees Celsius) by the 2030s.

1 The RMJOC comprises the Bonneville Power Administration (Bonneville), U.S. Army Corps of Engineers (Corps), and U.S. Bureau of Reclamation (Reclamation), also referred to collectively as the co-lead agencies throughout this EIS. An objective of the committee is to evaluate and anticipate vulnerabilities, risk, and resiliency of the Federal Columbia River Power System.

- Warming in the region is likely to be greatest in the interior with a greater range of possible outcomes. Less pronounced warming is projected near the coast.
- Future precipitation trends are more uncertain, but a general upward trend is likely for the rest of the twenty-first century, particularly in the winter months. Already dry summers could become drier.
- Average winter snowpacks are very likely to decline over time as more winter precipitation falls as rain instead of snow, especially on the United States side of the Columbia River Basin.
- By the 2030s, higher average fall and winter flows, earlier peak spring runoff, and longer periods of low summer flows are very likely. The earliest and greatest streamflow changes are likely to occur in the Snake River Basin, although that basin has the greatest modeling uncertainty.

The RMJOC-II report concludes that "such precipitation increases, along with a warming climate, could have profound implications on both the magnitude and seasonality of future streamflows for hydroregulation operations and planning."

4.1.1 Approach

This EIS uses climate and hydrology projections from the RMJOC-II study to assess potential effects to the resources and effectiveness of the alternatives of the EIS. In 2013, the RMJOC commissioned a research team from the University of Washington and Oregon State University to develop a set of unregulated streamflows derived from the latest global climate model projections from the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment (RMJOC 2018). These unregulated streamflows are largely unaffected by human activity in the Columbia River Basin (i.e., no human regulation, dams, or irrigation withdrawals). The resulting report provides air temperature, precipitation, snowpack, and streamflow changes that are projected to occur as the regional climate changes. A second part of the RMJOC-II study, which is not yet available, will provide an assessment of how these projected unregulated streamflows perform in a regulated Columbia River system.[2]

The RMJOC-II projections include scenarios for two Representative Concentration Pathways (RCPs), RCP 4.5 and RCP 8.5, which represent future scenarios for emissions of greenhouse gases (GHGs). Over the next 20- to 30-year time horizon, both RCP 4.5 and RCP 8.5 project a similar increase in regional temperatures (Moss et al. 2010; RMJOC 2018). However, where applicable, conclusions for the two different RCPs are identified separately.

The RMJOC-II study focused on changes in air temperature, precipitation, snowpack, and streamflow. Other aspects of climate change, such as water temperature and sea level rise, may have implications for regional resources as well, but were not modeled in the RMJOC-II study.

[2] The co-lead agencies expect this study to be published in spring 2020 after release of the draft EIS and will review the study to determine if any information presented in the draft EIS needs to be updated.

Where applicable, other climate research and literature are incorporated to assess these potential effects on resources.

4.1.2 Projected Changes in Hydroclimate

4.1.2.1 Air Temperature

Temperatures have already warmed in the Columbia River Basin by about 1.5 degrees Fahrenheit since the 1970s (Figure 4-1) (RMJOC 2018). The RMJOC-II study found that warming is nearly certain to continue with annual projected temperature increases from the historical period (1970 to 1999) to the 2030s, ranging from 2.0 to around 5.5 degrees Fahrenheit across the Columbia River Basin. However, these projections vary both by geographic location and seasonally. Interior areas of the basin are projected to experience more warming than areas near the Pacific Coast, where warming of 1.5 to 2.5 degrees Fahrenheit is projected. Warming is also projected to be greater during the summer months compared to the other seasons.

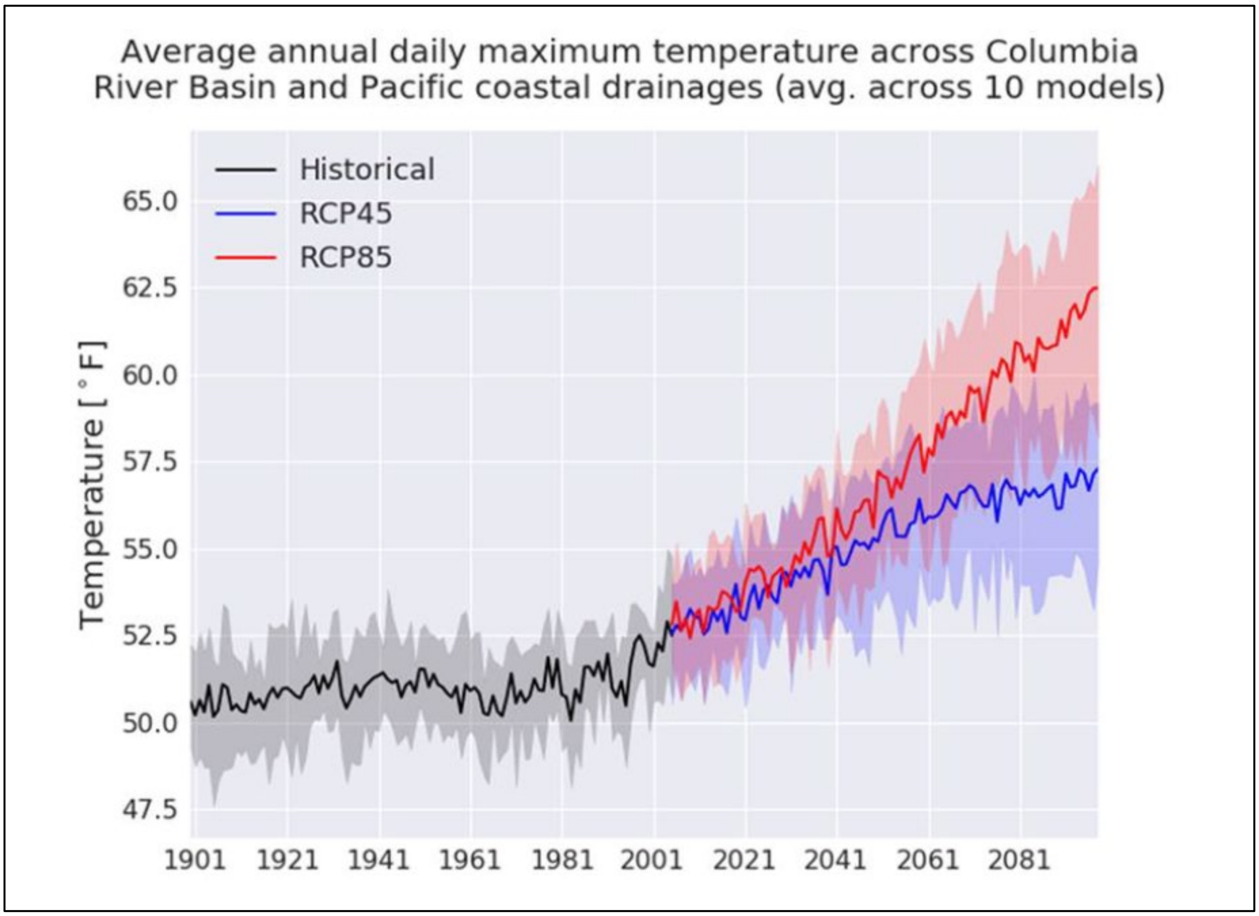

Figure 4-1. Average Annual Daily Maximum Temperatures for the Columbia River Basin and Pacific Coastal Drainages in Washington and Oregon Through 2100 for RCP 4.5 and 8.5

Source: RMJOC (2018)

4.1.2.2 Precipitation

The large annual variability in precipitation in the Columbia River Basin is projected to continue. However, there is a general tendency for precipitation to increase, and by the 2030s, precipitation will begin to exceed the long-term average more often than not (RMJOC 2018). Changes in precipitation are likely to vary across seasons, with a tendency for higher winter precipitation and lower summer precipitation. However, some model projections imply that summer precipitation could increase over the southern half of the Columbia River Basin. While precipitation trends are more uncertain than temperature trends, these results have been supported by other recent climate model projections (Salathé et al. 2014; Department of Energy [DOE] 2017; Rupp, Abatzoglou, and Mote 2017).

4.1.2.3 Snowpack

The RMJOC-II study projects that snowpack in the Columbia River Basin will decrease over time. Even with the possibility of more precipitation in the winter, warming temperatures are very likely to result in declining snowpacks available to support spring and summer runoff. Given that historically most of the Columbia River Basin's annual precipitation and flow have been snow-dominated, with at least half of the annual precipitation falling as snow, these changes over time represent perhaps the greatest hydroclimate change in the region.

As depicted in Figure 4-2, the snowpack on April 1 (the date near where the snowpack typically reaches its annual maximum in the U.S. portion of the Columbia River Basin) is projected to decrease. By the 2030s[3] (2020 to 2049), the April 1 Snow Water Equivalent is projected to be between 10 to 60 percent lower in the Cascades, coastal mountains, and lower portions of the Clearwater and Spokane River Basins, with continued decreases over time as more precipitation falls as rain instead of snow. One exception to these trends is in the Canadian portion of the Columbia River Basin where average winter temperatures, even with the degree of warming expected, are unlikely to be great enough to lead to significant reductions in snowpack through the 2030s (RMJOC 2018).

[3] Standard nomenclature for climate change studies referring to the 30-year period surrounding the 2020s (2010 to 2039).

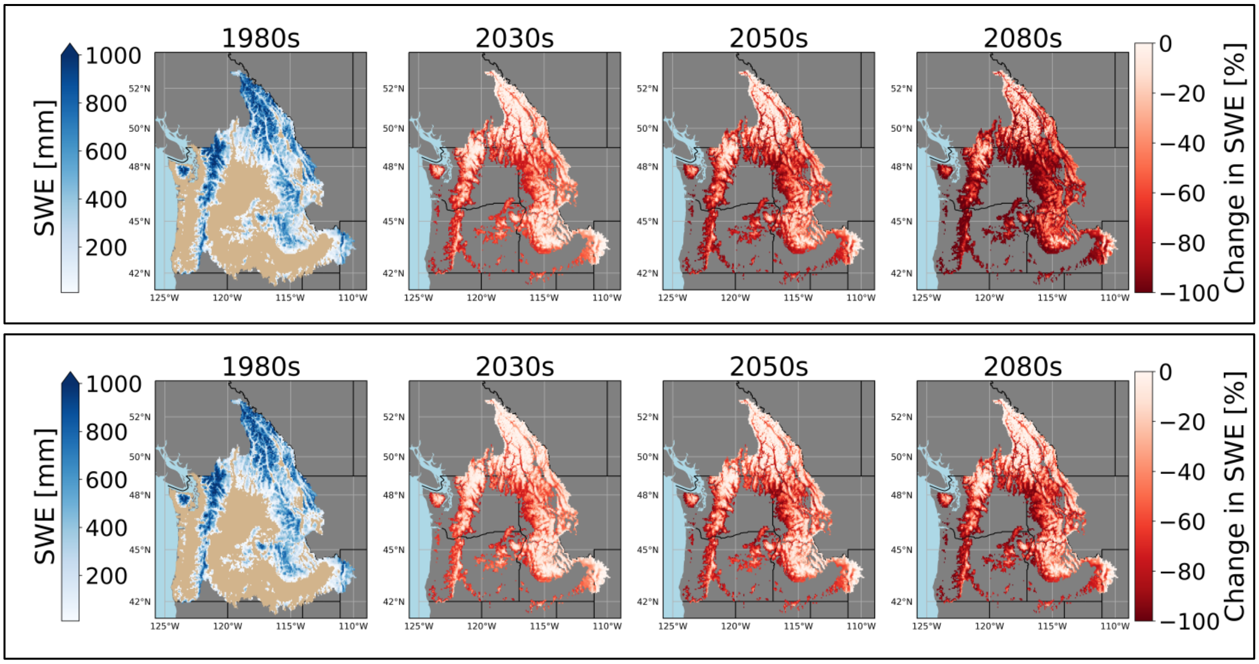

Figure 4-2. Columbia River Basin Snow Water Equivalent on April 1 in the 1980s, and Average Snow Water Equivalent Changes by the 2030s, 2050s (2040–2069), and 2080s (2070–2099)

Note: Top is RCP 8.5 and bottom is RCP 4.5. Areas in tan historically have less than 10 millimeters (0.4 inches) of snow-water equivalent. Although this EIS focuses on the 2030s, the 2050s and 2080s are included in the analysis to show trends.

Source: University of Washington

4.1.2.4 Streamflow

The RMJOC-II study (2018) concluded that by the 2030s, the Columbia River Basin will likely experience higher average winter flows, earlier peak spring runoff, lower average summer flows, a longer period of low summer flows, or a combination of all of these. These findings align with those of previous studies, including the RMJOC-I report (2010), the Fourth National Climate Assessment (USGCRP 2017), the DOE Report to Congress (DOE 2017), and the Reclamation SECURE Water Act Assessment (Reclamation 2016).

For the Columbia River Basin as a whole, the warming temperatures and tendency for increased precipitation, particularly in the already wet winter months, will result in higher winter and spring volumes with earlier spring flow peaks. In the summer, there is a tendency for slightly lower flows or a longer period of low flows. However, these results are not necessarily universal across all basins. The Willamette River Basin and coastal drainage areas have a tendency toward lower spring flows, and there is some disagreement across models in the Snake River Basin where some scenarios show the possibility of increased fall streamflows (RMJOC 2018). Figure 4-3 and Figure 4-4 show the projected changes in seasonal streamflow by location across the Columbia River Basin.

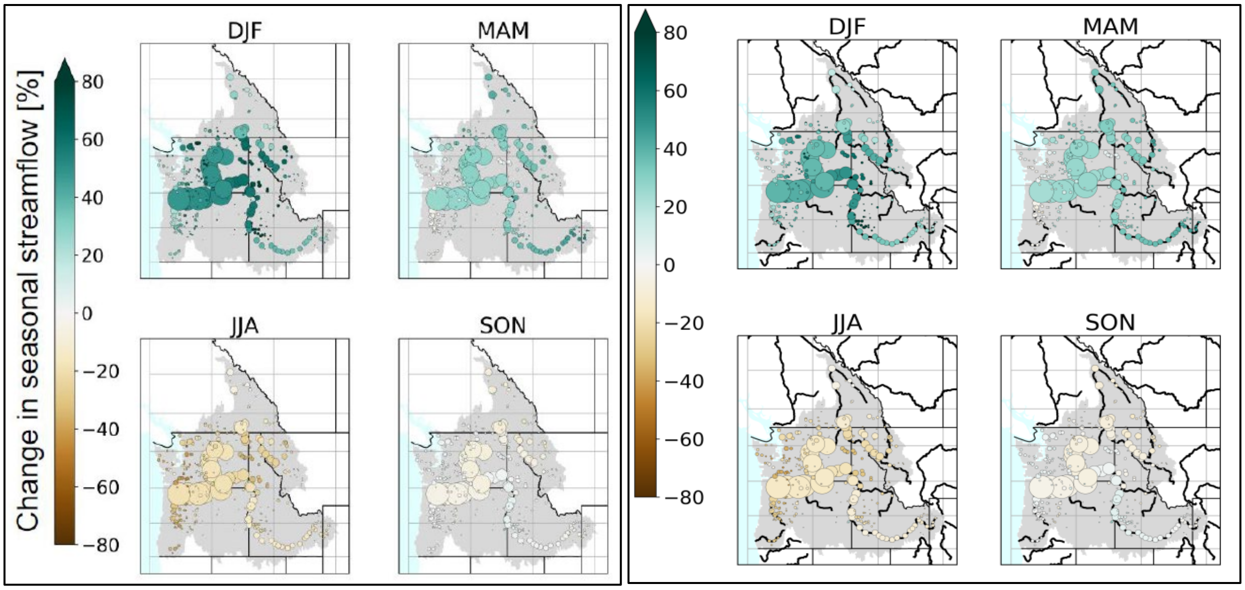

Figure 4-3. Percent Change in Annual Volume from the Historical Period (1976–2005) and the 2030s (2020–2049) by Season

Note: Left is RCP 8.5 and right is RCP 4.5. DJF = December to February/winter; MAM = March-May/spring; JJA = June to August/summer; SON = September to November/fall. Circle size denotes relative annual volumes in the historical period (1976–2005).

Source: University of Washington

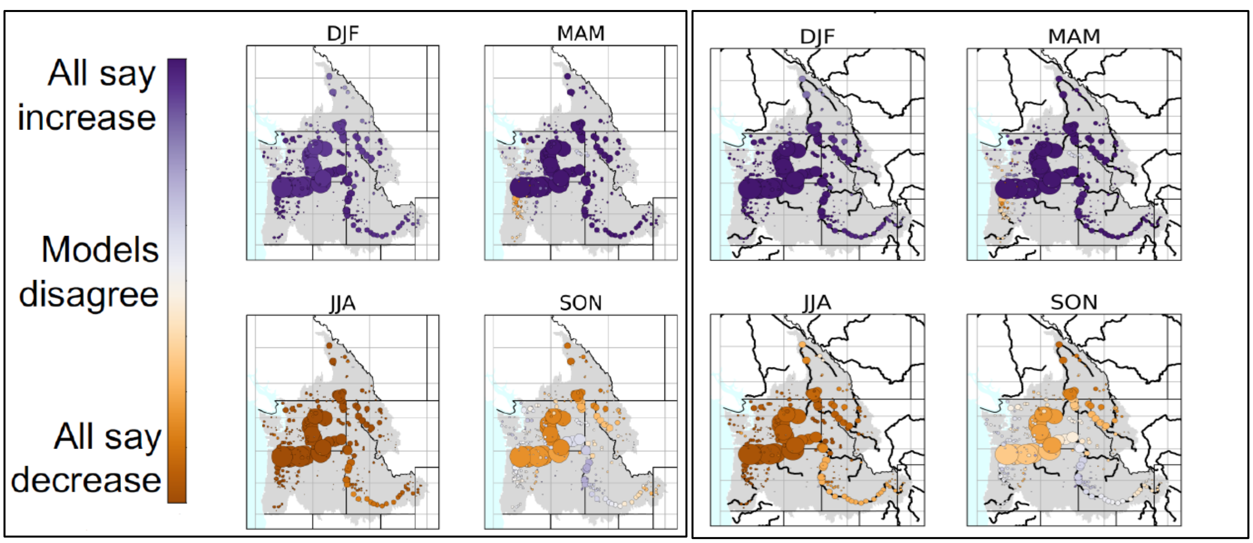

Figure 4-4. Annual Volume Change from the Historical Period (1976–2005) and the 2030s (2020–2049) by Season

Note: Left is RCP 8.5 and right is RCP 4.5. DJF = December to February/winter; MAM = March-May/spring; JJA = June to August/summer; SON = September to November/fall.

Source: University of Washington

REGION A – LIBBY, HUNGRY HORSE, AND ALBENI FALLS DAMS

Changes in these upper basins tend to be more modest through the 2030s, largely because winter precipitation is projected to continue to fall as snow for some time. However, even here the scenarios still project increased temperatures and annual precipitation, and changes in spring and early summer streamflow. Some scenarios indicate higher spring freshet peaks that tend to occur 1 or 2 weeks earlier, by the 2030s (RMJOC 2018). Decreasing summer flow volumes are pervasive in these basins. At the headwater of the Pend Oreille River, changes in inflows to Hungry Horse Dam are relatively modest by the 2030s, with slightly earlier timing and intensified high flows in winter and early spring (Table 4-1, Table 4-2, Table 4-3, Figure 4-5, Figure 4-6, and Figure 4-7).

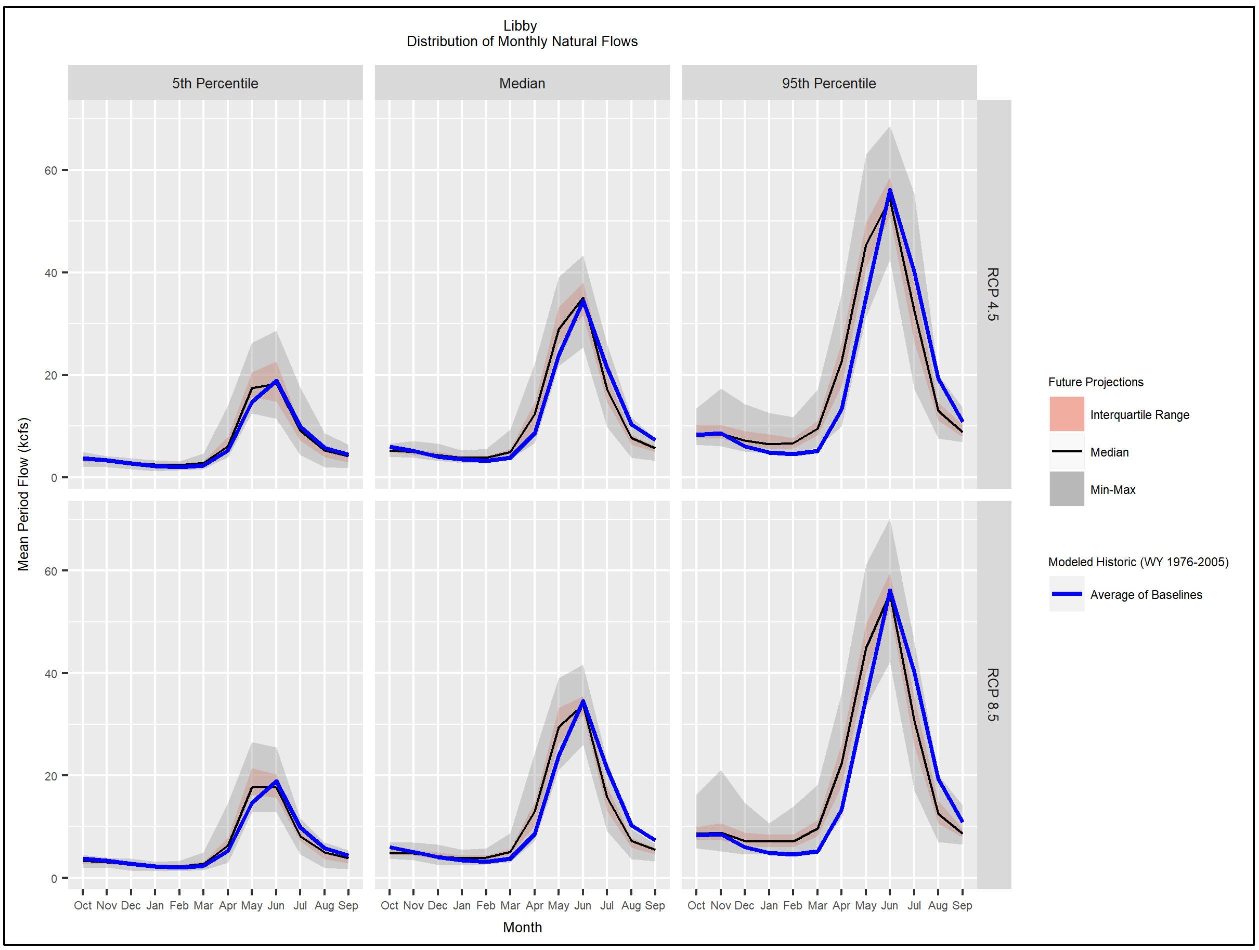

Figure 4-5. Distribution of the RMJOC-II Naturalized Flows, by Month at Libby Dam for the 2030s Time Period for RCP 4.5 and 8.5

Note: The “average of the baselines” represents four hydrology models/parameter sets that were used to model a 30-year historical (1976–2005) condition for RMJOC-II, with each historical condition being modeled. Each of the four historical conditions were modeled with a different hydrology model or parameter set. The RMJOC-II modeled historical conditions are not equivalent to the 80-year water conditions described previously in this EIS because they include adjustments for temperature biases in historical datasets (RMJOC 2018).

Table 4-1. Relative Change (%) in Unregulated Monthly Streamflow at Libby Dam

	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
Month	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Oct	-38 to 26 (-5)	-39 to 15 (-12)	**-31 to 12 (-12)**	**-37 to 20 (-18)**	-17 to 55 (4)	-29 to 88 (5)
Nov	-37 to 27 (-5)	-33 to 22 (-12)	-24 to 27 (-5)	-28 to 30 (-6)	-33 to 88 (3)	-33 to 128 (3)
Dec	-41 to 36 (2)	-46 to 36 (-5)	-25 to 54 (6)	-33 to 53 (2)	-16 to 152 (21)	-19-159 (21)
Jan	-46 to 50 (12)	-40 to 38 (8)	-25 to 58 (11)	-32 to 65 (11)	**-7 to 190 (33)**	**-8-146 (45)**
Feb	-40 to 60 (24)	-35 to 65 (18)	-19 to 72 (21)	-23 to 90 (25)	**0 to 177 (43)**	**-4-229 (60)**
Mar	-25 to 94 (18)	-26 to 92 (19)	**-1 to 136 (28)**	**-14 to 123 (34)**	**21 to 256 (82)**	**26-296 (83)**
Apr	**-16 to 142 (17)**	-34 to 115 (21)	**-5 to 130 (36)**	**0 to 139 (47)**	**-13 to 152 (70)**	**0-145 (63)**
May	**-17 to 82 (24)**	**-17 to 54 (27)**	**-9 to 52 (22)**	**-9 to 59 (25)**	**-2 to 74 (30)**	**-1-62 (28)**
Jun	-41 to 48 (-4)	-34 to 32 (-5)	-25 to 27 (2)	-23 to 15 (-3)	-27 to 24 (-4)	-28-27 (-2)
Jul	-46 to 60 (-13)	**-42 to 17 (-19)**	-43 to 11 (-23)	**-51 to 2 (-27)**	-45 to 27 (-21)	**-45 to -3 (-25)**
Aug	-48 to 30 (-17)	**-49 to 9 (-20)**	**-49 to 0 (-30)**	**-52 to -12 (-34)**	**-55 to -9 (-35)**	**-53 to -7 (-34)**
Sep	-40 to 23 (-14)	**-42 to 10 (-19)**	**-49 to -1 (-26)**	**-47 to -11 (-30)**	-38 to 22 (-18)	**-40 to 28 (-20)**

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections are presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections agree on the direction of change in volume.

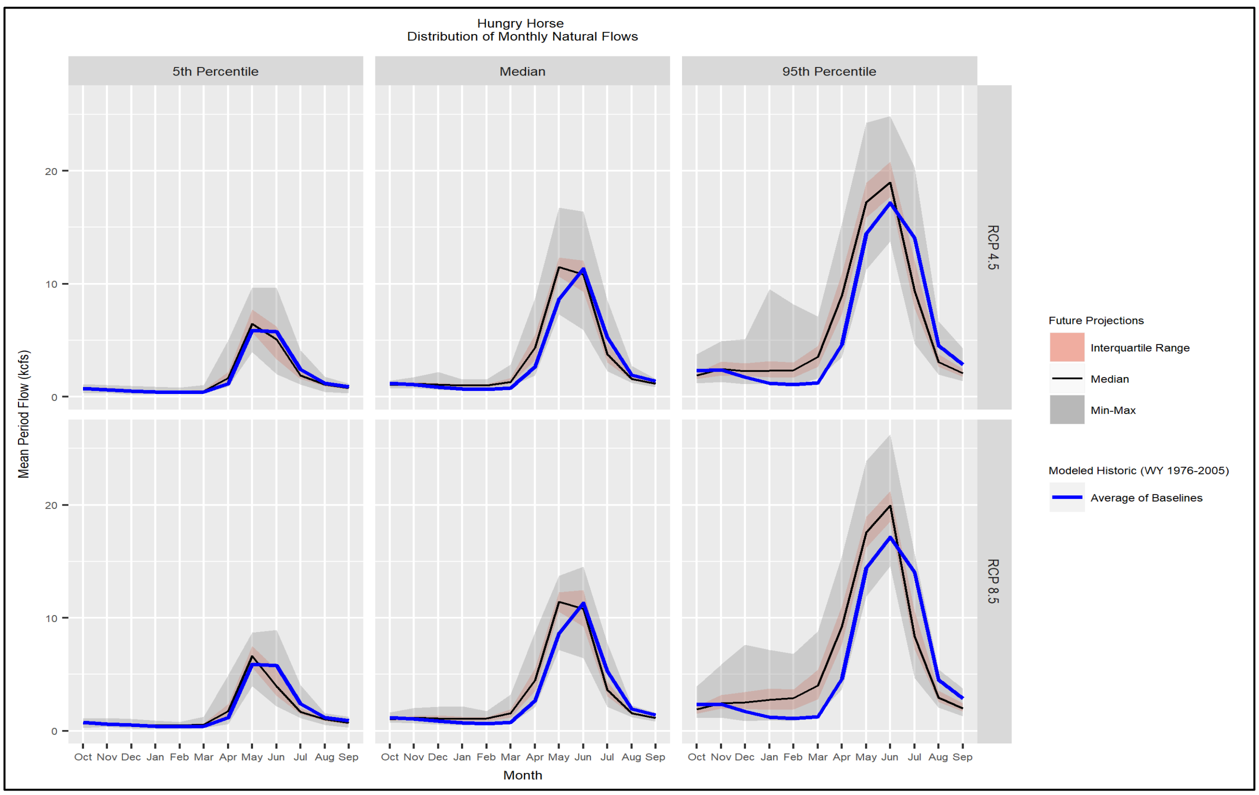

Figure 4-6. Distribution of the RMJOC-II Naturalized Flows, by Month at Hungry Horse Dam for the 2030s Time Period for RCP 4.5 and 8.5

Table 4-2. Relative Change (%) in Unregulated Monthly Streamflow at Hungry Horse Dam

	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
Month	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Oct	-50 to 31 (-4)	-64 to 29 (-12)	-42 to 24 (-13)	-39 to 41 (-15)	-53 to 70 (-19)	-54 to 79 (-19)
Nov	-36 to 58 (8)	-28 to 59 (6)	-25 to 70 (9)	-35 to 99 (12)	-33 to 88 (6)	-43 to 125 (4)
Dec	-54 to 57 (7)	-46 to 75 (6)	-22 to 158 (29)	-32 to 152 (34)	-27 to 161 (32)	**-44 to 288 (50)**
Jan	-40 to 96 (15)	-57 to 103 (15)	**-19 to 125 (40)**	-31 to 213 (51)	**-14 to 757 (100)**	**-27 to 546 (128)**
Feb	-35 to 127 (24)	-58 to 122 (25)	**-7 to 147 (54)**	**-15 to 178 (63)**	**-9 to 666 (120)**	**-23 to 538 (153)**
Mar	-28 to 158 (20)	-39 to 206 (31)	**12 to 269 (71)**	**-23 to 354 (95)**	**23 to 520 (186)**	**12 to 617 (222)**
Apr	**-24 to 261 (45)**	-48 to 313 (51)	**-14 to 215 (61)**	**-5 to 232 (64)**	**-3 to 186 (99)**	**8 to 210 (101)**
May	-30 to 67 (14)	-39 to 57 (13)	**5 to 74 (31)**	**4 to 78 (33)**	**-11 to 81 (19)**	**2 to 70 (23)**
Jun	-66 to 56 (-13)	-62 to 53 (-33)	-47 to 41 (-7)	-42 to 25 (-5)	-22 to 46 (12)	-11 to 55 (16)
Jul	-51 to 34 (-19)	-49 to 30 (-28)	-52 to 26 (-25)	**-51 to 14 (-31)**	**-62 to 23 (-31)**	**-63 to -10 (-37)**
Aug	-58 to 39 (-11)	-46 to 16 (-15)	-38 to 25 (-18)	**-39 to 4 (-18)**	**-57 to 19 (-29)**	**-54 to 14 (-31)**
Sep	-58 to 23 (-13)	-60 to 25 (-22)	-41 to 11 (-15)	**-40 to 14 (-16)**	-49 to 51 (-28)	**-52 to 32 (-30)**

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections are presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections agree on the direction of change in volume.

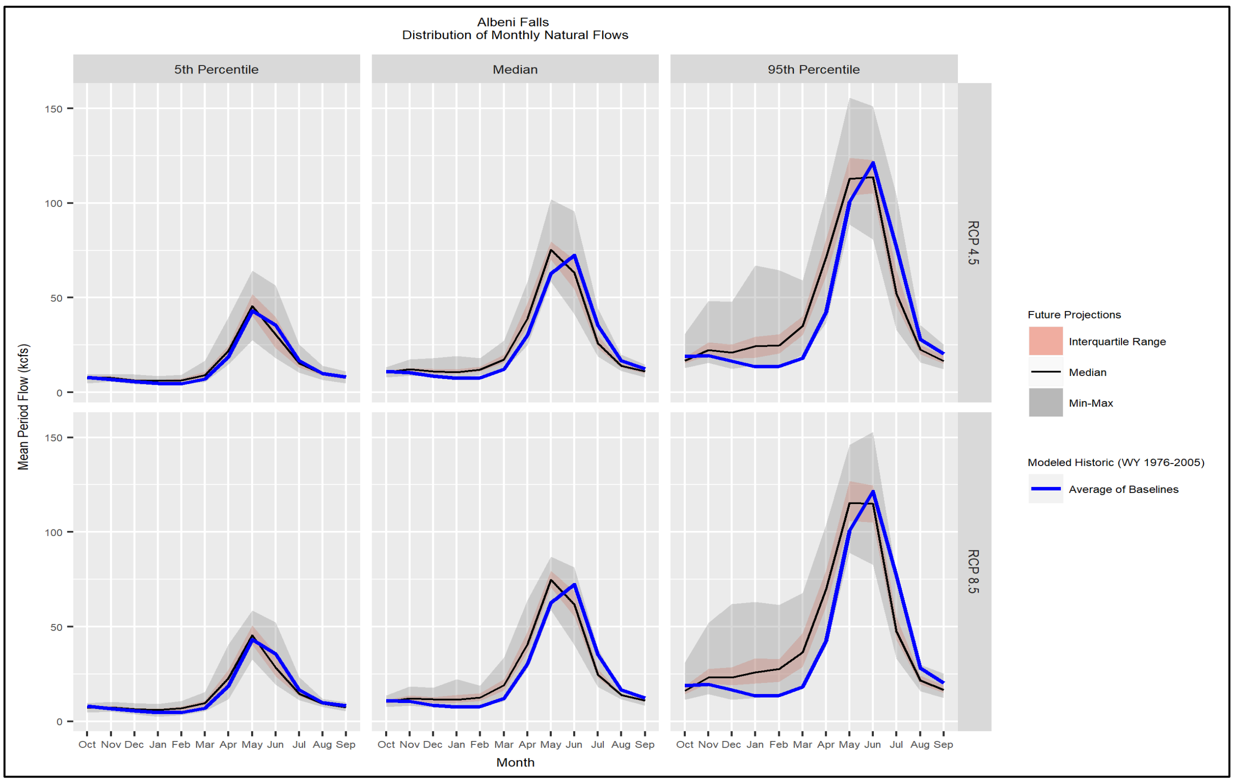

Figure 4-7. Distribution of the RMJOC-II Naturalized Flows, by Month at Albeni Falls Dam for the 2030s Time Period for RCP 4.5 and 8.5

Table 4-3. Relative Change (%) in Unregulated Monthly Streamflow at Albeni Falls Dam

	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
Month	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Oct	-35 to 18 (-5)	-36 to 15 (-10)	-25 to 15 (-4)	-29 to 26 (-7)	-25 to 41 (-10)	-33 to 42 (-14)
Nov	-11 to 53 (15)	-13 to 57 (9)	-11 to 68 (15)	-17 to 78 (17)	-17 to 117 (21)	-24 to 133 (23)
Dec	-12 to 62 (14)	-22 to 78 (14)	**1 to 115 (28)**	**-11 to 113 (35)**	-18 to 199 (26)	**-35 to 287 (39)**
Jan	**-16 to 86 (27)**	-49 to 94 (28)	**7 to 173 (41)**	**-2 to 217 (53)**	**1 to 429 (86)**	**-5 to 397 (93)**
Feb	**-9 to 129 (40)**	-33 to 133 (49)	**16 to 136 (56)**	**1 to 158 (68)**	**-1 to 370 (75)**	**5 to 348 (104)**
Mar	**-8 to 129 (30)**	**-19 to 124 (35)**	**4 to 133 (43)**	**-9 to 188 (57)**	**18 to 210 (88)**	**16 to 254 (105)**
Apr	-19 to 127 (15)	-37 to 133 (23)	**-9 to 92 (33)**	**3 to 99 (36)**	**-2 to 119 (72)**	**6 to 150 (68)**
May	-35 to 47 (9)	-29 to 35 (8)	-5 to 56 (20)	-2 to 38 (21)	-22 to 69 (11)	**-14 to 44 (15)**
Jun	-51 to 55 (-13)	-47 to 50 (-22)	-42 to 25 (-13)	**-39 to 14 (-12)**	-36 to 18 (-7)	-26 to 20 (-6)
Jul	-37 to 42 (-9)	-33 to 32 (-13)	-47 to 16 (-25)	**-50 to 1 (-28)**	**-57 to 20 (-29)**	**-53 to -19 (-35)**
Aug	-31 to 48 (-2)	-23 to 25 (-3)	-29 to 15 (-16)	**-29 to -5 (-17)**	**-44 to 9 (-21)**	**-44 to 10 (-22)**
Sep	-37 to 36 (0)	-29 to 17 (-7)	-33 to 14 (-11)	**-30 to 8 (-12)**	-34 to 16 (-17)	-36 to 20 (-17)

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections is presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections agree on the direction of change in volume.

REGION B – GRAND COULEE AND CHIEF JOSEPH DAMS

Cumulative streamflow in Region B integrates flows from Region A and the Upper Columbia, the northernmost part of the Columbia Basin in British Columbia. Similar to Region A, streamflow projections show modest change, as snowpack at high elevations of the upper basin display less sensitivity to lower amounts of warming (Figure 4-2). However, a shift toward earlier spring and summer streamflow volumes is projected. Some projections indicate higher spring freshet peaks, which tend to occur 1 or 2 weeks earlier by the 2030s as precipitation increases in this part of the basin and the climate warms. Nearly all projections indicate decreased volume of flow in the summer months (Figure 4-8 and Table 4-4).

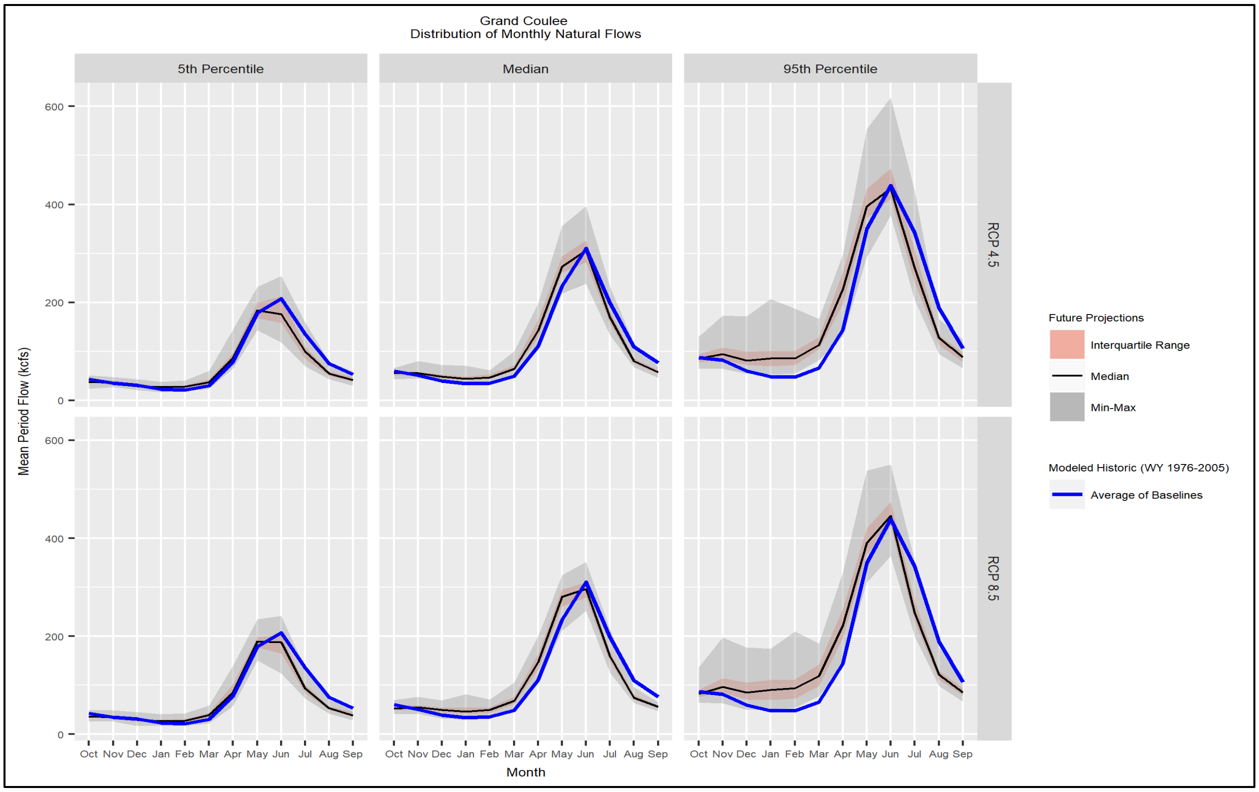

Figure 4-8. Distribution of the RMJOC-II Naturalized Flows, by Month, at Grand Coulee Dam for the 2030s Time Period for RCP 4.5 and 8.5

Table 4-4. Relative Change (%) in Unregulated Monthly Streamflow at Grand Coulee Dam

Month	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Oct	-45 to 17 (-10)	-40 to 14 (-13)	-27 to 14 (-8)	-31 to 20 (-13)	-20 to 38 (-1)	-26 to 45 (-5)
Nov	-22 to 33 (2)	-23 to 36 (-2)	-12 to 56 (8)	-17 to 49 (8)	-19 to 89 (17)	-15 to 116 (22)
Dec	-31 to 41 (-7)	-44 to 48 (-8)	**4 to 86 (19)**	-15 to 79 (27)	**-5 to 186 (34)**	**-12 to 195 (43)**
Jan	-27 to 73 (17)	-27 to 86 (14)	**4 to 116 (28)**	**-13 to 150 (37)**	**7 to 364 (74)**	**4 to 290 (82)**
Feb	**-17 to 108 (33)**	**-19 to 115 (31)**	**8 to 76 (31)**	**-8 to 100 (40)**	**13 to 302 (77)**	**9 to 349 (95)**
Mar	-18 to 103 (23)	**-23 to 99 (28)**	**3 to 103 (33)**	**-7 to 123 (41)**	**28 to 135 (72)**	**22 to 186 (82)**
Apr	-21 to 87 (9)	-31 to 80 (8)	**-2 to 82 (33)**	**4 to 82 (32)**	**4 to 97 (62)**	**13 to 119 (52)**
May	-22 to 31 (4)	-18 to 33 (6)	**0 to 42 (18)**	**0 to 43 (19)**	-8 to 56 (14)	**-9 to 58 (11)**
Jun	-43 to 20 (-15)	-41 to 15 (-10)	-22 to 25 (-1)	-17 to 11 (-4)	-15 to 38 (0)	-12 to 25 (2)
Jul	**-51 to 19 (-27)**	**-46 to -3 (-31)**	**-33 to 6 (-14)**	**-37 to -2 (-20)**	**-40 to 7 (-21)**	**-38 to -8 (-27)**
Aug	**-44 to 11 (-28)**	**-46 to -11 (-30)**	**-41 to 2 (-27)**	**-43 to -8 (-31)**	**-53 to -15 (-33)**	**-52 to -12 (-35)**
Sep	-46 to 19 (-23)	**-48 to 11 (-28)**	**-41 to -12 (-23)**	**-39 to -16 (-28)**	**-38 to 11 (-16)**	**-36 to 5 (-18)**

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections are presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections agree on the direction of change in volume.

REGION C – DWORSHAK, LOWER GRANITE, LITTLE GOOSE, LOWER MONUMENTAL, AND ICE HARBOR DAMS

In the Snake River Basin, most scenarios project even greater warming relative to the historical period compared to the other basins, but with a larger range of possible temperature outcomes. Precipitation is projected to increase in both winter and spring (RMJOC 2018). Projections for summer precipitation are more uncertain, with most indicating drier summers, but some also suggesting a potential for wetter summers. Models suggest that as early as the 2020s, snowpacks in this basin are likely to decrease with streamflow timing changes appearing earlier here than other parts of the Columbia River Basin. The RMJOC-II study projects higher fall and winter flows, with the potential for multiple winter flow peaks and earlier and higher spring flow peaks. The period of low summer flows that historically extend from mid-July to October may shift earlier over time (Table 4-5, Table 4-6, Figure 4-9 and Figure 4-10; RMJOC 2018).

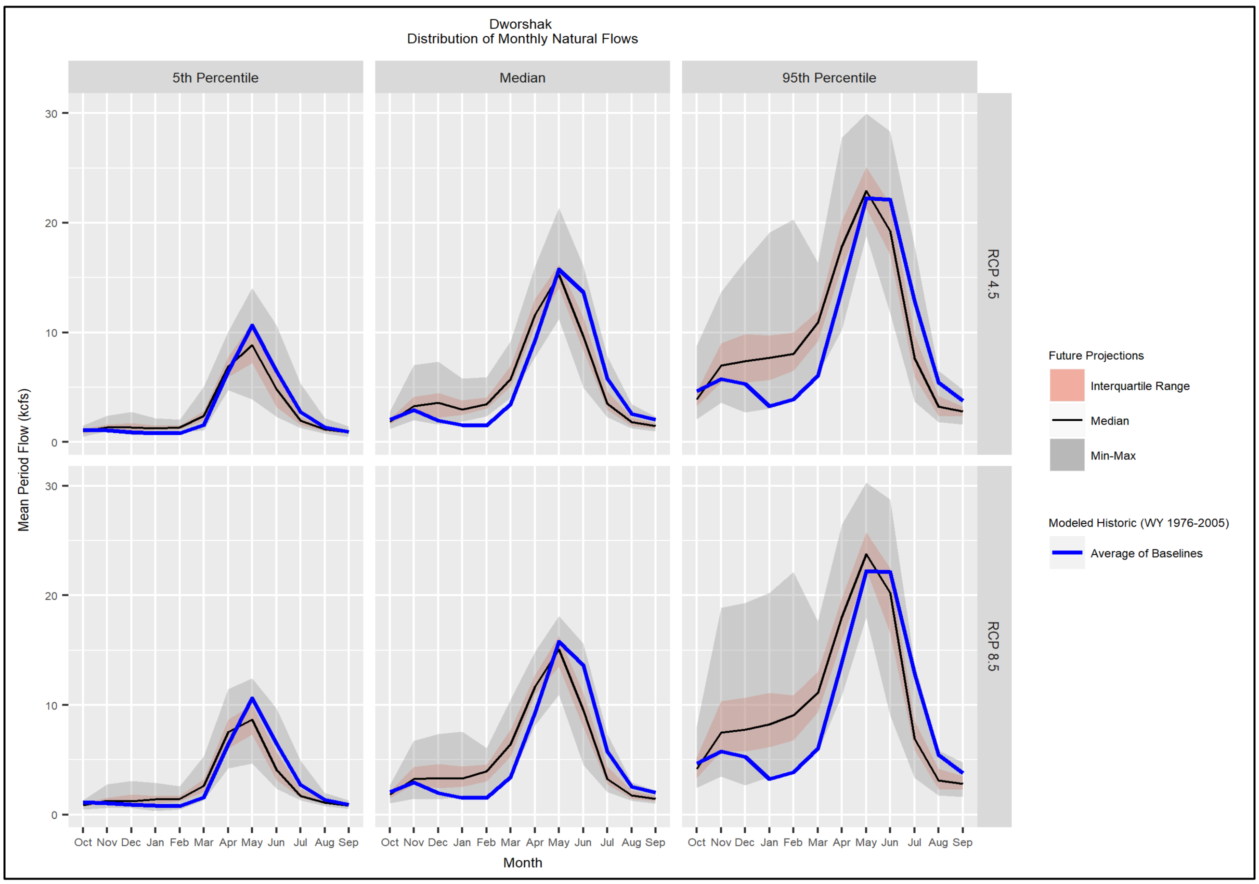

Figure 4-9. Distribution of the RMJOC-II Naturalized Flows, by Month at Dworshak Dam for the 2030s Time Period for RCP 4.5 and 8.5

Table 4-5. Relative Change (%) in Unregulated Monthly Streamflow at Dworshak Dam

	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
Month	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Oct	-51 to 63 (-13)	**-49 to 35 (-23)**	-25 to 12 (-10)	-37 to 21 (-11)	-48 to 85 (-18)	-38 to 69 (-13)
Nov	**-15 to 108 (31)**	-48 to 138 (22)	-14 to 99 (14)	-39 to 92 (15)	**-16 to 75 (31)**	**-14 to 141 (37)**
Dec	**-7 to 171 (48)**	-18 to 211 (56)	**11 to 207 (63)**	**-1 to 208 (80)**	**-23 to 143 (53)**	**-23 to 192 (61)**
Jan	**-25 to 166 (61)**	**-50 to 253 (66)**	**29 to 264 (98)**	**13 to 377 (120)**	**17 to 397 (147)**	**40 to 425 (160)**
Feb	**3 to 188 (66)**	**-46 to 262 (90)**	**45 to 287 (131)**	**3 to 297 (151)**	**13 to 323 (113)**	**24 to 361 (134)**
Mar	**-34 to 305 (51)**	**-22 to 310 (70)**	**15 to 177 (67)**	**8 to 198 (92)**	**18 to 146 (74)**	**9 to 159 (92)**
Apr	-23 to 76 (9)	-29 to 74 (15)	**-13 to 89 (23)**	**-10 to 80 (29)**	**-12 to 106 (27)**	**-7 to 102 (30)**
May	-64 to 34 (-15)	-56 to 13 (-18)	-32 to 54 (-2)	-34 to 29 (-3)	-23 to 38 (4)	-23 to 34 (8)
Jun	-64 to 51 (-29)	-63 to 35 (-37)	**-62 to -2 (-29)**	**-65 to 1 (-28)**	-44 to 18 (-10)	-58 to 18 (-7)
Jul	-56 to 40 (-25)	**-52 to 29 (-31)**	**-53 to -2 (-34)**	**-59 to -9 (-38)**	**-66 to 1 (-39)**	**-70 to -14 (-42)**
Aug	-39 to 36 (-14)	**-38 to 22 (-16)**	**-43 to 2 (-25)**	**-43 to -13 (-28)**	**-56 to -12 (-38)**	**-58 to -11 (-42)**
Sep	-50 to 43 (-4)	-34 to 30 (-6)	**-47 to 1 (-23)**	**-48 to 8 (-25)**	**-47 to 6 (-27)**	**-46 to 36 (-24)**

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections are presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections agree on the direction of change in volume.

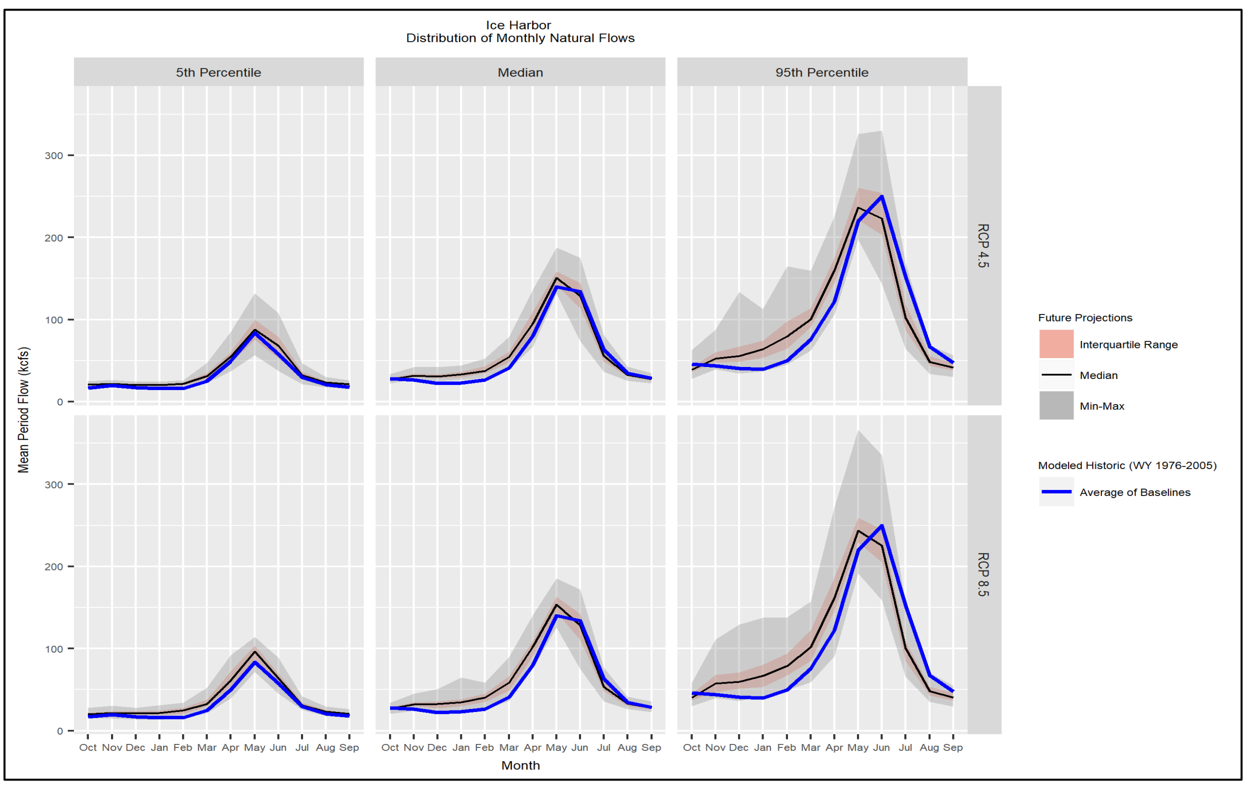

Figure 4-10. Distribution of the RMJOC-II Naturalized Flows, by Month at Ice Harbor Dam for the 2030s Time Period for RCP 4.5 and 8.5

Table 4-6. Relative Change (%) in Unregulated Monthly Streamflow at Ice Harbor Dam

	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
Month	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Oct	**3 to 59 (20)**	**-7 to 74 (15)**	-17 to 15 (-5)	-22 to 18 (-4)	-35 to 37 (-15)	-30 to 26 (-12)
Nov	**-3 to 33 (10)**	-20 to 51 (9)	**6 to 60 (20)**	**-6 to 59 (21)**	**-9 to 89 (21)**	**-9 to 139 (33)**
Dec	**-2 to 59 (21)**	-15 to 80 (23)	**7 to 96 (39)**	**-4 to 136 (45)**	**-15 to 205 (39)**	**-10 to 194 (50)**
Jan	**2 to 60 (25)**	-13 to 93 (31)	**15 to 95 (42)**	**0 to 188 (49)**	**-9 to 187 (61)**	**9 to 250 (71)**
Feb	**3 to 67 (35)**	**-3 to 113 (54)**	**11 to 98 (44)**	**-3 to 117 (53)**	**-8 to 198 (62)**	**-2 to 150 (65)**
Mar	-12 to 90 (26)	**-10 to 105 (33)**	**-9 to 88 (32)**	**-10 to 101 (44)**	**-11 to 88 (37)**	**-10 to 98 (36)**
Apr	-30 to 56 (9)	-19 to 76 (25)	-12 to 63 (20)	4 to 65 (25)	-1 to 70 (31)	-13 to 102 (38)
May	-26 to 57 (4)	-10 to 51 (14)	-16 to 45 (9)	-21 to 42 (11)	-11 to 49 (9)	-9 to 57 (11)
Jun	-35 to 81 (19)	-21 to 45 (12)	-41 to 30 (-4)	-40 to 26 (-4)	-39 to 25 (-9)	-33 to 30 (-11)
Jul	-21 to 49 (10)	-8 to 31 (7)	-36 to 20 (-11)	**-33 to 9 (-13)**	**-53 to -4 (-34)**	**-48 to -13 (-37)**
Aug	-10 to 40 (12)	-5 to 47 (13)	-22 to 12 (-2)	-19 to 14 (-5)	**-48 to -7 (-24)**	**-42 to 9 (-29)**
Sep	**-5 to 55 (17)**	**-5 to 59 (12)**	-14 to 21 (-4)	-16 to 23 (-2)	-35 to 26 (-11)	-31 to 17 (-15)

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections agree on the direction of change in volume.

REGION D – MCNARY, JOHN DAY, THE DALLES, AND BONNEVILLE DAMS

Region D integrates the flow volumes projected for upstream regions described in the preceding sections. Consistent with projected changes in precipitation (Section 4.1.2.2) and changes in seasonal snowpack (Section 4.1.2.3), changes in volume are concentrated by season, with higher winter and spring volumes, and generally lower summer volumes. The greatest amount of change is projected for high-flow extremes during winter months (Figure 4-11; Table 4-7).

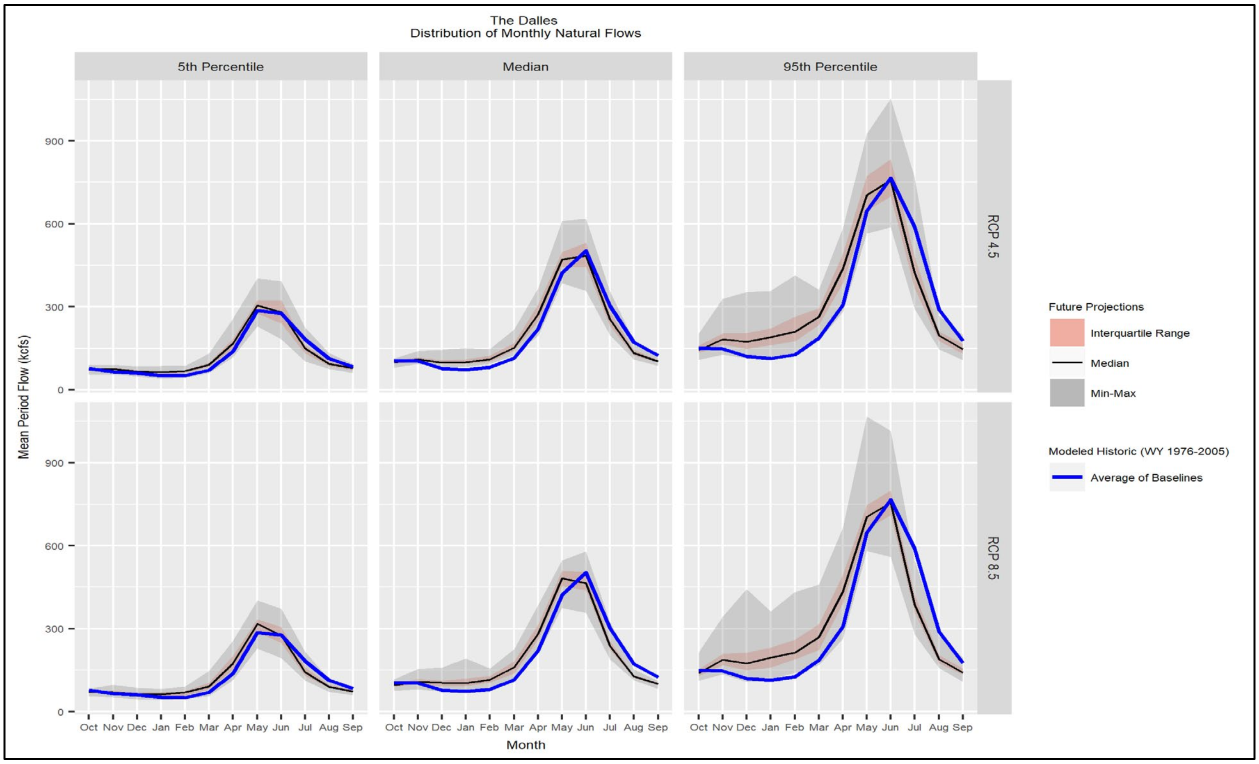

Figure 4-11. Distribution of the RMJOC-II Naturalized Flows, by Month at The Dalles Dam for the 2030s Time Period for RCP 4.5 and 8.5

Table 4-7. Relative Change (%) in Unregulated Monthly Streamflow at The Dalles Dam

	5th Percentile Flow		50th Percentile Flow		95th Percentile Flow	
Month	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Oct	-29 to 13 (-4)	-27 to 7 (-8)	-21 to 9 (-5)	-25 to 13 (-9)	-24 to 28 (-6)	-24 to 31 (-10)
Nov	-15 to 34 (13)	-12 to 43 (5)	-13 to 35 (4)	-21 to 49 (6)	**-12 to 75 (23)**	-9 to 100 (26)
Dec	-19 to 48 (7)	-21 to 47 (8)	**7 to 90 (28)**	**-4 to 109 (34)**	**0 to 183 (42)**	**-6 to 224 (46)**
Jan	**-11 to 68 (23)**	-14 to 64 (24)	**10 to 114 (39)**	**-3 to 172 (43)**	**4 to 221 (63)**	**12 to 235 (76)**
Feb	**-10 to 70 (34)**	**-4 to 76 (43)**	**17 to 84 (37)**	**-4 to 85 (45)**	**7 to 208 (64)**	**15 to 203 (67)**
Mar	**-11 to 94 (28)**	**-23 to 111 (32)**	**13 to 85 (32)**	**-2 to 98 (39)**	**11 to 88 (46)**	**-2 to 105 (48)**
Apr	-22 to 61 (17)	-17 to 75 (22)	**-5 to 61 (26)**	**6 to 64 (31)**	-3 to 82 (44)	**-1 to 106 (44)**
May	-20 to 30 (3)	-11 to 42 (8)	**-10 to 36 (13)**	**-10 to 30 (15)**	-11 to 53 (11)	-15 to 64 (11)
Jun	-38 to 37 (2)	-30 to 30 (-2)	-28 to 19 (-3)	-26 to 11 (-7)	-24 to 21 (-3)	-20 to 27 (-3)
Jul	-37 to 18 (-18)	**-34 to 7 (-21)**	**-31 to 7 (-15)**	**-36 to 0 (-21)**	**-48 to 1 (-28)**	**-46 to -18 (-32)**
Aug	-32 to 22 (-18)	**-36 to 4 (-19)**	**-37 to 2 (-23)**	**-35 to -10 (-26)**	**-51 to -16 (-31)**	**-45 to -15 (-35)**
Sep	-27 to 20 (-8)	-26 to 14 (-14)	**-33 to -3 (-18)**	**-34 to -5 (-20)**	**-34 to 5 (-17)**	**-33 to 10 (-20)**

Note: The relative change was computed by comparing the value of the flow quantile for the 2030s (2020–2049) to that of the historical modeled baseline period (1976–2005). The ranges of relative change for each set of 80 projections is presented, and the median change is reported in parentheses for each emission scenario. The color gradient scale of the shading reflects reductions of volume of the median projection of 50% or greater as dark brown and increases of 50% or greater dark green. These colors lighten to white as the relative change approaches zero. Bold text indicates that 90% of the projections are in agreement on the direction of change in volume.

4.1.2.5 Relative Sea level Change

Sea level rise is closely linked to increasing global temperatures. Global mean sea level has risen by about 7 to 8 inches since 1900 and is very likely to rise by another 0.5 to 1.3 feet by 2050 (USGCRP 2017). Locally affected future sea level is referred to as relative sea level change (RSLC). RSLC reflects integrated global effects, plus local changes of geologic or oceanographic origin. In the Pacific Northwest, the RSLC is likely to be less than the global average (USGCRP 2017). The RLSC has the potential to affect river water surface elevation as far inland as the extent of the tidal influence. Tidal effects in the Columbia River extend upriver to Bonneville Dam (River Mile [RM] 146).

Corps policy guidance (ER 1100-2-8162, Corps, 2013) applies a scenario-based approach to evaluate the effects of RSLC. This scenario approach bounds a range of RSLC using three equally plausible scenarios. Each of the three scenarios is based on the latest actionable science from the IPCC, National Oceanic and Atmospheric Administration (NOAA) and National Research Council (NRC). The RSLC scenarios are specific for a given coastal location and generated for each NOAA tide station that meets quality control protocol requirements (Corps 2013). The low, intermediate, and high scenarios for NOAA tide gauges can be obtained using the Corps online sea level calculator at http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html.

Figure 4-12 shows the three RSLC scenarios applicable for Astoria/Tongue Point, Oregon, NOAA Tidal Station 9439040. Corps projections for the future RSLC are based on a start date of 1992, which corresponds to the midpoint of the present National Tidal Datum Epoch[4] of 1983 to 2001.

The "USACE Low" scenario for future RSLC is extrapolated from the observed historical rate derived from NOAA tide gages. For 2050, the USACE Low scenario projection for Astoria is -0.05 feet using 2020 as the base year. The value is negative due to the regional rate of landmass uplift being greater than the sea level rise.

The "USACE Intermediate" scenario focuses its projection primarily on thermal expansion of the ocean and is computed from the modified NRC Curve I, considering both the most recent IPCC projections and modified NRC projections. For 2050, the USACE Intermediate scenario projection for Astoria is 0.15 feet using 2020 as the base year.

The "USACE High" scenario accounts for the thermal expansion of the ocean and accommodates for a potential rapid loss of ice from Antarctica and Greenland. It is estimated using the modified NRC Curve III. For 2050, the USACE High scenario projection for Astoria is 1.05 feet using 2020 as the base year.

[4] The National Tidal Datum Epoch (NTDE) is "the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years" (NOAA 2019).

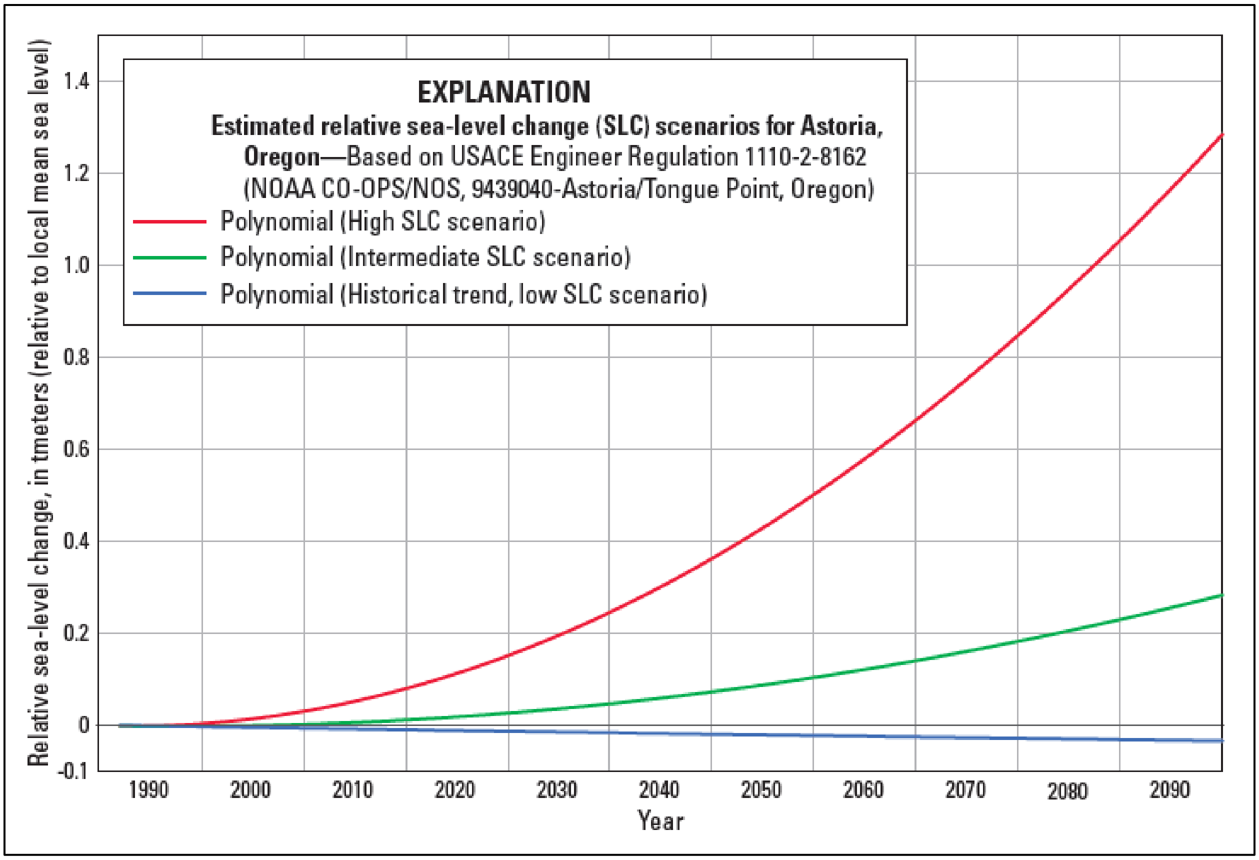

Figure 4-12. Estimated Sea Level Change Scenarios at Astoria, Oregon

Note: Figure taken from U.S. Geological Survey (USGS) (2019).

The amount that the RLSC surcharges river water surface elevation dissipates upriver from the mouth of the Columbia River at the Pacific Ocean (RM 0). This surcharge can also vary with river flow conditions, whereas low flow conditions will be affected more. At Woodland Islands, Washington, located in the lower Columbia River (RM 86), stage surcharge is estimated to be 0.5 foot, 0.15 foot, and 0.0 foot for the High, Intermediate, and Low RLSC scenarios, respectively (Corps 2019). During extreme high-flow conditions of the Columbia River near Vancouver, Washington (RM 106.5), 1 meter (3.3 feet) of RLSC results in a difference in peak river stage of approximately 0.5 foot (USGS 2019).

4.1.2.6 Increased Occurrences of Wildfire

The Cascade Range and Rocky Mountains of the Columbia River Basin are some of the most fire-prone regions in the western United States. The incidence of large forest fires has increased since the early 1980s and is projected to continue increasing as temperatures rise (USGCRP 2017). Wildfire alters the land surface and can have strong influences on runoff generation, vegetation dynamics, erosion and sediment transport, and ecosystem processes. Strong seasonality and dependence on spring snowmelt positions the basin to be at risk for increased fires due to the effects of climate change. Historically, the greatest increases in wildfire frequency have been in the heavily forested areas of the Kootenai and Lower Snake regions, followed by northwestern regions, including the lower and middle Columbia River (Westerling et al. 2003; Dennison et al. 2014).

Historical fire regimes and fire-climate relationships vary depending on topography, forest management practices, vegetation, soil moisture, and regional climate factors, including seasonal temperature and precipitation. Generally, the most severe fire activity occurs in the heavily forested areas of the Lower Snake region. Wildfire activity in forested regions across the basin exhibits strong negative correlations to precipitation and positive correlations to temperature (Littell et al. 2009). Drier and warmer summers lead to increased wildfire frequency and burned areas. For the semi-arid climatic regions of the middle and lower Columbia, fire-climate relationships exhibit moderate positive correlations to interannual precipitation due to the production of fine fuels (e.g., grass and shrubs) in the understory that become dead fuels (fuel with a moisture content < 30 percent) in subsequent years (Littell et al. 2009; McKenzie and Littell 2016).

Low soil moisture and high vegetative fuel are key drivers for wildfire potential. Recent hydroclimatic projections indicate that climate change will lead to declining mountain snowpack and advances in the timing of spring snowmelt, reducing summer soil moisture storage in heavily forested regions (Gergel et al. 2017). Projected increases in annual precipitation could moderately increase soil moisture in the semi-arid regions of the middle and lower Columbia (Gergel et al. 2017); however, a lack of agreement across projections for predicted precipitation patterns leads to greater uncertainty in future soil moisture. For all regions across the basin, vegetative fuel is projected to increase (Gergel et al. 2017). Overall, effects of climate change on wildfire potential are likely to be most severe in the Kootenai and Lower Snake regions that are already experiencing increasing wildfire activity, whereas there is more uncertainty in projected changes in wildfire potential for the semi-arid middle and lower Columbia regions.

4.2 POTENTIAL EFFECTS OF CLIMATE CHANGE BY RESOURCE

The following sections describe potential effects from projected hydroclimatic changes on the resources evaluated in the EIS. For each resource area, the potential effects are described for the No Action Alternative. Unless otherwise noted, the potential effects of climate change to the other alternatives are expected to be similar to the No Action Alternative. For some resources, there are no projected effects from climate change, including Noise, Visual, and Indian Trust Assets. While there are no projected effects to the identified Indian Trust Assets, any of the potential negative effects to habitat relied upon by treaty or trust resources (e.g., anadromous fish) is a significant concern for regional tribes.

During the evaluation, resource teams conducted a qualitative assessment using the climate change information provided in Section 4.1 along with resource effects for the alternatives as described in Chapter 3. The following question was used to focus the evaluation:

- What measures could ameliorate or exacerbate potential effects of climate change identified for the No Action Alternative?

In the following sections, the effects to the Multiple Objective Alternative (MO) operations are the same as those discussed in the No Action Alternative except where explicitly modified by a measure as described in each subsequent subsection. The effects described for each MO are relative to the No Action Alternative.

4.2.1 Hydrology and Hydraulics

The following regional descriptions of the climate change effects on hydrology and operations (regulated streamflows and reservoir elevations) rely on the hydrological projections described in Section 4.1. Potential effects to the regulation of the current system are inferred from these projections of climate and unregulated streamflow volumes and are described in the No Action Alternative subsections. The following regional descriptions use this qualitative analysis to describe expected effects to system operations under the No Action Alternative and with additional relevant MO measures under climate change.

4.2.1.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

At the headwater projects (project used to mean dams and their associated reservoirs), Libby Dam and Hungry Horse Dam, projected reduced late summer inflow volume (Section 4.1.2.4), coupled with fixed outflows to meet downstream summer minimum flow objectives, will likely result in lower pool elevations in late summer through October and November. Projected higher inflows during winter (Section 4.1.2.4) may support a faster recovery of reservoir storage from fall. Potential higher winter inflows and increased frequency of systemwide winter flood events (Section 4.1.2.4) could lead to more variable reservoir outflows and pool elevations during winter. Potential increases in spring runoff volumes (Section 4.1.2.4) could also lead to deeper reservoir drafts for spring flood risk management (FRM).

At Albeni Falls Dam, reservoir outflow during the summer and fall could decrease due to potential reduced inflows (Section 4.1.2.4). Higher winter inflows and increased frequency of systemwide winter flood events will likely lead to higher and more variable reservoir outflows and pool elevations, as water is stored and evacuated to manage system flood risk during winter. The reservoir is likely to fill earlier in the year as inflows shift earlier (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVES 1 AND 3

Hungry Horse is expected to be drafted deeper than under the No Action Alternative at the end of the water year due to the effects of the water supply measure. These effects could be exacerbated by decreased summer and early fall inflows. Projected higher inflows during winter may support a faster recovery of reservoir storage.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Hungry Horse and Libby are expected to be drafted deeper than the No Action Alternative in winter for the *Slightly Deeper Draft for Hydropower* measure. Potential increased winter flow

(Section 4.1.2.4) could reduce the need for this draft. Due to this measure, reservoir outflows in June and July would be less than the No Action Alternative. This could potentially exacerbate effects of the projected decreases in streamflow during these months (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVE 4

This alternative also includes the *McNary Flow Target* measure, that increases outflow from Libby and Hungry Horse May through July during dry years. This operation results in greater outflow early in the summer and less outflow during August to October compared to the No Action Alternative. This operation may increase in frequency as streamflow volumes are projected to shift to earlier in the year, and late spring/summer flow declines (Section 4.1.2.4). Streamflow volumes are projected to shift early in the year (Section 4.1.2.4), and late spring/summer flows are projected to decrease. The *McNary Flow Target* measure could reduce effects of lower late spring and early summer flows, but could exacerbate effects of lower flows later in the summer.

4.2.1.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

Projected decreases in late summer and early fall inflow (Section 4.1.2.4) could lead to lower outflow from Grand Coulee and Chief Joseph Dams and lower elevations at Lake Roosevelt during fall, with respect to historical fall conditions. During winter, higher inflows to the reservoir and Columbia River downstream are projected (Section 4.1.2.4). This could result in higher outflows and variability of storage, as Grand Coulee stores and evacuates water for downstream system FRM objectives. This could lead to increased spills from Grand Coulee and Chief Joseph Dams. The peak spring freshet is projected to occur earlier in the year (Section 4.1.2.4). This could result in increased outflows in March and April and therefore causes a reduction of outflows earlier in the year than occurred historically in order to refill the reservoir. Operations for mitigating winter flood events and operations for meeting system spring FRM space requirements may conflict more often, as inflow from winter flood events is stored during periods that the reservoirs are typically drafting for spring flood risk.

During summer, flow volumes are projected to decrease (Section 4.1.2.4), resulting in lower outflows. Grand Coulee would continue to refill in early July and draft to meet summer elevation targets. Meeting minimum flows at Bonneville Dam through drafting more often may be necessary. Lower inflows could challenge Grand Coulee’s ability to refill to 1,283 feet by the end of September and potentially to fill the reservoir (1,288 feet) by the end of October in preparation for winter chum and hydropower operations. Lower inflows could result in longer reservoir retention times.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 includes the *Winter System FRM Space* measure, providing additional storage for flood operations in December. With projected winter inflow increases (Section 4.1.2.4), this space may be filled and evacuated during and after winter flood events more frequently, leading to greater fluctuations in reservoir elevation and outflows. The measure could reduce potential increases in winter peak flows in the lower river that may result from climate change.

Higher projected winter unregulated flows (Section 4.1.2.4) and winter FRM operations could lead to upstream projects having more trapped storage for spring FRM. Trapped storage is when reservoirs fail to evacuate storage for FRM requirements. In response to potential increases in trapped storage, the *Update System FRM Calculation* measure could require Lake Roosevelt to be drafted deeper than the No Action Alternative.

Upstream measures could reduce reservoir inflows in the fall (e.g., *Hungry Horse Additional Water Supply*). The Lake Roosevelt Additional Water Supply measure could make it more difficult to meet summer flow targets due to projected lower inflows.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Lake Roosevelt is expected to be drafted deeper than the No Action Alternative in winter for the *Slightly Deeper Draft for Hydropower* measure. Projected increased winter flow (Section 4.1.2.4) could reduce the need for this draft. Due to this measure reservoir outflows in June and July would be less than the No Action Alternative. This could potentially exacerbate effects of the projected decreases in streamflow during these months (Section 4.1.2.4). See MO1 for effects of FRM measures included in this alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Upstream measures could reduce reservoir inflows in the fall (e.g., Hungry Horse Additional Water Supply and McNary Flow Target) in addition to the projected decreases in unregulated flows (Section 4.1.2.4). This could lead to deeper drafts to support downstream flows for power and navigation. See MO1 for potential effects of FRM measures.

This alternative also includes the *McNary Flow Target* measure that increases outflow from Grand Coulee in May through July during dry years. This operation may increase in frequency as streamflow volumes are projected to shift to earlier in the year, and late spring/summer flow declines (Section 4.1.2.4). This operation results in greater outflow early in the summer and less outflow during August to October compared to the No Action Alternative. Streamflow volumes are projected to shift early in the year (Section 4.1.2.4), and late spring/summer flows are projected to decrease. The *McNary Flow Target* measure could reduce effects of lower late spring and early summer flows, but could exacerbate effects of lower flows later in the summer. The *Lake Roosevelt Additional Water Supply* measure could further exacerbate the effects of projected decreases in summer flow on meeting summer flow targets.

4.2.1.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

Higher inflows are projected (Section 4.1.2.4) through the winter. These will result in higher elevations in the Dworshak reservoir and higher releases. Increasing frequency of winter floods will also increase system winter FRM operations. That could lead to higher and more variable outflows and pool elevations as water is stored and evacuated during the winter. In the spring, inflow from the snowmelt freshet is projected to occur earlier and could lead to higher outflow in April and earlier refill. Projected decreases in summer inflow (Section 4.1.2.4) will likely lead to decreased outflow as the reservoir maintains a similar elevation.

In the lower Snake River, changes in regulated streamflow will mimic the direction and seasonal patterns of changes in unregulated volumes (Section 4.1.2.4). Streamflow volumes in late fall and winter are projected to be greater (Section 4.1.2.4). Due to the projected changes in flow timing in spring (Section4.1.2.4), streamflow in April and May could increase, and flow in June could be less than historical levels. Lower flow is projected throughout the summer months (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVE 1

The *Modified Dworshak Summer Draft* measure will result in higher releases in July and September and lower releases in August compared to the No Action Alternative. The increased releases from this measure may partially offset projected flow decreases in July and September (Section 4.1.2.4), while the outflow reduction in August could exacerbate the projected decreases in August flow (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVE 2

Dworshak Reservoir is expected to be drafted deeper in the winter as a result of the *Slightly Deeper Draft for Hydropower* measure. Projected increases in winter flow (Section 4.1.2.4) could reduce the need for this draft. Due to this measure reservoir outflows in spring and summer could be less than the No Action Alternative. This could potentially exacerbate effects of the projected decreases in streamflow during these months (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVES 3 AND 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

4.2.1.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Flows are likely to be higher than historical conditions in the late fall and winter months of October through March due to increased likelihood of rainfall events and higher winter baseflow in the drainages that feed into Region D: the lower Columbia, lower Snake, and Clearwater Rivers (Section 4.1.2.4). Winter outflows and storage fluctuations could become more variable as reservoirs store and evacuate water for downstream FRM. Unregulated spring flow from snowmelt that passes through the dams in Region D is projected to occur earlier, with potential decreases in flow starting in June (Section 4.1.2.4). Streamflow in the summer is projected to decrease, and lower flows could span longer durations compared to historical conditions (Section 4.1.2.4). This could lead to difficulty in meeting the minimum flow objectives of these dams during summer. In years with exceptionally low summer flow volumes, fall and early winter outflow could be less than historical conditions as the upstream storage projects recover from depleted storage. Sea level rise could increase river stages below Bonneville Dam (Section 4.1.2.4). The effects of sea level rise will be larger at lower-flow conditions and with increasing proximity to the Pacific Ocean.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 includes the *Winter System FRM Space* measure, providing additional storage for system flood operations at Grand Coulee in December. With projected increases in winter inflow (Section 4.1.2.4), Lake Roosevelt could store more inflow during system flood events, which could decrease peak flood stages in Region D.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Streamflow in the lower Columbia River will be higher than the No Action Alternative in winter due to the *Deeper Draft for Hydropower* measure at upstream projects. This measure could further increase the projected increase in winter flows in the lower Columbia River.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

The effects of MO4 from the *Winter System FRM Space* measure are expected to be similar to those effects described in MO1. This alternative also includes the *McNary Flow Target* measure that increases outflow from Grand Coulee in May through July during dry years. This operation may increase in frequency as streamflow volumes are projected to shift earlier in the year and projected late spring/summer flow declines (Section 4.1.2.4). This operation results in greater outflow early in the summer and less outflow during August to October compared to the No Action Alternative. The *Lake Roosevelt Additional Water Supply* measure could further exacerbate the effects of projected decreases in summer flow on meeting summer flow targets.

4.2.2 River Mechanics

Climate changes have the potential to substantially influence erosion, sediment transport, and sediment deposition throughout river basins. Several key climate-influenced mechanisms linked with geomorphological processes have been identified (Mauger et al. 2015) and are summarized in Table 4-8. Qualitative assessments of how these drivers will change and their associated effects for the Columbia River Basin are discussed in subsequent sections. Potential effects of climate change are described for the No Action Alternative condition. These effects are assumed to be the same for each MO, unless a measure is expected to explicitly alter the response to climate change compared to the No Action Alternative.

Table 4-8. Climate Influenced Processes and Mechanisms That Shape Geomorphological Change in River Basins

Mechanism	Description
Temperature	Higher temperatures enhance thermal breakdown of rock. Warmer conditions can dry soils leading to higher stability of deeper soil layers. Warming can intensify warm and dry cycles, widening gaps in rock and soil.
Precipitation	Increased precipitation can increase soil water content and surface runoff. Intense rainfall can erode surface sediments.
Soil Water Content	Wetter soils have higher pore pressure and greater landslide susceptibility. Wetter soils absorb less precipitation and produce more subsurface flow, increasing runoff.
Snowpack and Glaciers	Snowpack loss in area and duration increases the amount of time underlying erodible soils are exposed to surface erosion. Receding glaciers expose loose, unconsolidated sediment that is susceptible to mobilization and increases sediment load downstream of deglacierized areas.
Streamflow	Higher streamflow can erode streambeds and banks, increasing transportation and deposition of sediment in alluvial reaches.
Vegetation	Vegetation can be influenced by climate change through its influence on frequencies of disturbance (wildfires, insects, disease) or water stress. Reduction in vegetative cover can increase surface erosion during rain events and elevate soil moisture. After wildfires, soils have the decreased ability to absorb water, leading to increased surface runoff, surface erosion, and sediment transport.
Sea Level Rise	Sea level rise could reduce stream velocities, trapping sediment in coastal rivers and deltas. Sea level rise could increase inland conveyance of wave energy, increasing shoreline erosion.

Note: Adapted from Mauger et al. (2015).

4.2.2.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

Surface erosion and sediment supply could increase in Region A. Primary mechanisms of sediment delivery to the upper Columbia River Basin within the United States are landslides and bank erosion (Section 3.3.2.3), which can increase after wildfires and from high-intensity precipitation events. The Northern Rocky Mountains have high wildfire potential, which could increase with climate change (Section 4.1.2.6). Furthermore, declining snowpack (Section 4.1.2.3) and upland glacier area could increase the amount of land surface area exposed to erosion and increase the seasonal duration of exposure.

Bank erosion in the Kootenai River, Clark Fork, and Pend Oreille Rivers could increase during winter months as the phase of precipitation for storm events transitions from snowfall to rainfall, increasing winter flows (Section 4.1.2.4) and variability of local runoff response. Banks of these rivers, aside from those areas consisting of boulders and bedrock, are already highly susceptible to erosion (Section 3.3.2.9).

Conveyance of sediment from landslides or bank erosion to the riverine reaches could increase during winter months with projected increases in median and high flows (Section 4.1.2.4). However, only a small percentage of sediment—regardless of moderate rates of increase in supply—will make it to the Columbia River mainstem, based on theoretical trapping efficiencies of 91 and 71 percent at Libby Dam and Albeni Falls Dam, respectively (Section 3.3.2.3). Depositional reaches in these systems, such as the Braided and the Meander Reach of the Kootenai River and the mouth of Lightning Creek on the Clark Fork River, are expected to remain depositional zones as sediment supply increases with rainier winters. Sediment deposition near mainstem confluences could potentially influence fish passage, especially during the warmer/drier summer season. Increased sedimentation will be monitored and evaluated for maintenance activities. Transport reaches are expected to maintain or increase sediment conveyance capability until reaching sediment sink zones such as Flathead Lake, Kootenay Lake, and Lake Pend Oreille.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, 3, AND 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

4.2.2.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

Surface erosion, sources of sediment, and landslides from reservoir margins could increase in response to climate change in Region B. Upland forests of the eastern slopes of the Cascade Range display high wildfire potential that is likely to continue to increase with climate change (Section 4.1.2.6). Changes in wildfire potential for the lower elevation semi-arid ecosystems are more uncertain (Section 4.1.2.6). Furthermore, sediment production could also increase from upland areas following projected declines in snowpack (Section 4.1.2.3), which will increase the land surface area exposed to erosion and increase the seasonal duration of exposure. The conveyance of gains in sediment supply could increase with projected higher median and high unregulated winter flow volumes (Section 4.1.2.4). Fluvial transported sediment through this region will continue to be largely deposited in reservoir-impounded mainstem locations.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 includes the *Winter System FRM Space* measure, providing additional space in Lake Roosevelt for Grand Coulee system flood operations in December. With projected increased frequency of system winter flood events and elevated winter inflow volumes (Section 4.1.2.4), this space could be more frequently filled and evacuated during and after winter flood events. This could result in greater reservoir fluctuations and associated bank sloughing and erosion in non-bedrock shoreline areas.

MULTIPLE OBJECTIVE ALTERNATIVES 2 AND 4

See the MO1 discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

4.2.2.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

Mid-elevation forests of the Central Rockies could exhibit a strong response in wildfire (Section 4.1.2.6) to increased spring and summer temperatures (Section 4.1.2.1) and earlier snowmelt (Section 4.1.2.3). The combined effect of warming, hydrological drought, wildfire, and intense storms could enhance the potential for erosion and sediment delivery by altering land surface vegetation which plays a primary role in modulating sediment dynamics in semi-arid landscapes (e.g., Goode, Luce, and Buffington 2010). This increase in sediment supply could be coupled with increased sediment transport in Region C rivers with projected increased median and high-flow volumes during winter and early spring (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, AND 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 includes breaching the lower four Snake River dam embankments. Without these impoundments, the lower Snake River will no longer act as a sediment sink for watershed contributions that predominately accumulate upstream of Lower Granite Dam. Increased upstream sources of sediment and enhanced conveyance linked to projected hydrological change could lead to increased sediment transport through this region to Region D, downstream. Similar to non-climate change MO3 response, this additional bed material load (coarser than 62 microns) is expected to accumulate within the upper 10 miles of the McNary Reservoir between the Snake River confluence with the Columbia River and Wallula, Washington. The routing of flood peaks from intense storms through the lower Snake River also has potential to increase erosion and transport of higher-elevation residual sediment deposits abandoned after the near-term dam breach activities. This could result in episodic increases in localized suspended sediment concentrations.

4.2.2.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Surface erosion and sources of sediment could increase in Region D. Forests of the central and southern Cascade Range, which contribute to sediment loads in the rivers and reservoirs of Region D, display moderate wildfire potential that could continue to increase with climate change, whereas changes to fire potential in lower elevation semi-arid ecosystems display more uncertainty (Section 4.1.2.6). Surface erosion could increase from upland areas following projected declines in snowpack (Section 4.1.2.3), which could increase the land surface area exposed to erosion and increase the seasonal duration of exposure. The conveyance of increased sediment supply could also increase coincidentally with projected higher median and high winter flow volumes (Section 4.1.2.4). McNary, John Day, The Dalles, and Bonneville Dams will continue to act as a sink for the coarse fractions of this potential increased upstream sediment yield.

Sea level rise is projected to influence water surface elevations downstream of Bonneville Dam (Section 4.1.2.4). This could affect sediment dynamics, including conveyance, deposition, and shoreline erosion processes. Potential effects will be strongest in downstream locations closest to the estuary and confluence with the Pacific Ocean.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, AND 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 includes breaching the lower four Snake River dams, eliminating sediment sinks in the Lower Snake reach. Increased sources of sediment and increased conveyance from the Snake River linked to projected hydrological changes could lead to increased sediment supply being delivered from Region C to this region. Deposition of the increased Snake River bed material load sediments (fractions coarser than 62 microns) is expected to remain upstream of McNary, while the flux of increased washload fractions (finer than 62 microns) will propagate further downstream into the lower Columbia projects and estuary.

4.2.3 Water Quality

Many water quality issues are linked to water temperature. A recent assessment of water temperature trends in the Columbia Basin (O'Connor 2020) found long-term warming trends in water temperature on the order of 0.5 degree Fahrenheit (0.3 degree Celsius) per decade. While water temperature trends vary between measurement sites, periods of analysis, and season, this estimate is consistent with the range of the observed trends reported in other studies (e.g., Quinn, Hodgson, and Peven 1997; Isaak et al. 2012; EPA 2019). Long-term (greater than 20 years) increases in water temperature are primarily associated with increases in air temperature. Cold water releases from storage dams have contributed to cooling trends at some locations (O'Connor 2020). Cooling trends are identified on the mainstem of the Columbia River above Grand Coulee Dam and at locations on the Clearwater River below Dworshak Dam.

Changes to seasonal patterns in stream temperature occurred during the 1950 to 1970 period as flow patterns changed with increased river regulation and dam construction. Construction of dams in the Columbia River Basin resulted in an approximately 1 degree Fahrenheit (0.6 degree Celsius) increase in water temperature, a shift in the timing of annual maximum temperatures, and expanded the period of seasonally warm water. There were few detected trends relating to these effects in the near-term period, suggesting that the effects experienced in the 1950 to 1970 period remain today and do not appear to contribute to near-term statistically significant trends in water temperature (O'Connor 2019). Isaak et al. (2018) found that water temperature trends of large regulated and unregulated river basins across the northwest are generally consistent over recent periods of observation. The warming trend in global air temperatures is expected to continue in the coming decades. Projecting river water temperature has been a continued focus in the research community. Several studies have developed projections that suggest that the Columbia River summer mainstem river temperature could increase 3.1 to 3.6 degrees Fahrenheit (1.7 to 2.0 degrees Celsius) by the end of the century (e.g., Yearsley 2009; Isaak et al. 2018). Projected increases in summer water temperatures for Columbia River tributaries by the end of the century span a wider range, 1.8 to 9.0 degrees Fahrenheit (1 to 5 degrees Celsius) (e.g., Cristea and Burges 2010; Mantua, Tohver, and Hamlet 2010; Wu et al. 2012; Beechie et al. 2013; Caldwell et al. 2013; Isaak et al. 2017).

4.2.3.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

Air temperature is projected to be warmer throughout Region A during the 2030s (Section 4.1.2.1). Warmer air temperature combined with projected decreased summer and fall flow volumes (Section 4.1.2.4) could lead to increased riverine and reservoir surface water temperature. This could exacerbate algal and nutrient problems (Appendix D, *Water and Sediment Quality Technical Appendix*, Section 3.1.3.1) within the region's reservoirs and river reaches. This warming could also increase the prevalence of invasive species.

Currently, selective withdrawal systems (SWSs) are used at Libby and Hungry Horse Dams to manage downstream temperatures. These SWSs are operated to release warmer waters to better reflect normative temperatures in the local river systems. Warmer air and water temperature could allow SWS operations to meet temperature objectives for longer periods throughout the spring and summer months. Fall water temperatures, however, are likely to be negatively affected and remain warmer for longer. Deeper reservoir drafts for spring FRM at Libby and Hungry Horse could result in warmer spring water temperatures downstream, which may benefit downstream fish and in-river productivity.

The timing of the spring freshet inflow volume is projected to shift earlier in the year (Section 4.1.2.4), resulting in reservoirs filling earlier than historically. Depending on how early the refill occurs, this could improve (make warmer) or exacerbate (make colder) temperature issues downstream of Libby and Hungry Horse.

Inflow volumes to the reservoirs are projected to increase during winter and spring (Section 4.1.2.4). Higher inflow and outflow from these reservoirs could increase total dissolved gas (TDG) and turbidity, and may result in suspended solids (nutrients, selenium) to move further down into the reservoir and downstream of Libby Dam. Higher winter flows may also affect the natural cooling of the downstream river.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Under MO1, the change to the *December Libby Target Elevation* measure allows for higher winter (November to December) reservoir elevations at Libby Reservoir to mitigate for potential over-drafting in years with a drier forecast. This is followed by the *Modified Draft at Libby* measure, which creates higher outflows (aggressive drafting) in late winter/early spring that could be exacerbated by anticipated higher winter flows under climate change. High winter flows prevent the natural cooling of the Kootenai River in the winter downstream of Libby Dam. Warmer winter water temperatures can be detrimental to fish, such as burbot, that require near-freezing water temperatures to successfully spawn. Higher winter flows and runoff anticipated under climate change (Section 4.1.2.4) may result in suspended solids (nutrients, selenium) to move further down into the reservoir and downstream of Libby Dam as well.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Under MO2, the *Slightly Deeper Draft for Hydropower* measure calls for a deeper drawdown of Libby Reservoir to provide additional hydropower generation. This drawdown may help to ameliorate higher inflows anticipated in the winter under climate change (Section 4.1.2.4). Deeper reservoir drafts and higher outflows may result in suspended solids (nutrients, selenium) to move further down into the reservoir and downstream of Libby Dam and increase downstream water temperature.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 is similar to MO2 at Libby Reservoir and includes operational changes that could result in changes to draft and refill operations when compared to the No Action Alternative. Anticipated additional winter and early spring storage may help to ameliorate higher inflows anticipated in the winter under climate change (Section 4.1.2.4). Deeper reservoir drafts and higher outflows may result in suspended solids (nutrients, selenium) to move further down into the reservoir and downstream of Libby Dam and increase downstream water temperature. These deeper drafts may also affect in-reservoir food availability for resident fish.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Under MO4, in low water years, the *McNary Flow Target* measure would release an additional 600 thousand acre-feet from Libby, resulting in lower reservoir elevations, which could reduce productivity in the reservoir and affect fish growth. This operation may increase in frequency as streamflow volumes are likely to shift to occur earlier in the year, and late spring/summer flow declines (Section 4.1.2.4).

4.2.3.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

Air temperature is projected to be warmer throughout Region B (Section 4.1.2.1). Warmer air temperature combined with reduced summer and fall flow volume (Section 4.1.2.4) could lead to increased riverine and reservoir surface water temperature. Periods of higher temperatures may occur earlier in the year and last longer than historically. This could exacerbate algal, nutrient, pH, and dissolved oxygen (DO) issues (Appendix D, *Water and Sediment Quality Technical Appendix*, Section 3.1.3.3) within the region's reservoirs and river reaches.

Flow volume is projected to increase during winter months (Section 4.1.2.4), which could result in higher outflows. Periods of higher outflows from Grand Coulee and Chief Joseph could result in higher spill. Increased inflow and spill volume is likely to result in higher TDG than historical levels during winter. In the summer, TDG could decrease as a result of projected lower flow volumes (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 includes the *Winter System FRM Space* measure, providing additional storage for flood operations in December. With increased winter flow, this space may be filled and evacuated during and after winter flood events more frequently, leading to greater reservoir fluctuations and associated bank sloughing and turbidity, with higher spill and TDG in December. Increased seasonal water surface elevations are anticipated to result in an increased amount of mercury that is converted to methylmercury upon rewatering of shorelines. Methylmercury is the more toxic form of mercury that bioaccumulates in fish tissue.

This alternative includes the *Lake Roosevelt Additional Water Supply* measure. This measure reduces outflow from Grand Coulee. Reduced outflow could exacerbate warming of downstream summer temperature.

MULTIPLE OBJECTIVE ALTERNATIVE 2

See MO1 for discussion of the effects of FRM measures, as they are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See MO1 for discussion of the effects of water supply measures, as they are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

See MO1 for the effects of FRM measures, as they are anticipated to be similar. Additionally, MO4 includes the *McNary Flow Target* measure, which increases outflow from Grand Coulee, May through July, during dry years. This operation may increase in frequency as streamflow volumes are likely to shift to occur earlier in the year, and late spring/summer flow declines (Section 4.1.2.4). This operation results in greater outflow early in the summer, with less outflow during August to October. Water temperatures downstream of Grand Coulee are expected to continue to exceed water quality standards in late summer and early fall; this could be exacerbated in dry years by the early release of flows and missed refill due to the *McNary Flow Objective* measure.

4.2.3.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

Air temperature is projected to be warmer throughout Region C (Section 4.1.2.1). Warmer air temperature combined with projected reduced summer and fall flow volume (Section 4.1.2.4) will likely lead to increased riverine and reservoir surface water temperature. Periods of higher temperature are projected to occur earlier in the year and last for longer durations than historically. This could exacerbate cyanobacterial blooms, microbial activity at swim beaches, increase pH, or reduce DO within the region's reservoirs and river reaches (Appendix D, *Water and Sediment Quality Technical Appendix*, Section 3.2.3.2).

Winter flows and the frequency of winter flood events are projected to increase in Region C (Section 4.1.2.4). In response to this change, Dworshak Dam could store and evacuate inflow volumes for system winter flood events more frequently than during the historical period. The projected higher volumes and variability in flows could result in increased TDG and turbidity during winter months.

During spring, the freshet volume is projected to occur earlier resulting in an earlier fill period for Dworshak reservoir and higher outflows in April (Section 4.1.2.4). This could result in higher TDG in spring and could increase reservoir productivity.

Projected decreases in summer flow volumes through the dams on the Lower Snake river could make meeting downstream juvenile fish passage spill objectives more difficult since there could be less total river flow to pass over the spillways of these dams and still provide minimum turbine generation (Section 2.3.2.2).

MULTIPLE OBJECTIVE ALTERNATIVE 1

The *Dworshak Temperature Control* measure results in significantly higher water temperature than NAA in August and early September. These effects are greatest at Lower Granite and decrease downstream. This measure could exacerbate potential warming water temperature from climate change.

MULTIPLE OBJECTIVE ALTERNATIVE 2

MO2 includes the *Slightly Deeper Draft for Hydropower* measure that will lead to lower pool elevations of Dworshak reservoir during winter. Lower winter pool elevations could reduce the increases in TDG resulting from projected increases in winter inflow and outflow for winter flood operations due to climate change (Section 4.1.2.4).

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 includes breaching the lower four Snake River dams. Water quality effects of dams and reservoirs would be eliminated with the breaching of the dams. Under MO3 water temperature in the river will respond faster to seasonal changes in air temperature (Section 3.4, Appendix D) which is projected to be warmer throughout the year, but with the highest degree of warming in the spring and summer (Section 4.1.2.1; RMJOC, 2018). As compared to NAA, MO3 is expected to result in warmer water temperature in the spring, similar water temperatures in the summer, and cooler water temperatures in the fall with the overall duration of warm water reduced. Furthermore, the shallower free flowing river condition of MO3 will lead to greater diurnal fluctuations in water temperature, including night time cooling. Daily low temperatures (occurring at night) are projected to warm faster than daily high temperatures. The effects of projected increasing nighttime temperatures could reduce night time cooling of the river. The effects of projected increased water temperature could result in increased periphyton growth in the river.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 includes the *Spill to 125% TDG* measure. Projected decreases in summer flow volumes (Section 4.1.2.4) could make meeting this target more difficult since there would be less total river flow to pass over the spillways of these dams and still provide minimum turbine generation (Section 2.3.2.2).

4.2.3.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Air temperature is projected to be warmer throughout Region D and upstream regions (Section 4.1.2.1). Warmer air temperature combined with reduced summer and fall flow volume (Section 4.1.2.4) will likely lead to increased riverine and reservoir surface water temperature. Periods of higher temperature are likely to occur earlier in the year and last for longer durations than historically. This could exacerbate cyanobacterial blooms, microbial activity at swim beaches, increase pH, or reduce DO within the region's reservoirs and river reaches.

Winter flows and the frequency of winter flood events are projected to increase in Region D (Section 4.1.2.4). This could lead to increases in TDG through the winter and early spring because TDG increases with higher flows.

Projected decreases in summer flow volumes (Section 4.1.2.4) through these dams could make meeting downstream juvenile fish passage spill objectives more difficult since there could be less total river flow to pass over the spillways of these dams and still provide minimum turbine generation.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, AND 3

See the No Action Alternative discussion above, as it is anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 includes the *Spill to 125% TDG* measure. Projected decreases in summer flow volumes could make meeting this target more difficult. MO4 also includes the *McNary Flow Target* measure. This measure will provide more flow early in summer for dry years and potentially lead to reduced flows in late summer and fall. This operation may increase in frequency as streamflow volumes are projected to shift to occur earlier in the year and late spring/summer flow declines (Section 4.1.2.4). Flow changes associated with this measure have the potential to partially buffer early summer warming water temperature and exacerbate warming during late summer and early fall.

4.2.3.5 Anadromous Fish

The Columbia River Basin hosts many anadromous fish species. These fish use freshwater habitat for spawning and early juvenile life stages before migrating to marine waters to grow and mature for part of their lifecycle. These species include 16 salmon and steelhead species or ESUs as well as Pacific Eulachon, green sturgeon, Pacific lamprey, and American shad.

This section evaluates how the projected changes in regional climate may affect anadromous fish. The structure of this section differs from other resource areas in that environmental changes due to climate change can affect how project operations affect anadromous fish differently as they migrate through multiple regions. Thus, expected effects on anadromous fish species are discussed collectively rather than by separate regions.

Projected changes in air temperature, precipitation, hydrology and stream temperature have negative implications for the freshwater, estuarine, and marine environments of many fish species in the Pacific Northwest (Climate Impacts Group 2015; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007).

NO ACTION ALTERNATIVE

For salmon and steelhead (*Oncorhynchus mykiss*) in the Columbia basin, climate change may affect the timing of spawning, emergence and migration, cause changes in growth and development, increase predation rates, and affect the availability of critical habitat. In turn, these physiological changes could affect species productivity and abundance (Link, Griffis, and Busch 2015). While habitat conditions may improve for some life stages in certain locations that are currently colder than optimum (Zhang et al. 2019), overall effects on populations due to climate changes that have already occurred in recent decades have been negative (Crozier and Hutchings 2014). Many populations that are sensitive to non-climate threats are also most vulnerable to climate change (Crozier et al. 2008; Crozier 2013). Overall, a warming climate could cause moderate to severe declines in salmon and steelhead populations (Crozier 2015).

Increased variability in flows and reservoir levels could increase stranding/dewatering of larval Pacific lamprey (*Entosphenus tridentatus*). Pacific eulachon (*Thaleichthys pacificus*) could experience a mismatch in adult spawning triggers and larval dispersal if winter spawning triggers remain similar but spring freshets peak sooner. Lower summer flows could decrease foraging habitat for green sturgeon (*Acipenser medirostris*) in the estuary and lower Columbia River.

There are several potential outcomes from climate change that could lead to consequences for anadromous fish during the periods of their lifecycle where they reside in the inland water bodies of the Columbia River and its tributaries:

- Warming water temperatures

  Projected changes in stream and river temperatures (as described in Section 4.2.3) may cause direct mortality due to heat stress and greater disease susceptibility if the range of physiological tolerance is exceeded (Benda et al. 2015). For example, in the Columbia Basin, Snake River sockeye salmon (*Oncorhynchus nerka*) are at high risk from heat waves during their mid-summer adult migration (Keefer, Peery, and Caudill 2008; National Marine Fisheries Service 2016). Historical water temperatures have already approached lethal limits for adult steelhead in the upper Snake and middle Columbia Rivers (Wade et. al 2013). Thus, even minor increases in thermal exposure put some of these populations above lethal limits. Increases in water temperatures could result in increased use of cold water refuges by adult salmon and steelhead (EPA, 2019).

  Warming streams may also affect early life stage development of Chinook salmon (*Oncorhynchus tshawytscha*), steelhead, and other salmon species, however effects are not linear and can depend on specific life stage. For example, after modeling several climate change scenarios for all West Coast populations of steelhead and Chinook salmon, Beer and Anderson (2013) concluded that Chinook salmon could spawn later in the year. Juvenile salmon in warm-region streams of the Columbia Basin will likely experience lower growth rates if stream temperatures increase in the future, whereas fish in currently cold mountain streams that will begin to warm could experience the same or higher growth by 2050 (Beer and Anderson 2013). While warmer stream temperatures tend to increase production of plankton and insects (food supply), they also increase fish metabolism and daily requirements for food (Daly and Brodeur 2015; Haskell, Beauchamps, and Bollens 2017). Overall, juvenile salmon weights are projected to be lower in the Columbia Basin by 2050 due to climate change, which could affect survival in the estuary and ocean (Faulkner et al. 2019). Effects of climate change on marine survival and growth of salmon will depend on their natal rivers and movements at sea. But, salmon are becoming smaller and sometimes younger when they return to freshwater, potentially as a result of decreasing pH and increasing temperature (Bisson et al. 2018).

  Where high temperature exposure is already an issue, increasing temperatures inside fishways of dams could worsen thermal exposure for migrating adult sockeye, Chinook salmon, and steelhead (Keefer and Caudill 2015). Temperature gradients up to 4 degrees Celsius within fish ladders at dams in the Columbia River appear to block migration by causing adult fish to reverse movement in ladders and fall back downstream (Caudill et al. 2013). Already a serious concern, temperature-related fallback may increase if river temperatures continue to rise (Crozier 2013).

- Streamflow changes

  Variability in streamflow, shifts in seasonal volume and the transitioning of snowmelt to rain dominated streamflow regimes, could influence spawning, habitat occupancy, and run timing (Ward et al. 2015; Beechie et al. 2006). Consequently, expected changes in the timing and volume of flows (as described in Section 4.1.2.4) could alter run timing, reduce spawning habitat access/availability, change egg and juvenile survival, and change overwintering habitat for many juveniles. For example, Artaud et al. (2010) found that higher tributary streamflow during spring was strongly positively correlated with egg-to-smolt and egg-to adult survival rates for Chinook in the Lemhi River of Idaho. Timing of smolt and adult migration may also change due to modified timing of the spring freshet (Crozier and Hutchings 2014; Keefer, Peery, and Caudill 2008).

  Lower flow during the late spring through fall (Section 4.1.2.4) increases travel time for outmigrating juvenile species, making them more susceptible to predation by birds and predatory fish.

- Invasive Species

  Warming water temperatures lead to habit conditions that are favorable for non-native warm-water adapted fish species, which compete with or prey upon native salmon (Petersen and Kitchell 2001). Smallmouth bass (*Micropterus dolomieu*) have expanded their range, increasing their overlap with subyearling Chinook rearing habitat in summer (Lawrence, Olden, and Torgersen 2012; Kuehne, Olden, and Duda 2012). Also, invasive non-native plankton species are now widespread and can dominate reservoir and the estuary plankton communities (Emerson, Bollens, and Counihan 2015; Bowen et al. 2015). While Chinook salmon eat these species, they are not necessarily preferred prey.

  American shad (*Alosa sapidissima*) has come to dominate the anadromous fish migration in the lower Columbia River with abundances often exceeding 2 million in recent years (Hinrichsen et al. 2013). The incursion of shad upstream past McNary Dam in recent decades is correlated with higher water temperatures and lower flows (Crozier 2015). The influence of shad on the reservoir food web is complex; shad may compete with juvenile salmon for invertebrate prey but juvenile shad are also an important food source for adult fall Chinook in summer (Haskell, Beauchamp, and Bollens 2017).

Climate change is also projected to have consequences for the habitat of anadromous fish during the period of their lifecycle where they reside in the Pacific Ocean and Columbia River estuary. Several trends are expected:

- Reduction in thermal habitat for salmon

Future climate projections indicate there will be a reduction in thermal habitat preferred by salmon in the ocean (Cheung et al. 2015). However, warming may not be uniform across the northeast Pacific Ocean and the effects of localized wind and current patterns make it challenging to project (Barth et al. 2007).

- Increasing ocean acidification

  Increased concentrations of carbon dioxide in the atmosphere leads to increased absorption by the oceans and results in ocean acidification. This has already been detected both on the Washington and Oregon coast and in the Puget Sound (Feely et al. 2010; Harris et al. 2013; Hauri et al. 2013). Generally, acidification can change the food web (reduce productivity) and have negative consequences on fish. For lower Columbia River coho salmon (*Oncorhynchus kisutch*), for example, acidification affects their olfactory senses, interfering with avoidance of predators, hunting of prey, and navigating their return to spawning grounds.

- Changing estuarine and plume environments

  The confluence of the Columbia River and the Pacific Ocean is critical habitat for anadromous fish as they transition from fresh to salt water as juveniles. Changes in water temperature and flows could bring changes in this habitat, the food web, and predation (CRSO BiOp 2019). Sea level rise (see Section 4.1.2.5) has the potential to convert shallow estuary rearing habitat into deeper channels (Flitcroft et al. 2013) and alter habitat elevation bands as inundation patterns change. Lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of prey and predators (Bottom and Jones 1990); and increased temperature of freshwater inflows and seasonal expansion of freshwater habitats may extend the range of non-native, warm-water species in the estuary (CRSO BiOp 2019). Multiple Objective Alternative 1

Improvements for juvenile anadromous salmon and steelhead in MO1, such as higher juvenile survival rates, faster travel time, lower powerhouse encounter rates, and structural improvements may be offset by the projected changes in flows and temperatures. Lower flows could result in increased travel times and likely lower powerhouse encounter rates as juveniles are better able to detect spillway routes in the forebay (McCann et al. 2017). Outmigrating juveniles could experience increased predation risk as projected warmer water temperatures throughout the Columbia River Basin may increase the proportion of non-native predatory fish and their predation rates on juvenile salmon and steelhead.

MO1 includes measures to improve adult upstream passage that could be improved further by lower flows and lower spill volumes, but the level of improvement could be reduced by increased temperatures due to climate change. Temperatures in the Snake River under MO1 were found to be higher than under the No Action Alternative during August and early September, which could cause delayed migration for summer steelhead, fall Chinook, or lamprey; climate change could increase these temperatures even further. Throughout the basin, increased fish ladder temperature differentials and more shad in fishways could also decrease adult salmon migration success, offsetting gains in ladder improvements from structural measures.

Climate change effects outside of the influence of the CRSO, such as decreased early life stage survival due to tributary flows and habitat changes, as well as ocean conditions that reduce survival in the adult ocean phase, could also diminish and likely overwhelm the minor increases in survival in MO1.

In MO1 there are more years than in the No Action Alternative where chum flows would not be met without additional flow augmentation. The minor effects to eulachon caused by lower spring flows under MO1 could be reduced by climate change which could result in earlier and higher spring flow peaks. Higher spring flows in April could increase the distribution of eulachon larvae to feeding areas, but could also result in a mismatch between the temperature trigger for upstream adult migration and spawning and the spring freshet for larval distribution. If the freshet peaks and declines too soon, the slightly reduced larval distribution could be further impaired because larvae could miss the freshet. Lower summer flows could further decrease summer foraging habitat for green sturgeon. The seasonal changes in flow from MO1 were found to have minor effects but could be compounded with climate change to become an issue for these species.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Climate change effects described in the No Action Alternative could further reduce juvenile survival and increase travel time. Due to higher water temperatures, juveniles could likely encounter higher predation rates, and more non-native fish in the river. In MO2, there is a measure that would potentially cease installation of fish screens to increase the efficiency of hydropower turbines at the Ice Harbor, McNary, and John Day Dams once improved Fish Passage turbines are installed. If this measure is implemented, then fewer fish screens could result in more juveniles passing through turbines rather than juvenile fish bypasses. Lower flows could improve the ability of juveniles to find spill routes in the forebay and could tend to decrease powerhouse passage (McCann et al. 2017).

Adult migration under MO2 may be improved by lower spill, but the overall warming of the river water could offset this effect and result in poorer upstream migration and adult survival. Increased transportation of juveniles may benefit some adult returns to Bonneville Dam, but could also increase the incidence of fallback and straying of adult salmonids. Ocean and tributary life stage effects could reduce abundances of adult spawners.

In the lower river, chum flows would be more difficult to meet under MO2. MO2 winter flows are 10 percent higher than the No Action Alternative during the month of December, which would increase minor effects to eulachon predation risk; climate change could make these flows even higher and may result in this effect being biologically detectable.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Increases in juvenile salmon and steelhead survival, decreases in travel time, and reductions in powerhouse encounters in MO3 could be reduced or offset by the effects of climate change. In MO3, the Snake River would be free-flowing (long-term) so powerhouse encounters in the Snake River would still be zero with climate change. Potential increased water temperature from MO3 in the spring could be further amplified by warming from climate change (Section 4.2.3.3) and migration could initiate earlier. The benefits of decreased travel time through the lower Snake River could also be reduced or offset with lower summer flows (Section 4.1.2.4), and increased predator populations (warm water predators could increase with warmer water temperatures). The rate of powerhouse passage in the four lower Columbia dams should decrease under low-flow conditions, due to the increased ability of juveniles to detect spillway routes in the forebay (McCann et al. 2017).

Analyses of adult migrations up the Snake River in MO3 showed the temperature effects of dam breaching under historical conditions (higher early summer) would be offset by the diel fluctuations providing nighttime refuge and by faster migration times with the dams breached. However, potential decreases in nighttime cooling from increasing air temperature could reduce the amount of cooling to protect upstream migrating adults from the faster increase in spring/early summer temperatures. Lower DO associated with warmer temperatures could also increase the magnitude of short-term effects noted in MO3 to all fish. Fall Chinook salmon habitat increases in MO3, but may be reduced by climate change effects. Predictions of Fall Chinook rearing strategies due to dam breach may be altered with warmer temperatures. In the Columbia River, slower adult migrations under MO3 may be further slowed by increased water temperatures and ladder differential issues.

In the lower River, chum flows could be met more often than the No Action Alternative under MO3, and climate change could increase the frequency of meeting chum objectives further with projected increases in winter flow volumes. Winter flows would be slightly higher than in the No Action Alternative in MO3 and could be further increased; this may increase eulachon predation risk. Summer foraging for green sturgeon could be decreased further with climate change. These are minor effects in the alternative that may become biologically noticeable with climate change.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 includes several measures to increase juvenile survival and decrease travel time and powerhouse encounters. Lower flows in late spring/summer with climate change could reduce the effectiveness of these measures for most migrants. Earlier spring runoff could shift the timing of outmigrations earlier and reduce the effectiveness of flow augmentation. Water temperatures downstream of Chief Joseph Dam are expected to continue to exceed water quality standards in late summer and early fall, this could be exacerbated in dry years by the early release of flows and missed refill due to the *McNary Flow Objective* measure. This could reduce survival of later migrants. The flow operation that causes this effect may increase in frequency as streamflow volumes are likely to shift to occur earlier in the year and late spring/summer flow declines. This alternative was the only one with substantial increases in TDG effects; these could be reduced with lower spill volumes due to lower flows due to climate change (Geldert, Gulliver, and Wilhelms 1998).

Adult upstream migrations would be challenged by MO4 flow and spill conditions and may be further complicated by the effects of climate change. The additional flow augmentation (*McNary Flow Target* measure) delivery would increase flows in spring but then reduce them later in summer, resulting in increased water temperature in the Columbia River from Chief Joseph downstream. These temperatures could be further elevated with climate change and could increase delays and fallback. Temperatures would be elevated in MO4, which could make Upper Columbia River sockeye more frequently encounter conditions in the lower Columbia River where it is too warm to migrate, and where there is a thermal block downstream of spawning habitat in the Wenatchee or Okanogan Rivers (Hyatt, Stockwell, and Rankin 2003). Similarly, Pacific lamprey could experience even more days over their thermal stress threshold (temperature above which the fish experience stress) in the Columbia River from Chief Joseph Dam to McNary Dam, where temperatures would be elevated in MO4.

In the lower Columbia River, MO4 would increase the risk of not meeting chum operations without flow augmentation, which could be even more difficult with climate change. May outflows in dry water years would be 10 percent higher than the No Action Alternative and could be even higher with a climate change shift in peak flows; this could increase predation risk for eulachon. Forage habitat for green sturgeon could be decreased or disrupted by lower summer flows and flow fluctuations in July and August, and this could be enhanced by climate change effects.

4.2.3.6 Resident Fish, Aquatic Invertebrates, and Aquatic Habitat

Resident fish species that remain in one location or display limited migrations between reservoirs and tributaries must be able to tolerate the annual range of temperatures and flows within a small areal range. A warming climate could affect the distribution and abundance of many resident fish, increasing the range of some species while reducing the range of others, as well as resulting in isolated populations in separated, deeper water habitats.

Like anadromous fish, projected changes in air temperature, precipitation, hydrology and stream temperature have negative implications for the freshwater, estuarine, and marine environments of many fish species in the Pacific Northwest (Climate Impacts Group 2015; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007).

REGION A - LIBBY, HUNGRY HORSE, AND ALBENI FALLS DAMS

No Action Alternative

Potentially lower pool elevations in late summer through October in Hungry Horse Reservoir could reduce the productive zone for phytoplankton and zooplankton production, dewater benthic insect production faster, and reduce the surface area available for fish to feed on terrestrial insects in the summer. If fall elevations are lower due to changes in runoff (Section 4.2.2.1) it could also increase varial zone effects to bull trout (*Salvelinus confluentus*). These effects could be reduced on spring-spawning fish such as westslope cutthroat trout as spring levels could be higher. Faster recovery of storage through the winter could increase habitat available for spring benthic insect production, but deeper drafts and more variability in outflows and pool elevations could result in more dewatering of this food resource. Likewise, if the reservoir were drafted deeper in spring for FRM because of higher runoff volumes (Section 4.2.2.1), it could also increase dewatering of benthic production. More potential variability in outflows could also disrupt the production of aquatic invertebrates in the rivers below these projects, and if outflows were to increase through winter months there could be more entrainment of fish and zooplankton, and a decrease in suitable winter habitat for bull trout and other fish. Potentially lower summer outflows could decrease entrainment risk in summer. Minimum flows would likely maintain habitat in the rivers below these reservoirs.

At Albeni Falls dam, higher, more variable pool elevations and flows could disrupt food production in winter. More variability through the winter could disrupt the spawning and rearing success of kokanee (non-anadromous form of the sockeye salmon) as eggs could be deposited at a higher location and then dewatered if the reservoir drops. In Lake Pend Oreille, kokanee avoid predatory lake trout, which occupy deeper areas, by migrating closer to the surface. If surface temperatures become too warm during the summer period of stratification, they may no longer be able to use this refuge (Stockwell and Johnson 1999). Lower and more variable lake elevations could decrease the spawning success of warm water gamefish. Higher and earlier spring freshet flows could increase entrainment of invasive northern pike (*Esox lucius*) from Clark Fork River reservoirs into Lake Pend Oreille. Lower summer and fall flows with warming temperatures could favor non-native fish species in the Pend Oreille River.

Libby Reservoir may experience similar effects as Hungry Horse Reservoir, with elevations and flows combining for lower productivity of food resources for fish, increased varial zone effects to bull trout but lower effects to spring spawning species. Earlier spring peaks may change the spawn timing of Kootenai River white sturgeon (*Acipenser transmontanus*) with unknown spawning success effects, but warmer water temperatures in spring may increase recruitment success, depending on the timing between higher spring flows to trigger spawning and warmer water for egg and larvae development (Paragamian and Kruse 2001).

Potentially warmer water in these reservoirs could reduce the suitability of these habitats for native fish such as bull trout, westslope cutthroat trout (*Oncorhynchus clarki lewisi*), and mountain whitefish (*Prosopium williamsoni*). Hungry Horse Reservoir is protected from invasion of non-native fish by Hungry Horse Dam, but Lake Pend Oreille could see a shift to more non-native species with warmer temperatures. Downstream habitats may see benefits of the selective withdrawal structures being usable for longer periods and be at optimum temperatures sooner in the spring with warmer flows, but warmer fall temperatures could limit habitat for cold water fish (Section 4.2.3). Higher winter temperatures (Section 4.2.3) may be detrimental for certain fish species, such as burbot (*Lota lota*), which require near freezing river temperatures (<2°C) to spawn. Higher TDG and turbidity could increase effects to fish.

In the spawning tributaries above Columbia River System projects, bull trout may be especially vulnerable to climate change given that spawning and early rearing are constrained by cold water temperatures, creating a patchwork of preferred headwater habitats across river networks. Climate warming could increase fragmentation of remaining bull trout habitats and accelerate decline of this species. In fact, predicted warming could result in losses of 18 to 92 percent of thermally suitable habitat area (Rieman et al. 2007). Even with no further habitat loss, existing fragmentation could contribute to continuing local extinctions due to the expansion of introduced species (Rieman, Lee, and Thurow 1997).

Multiple Objective Alternative 1

At Hungry Horse Reservoir, lower late September lake elevations from the Water Supply measure coupled with projected decreases in summer inflow (Section 4.1.2.4) could increase varial zone effects to bull trout. Entrainment risk could be increased with higher spring flows, but reduced in summertime when MO1 outflows would be increased; this would likely offset the entrainment risk to bull trout in summer. MO1 would reduce summer habitat suitability in the South Fork and mainstem Flathead Rivers, which could be alleviated somewhat with lower summer flows projected under climate change (Section 4.1.2.4), but the tradeoff with lower reservoir elevations would be considerable. Habitat channel maintenance that would be slightly reduced in MO1 could be enhanced with higher spring flows. Hungry Horse Reservoir is critical habitat for bull trout; therefore, effects on bull trout in the reservoir would have a greater effect than downstream.

In the Pend Oreille basin, MO1 had only minor effects to resident fish so the effects of climate change would be similar to the No Action Alternative.

In the Kootenai basin, reduced summer productivity described in the No Action Alternative due to climate change could offset slight increases seen in MO1 analyses. Winter production of benthic insects would be disrupted in MO1 and this effect could be exacerbated by increased fluctuations in winter and potentially deeper drafts (Section 4.2.1.1). Under MO1, the *Modified Draft at Libby* measure increases outflow from Libby Dam in late winter and early spring, potentially increasing downstream water temperature in the Kootenai River. This could exacerbate negative effects of warming winter water temperatures (Section 4.2.3.1) on burbot spawning. MO1 would slightly reduce sturgeon spawning success but this could be offset with enhanced sturgeon recruitment opportunities if climate change produces higher spring freshets (Section 4.1.2.4) and warmer spring temperatures in the Kootenai River. Burbot success could be lower, however, with warming temperatures.

Multiple Objective Alternative 2

Hungry Horse Reservoir summer elevation and food production would be similar to the No Action Alternative; therefore, the climate change effects would be the same as described in the No Action Alternative. In winter, however, the production of benthic insects would be decreased with deeper, steeper drops in elevation that could be even deeper, steeper, and more variable with climate change. Varial zone effects would be similar to the No Action

Alternative. In the South Fork and mainstem Flathead Rivers, MO2 would limit winter habitat for bull trout with much higher outflows that could be further damaging with higher flows under climate change. MO2 was the only alternative where effects to Flathead Lake bull trout were noted; bull trout entrainment would increase and could be increased even further with projected increases in winter flows (Section 4.1.2.4). The lower Flathead River (below Flathead Lake) would also see reduced habitat for bull trout and other native fish under MO2 that could be worsened by increased winter flows due to climate change.

Under MO2, the *Slightly Deeper Draft for Hydropower* measure calls for a deeper drawdown of Libby Reservoir to provide additional hydropower generation. Increasing outflow from Libby Dam could increase downstream water temperature in the Kootenai River. This could exacerbate negative effects of warming winter water temperatures on burbot spawning.

MO2 effects in the Pend Oreille basin were similar to the No Action Alternative so the climate change effects would be similar to those described for climate change in the No Action Alternative.

In MO2, Libby Reservoir levels are lower than the No Action Alternative in winter, reducing productivity. Kootenai River effects of MO2 include lower spring flows and fewer days of potential sturgeon spawning trigger flows. Sturgeon recruitment potential under MO2 would be diminished; it could be enhanced with projected potentially higher and earlier spring freshets (Section 4.1.2.4), but this likely would not be enough to incite successful recruitment.

Multiple Objective Alternative 3

Effects in Hungry Horse Reservoir, South Fork Flathead River, the mainstem Flathead River, Flathead Lake, and Clark Fork Rivers would all be similar to those described in MO1. One difference would be that MO3 would lift ramping rate restrictions that could increase disruption of benthic production in the South Fork Flathead and mainstem Flathead Rivers; this could be exacerbated with increased variability in outflows during winter (Section 4.2.1.1).

MO3 effects in the Pend Oreille River Basin would be similar to the No Action Alternative, so climate change effects would also be similar to those described in the No Action Alternative.

In the Kootenai River Basin, MO3 would have lower elevations and higher draft rates than the No Action Alternative through the winter, which decrease benthic production. This could be further reduced with potentially deeper drafts and more variability (Section 4.2.1.1). Fewer days of optimal sturgeon recruitment conditions in MO3 could be ameliorated by better recruitment caused by higher projected spring flows, and an earlier freshet coupled with warmer water in the Kootenai River in spring. MO3 could improve burbot spawning conditions with cooler temperatures potentially partially ameliorating the increased winter water temperature from climate change (Section 4.2.3.3).

Multiple Objective Alternative 4

In Hungry Horse Reservoir, in wet and average years the effects of MO4 would be similar to MO1 effects and climate change would either enhance or offset those effects as described in MO1. MO4 also includes the *McNary Flow Target* measure, which would cause effects through similar mechanisms as those in MO1, but the magnitude would be higher in the summer months due to higher outflows and deeper reservoir drawdowns. These could be exacerbated further with the potentially lower summer elevations under climate change inflows (Section 4.2.1.1). Food productivity effects could be even higher and varial zone effects that would reduce access to tributaries and increase predation risk for bull trout, westslope cutthroat trout, and other native species could be increased with climate change. Furthermore, these dry year effects could happen more frequently as climate change could increase the frequency that the trigger for the *McNary Flow Target* measure would be met.

In Libby Reservoir, MO4 would cause decreases in reservoir productivity with lower elevations. Reservoir elevations could be further reduced due to projected decreases in late summer and fall flow (Section 4.1.2.4). Reductions in suitable habitat under MO4 for bull trout in the Kootenai River could be further reduced with projected higher flows in early summer. MO4 would reduce the volume of the spring freshet; however, projected higher, earlier spring flows resulting from climate change could increase the habitat maintenance flows naturally occurring in the river. Kootenai River white sturgeon would experience fewer days of spawning and recruitment potential under MO4 (see Section 3.5.2, *Hydrology and Hydraulics*), but this could be offset somewhat with potentially earlier and higher spring freshets. Potentially warmer temperatures under climate change scenarios could offset the higher pool elevations that cool water temperatures in MO4.

REGION B – GRAND COULEE AND CHIEF JOSEPH DAMS

No Action Alternative

In the Columbia River from the U.S.-Canada border to Lake Roosevelt, projected earlier and higher flows of the spring freshet (Section 4.1.2.4) may provide stronger spawning cues for white sturgeon and increase opportunities for recruitment if water temperatures could remain suitable. Projected decreases in streamflow by June and July coupled with potential increases in water temperatures (Section 4.2.3.2) could reduce spawning success.

In Lake Roosevelt, projected increases in winter inflow could decrease retention time, resulting in higher entrainment of fish in winter. Projected lower summer flows could result in longer retention times and therefore less entrainment of fish and zooplankton in the summer. Lower elevations in fall could increase varial zone effects to kokanee in the late fall and redband rainbow trout (*Oncorhynchus mykiss gairdneri*) in spring as these fish move from the reservoir to spawning tributaries and could be exposed to higher predation and experience potential access issues. The net pens in Lake Roosevelt (operated in spring) could become dewatered or experience higher temperatures and lower DO before the current average release date for hatchery rainbow trout in late spring. Potentially higher early spring lake elevations could increase the time boat ramps would be useable for boat-based northern pike suppression efforts, but projected overall changes in temperatures and elevations could increase northern pike populations, thus negating the suppression efforts.

Potentially lower summer outflows could reduce fish entrainment in summer and reduce fish in Lake Rufus Woods. Potentially higher TDG in winter (Section 4.2.3.2) could cause more injury or mortality to fish from gas bubble trauma at times when it currently is near the threshold for effects.

From Chief Joseph Dam to McNary Dam, resident fish would experience lower summer flows and higher temperatures that could further increase the ratio of non-native fish that thrive in warmer water. White sturgeon in this reach could be cued to spawn earlier, resulting in a longer recruitment window, but one that could result in a mismatch with temperatures and reduce success.

Multiple Objective Alternative 1

Projected earlier and higher freshet flows would increase the risk of entrainment of fish and zooplankton out of Lake Roosevelt in late winter and early spring. Redband rainbow trout access to tributaries and varial zone effects from MO1 could be enhanced with climate change. MO1 would cause elevation changes in the winter that could increase stranding of kokanee and burbot eggs; potentially more variable winter elevations (Section 4.2.1.2) could increase this effect. Early spring northern pike suppression efforts that are reduced under MO1 could be offset with higher elevations, but overall warming and reservoir habitat could increase these non-native predators. MO1 effects to fish in Lake Rufus Woods and the river from Chief Joseph Dam to McNary Dam would be similar to the No Action Alternative so the effects of climate change would be the same as described in the No Action Alternative.

Multiple Objective Alternative 2

The effects to fish in the Columbia River from the U.S.-Canada border to Lake Roosevelt would be the same as the No Action Alternative so climate change effects would be the same. In Lake Roosevelt, MO2 would increase winter zooplankton and fish entrainment in winter; this effect could be increased with additional outflows and lower retention time in winter and early spring that could result from the projected changes in streamflow (Section 4.2.1.2). In some years, varial zone effects to fish in Lake Roosevelt as they access tributaries for spawning that would occur under MO2 operations could be increased by climate change. Increased stranding of kokanee eggs in MO2 could be exacerbated by climate change variability in winter elevations. Northern pike are tolerant of temperatures up to 28°C and could benefit from warming due to climate change (Eaton and Scheller 1996). The increased entrainment of pike caused by higher outflows in May under MO2 could be offset by potential lower summer outflows. MO2 effects to fish in Lake Rufus Woods and the Columbia River between Chief Joseph Dam to McNary Dam would be similar to the No Action Alternative.

Multiple Objective Alternative 3

MO3 effects to white sturgeon in the Columbia River above Lake Roosevelt would be the same as MO1. Increased winter entrainment out of Lake Roosevelt in MO3 could be further increased with the projected higher winter flows (Section 4.1.2.4). Varial zone effects to migrating kokanee and redband rainbow trout, stranding/dewatering risk, northern pike suppression efforts, and net pen fish would all be similar to the No Action Alternative so the climate change effects would be the same as described in the No Action Alternative section. Fish in Lake Rufus Woods may see an increase in population from entrained fish out of Lake Roosevelt under MO3. This could be further increased by the projected higher winter flows in the future. Fish in the Columbia River from Chief Joseph Dam to McNary Dam would be similar to the No Action Alternative, with the notable exception that white sturgeon in the McNary Reservoir would be affected short term by increased turbidity but in the long term would likely experience increased reproduction success and reconnection with Snake River populations with the breach of the Snake River dams (Hatten et al. 2018). The enhanced success of these fish in MO3 could be decreased with projected higher temperature effects. Additionally, higher temperatures and changes in the timing of flows due to climate change could decrease spawning cues due to climate change.

Multiple Objective Alternative 4

White sturgeon recruitment effects would be the same as MO1. MO4 would increase entrainment risk of zooplankton and fish in the summer months when they are most susceptible (*McNary Flow Target* measure). Potentially lower retention time with climate change effects could reduce this risk somewhat. MO4 also would increase entrainment in winter and when climate change could potentially further increase entrainment. Potential climate change effects could exacerbate these risks with lower summer/fall elevations and more winter variability (Section 4.2.1.2). MO4 would also increase the risk of northern pike invasion downstream with much higher entrainment risk at times when juveniles would be most susceptible to entrainment. The projected changes in flow volumes and resulting operations (Sections 4.1.2.4, 4.2.1.2) could reduce the risk slightly in summer but increase it in early spring. MO4 could cause water quality effects to net pen fish that could be increased by changes to lake elevation and water quality issues linked with climate change.

In the Columbia River from Chief Joseph Dam to McNary Dam, water temperatures would increase in late July as compared to the No Action Alternative. This would negatively affect most native fish in this reach and especially be harmful to white sturgeon. Potential warming with climate change (Section 4.2.3.2) could exacerbate this effect.

REGION C – DWORSHAK, LOWER GRANITE, LITTLE GOOSE, LOWER MONUMENTAL, AND ICE HARBOR DAMS

No Action Alternative

In Dworshak reservoir, higher winter elevations and higher releases could increase the loss of kokanee from the reservoir, and more variability in winter elevations could cause stranding of kokanee eggs and fry. Lower summer lake elevations could hamper the migration of bull trout to their spawning tributaries in late June and early July.

Warmer temperatures in the Clearwater and Snake Rivers could shift the fish community further towards dominance by non-native fish, reducing native fish populations that need cooler water. Bull trout, specifically, require very cold water and are often challenged to find suitable refugia in the Snake River and could become more stressed with projected increases in water temperatures (Section 4.2.3.3). While higher, early spring flows may cue white sturgeon to spawn earlier, projected elevated water temperatures and lower summer flows may reduce successful larval recruitment in these populations.

Multiple Objective Alternative 1

The *Modified Dworshak Summer Draft* measure was intended to increase cooling water earlier in the season and later in the season. Water quality modeling showed the result would have negligible benefits to early cooling. This would be harmful to native fish in the Snake River, particularly white sturgeon, and would be beneficial to non-native warm water species. This temperature effect could be increased with potential warming under climate change.

Multiple Objective Alternative 2

Under MO2, Dworshak releases increase in winter, resulting in much higher loss of kokanee from the reservoir; climate change could potentially increase this loss even further as releases could increase due to projected increased winter inflow and operations for system winter flood events (Section 4.2.1.3). Dworshak elevations from May through July would be lower and result in potential access issues for bull trout migrating to their tributaries to spawn. This effect could be ameliorated by projected shifts in inflow timing as the reservoir could refill earlier, leading to higher pool elevations in May and June than historical levels (Section 4.2.1.3). Potential warming of the reservoir could also decrease the annual period when bull trout can migrate to tributaries.

On the Snake River, MO2 operations would result in less spill and resident fish may increase their passage through turbines where they are more subject to injury or mortality. Potential thermal issues due to projected warmer water temperatures (Section 4.2.3.3) may increase the susceptibility of injured fish to disease, resulting in higher mortality.

Multiple Objective Alternative 3

Over time, as the river would clear itself and work back towards equilibrium, the potential flow and water quality changes under climate change could favor the recolonization and success of non-native macroinvertebrates and fish. Long term, the return of the river to a more naturalized river and less reservoir habitat could result in more native species. Bull trout and white sturgeon populations would become more connected populations rather than isolated groups, but potential warming due to climate change may result in suboptimal conditions for adults in the mainstem in summer. Additionally, the increase in spring flows may provide earlier spawning cues for white sturgeon, but likely would not be sustained long enough to provide adequate conditions for recruitment success due to reduced summer flows and higher temperatures (Counihan and Chapman 2018).

MO3 would result in major changes to the temperature regime as the thermal mass of reservoirs would converted to free-flowing river. The river would heat up sooner in the summer and cool down sooner in the fall, but experience wider fluctuations between day and night. Fish could be negatively affected by the earlier warming, but this would be mitigated by the nighttime cool refuge. Climate change could potentially warm the river more and earlier to the point that nighttime refugia may not be enough to offset the earlier seasonal warming.

Multiple Objective Alternative 4

The key effect of MO4 on Snake River resident fish would be the increase in TDG exposure in spring and early summer. Additionally, increased spill may delay bull trout as they are moving out of the system to avoid warming temperatures in May and June. Potential reductions in spill and TDG due to climate change (Section 4.2.3.3) could offset TDG and spill effects, but increased temperatures could exacerbate the early season warming water temperature and hamper bull trout migrations even more.

REGION D – MCNARY, JOHN DAY, THE DALLES, AND BONNEVILLE DAMS

No Action Alternative

Overall potential warming, higher winter flows, and lower late spring and summer flows could increase the success of warm water, non-native fish and further challenge native fish to survive in Region D. Bull trout use the mainstem Columbia River intermittently as thermal conditions allow; with potential warming they could be able to use it less and become more isolated. White sturgeon in Region D are limited to occasional high water year events where recruitment would be successful. Higher, earlier spring freshets could potentially provide better spawning cues, but could result in a mismatch of spawning and recruitment conditions more often than without climate change. Potentially reduced early summer flows and warmer temperatures could result in more temperature stress events on white sturgeon populations.

Multiple Objective Alternative 1

See No Action Alternative discussion above, as effects are anticipated to be similar.

Multiple Objective Alternative 2

See No Action Alternative discussion above, as effects are anticipated to be similar.

Multiple Objective Alternative 3

See No Action Alternative discussion above, as effects are anticipated to be similar. Multiple Objective Alternative 4

The *McNary Flow Target* measure would increase river flows in May and June of dry years, but reduce flows later in June and July, compared to the No Action Alternative. Potential climate change effects could further enhance early spring flows but reduce summer flows (Section 4.1.2.4); though the potential change to resident fish is difficult to discern. White sturgeon success and bull trout use of the mainstem river would likely remain similar to the No Action Alternative. TDG would be higher under MO4 but if spill were lowered, then exposure to TDG could reduce this effect. Flows would increase in July with additional flow augmentation about 3 percent higher than the No Action Alternative; this change was not found to have discernable effects to resident fish, but the augmentation could be more beneficial under projected decreases in summer flows (Section 4.1.2.4). In dry years, warmer water temperatures could reduce native fish reproductive success and favor non-native fish. Potential effects of climate change on water temperature (Section 4.2.3.4) could exacerbate this effect and shift the fish community further towards non-native, warm-water fish.

4.2.4 Vegetation, Wildlife, Wetlands, and Floodplains

Projected changes in climate, such as warmer air temperatures and changes to hydrology, will likely affect the ecosystem. Warming air temperatures coupled with changing rainfall amounts and timing will likely affect soil conditions, plant communities, insects, and wildlife. Warm weather is projected to occur earlier in the spring and stay later into the fall (Section 4.1.2.1). This will likely lead to longer plant-growing seasons (USGCRP 2018) and changes in timing of phenological events (such as when plants begin to grow, bloom, and set seed). Precipitation amounts and timing are also projected to change, with a tendency for increased winter precipitation and decreased summer precipitation (Section 4.1.2.2), which could affect soil and growing conditions. To the extent drought conditions become more frequent and severe, (USGCRP 2018), it could stress[5] and alter plant communities and ecosystems that are more sensitive to drought conditions.

As the climate warms, the symbiotic relationships between plants, insects, and wildlife may become out of sync and be at risk due to climate change (Bellard et al. 2012; United Nations

[5] Drought is an environmental stressor for many species and makes them vulnerable to other stressors or even normal environmental events, such as wildlife or insect outbreaks (USFS 2019c).

Environmental Programme 2018). Life cycles of insects, including pollinators, and wildlife, such as birds which depend on insects and help keep them in check, have evolved over time with each other. Insects rely on plants for food; plants rely on insects and other pollinators to fertilize flowers; and wildlife depend on plants and insects for food. Phenological events, such as when a pollinator or migrating bird arrives to an area, may not mesh with changes in plants, or vice versa, resulting in increased environmental stress that cause ecosystem changes (MacMynowski et al. 2007; Van Buskirk, Mulvihill, and Leberman 2009; Case, Lawler, and Tomasevic 2015; Wadgymar et al. 2018). These include changes in compositions of plant and animal communities, such as reductions in population or disappearance from regions of species that are particularly sensitive to soil and climatic conditions or depend on particular niches (USGCRP 2018). Some plants may be able to adapt more quickly to changing environmental conditions (soil, air temperature, precipitation), while others may not. For example, cheat grass flourishes in many different environments, whereas bluebunch wheatgrass (*Pseudoroegneria spicata*), a native grass, is more sensitive to climatic conditions and its range, and may shrink in response to changing precipitation patterns and warmer air temperatures (Ganksopp and Bedell 1979; Bradley, Curtis, and Chambers 2016; Kray 2019).

Changes to timing and volumes of streamflow will likely affect riparian area extent and species composition: aspen, willow, cottonwood, and herbaceous communities dependent on water availability during the growing season may decline along with the ecosystem services they provide (USFS 2019a). Changes to vegetative cover can affect streamflow and water quality, reducing the ability for ecosystems to improve water quality and regulate water flows (USGCRP 2018; USFS 2019a). Changes in hydrology will affect the lifestyle, survival, and reproductive success of aquatic and semi-aquatic invertebrate and amphibian species (USFS 2019a). For example, shallow water areas or pools that typically provide habitat for amphibians, such as frogs, may dry out earlier or faster and cause tadpoles to die. This could affect local populations of amphibians.

At the same time, climate change may enhance the expansion of invasive species by giving non-native species an advantage over stressed native species (USGCRP 2018; USFS 2019b). Increased outbreaks of insects and other pests are likely to become more common and widespread. Disturbances such as wildland fire will also increase in frequency and severity (Section 4.1.2.6). The effects of wildland fire on wildlife habitat can be exacerbated in areas stressed by drought, insect outbreak, or dominated by invasive species.

Climate change can also have positive effects. A longer growing season (USGCRP 2018) may benefit some plant species and allow for greater productivity and nutrient cycling (USFS 2019b). Warmer air temperatures combined with earlier winter and spring flows (Section 4.1.2.4) could allow wetlands to recharge earlier in the growing season and could increase riparian and wetland vegetation along reservoir shorelines and rivers. This could increase available habitat for some wildlife species. For example, if a wetland area has greater productivity and provides cooler and cleaner water, this could enhance amphibian and waterfowl habitat. Additionally, species are adapting and responding to climate change by altering individual characteristics, the timing of biological events, and geographic ranges (USGCRP 2018).

The projected changes in precipitation (Section 4.1.2.2) coupled with warming temperatures (Section 4.1.2.1) could result in increased winter flood frequency and magnitude (Section 4.1.2.4). Increases in winter precipitation can also lead to increased snowmelt flooding in the spring, particularly in high elevation regions where winter temperatures will remain below freezing even with moderate amounts of warming (Hamlet et al. 2013; Salathé et al. 2014; RMJOC 2018; Chegwidden et al. 2019). Floodplains could experience increased frequency, duration, and extent of inundation due to these projected increases in flooding.

4.2.4.1 Region A - Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

Potential higher winter inflows and increased frequency of systemwide winter flood events could lead to more variable reservoir outflows and pool elevations during winter (Section 4.2.1.1). This could lead to bank sloughing and increased erosion, which would erode wildlife habitat adjacent to the reservoir thus reducing nearby wildlife habitat. Downstream of Libby, projected increases in winter rains and spring flows could increase erosion/frozen bank sloughing (Section 4.2.2.1), which could discourage cottonwood establishment and impair wildlife habitat.

Lower inflows and lower reservoir levels are projected during the summer and early fall (Section 4.2.1.1). This could lead to the establishment of invasive species (e.g., flowering rush [*Butomus umbellatus*]). At Hungry Horse, the lower inflows and deeper pool levels may influence habitat, including wetland communities that border the reservoir. Wetland habitats may become drier and shift downslope of current elevations, and gradually transition to plant communities more tolerant of drought conditions or more traditionally upland communities like conifers.

At Libby, shallow water habitat may become unvegetated mudflats due to decreased inflows (Section 4.1.2.4). As described above, this could affect insects and amphibians. Lower water surface elevations or levels surrounding reservoirs may lead to changes in shallow water habitat. Increased exposure and reduced water levels could cause the habitat to transition to mudflats.

Floodplains in Region A could experience increased frequency, duration, and extent of inundation due to projected increases in flooding.

MULTIPLE OBJECTIVE ALTERNATIVES 1 AND 3

Same as the No Action Alternative discussion above, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Same as the No Action Alternative, except for at Hungry Horse. Projected increases in winter flow could reduce the need for deeper drafts at Hungry Horse and Libby (section 4.2.1.1), potentially reducing the exposure of the barren zone (the area where small animals become prey because of lack of cover) by increasing the duration and the extent (or width) of the exposed barren zone.

MULTIPLE OBJECTIVE ALTERNATIVES 4

MO4 includes measure that provide deeper drafts during dry years at Libby and Albeni Falls and in all years at Hungry Horse. These deeper drafts could exacerbate the effects of climate change on vegetation and wildlife discussed under NAA.

4.2.4.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

Vegetation and wildlife habitat surrounding the reservoirs and streams coming into the reservoirs could experience higher inflows during the winter (Section 4.2.1.2) that could increase surface erosion. Increased erosion could decrease riparian vegetation and habitat as banks fall into the reservoirs.

Projected warmer air temperatures (Section 4.1.2.1) combined with projected lower summer and fall reservoir levels (Section 4.2.1.2) could favor invasive species along banks and shallow water areas vulnerable to drying. Likewise, there could be subsequent effects to amphibians and other species if shallow water habitat is reduced.

Floodplains in Region B could experience increased frequency, duration, and extent of inundation due to projected increases in flooding.

MULTIPLE OBJECTIVE ALTERNATIVE 1 AND 2

The *Winter System FRM Space* measure may be used more frequently, leading to greater reservoir fluctuations and associated bank sloughing. Increased erosion from this measure being activated more frequently could erode wildlife habitat adjacent to the reservoir, thus reducing nearby wildlife habitat locally.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See No Action Alternative discussion above, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

The McNary Flow Target, which could increase in frequency as streamflow volumes shift earlier in the year, could result in greater outflow earlier in the summer and reduced outflow from August to October (Section 4.2.1.2). Combined with additional projected deeper drafts in the fall for navigation (Section 4.2.1.2) and more frequent use of the Winter System FRM (see MO1), this could lead to bank sloughing and increased erosion. This would erode wildlife habitat adjacent to the reservoir, thus reducing nearby wildlife habitat. It could also provide additional opportunity for the establishment of invasive species in areas where there is drawdown.

4.2.4.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

At Dworshak, projected higher inflows (Section 4.1.2.4) and pool levels in the winter could decrease extent and duration of exposure of the barren zone, allowing for increased survival of small prey animals. Projected warmer air temperature (Section 4.1.2.1) combined with earlier spring inflows (Sections 4.1.2.4, 4.2.3.3) will likely allow for wetlands to recharge earlier in the growing season. This could allow for the establishment of riparian and wetland vegetation along the shoreline, including cottonwoods. Warmer air temperature and lower releases on the lower Snake River projects during the summer could lead to establishment of invasive vegetation (i.e., flowering rush) in areas with drawdown. Shallow water habitat may become unvegetated mudflats more frequently, allowing for colonization of invasive species. Amphibian eggs may desiccate if pools dry up faster.

Floodplains in Region C could experience increased frequency, duration, and extent of inundation due to projected increases in winter and spring flooding.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Same as the No Action Alternative discussion above, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Deeper drafting in the winter at Dworshak reservoir increases the barren zone (area where small animals become prey because of lack of cover). In the spring, pool levels at Dworshak may be lower (Section 4.2.1.3). This may delay recharge of wetlands in the spring, allowing for establishment of vegetation species adapted to drier conditions.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Breaching the lower Snake River dams will lead to perched habitat and exposed sediment and shoreline (Section 3.6.3.5). The exposed shoreline would be at increased risk of invasion by invasive plant species. Climate change could exacerbate shifts in wetland and riparian habitats by allowing vegetation to colonize earlier in the growing season, thereby increasing the likelihood of invasive species. The stage of the un-impounded river could be more responsive to local inflow as compared to the NAA. Variability of local inflows could increase during winter months as more precipitation falls as rain (Section 4.1.2.2) and outflow of Dworshak Dam could become more variable (Section 4.2.1.3). This could cause a larger band of riparian vegetation to establish and possibly a larger barren zone than what could occur with the No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Same as the No Action Alternative discussion above, as effects are anticipated to be similar.

4.2.4.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Increased likelihood of heavy precipitation events in the fall and winter, mostly in the form of rain, may lead to higher flows in Region D (Section 4.2.3.4). This could lead to more flood storage in adjacent wetlands and floodplains. Wetlands could act as a stormwater retention area and stay wetter longer during the spring growing season. Additionally, earlier inflows in the spring could allow for wetlands to recharge earlier in the growing season. This could allow for establishment of riparian and wetland vegetation along the shoreline, including cottonwoods. Longer periods of low flows in the summer could lead to the establishment of invasive vegetation in areas where there is drawdown. Shallow water habitat could become unvegetated mudflats, allowing for colonization of invasive species and may lead to amphibian habitat drying up and killing eggs and tadpoles.

Floodplains in Region D could experience increased frequency, duration, and extent of inundation due to projected increases in winter flooding.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 4

Same as the No Action Alternative discussion above, as effects are anticipated to be similar.

4.2.5 Power Generation and Transmission

4.2.5.1 Power Generation

Projected future changes in temperature, precipitation, snowpack, and streamflow will likely impact hydropower generation and load in the basin. Climate change is likely to add uncertainty to the annual magnitude of generation, and significant uncertainty to the monthly magnitude of the effect of the MOs relative to the No Action Alternative due to the increase in variability of streamflow (Section 4.1.2.4).However, climate change is not likely to change the general conclusions from the power analysis of the relative effect of one MO versus another. The projected changes in climate are likely to affect hydropower generation in all alternatives relative to the No Action Alternative roughly the same on an annual basis (though with a little more variability on a monthly basis). More detailed analyses on the projected effect of climate change on power is in the hydropower appendix (Appendix H).

NO ACTION ALTERNATIVE

The projected changes in streamflow (section 4.1.2.4) will affect hydropower generation. For the No Action Alternative, climate change adds uncertainty to the annual magnitude of generation, and significant uncertainty to the monthly shaping of generation with longer periods of low generation in the summer. Additionally, rising temperatures will likely decrease winter and increase summer energy demand in the region, which is likely to decrease winter shortfalls and increase summer shortfalls.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 produces less energy than the No Action Alternative on average under historical hydrological conditions. MO1 has a higher spill operation than No Action, thus the projected increased runoff (Section 4.1.2.4) in the spring (mid-April to June) does not reduce generation in MO1 as much as in No Action. Projected increases in runoff could somewhat offset the higher spill operation effects and result in an increase in generation under climate change for MO1 as compared to No Action. Lower summer flows (first half of August; Section 4.1.2.4) may cause similar or exacerbate the already lowered generation when compared to the No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 2

MO2 produces more energy than the No Action Alternative under historical hydrological conditions. Projected changes in runoff timing with potentially more flow in the winter and less in the spring (Section 4.1.2.4) combined with the measures in MO2 may somewhat reduce the magnitude of the increase in annual generation under historical conditions. This is because generation in MO2 is more sensitive to decreases in spring flows since MO2 includes more spring generation than the No Action Alternative or the other MOs. Monthly generation is more uncertain and may experience more variability under climate change. MO2 is projected to provide the most resiliency for meeting projected energy demand increases in the summer.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 produces less average energy than in the No Action Alternative under historical hydrological conditions, largely due to the measure that breaches the lower Snake River dams and ends generation at those projects. Projected increases in winter and spring runoff (Section 4.1.2.4) will likely lead to increased generation from the Lower Snake River dams during that time period Breaching of the lower Snake River dams eliminates the potential opportunity for increased seasonal generation gains, particularly in March and April. Thus, climate change may result in MO3 having even less generation compared to the No Action Alternative than what was modeled with the historical conditions. In the summer, when the loss of generation from the lower Snake River dams contributes to significant reliability concerns, climate change could exacerbate these concerns given the decrease in potential generation over the summer with lower flows.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 produces considerably less energy than the No Action Alternative under historical hydrological conditions, largely in the spring and summer with large reliability concerns especially in August (Section 3.7.3.6). Projected decreases in summer flows (Section 4.1.2.4) with climate change may further decrease summer generation under MO4. Monthly generation is more uncertain and may experience more variability under climate change.

4.2.5.2 Energy Demand (Loads)

Projected warming regional temperatures (Section 4.1.2.1) are expected to affect energy demand (load) as well. By the 2030s, loads are likely to increase in the June through August period, and possibly into September as well, due to increasing air conditioning demand and a longer air conditioning season. In the winter months (roughly December through February), loads are likely to decrease as increasing regional temperatures lower the need for heating. This change in energy demand has important potential implications for reliability.

The power shortages (Section 3.7.3) in December through February under all alternatives are likely to be reduced into the 2030s as loads in those months decrease (absent other changes). Conversely, the summer power shortages that increase in MO1, MO3, and MO4 as compared to the No Action Alternative are likely to be further exacerbated as temperatures and load in those months increase. Under MO2, climate change could somewhat decrease the increases in power reliability in summer months (section 3.7.3.4). Recent research supports these conclusions. A Northwest Power and Conservation Council and Pacific Northwest National Laboratories study found that combined climate change effects on loads and hydropower may lead to decreases in winter shortfalls and increases in summer shortfalls as increases in peak loads for cooling coincide with decreases in hydropower generation (Voisin et al. 2019).

4.2.5.3 Coal Plant Retirement

Changes in economics and GHG emissions reduction policy in the region are resulting in increased and accelerated retirements of coal plants serving Pacific Northwest loads (Section 3.7.3.1). These retirements will change the Loss of Load Probability of No Action Alternative and MOs as well as resources required to maintain regional reliability (Section 3.7.3). Summer power shortages are projected for MO1, MO3, and MO4 and are likely to increase with climate change due to increased loads. This will be further exacerbated with the retirement of baseload coal generation. The retirement of coal generation could also lead to reliability concerns with MO2 with climate change as well.

4.2.6 Air Quality and Greenhouse Gases

While the relationship between meteorological factors and air pollutants is complex, studies indicate that climate change-related weather patterns are a driving force in establishing conditions that are conducive to ozone formation and accumulation, including abundant sunshine, high temperatures, more frequent stagnation, less frequent rainfall, reduced ventilation, and increased biogenic emissions (e.g., from air conditioning) due to temperature (Leung et al. 2004; Leung and Gustafson 2005; Steiner et al. 2006; Grambsch, Hemming, and Weaver 2009; Jacob and Winner 2009). The Pacific Northwest, and the Columbia River Basin in particular, already experiences an isolated, sometimes stagnant atmosphere as a result of topographic features (Ferguson 1998; Leung et al. 2004; Zhang et al. 2008). This could be enhanced under projected climate conditions. Specifically, the development of a low-level thermal trough and upper-level ridge are climatologically significant factors that could increase summer ozone concentrations over time in the Pacific Northwest (McKendry 1994; Leung et al. 2004).

The relationship of meteorological factors to particulate matter (PM) concentrations is not as well understood as the relationship to ozone. However, wildland fires fueled by projected changes to climate (Section 4.1.2.6) could become an increasing source of PM emissions (Grambsch, Hemming, and Weaver 2009; Jacob and Winner 2009). This could affect air quality across the basin.

Beyond the more direct effects on air pollutant concentrations, climate change may also affect activities that generate emissions across the region, including power generation and navigation and transportation (e.g., by affecting reservoir levels and stream flows). For example, to the extent climate change results in changes in hydropower generation (Section 4.2.7; Appendix H), it could therefore result in changes in emissions from power generation: GHGs and ozone precursors (i.e., nitrogen oxides, carbon monoxide, and volatile organic compounds). The following sections describe how climate change may influence how the CRSO EIS alternatives affect air quality and GHG emissions, and due to the nature of airsheds, effects on the resource are discussed collectively rather than by region.

4.2.6.1 No Action Alternative

Climate change may degrade air quality by increasing ground-level ozone concentrations (see previous section) and potentially increasing PM and GHG emissions from wildland fires (Section 4.1.2.6). Climate change will add uncertainty to the annual and monthly magnitude of hydropower generation in the region (Section 4.2.7, Appendix H).

Projected increasing temperatures will likely also affect electricity demand (Section 4.2.5.2). In the winter, decreased heating demands due to projected higher temperatures could reduce generation needs, and therefore emissions, from fossil-fuel plants. Conversely, increased air conditioning loads in summer months due to projected increased temperatures could increase emissions from fossil-fuel combustion.

Potentially offsetting this effect to some degree, both with and without climate change, the region could increasingly rely on power generation from renewable sources and reduce generation from fossil fuel combustion, which would curtail emissions of ozone precursors, PM, and GHGs. Existing coal and natural gas plants are concentrated in Region D (as well as areas across the Pacific Northwest outside of the CRSO regions) (section 3.8.3, figure 3-156; Oregon Department of Energy, 2020); therefore, Region D may experience improvements in air quality.

Further, climate change is not likely to affect emissions from navigation/transportation, or construction activities.

4.2.6.2 Multiple Objective Alternative 1

MO1 produces less hydropower than the No Action Alternative under historical hydrological conditions, but projected increased runoff with climate change may increase generation (see Section 4.2.5.1) compared with No Action. The increased hydropower generation may reduce reliance on, and associated air pollutant and GHG emissions from, existing fossil fuel plants. Air quality improvements would most likely occur in Region D, where the existing fossil fuel plants are concentrated, and in other areas across the Pacific Northwest, outside of the CRSO regions.

4.2.6.3 Multiple Objective Alternative 2

MO2 results in more hydropower generation than the No Action Alternative under historical hydrological conditions, but projected changes in seasonal streamflow timing may reduce the magnitude of the increased hydropower generation relative to No Action (Section 4.2.5.1). MO2 would still be beneficial to air quality relative to the No Action Alternative by reducing reliance on fossil fuel power plants (currently concentrated in Region D, as well as areas across the Pacific Northwest outside of the CRSO regions).

4.2.6.4 Multiple Objective Alternative 3

MO3 produces less hydropower generation than the No Action Alternative under historical hydrological conditions, and projected changes in runoff could further reduce generation under MO3 (Section 4.2.7.1). This would further increase the need for additional power resources to replace the reduced hydropower generation. While the type (i.e., mix of renewables and natural gas) and location of additional power resources is uncertain, increased generation from existing fossil fuel plants in Region D, and any added natural gas capacity across the CRSO regions would further degrade air quality relative to the No Action Alternative if these existing fossil fuel plants replace the reduced hydropower generation.

4.2.6.5 Multiple Objective Alternative 4

Hydropower generation under MO4 is less than under the No Action Alternative under historical hydrological conditions, but projected changes in runoff could slightly lessen the difference (Section 4.2.5.1) based on various influences that increase or decrease generation in different months. The effects of this alternative on air quality would likely still be adverse due to the potential increased reliance on high-emitting fossil fuel generation as compared to the No Action Alternative if these existing fossil fuel plants replace the reduced hydropower generation. However, the effects of climate change could slightly lessen these effects.

4.2.6 Flood Risk Management

Winter flooding and large accumulations of snowfall, which contribute to snowmelt flooding during spring, are associated with atmospheric rivers (ARs). ARs are enhanced water vapor plumes in the atmosphere from extratropical cyclones sourced from tropical latitudes. These typically only last several days, but deliver a significant amount of intense precipitation, wind, and often warm temperatures. The frequency and severity of landfalling atmospheric rivers in the Pacific Northwest is projected to increase (Warner, Mass, and Salathé 2015; Hagos et al.

2016). The projected changes in precipitation (Section 4.1.2.2) coupled with warming temperatures (Section 4.1.2.1) could result in increased winter flood frequency and magnitude (Section 4.1.2.4). Increases in winter precipitation can also lead to increased snowmelt flooding in the spring, particularly in high elevation regions where winter temperatures will remain below freezing even with moderate amounts of warming (Hamlet et al. 2013; Salathé et al. 2014; RMJOC 2018; Chegwidden et al. 2019).

4.2.7.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

Historically, flood mechanisms in this region have been driven by snowmelt. This flood hydrological regime is expected to continue through the 2030s.

An earlier shift in flood freshet volumes is projected for the headwaters of the Kootenai River (Section 4.1.2.4); however extreme peak freshet volumes (95th percentile volume) are expected still to occur in June. The projections show both increases and decreases in the peak volume magnitude, indicating future uncertainty (Libby Dam inflow, Section 4.1.2.4). Increased flow volume in winter is unlikely to affect local FRM at Bonner's Ferry, Idaho; however, increased peak local inflows from spring snowmelt linked to increased precipitation and warmer spring temperatures could elevate local flood risk at Bonner's Ferry.

An earlier shift in flood freshet volumes is projected for the headwater regions of the Flathead River and Clark Fork tributaries, with peaks occurring in both May and June (Hungry Horse inflow, Section 4.1.2.4). A large fraction of the projections indicate peak snowmelt volumes that are larger than historical values for unregulated headwater areas. These are likely to elevate local flood risk of the Flathead River at Columbia Falls, Montana, and of the Clark Fork River near Plains, Montana.

On average, the center of timing of the peak spring freshet at Albeni Falls Damis projected to occur a month earlier, in May, where nearly all projections indicate increasing peak monthly volumes in median (50th percentile) and extreme (95th percentile) flows conditions (Section 4.1.2.4). The timing of flood risk on Lake Pend Oreille is likely to shift earlier, however, there are not clear trends to indicate directional changes in the probability of exceeding flood stage at this Lake.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, 3, AND 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

4.2.7.2 Region B – Grand Coulee and Chief Joseph Dams

This region includes one flood risk consequence area, "Below Priest Rapids." Flood risk was determined to be negligible at this location in the historical period analysis (Section 3.9.3.2). Effects of climate change on flood risk at this location are not expected under any of the MOs or the No Action Alternative.

4.2.7.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

Historically, flood mechanisms in this region have been driven by snowmelt. This hydrological flooding regime is expected to continue through the 2030s.

An earlier shift in unregulated flood freshet volumes is projected for drainages in the lower Snake River. Extreme peak freshet volumes (95th percentile volume) are projected to occur in May. The projections indicate potential increases and decreases in the spring freshet peak volume (Dworshak Dam inflow, Ice Harbor natural flow, Section 4.1.2.4). Increased local flood risk for the Clearwater River at Orofino and Spalding, Idaho, and the Snake River at Anatone, Idaho, is possible. In the Clearwater River, seasonal extremes in winter flow volume are indicated by nearly all projections (section 4.1.2.4). Increased winter volumes could impose challenges in meeting draft requirements for spring FRM operations, potentially elevating spring flood risk on the Clearwater River at Spalding.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

4.2.7.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Historically, flood mechanisms in this region have been driven by both winter rainfall and spring snowmelt events. Both hydrological flooding regimes are expected to persist through the 2030s.

Potential increases in winter rainfall driven events effecting the coastal ranges, Southern Cascades range, and lower Columbia are projected (RMJOC 2018). Potential increases in intense rainfall events associated with atmospheric rivers, coupled with increasing winter flow volumes from the mainstem of the Columbia River (Section 4.1.2.4) are likely to elevate flood risk at flood consequences areas in this region.

An earlier shift in flood freshet volumes is projected for the Columbia River. The extreme peak freshet volumes (95th percentile) are expected to still occur in the May to June period. The projections show both increases and decreases in the peak volume, indicating future uncertainty (The Dalles natural flow, Section 4.1.2.4).

Sea level rise could elevate flood stages at locations below Bonneville Dam (Section 4.1.2.5, USGS 2019). The influence of sea level rise increases with proximity to the outlet of the Columbia River at the Pacific Ocean.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 includes the *Winter System FRM Space* measure, providing additional flood storage for system flood operations through the winter. This additional space allows Grand Coulee to reduce outflows and store inflow volume during December flood events. This measure could partially buffer projected increases in winter flood risk for consequence locations affected by flow on the Columbia River in this region.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVES 2 AND 4

See the MO1 discussion above, as the effects are anticipated to be similar.

4.2.7 Navigation and Transportation

Navigation and transportation could be affected by climate change through changes in seasonal patterns and variability of streamflow and the consequences for riverbed profiles. The water surface elevation of rivers and reservoirs, and channel depths affect access to shoreline transportation infrastructure and drafts of freight vessels.

4.2.7.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

No effects from climate change to Navigation and Transportation are identified in this region. The region does not include significant riverine navigation and transportation activities or infrastructure.

4.2.7.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

When the Lake Roosevelt forebay elevation falls below 1,229 feet National Geodetic Vertical Datum of 1929 (NGVD29), the Inchelium-Gifford Ferry is inoperable (Section 3.10.3.2). The projected shift toward earlier freshet timing (Section 4.1.2.4) could result in refill being initiated earlier more frequently, reducing the amount of time that Lake Roosevelt is drafted to this inoperable range.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

4.2.7.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

Lower unregulated flows are projected June through October (Section 4.1.2.4). This could result in an increased frequency of shallow river conditions that may affect navigation at some locations. Projected higher flows and higher extreme flows November through March could slow or interrupt barge traffic more frequently in this region.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, AND 4

See the No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 3

This alternative includes the *Breach Snake Embankments* measure. This measure could increase the conveyance of sediment downstream in the lower Snake River (Section 3.3.3.5). The potential supply of sediment from the land surface could increase as a consequence of projected hydrological changes (Section 4.2.2.3) and could result in increases in dredging for maintenance of ports (e.g., berthing areas) in the lower Snake River.

4.2.7.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Lower unregulated flows are projected June through October (Section 4.1.2.4). This could result in an increased frequency of shallow river conditions that may affect navigation at some locations. Projected higher flows and higher extreme flows November through March could slow or interrupt barge traffic more frequently in this region.

Projected sea level rise could affect river surface elevations downstream of Bonneville Dam (4.2.2.5). The effects of sea level rise on river elevations could provide a marginal benefit for navigation of the channel below Bonneville and have limited effects on shoreline transportation infrastructure.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 3

See the No Action Alternative discussion above, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 also includes the *McNary Flow Target* measure. This measure will provide more flow early in summer for dry years and potentially lead to reduced flows in late summer and fall. This operation may increase in frequency as streamflow volumes are projected to shift to occur earlier in the year and late spring/summer flow declines (Section 4.1.2.4). Flow changes associated with this measure have the potential to exacerbate low flow conditions effecting navigation in late summer.

4.2.8 Recreation

Recreational opportunities could be affected by climate change primarily by changing seasonal access for in-water activities. Projected effects to other resources could also influence visitation related to specific recreational activities. For instance, potential effects to fish and wildlife (Section 4.2.4, 4.2.5) could influence sport fishing and hunting opportunities. Potential effects to water quality (Section 4.2.3) could affect swimming opportunities.

4.2.8.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

The timing of the spring freshet inflow volume is projected to shift earlier in the year (Section 4.1.2.4), resulting in headwater reservoirs, Libby Dam/Lake Koocanusa and Hungry Horse Dam and reservoir, filling earlier than historically. The seasonal period for recreational activities that depend on high lake levels for water access (fishing, boating, paddling, and camping) could begin earlier in the year. Decreased summer and fall flow volume (Section 4.1.2.4) will likely lead to lower lake levels in the late summer and fall resulting in less recreational access during this time of year.

The operations of Albeni Falls Dam/Lake Pend Oreille follow a fixed seasonal draft; changes in seasonal inflow patterns will not affect draft and refill timing. However, increased frequency of system wide winter flood events (Section 4.2.1.1) will result in flood volumes being stored and evacuated more frequently during winter. This potential increase in fluctuations of Lake Pend Oreille could negatively affect winter recreational activities that use the lakeshore and ice surface (ice fishing). Projected increases in winter temperature could decrease the duration and frequency of periods where ice conditions suitable for ice fishing. Increases in summer water temperature (Section 4.2.3.1) could increase visitation for in-water activities.

Sport fishing opportunities may increase for resident species that may benefit from warming water temperature at some headwater locations, and warm water adapted invasive species. Opportunities could decrease for potentially negatively affected resident species (Section 4.2.3.6).

MULTIPLE OBJECTIVE ALTERNATIVE 1

Under MO1, the *December Libby Target Elevation* measure allows for higher winter (November to December) reservoir elevations at Libby Reservoir to mitigate for potential over-drafting in years with a drier forecast. Projected changes in inflow timing combined with this measure could support higher spring and summer pool elevations (Section 4.2.1.1) that would support increased periods of water access.

MULTIPLE OBJECTIVE ALTERNATIVE 2

See the No Action Alternative discussion above, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Similar to effects of MO1 however through the combined influence of different measures.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Under MO4, in low water years, the *McNary Flow Target* measure would release an additional water from Libby, Hungry Horse, and Albeni Falls, resulting in lower reservoir elevations on April 10, which could affect refill during dry water years. Projected decreases in summer inflow volume with climate change may further exacerbate the effects of refill during drier years. Projected increases in winter flows could aid in storage recovery.

4.2.9.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

The timing of the spring freshet inflow volume is projected to shift earlier in the year (Section 4.1.2.4), resulting in Lake Roosevelt filling earlier than historically. The seasonal period for recreational activities that depend on high lake levels for water access (fishing, boating, and camping) could begin earlier in the year. Decreased summer and fall flow volume (Section 4.1.2.4) will likely lead to lower lake levels in the late summer and fall resulting in less recreational access during this time of year. Increases in water temperature (Section 4.2.3.2) could increase visitation for in-water activities. However, it could also increase algal growth, including at recreational areas where cyanobacteria is currently present (Lake Roosevelt, Rufus Woods Lake). Potential negative effects of climate change to native anadromous fish (Section 4.2.3.5) could lead to decreased sport fishing opportunities. Sport fishing opportunities for warm water adapted species may increase.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, AND 3

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 includes the *McNary Flow Target* measure that increases outflow from Grand Coulee from May through July during dry years. This operation may increase in frequency as streamflow volumes are projected to shift to occur earlier in the year and late spring/summer flow declines (Section 4.1.2.4). This operation could result in lower elevations of Lake Roosevelt during the summer recreation period, thus effecting recreational access.

4.2.9.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

The timing of the spring freshet inflow volume is projected to shift earlier in the year (Section 4.1.2.4), resulting in Dworshak filling earlier than historically. This means the seasonal period for recreational activities that depends on high lake levels for water access (fishing, boating, and camping) could begin earlier in the year. Projected decreased summer and fall flow volume (Section 4.1.2.4) will likely lead to lower lake levels at Dworshak in the late summer and fall, resulting in less recreational access during this time of year. Projected increases in summer water temperature (Section 4.2.3.3) could increase visitation for in-water activities, which could potentially be offset by potential increases in harmful water quality conditions (e.g., harmful algae blooms). Potential negative effects of climate change to native anadromous fish (Section 4.2.3.5) could lead to decreased sport fishing opportunities. Sport fishing opportunities for warm water adapted species could increase.

MULTIPLE OBJECTIVE ALTERNATIVES 1, 2, AND 4

See the No Action Alternative discussion above, as the effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

This alternative includes the *Breach Snake Embankments* measure. Recreational activities would change after dam breaching (Section 3.11.3.5). Projected increased spring water temperature amplified by MO3 could increase the period for in-water activities, starting earlier in the year. River flows through the affected lower Snake River mainstem reach will more closely mimic and be more responsive to inflow patterns. Projected increased variability in winter flow volumes and lower summer volumes (Section 4.1.2.4) could negatively affect recreational boating opportunities and activities that rely on consistent shoreline water access.

4.2.9.4 *Region D – McNary, John Day, The Dalles, and Bonneville Dams*

NO ACTION ALTERNATIVE

Inflow volumes may be stored and evacuated more frequently within the series of the four lower Columbia River dams and reservoirs for winter system flood events (Section 4.2.1.4). The projected variability of winter pool elevations and outflow from Bonneville Dam could restrict winter recreational activities. Sea-level rise is not expected to affect recreational activities. Potential negative effects of climate change to native anadromous fish (Section 4.2.4.1) could lead to decreased sport fishing opportunities. Sport fishing opportunities for warm water adapted species may increase.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 4

Similar to the No Action Alternative discussion above, as effects are anticipated to be similar.

4.2.9 Water Supply (Irrigation, Municipal, Industrial, Groundwater, and Aquifers)

Climate change has the potential to disrupt hydrological processes that in turn may affect current water supply practices. These changes could affect surface and groundwater users, including users that use free flowing or natural/live[6] flow systems.

Climate change has the potential to affect water supply for irrigation, municipal, and industrial uses from surface water sources. Changes in natural/live flow to the system that reduces summer and fall stream flows may reduce the amount of available supply. These live flow rights will be regulated based on states water law. This is true for all the CRSO regions in the No Action Alternative and MOs.

An example of water supply that may be affected is the State of Washington "interruptible water rights." This group of water rights is curtailed (not allowed to divert) when the March 1, April to September Dalles forecast[7] drops below 60 million acre-feet. From the ResSim, No Action Alternative model, there is a 2.4 percent probability of the 5,000-year simulations where The Dalles forecast drops below 60 million acre-feet, therefore causing these rights to be curtailed. Using the RMJOC-II inflow projections, there is not a clear indication of a directional change in the relative frequency of The Dalles forecast volumes below the curtailment threshold.

Effects to groundwater from climate change are not as well understood as potential effects to surface water. However, some studies have suggested that the projected decrease in snowpack and higher intensity winter storms may decrease groundwater recharge (Doll 2009). In addition, it is possible that the decreased ability to rely on surface water may cause some to rely more on groundwater, thus decreasing supplies (Reclamation 2016).

4.2.9.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

Under the No Action Alternative and MOs, water supply in these reaches could potentially be affected by changes in live/natural flow. Specifically, water supply uses that rely on the live/natural flow water rights for delivery may experience increased shortage in the summer or fall as flows are projected to decrease during this period (Section 4.1.2.4). Changes to

[6] Live or natural flow is water appropriated by the individual states and is distributed in priority or by other rules defined by the states.
[7] This is the volume of runoff forecasted to flow past the Dalles between April and September and is calculated on March 1 each year.

operations should not affect live/natural flow distributions as they are based on state prior appropriation law under all alternatives, including No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 3

See the No Action Alternative discussion above, as effects are expected to be similar.

4.2.9.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

Water supply is pumped from Lake Roosevelt for irrigation, municipal, and industrial needs in the Columbia Basin Project. Water flowing into Lake Roosevelt could be affected by climate change, both in volume and timing. Changes to operations should not affect live/natural flow distributions as they are based on state prior appropriation law under all alternatives, including No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVES 1 TO 4

See the No Action Alternative discussion above, as effects are expected to be similar. Additionally, pumping costs at the John W Keys pumping plant may change if climate change causes further decreases in Lake Roosevelt water surface elevation.

4.2.9.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

Water supply is available out of the pools behind Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. Water is available using live/natural flow rights and is accessible to water users due to the elevated pool levels for navigation and power production. These run-of-the-river dams do not provide water storage for water rights holders, but make is easier for users to access the water. Projected changes in climate are unlikely to affect the elevation in these pools and therefore the availability of water is unlikely to change.

MULTIPLE OBJECTIVE ALTERNATIVE 1, 2 AND 4

See the No Action Alternative discussion above, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Under MO3, water supply is not expected to continue from the pools in Region C with the breaching of the dams. This would not be affected by climate change.

4.2.9.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

Water supply is available out of the pool behind McNary and John Day using live/natural flow rights and is accessible to users due to elevated pool levels for navigation and power production. In the John Day pool, the elevation is held higher though the irrigation season to allow pumps to operate. Projected changes in climate are unlikely to change the elevation in these pools and therefore the ability to supply the current level of water is not expected to change.

MULTIPLE OBJECTIVE ALTERNATIVE 1, 2 AND 3

See the No Action Alternative discussion, as effects are anticipated to be similar.

MULTIPLE OBJECTIVE ALTERNATIVE 4

In MO4, the John Day pool is operated 1.5 feet lower than current irrigation season elevations, which may limit the ability of some pumps to operate. It is unlikely that climate change will have an effect on this operation.

4.2.7 Visual

Climate change is not expected to ameliorate or exacerbate effects to visual resources.

4.2.8 Noise

Climate change is not expected to ameliorate or exacerbate effects to noise resources.

4.2.9 Fisheries

Although fish abundance is only one of many considerations with respect to determining allowable fish harvest, this analysis evaluates potential impacts on fisheries by referencing the potential effects on relevant fish populations only. The anadromous and resident fish resources of the Columbia River Basin are caught in commercial and ceremonial and subsistence fisheries within the Basin and in the ocean off the coasts of Washington, Oregon, California, British Columbia, and Alaska.[8] Commercial salmonid catch within the Columbia River Basin includes Chinook salmon, coho salmon, sockeye salmon, and steelhead. Other anadromous fish, including certain white sturgeon populations, American shad, and Pacific eulachon, are also caught commercially in the Columbia River Basin. Resident fish are not targeted in the Basin commercially, though some are caught incidentally and sold in tribal fisheries. To the extent that climate change effects ameliorate or exacerbate the effects of the Multiple Objective Alternatives on fish in a way that increases or decreases abundance of target species, commercial and ceremonial and subsistence fishing opportunities, and the economic, social, and cultural values associated with them, then fisheries could be affected. Climate change may also affect fisheries if it results in a change in distribution of fish populations that increases the cost associated with fishing, or limits access in some way.

4.2.9.1 No Action Alternative

As described in Section 4.2.4, the effects of climate change are expected to have an adverse effect overall on anadromous fish populations, which could lead to moderate to severe declines in salmon and steelhead populations. Available information also suggests that species such as Pacific lamprey, Pacific eulachon, and green sturgeon may also experience adverse impacts from the effects of climate change. Changes in air temperature, precipitation, stream flows, and water temperatures may also have adverse implications for resident fish, including changes in their distribution and abundance (see Section 4.2.3.6). Decreased abundance of anadromous and resident species of importance in commercial and ceremonial and subsistence fisheries could result in a decreased opportunity for harvest, and a decrease in the economic, social, and cultural values associated with fishing. Additionally, changes in the distribution of species associated with the effects of climate change could mean a loss of access to certain species, or increased costs associated with harvesting those species, which could adversely affect those fisheries.

4.2.9.2 All Multiple Objective Alternatives

Under all Multiple Objective Alternatives, climate change has the potential to exacerbate or ameliorate the full range of predicted effects of the alternative on fish that differ by species, region, and life history stage, and the resulting effects may work in competing directions. Thus, it is difficult to discern how the effects of climate change and the MO itself would collectively influence the abundance of a population overall. Sections 4.2.4. and 4.2.3.6. describe how fish may be affected by climate change under each of the MOs. Where these effects result in an overall change in abundance of a given population of commercial or ceremonial and subsistence value, the fisheries that depend upon them could be affected. The potential for redistribution of fish populations resulting in an increased cost of harvest or loss of access remains the same as under the No Action Alternative.

4.2.10 ITAs, Tribal Perspectives and Tribal Interests

No direct or indirect effects to Indian Trust Assets were identified for any of the alternatives, including the Preferred Alternative. Trust lands identified during the geospatial database query and tribal outreach are located outside of any direct or indirect effects identified in the alternatives. These include lands from the Confederated Tribes of Warm Springs Reservation, the Yakama Nation, and the Kootenai Tribe of Idaho, as well as the following Indian reservations: The Confederated Tribes of the Colville Indian Reservation; Spokane Tribe of Indians; Kootenai Tribe of Idaho; Nez Perce Tribe; and The Confederated Salish & Kootenai Tribes of the Flathead Reservation.

"Climate change impacts have the potential to affect the entire Basin and resources the Tribes stewarded from time immemorial. The change has the potential to impact both aquatic systems across the Basin and the generation of electricity from the System." (The Shoshone-Bannock Tribes Tribal Perspective Submittal, See 3.17.2.2)

The Tribes of the Pacific Northwest are focused on the challenges posed by the projected changes in climate. These changes have the potential to adversely affect tribal culture given the relationship these cultures have with the natural environment. For many tribes, their culture of stewardship is an effort to restore the ecosystem to its natural condition. This is considered an essential element in their fight against, and to counteract the effects of climate change. Climate change presents a threat to critical cultural resources, thereby also threatening the lifeways and wellbeing of the Tribes. Some tribes view the CRS, particularly reservoirs and loss of riverine ecosystem structure and function, as a contributor to climate change.

"Climate change impacts have the potential to affect the entire Basin and resources the Tribes stewarded from time immemorial. The change has the potential to impact both aquatic systems across the Basin and the generation of electricity from the System." (The Shoshone-Bannock Tribes Tribal Perspective Submittal, See 3.17.2.2)

The Tribes of the Pacific Northwest are focused on the challenges posed by the projected changes in climate. These changes have the potential to severely affect tribal culture given the relationship these cultures have with the natural environment. The Tribes' view of their culture of stewardship, which speaks to this relationship, means that for many of the tribes they see their work as an effort to restore the ecosystem to its natural condition as an essential element in the fight against, and to counteract, the effects of climate change because its "impacts have the potential to affect the entire Basin and resources the Tribes stewarded from time immemorial." Climate change presents a threat to critical cultural resources, thereby also threatening the lifeways and well-being of the Tribes. Some Tribes' view the CRSO, particularly through effects from slack-water reservoirs and a loss of riverine ecosystem structure and function, as contributors to climate change.

4.2.10 Cultural Resources

Cultural resources around reservoirs experience erosion-driven decay when exposed during drawdown periods of storage reservoirs. Exposed to the elements (not inundated), sites undergo more erosion from heavy rainfall events and wave action. Exposed sites are also subject to looting and recreation-related damage. Stability of environmental conditions is also important for preservation of organic remains in sites, which decay faster under increased variability, especially rapid changes in soil moisture and acidity.

Increased reservoir fluctuations associated with changes in operations or changes in climate are likely to have increasing effects on cultural resources. Climate change projections for the region include increases in winter precipitation and earlier and potentially larger spring runoff volumes (4.1.2.4). Atmospheric rivers are also projected to increase. These intense storms often produce gulley erosion on exposed drawdown zones, which can quickly diminish the integrity of cultural resources.

The extent to which the Action Alternatives accelerate the erosion and decay of cultural resources is largely tied to the extent that they would increase the exposure of sites. For most of the Action Alternatives, the changes in operations from the No Action Alternative are minimal, and this means that the alternatives do not have the potential to worsen the effects driven by climate change.

There are numerous locations in the Columbia River Basin that tribes consider as “sacred sites”. Sacred sites can be affected by climate change through its influence on environmental drivers of landscape change (e.g., erosion, deposition) and potential to impede access to the sites. The tribes contacted as a part of the compilation of this EIS identified two locations that fall in line with the definition of “sacred sites” in Presidential Executive Order 13007: Kettle Falls, which is located behind Grand Coulee Dam on Lake Roosevelt in northeast Washington State, and Bear Paw Rock, which is located on Lake Pend Oreille behind Albeni Falls Dam.

4.2.10.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

Projected changes to reservoir operations (Section 4.2.1.1) such as more variable reservoir elevations and also deeper reservoir drafts could expose more cultural resources. Additionally, the lack of water coverage means that the sites could undergo more erosion from heavy rainfall events and wave action. The exposed sites could also be more subject to looting and recreation-related damage.

The only sacred site identified in Region A is Bear Paw Rock at Albeni Falls Dam. Changes in operations related to projected changes in climate under this alternative would have negligible effects on this sacred site.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Projected changes in climate could further increase the drawdowns (Section 4.2.1.1) that could already be happening as a response to MO1 at Libby and Hungry Horse. This could amplify the effects on cultural resources.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Same as MO1, except with an even greater, extended drawdown risk and subsequent resource exposure at Libby due to increased spring draft requirements for projected increases in spring inflow volume (Section 4.1.2.4). The effects at Hungry Horse and Albeni Falls would be more muted as draft patterns are not anticipated to change significantly in response to projected changes in flow volumes (Section 4.2.1.1).

MULTIPLE OBJECTIVE ALTERNATIVE 3

Under MO3, operations at Hungry Horse would result in increased exposure of cultural resources (Section 3.16.2.6), and the deeper drawdowns associated with climate change (Section 4.2.1.1) could likely to exacerbate these effects.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 causes deep drafts at Hungry Horse (Section 3.2.2.7), and the addition of climate change driven drafts of the reservoir could exacerbate these effects.

4.2.10.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

Changes in Lake Roosevelt pool elevations in the winter could be further exacerbated by changes in inflow due to changes in climate (Section 4.2.1.2). This could result in more cultural resources being exposed and thus subjected to accelerated decay due to erosion and amplified wetting and drying cycles.

The only sacred site identified in Region B is Kettle Falls. Changes in operations related to climate change may cause increased exposure to landforms associated with the Kettle Falls sacred site (especially Hayes Island), which is not expected to impede access to the site, but may cause adverse effects at the site.

MULTIPLE OBJECTIVE ALTERNATIVE 1

The changes in operations anticipated from MO1 (section 3.2.2.4) could be amplified by the changes in climate potentially resulting in longer and deeper drawdowns at Grand Coulee than were seen in the No Action Alternative. Changes in the operations for FRM result in deeper drafts in the winter and spring, increasing the potential impacts to cultural resources from exposure, including accelerated decay due to erosion and amplified wetting and drying cycles.

The changes in operations anticipated in MO1 from FRM, which result in deeper drafts in the winter and spring, could be amplified by projected changes in climate, potentially resulting in longer and deeper drawdowns at Grand Coulee than in the No Action Alternative. The projected increases in exposure under climate change is not expected to impede access to the site, but may cause adverse effects at the site.

MULTIPLE OBJECTIVE ALTERNATIVE 2

In MO2 deeper drafts for hydropower would result in increased exposure. Cultural resources may be exposed to a greater degree during a period that also coincides with projected increased precipitation, so this exposure may not occur. However, if the exposure occurs, it means that sites may be more subject to erosion, especially from intense winter rain events.

In MO2 deeper drafts for hydropower would result in increased exposure of some of the landforms associated with Kettle Falls. The projected increases in exposure under climate change are not likely to impede access to the site, but may cause adverse effects at the site.

MULTIPLE OBJECTIVE ALTERNATIVE 3

See the No Action Alternative discussion above.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Under MO4, the lack of refill during the summer in driest years (due to the flow augmentation for the *McNary Flow Target* measure) could result in more exposure of cultural resources during the season when the most people are using the Lake Roosevelt National Recreation Area. This will likely be exacerbated by projected hydrological changes. This will lead to an increase in damage related to camping on the cultural resources (especially archaeological sites) and resultant casual looting would amplify these effects.

Under MO4, the lack of refill during the summer in the driest years (due to the *McNary Flow Target* measure) will result in more exposure of the Kettle Falls sacred site during that season, when the most people are using the Lake Roosevelt National Recreation Area. The projected increases in exposure under climate change are not likely to impede access to the site, but may cause adverse effects at the site.

4.2.10.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

It is important to note first that the operations of Dworshak, a storage reservoir, will not follow the same pattern as the other four projects in Region C, as they are all run-of-river projects that would be operated to maintain fairly consistent reservoir levels.

No sacred sites were identified in Region C.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Deeper drafts during the spring at Dworshak will expose more archaeological sites and will increase the rates of erosion, particularly gulley formation resulting from rain and melting snow. There would be little change relative to the No Action Alternative for the lower four Snake projects.

MULTIPLE OBJECTIVE ALTERNATIVE 2

See the MO1 discussion above. Additionally, operations under MO2 at Dworshak would tend to expose cultural resources to a greater degree than under the No Action Alternative due to increase reservoir drawdown, and the operational changes in response to climate change could amplify these effects. At the run-of-river projects, no changes are expected.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 would result in significant changes in flow and stage in the lower Snake River. Dam breach would have varied effects on cultural resources, especially over the short term. Increased aridity during the summer months may make it harder to re-establish vegetation over the exposed draw down zones of the four reservoirs. This lack of plant cover means that sites would continue to be exposed for a longer period and, as a result, would decay more quickly, or be more susceptible to looting/pothunters.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Operational effects to cultural resources under MO4 for Dworshak would closely follow MO1. At the run-of-river projects, MO4 would tend to result in slightly higher reservoir elevations, which may slightly reduce decay related to exposure. Climate change is not expected to alter these conditions.

4.2.10.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

In general, it appears that changes in operations driven by climate change in the four lower Columbia River projects would be minimal because the storage in the reservoirs does not undergo large changes in response to changing inflows.

No sacred sites were identified in Region C.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Operations under MO1 would generally follow the same patterns as under the No Action Alternative, but this alternative calls for slightly higher median pool elevations in April and May. These higher elevations would not alter conditions driven by climate change.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Operations under MO2 would not differ from the No Action Alternative to any significant degree, especially when focusing on median reservoir elevations. Climate change implications are not expected to be amplified.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Conditions under MO3 are expected to closely follow those found under MO1.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Operations under MO4 would feature lower elevations in spring and summer months, increasing the degree of cultural resource exposure during low flow years.

4.2.11 Environmental Justice

Climate change can exacerbate effects on minority populations, low-income populations, and Indian tribes. All the tribes expressed in meetings with the lead agencies their concern and focus on climate change and what it means for tribal culture and resources. The Shoshone-Bannock Tribes encapsulated these concerns in their tribal perspective "Projected changes in temperature, precipitation, hydrology, and ocean chemistry threaten not only the lands, resources, and economies of the Shoshone-Bannock Tribes (Tribes), but also tribal homelands, ceremonial sites, burial sites, tribal traditions, and cultural practices that have relied on native plants, fish, and animal species since time immemorial" (Tribal Perspective Submittal from the Shoshone-Bannock Tribes, Page 12. See Appendix P). At the same time, these populations are often less able to adapt or recover from these effects (EPA 2016a). This section evaluates whether there would be disproportionately high and adverse effects on minority populations, low-income populations, or Indian tribes considering how projected changes in climate may affect resources given effects from the CRSO EIS alternatives.

For the following resources, the environmental justice analysis compares effects to the general population and effects to minority populations, low-income populations, and Indian tribes by region and by alternative.

- **Navigation and transportation**. Changes to in-river and reservoir conditions under the CRSO EIS alternatives could affect the availability of ports for commercial navigation activities (including commercial shipping barges, cruise ships, and ferries) (Section 3.15.3). Inchelium-Gifford Ferry operations on Lake Roosevelt could also be affected by operational measures in some CRSO alternatives that would result in additional reservoir fluctuations, including drawdowns in some years. This ferry is operated by the Confederated Tribes of the Colville Reservation and primarily serves the tribal population. Climate change could affect navigation and transportation through changes to seasonal patterns and variability of streamflow and consequences for riverbed profiles (Section 4.2.7). The water surface elevation of rivers and reservoirs, and channel depths affect access to shoreline transportation infrastructure and drafts of freight vessels (Section 4.2.7).
- **Cultural resources.** The CRSO EIS alternatives have the potential to affect cultural resources (including archaeological resources, traditional cultural properties, and historic built resources) as a result of changes in reservoir elevations or construction activities (Section 3.15.3.2). As discussed in the Cultural Resources section in chapter 3, ongoing effects of inundation and reservoir fluctuation would continue to have substantial adverse effects on traditional cultural properties under the No Action Alternative. Implementation of the action alternatives could negatively affect cultural resources through increasing exposure and erosion associated with increased reservoir level fluctuations and, thus creating the potential for effects associated with public access including looting, vandalism, creation of trails, and unauthorized activities (Section 3.15.3.2). Projected changes in climate could exacerbate these effects by increasing decay through operations resulting in deeper drawdowns, changes in precipitation (as more snow falls as rain), and increased variability (especially rapid changes in soil moisture and acidity).

- **Fish.** Warming water temperatures, streamflow changes, increased pervasiveness of invasive species, and changing ocean conditions (reduction in thermal habitat for salmon, increasing ocean acidification, changing estuarine and plume environments) are projected to have negative implications for the freshwater, estuarine, and marine environments of many fish species in the Pacific Northwest (section 4.2.3). The CRSO EIS alternatives have the potential to affect the availability of fish for harvest for low-income populations, minority populations, and Indian tribes participating in these activities (section 3.15.3.2). The environmental justice analysis in chapter 3 concludes that, while the construction of the dams and current system operations have ongoing effects on tribal culture, lifeways (e.g., customs and practices), and traditions, site-specific information is not available to identify precisely where these subsistence activities occur, and whether plant or wildlife species that are important for ceremonial or subsistence use would be affected by the changing water levels (section 3.15.3). Climate change does not alter that conclusion. Therefore, this resource is not analyzed in further detail for this analysis.
- **Vegetation, wetlands, and wildlife.** In general, the analyses of effects to vegetation, wetlands, and wildlife, identified negligible to minor effects to these resources across most CRSO EIS alternatives (Section 3.15.3.1) with no expected disproportionality high and adverse human health or environmental effects on minority populations, low-income populations, or Indian tribes. Climate change is projected to have minimal effects on these conclusions; therefore, no change is expected in effects from the alternatives.
- **Air quality.** There are a number of uncertainties surrounding the likelihood, volume and specific location of future emissions that render making a determination of effects to specific communities speculative (Section 3.15.3.1). Climate change adds additional uncertainties that make further evaluation even more difficult and uncertain, so it is too speculative to know whether there would be expected disproportionate high and adverse human health or environmental effects on minority populations, low-income populations, or Indian tribes.
- **Power generation.** Projected changes in climate are not likely to change the general conclusions from the power analysis of the relative effect of one MO versus another because the projected changes in climate are likely to affect hydropower generation in all alternatives relative to the No Action Alternative roughly the same on an annual basis (though with a little more variability on a monthly basis) (Section 4.2.5). Therefore, climate change does not alter the relative conclusions of the environmental justice analysis identified in Chapter 3.15.3.
- **Flood risk management.** The flood risk analysis in this EIS does not anticipate changes to flood risk from any of the proposed CRSO EIS alternatives therefore no additional environmental justice analysis is necessary (Section 3.15.3.1). Climate change is projected to have minimal effects on these conclusions; therefore, this resource is not analyzed in detail in this section.
- **Recreation**. The analyses of effects to recreation identified negligible to minor effects to the resources across most CRSO EIS alternatives (Section 3.15.3.1). The adverse effects on

resources identified in Region C under MO3 do not appear likely to disproportionately affect minority populations, low-income populations, or Indian tribes (Section 3.15.3.1). Climate change does not alter this conclusion.

- **Water supply**. Effects to water sources are focused on a need to extend pumps under MO4 to allow for continued water supply and the potential loss of irrigation under MO3 because the pumps that supply this water would no longer be operational once the dams are breached and the nearby groundwater elevations could be adversely affected (Section 3.15.3). These effects are relatively small and are not expected to result in disproportionately high and adverse effects on minority populations, low-income populations, or Indian tribes (Sections 3.15.3.7, 3.15.3.8). Moreover, projected changes in climate are unlikely change the supply of water in regions A, B, C, and D (Sections 4.2.9.3, 4.2.9.4).
- **Sacred sites.** The effects to sacred sites (Bear Paw Rock and Kettle Falls) created by construction of the Federal dams are not expected to increase markedly as a result of the CRSO EIS alternatives (Section 3.15.3.1). Climate change is projected to have minimal to negligible effects on these conclusions (Section 4.2.13); therefore, this resource is not discussed further in this section.

4.2.11.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

NO ACTION ALTERNATIVE

- **Navigation and transportation.** Commercial navigation, cruise ships, and ferries do not occur in Region A. This would not change under the No Action Alternative (Section 3.15.3.4).
- **Cultural resources.** Numerous types of cultural resources have been identified in the vicinity of the projects in Region A, including sites of particular importance in the vicinity of the storage reservoirs: Albeni Falls, Hungry Horse, and Libby. Cultural resources would continue to be adversely affected under the No Action Alternative due to ongoing operations and maintenance of the Columbia River System (Section 3.15.3.4). Projected changes to operations in response to changes in climate (Section 4.2.1.1) could expose more cultural resource sites, potentially leading to more erosion from heavy rainfall events and wave action. In addition, the exposed sites could potentially be subject to looting and recreational-related damage (Section 4.2.10.1).

MULTIPLE OBJECTIVE ALTERNATIVE 1

- **Navigation and transportation.** See No Action Alternative discussed above.
- **Cultural resources**. Effects on cultural resources are anticipated to be negligible in Region A under MO1, with the exception of moderate effects to archaeological resources at Hungry Horse Reservoir (Section 3.15.3.5). Projected changes in climate could further increase the drawdowns that would already be happening as a response to MO1 at Libby and Hungry

Horse (section 4.2.1.1), thereby further increasing those effects to archaeological resources at Hungry Horse Reservoir.

MULTIPLE OBJECTIVE ALTERNATIVE 2

- **Navigation and transportation.** See No Action Alternative discussed above.
- **Cultural resources.** Implementation of MO2 could negatively affect cultural resources through increasing exposure and erosion associated with increased reservoir level fluctuations at Libby and Hungry Horse (Section 3.15.3.6). Projected changes in climate could further increase the drawdowns that could already be happening as a response to MO2 at Libby, while effects at Hungry Horse could be more muted due to smaller changes in projected spring inflow volumes and FRM draft requirements (section 4.2.1.1).

MULTIPLE OBJECTIVE ALTERNATIVE 3

- **Navigation and transportation.** See No Action Alternative discussed above.
- **Cultural resources.** Implementation of MO3 could negatively affect archaeological resources through increasing exposure and erosion associated with increased reservoir level fluctuations at Libby Dam and Hungry Horse Reservoir (Section 3.15.3.7). Deeper drawdowns at Hungry Horse associated with climate change would likely exacerbate these effects (Section 4.2.10.1).

MULTIPLE OBJECTIVE ALTERNATIVE 4

- **Navigation and transportation.** See No Action Alternative discussed above.
- **Cultural resources.** Implementation of MO4 would increase the exposure of archaeological resources at Hungry Horse Reservoir (Section 3.15.3.8), and projected changes in climate could further increase drawdowns and exposure of those archaeological resources (Section 4.2.10.1). Climate change is not projected to alter conclusions for sites at Libby Dam, where effects to archaeological resources are expected to be negligible (Section 3.15.3.8), or at Albeni Falls, where MO4 would not increase the exposure of archaeological resources (Section 3.15.3.8).

4.2.11.2 Region B – Grand Coulee and Chief Joseph Dams

NO ACTION ALTERNATIVE

- **Navigation and Transportation.** When the Lake Roosevelt forebay elevation falls below 1,229 feed NGVD29, the Inchelium-Gifford Ferry is inoperable (section 3.10.3.2). With climate change, refill could be initiated earlier more frequently, reducing the amount of time that Lake Roosevelt is drafted to inoperable range, thus potentially reducing the effects identified in (Section 3.10.3.2), including effects to the Confederated Tribes of the Colville Reservation (section 4.2.7.2).

- **Cultural Resources.** Numerous types of cultural resources have been identified in the vicinity of the projects in Region B, including sites of particular importance near the historic location of Kettle Falls. Cultural resources could continue to be adversely affected under the No Action Alternative due to ongoing operations and maintenance of the Columbia River System (Section 3.15.3.4). Changes in Lake Roosevelt pool elevations in the winter could be further exacerbated by changes in inflow due to changes in climate, resulting in more cultural resources being exposed and thus subjected to accelerated decay, which could further heighten the effects to these resources and the tribal populations that consider these resources culturally important (Section 4.2.10.2).

MULTIPLE OBJECTIVE ALTERNATIVE 1

- **Navigation and Transportation.** MO1 is expected to disproportionally and adversely affect environmental justice populations due to effects on navigation and transportation resources, with effects primarily falling on the Confederated Tribes of the Colville Reservation community (Section 3.15.3). The Inchelium-Gifford Ferry is expected to have 9 fewer operational days during wet years under MO1. With climate change, refill could be initiated earlier more frequently, reducing the number of days that Lake Roosevelt is drafted to inoperable range (Section 4.2.7.2) and at least partially alleviating the effects to environmental justice populations.
- **Cultural resources.** Implementation of MO1 could negatively affect cultural resources through increasing exposure and erosion of reservoir areas associated with increased reservoir level fluctuations, particularly at Grand Coulee Dam (Lake Roosevelt) (Section 3.15.3.5). Climate change could amplify the changes in operations anticipated from MO1, potentially resulting in longer and deeper drawdowns at Grand Coulee as compared to the No Action Alternative (Section 4.2.1.2).

MULTIPLE OBJECTIVE ALTERNATIVE 2

- **Navigation and Transportation.** See MO1 discussion above.
- **Cultural resources.** Implementation of MO2 could negatively affect cultural resources through increasing exposure and erosion associated with increased reservoir level fluctuations, specifically at Grand Coulee (Section 3.15.3.6). Cultural resources may be exposed to a greater degree during a period that also coincides with projected increases in precipitation, thus potentially subjecting the site to more erosion (Section 4.2.10.2).

MULTIPLE OBJECTIVE ALTERNATIVE 3

- **Navigation and Transportation.** Under MO3, the Inchelium-Gifford Ferry is expected to operate approximately 2 days more than anticipated under the No Action Alternative (Section 3.15.3.7). With climate change, refill could be initiated earlier more frequently, reducing the amount of time that Lake Roosevelt is drafted to inoperable range (Section 4.2.7.2). Thus, this effect could potentially result in lessening the effects described in Section 3.15.3.7.

- **Cultural resources.** Effects on cultural resources are anticipated to be negligible in Region B under MO3 (section 3.15.3.7). Climate change could further exacerbate changes in Lake Roosevelt pool elevations in the winter, potentially resulting in more cultural resources being exposed and thus subjected to accelerated decay, which could have disproportionately high and adverse effects on Indian tribes who find these resources culturally important (Section 4.2.10.2).

MULTIPLE OBJECTIVE ALTERNATIVE 4

- **Navigation and Transportation.** See MO1 discussion above.
- **Cultural resources.** Implementation of MO4 could negatively affect cultural resources through increasing exposure and erosion associated with increased reservoir level fluctuations, specifically at Grand Coulee (Section 3.15.3.8). Climate change could exacerbate this by resulting in Lake Roosevelt not being able to refill in early July, leaving sites exposed during times of heavy use (Section 4.2.10.2). Thus, climate change could further exacerbate the effects to cultural resource sites near Grand Coulee valued by the Confederated Tribes of the Colville Reservation and the Spokane Tribe.

4.2.11.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

NO ACTION ALTERNATIVE

- **Navigation and transportation.** This region includes low-cost barge transportation, ports, and a growing cruise ship industry, bringing development and commercial activity to the region (Section 3.15.3.4). Climate change could result in increased frequency of shallow river conditions that may affect navigation at some locations, and projected higher flows and higher extreme flows November through March could slow or interrupt barge traffic more frequently in this region (Section 4.2.7.3).

- **Cultural resources.** Numerous types of cultural resources have been identified in the vicinity of the projects in Region C. Cultural resources would continue to be adversely affected under the No Action Alternative due to ongoing operations and maintenance of the Columbia River System (Section 3.15.3.4). Climate change is projected to have minimal effects to operations at Dworshak or the four lower Snake River projects so increased effects to cultural resources are not expected (Section 4.2.10.3).

MULTIPLE OBJECTIVE ALTERNATIVE 1

- **Navigation and transportation.** Effects on navigation and transportation are anticipated to be negligible in Region C under MO1 (section 3.15.3). Climate change is not projected to alter these conclusions. As such, disproportionate and adverse effects to low-income, minority or Indian tribes are not anticipated.
- **Cultural resources**. See No Action Alternative discussion above.

MULTIPLE OBJECTIVE ALTERNATIVE 2

See MO1 discussion above.

MULTIPLE OBJECTIVE ALTERNATIVE 3

- **Navigation and Transportation.** Dam breach would result in regional economic effects of changes in navigation mode from river to rail and truck, as well as likely lead to some displacement of workers. While some laborers are likely to be low-income, minority, or members of Tribal communities, these effects do not appear likely to be concentrated in one group or area (Section 3.15.3.7). Climate change is not projected to alter these conclusions. As such, disproportionate and adverse effects to low-income, minority or Indian tribes are not anticipated.
- **Cultural resources.** Following dam breach, the Ice Harbor, Lower Monumental, Little Goose, and Lower Granite projects would experience significant effects to archaeological sites associated with sediment erosion and deposition (Section 3.15.3.7). Climate change is not projected to amplify or diminish these effects (Section 4.2.10.3).

MULTIPLE OBJECTIVE ALTERNATIVE 4

See MO1 discussion above.

4.2.11.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

NO ACTION ALTERNATIVE

- **Navigation and transportation.** This region benefits from low-cost barge transportation, deep water ports located along the Lower Columbia River below Bonneville Dam, and cruise ships that board in the Portland Area and travel both downstream and upstream on the mainstem Columbia (Section 3.15.3.4). Climate change could increase the frequency of shallow river conditions that may affect navigation at some locations (Section 4.2.7.4). The effects of sea level rise on river elevations could provide a marginal benefit for navigation of the channel below Bonneville Dam and have limited effects on shoreline transportation infrastructure (Section 4.2.7.4).
- **Cultural resources.** Numerous types of cultural resources have been identified in the vicinity of the projects in Region D. Cultural resources would continue to be adversely affected under the No Action Alternative due to ongoing operations and maintenance of the Columbia River System (Section 3.15.3.4). Climate change is projected to have minimal effects to changes in operations in the four lower Columbia River projects (Section 4.2.10.4).

MULTIPLE OBJECTIVE ALTERNATIVE 1

- **Navigation and Transportation.** Effects on navigation and transportation are anticipated to be negligible in Region D under MO1 (Section 3.15.3). Climate change is not projected to alter these conclusions. As such, effects to low-income, minority or Indian tribes are not anticipated.

- **Cultural Resources.** Effects to cultural resources are anticipated to be negligible. As such, effects to low-income, minority or Indian tribes are not anticipated (Section 3.15.3). Climate change is projected to have minimal effects to changes in operations in the four lower Columbia River projects (Section 4.2.10.4) and does not change this conclusion.

MULTIPLE OBJECTIVE ALTERNATIVE 2

See MO1 discussion above.

MULTIPLE OBJECTIVE ALTERNATIVE 3

- **Navigation and transportation.** Dam breach would result in regional economic effects of changes in navigation mode from river to rail and truck, as well as likely lead to some displacement of workers. While some laborers are likely to be low-income, minority, or members of Tribal communities, these effects do not appear likely to be concentrated in one group or area (Section 3.15.3.7). Climate change is not projected to alter these conclusions. As such, effects to low-income, minority or Indian tribes are not anticipated.
- **Cultural Resources.** Effects to cultural resources are anticipated to be negligible. As such, effects to low-income, minority or Indian tribes are not anticipated (section 3.15.3). Climate change is projected to have minimal effects to changes in operations in the four lower Columbia River projects (Section 4.2.10.4).

MULTIPLE OBJECTIVE ALTERNATIVE 4

See MO1 discussion above.

CHAPTER 5 - MITIGATION

5.1 INTRODUCTION

When preparing an environmental impact statement (EIS), the Council on Environmental Quality (CEQ) regulations state that Federal agencies shall include appropriate mitigation measures to address environmental impacts, if not already included in the alternatives (40 Code of Federal Regulations [C.F.R.] §§ 1502.14(f) and 1502.16(h)). This chapter provides an overview of possible mitigation measures being considered to avoid, minimize, and reduce impacts to the human environment associated with the four Multiple Objective Alternatives (MOs). Mitigation associated with the Preferred Alternative is described in Chapter 7; however, it relies on the same measures for avoidance and mitigation identified in this process. The Records of Decision, which conclude the National Environmental Policy Act (NEPA) process, will identify the co-lead agencies' preferred alternative and associated mitigation measures.

5.1.1 Overview of Mitigation

As part of the NEPA process, Federal agencies consider appropriate mitigation measures to avoid, minimize, rectify, reduce or eliminate, and/or compensate for specific impacts (CEQ 2011). The mitigation measures summarized in this chapter are intended to reduce the duration and severity of impacts from implementing a specific action.

CEQ defines mitigation as the following (40 C.F.R. 1508.20):

- Avoiding the impact altogether by not taking a certain action or parts of an action.
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
- Compensating for the impact by replacing or providing substitute resources or environment.

Avoidance and minimization measures include operational and construction measures such as standard operating procedures, best management practices (BMPs) such as minimizing ground disturbance, and industry standards. When physical or functional impacts to a resource cannot be avoided or minimized, agencies can implement specific measures to mitigate adverse impacts. Where possible in the mitigation analysis, the co-lead agencies identified in-kind and in-place mitigation to address impacted resources at the location of impact. However, if there were no feasible options to mitigate impacted resources at the project location, out-of-kind or out-of-place mitigation was proposed for unavoidable environmental impacts. Mitigation falls into four categories of actions to restore, replace, substitute, or supplement resources:

1. In-kind and in-place mitigation, which consists of actions to offset an impacted resource at the location of impact or an area immediately adjacent to the project site.
2. In-kind and out-of-place mitigation, which consists of actions that address the impacted resource at a different location.
3. Out-of-kind and in-place mitigation, which consists of actions that address a different resource at the location of impact or an area immediately adjacent to the project site.
4. Out-of-kind and out-of-place mitigation, which consists of actions that addresses a different resource at a different location.

NEPA requires that all relevant, reasonable mitigation measures that could diminish the adverse impacts of the project be identified in the document, even if they are outside the jurisdiction of the lead agency or the cooperating agencies. See 40 C.F.R. §§ 1502.16(h) and 1505.2(c); 46 Fed. Reg. 18026. The inclusion of mitigation measures in this chapter is not intended to indicate that the co-lead agencies, or the Federal government as a whole, has the authority to perform all of the measures listed. If the measures are outside the jurisdiction of the co-lead agencies, those measures will not be included in the Preferred Alternative or Records of Decision (ROD). Their inclusion in this chapter serves to alert other agencies, officials, and the public who can implement the measures to the potential benefits of the measure.

Implementation and effectiveness monitoring should be used to evaluate mitigation actions in accordance with CEQ regulations (40 C.F.R. §§1505.2(c) and 1505.3). Implementation monitoring ensures that mitigation is carried out as described in the NEPA documents and committed as part of the decision as documented in the ROD. Where implementation and effectiveness monitoring are planned in conjunction with mitigation, these actions are described in Section 5.5, *Monitoring and Adaptive Management*; Appendix R, part 1, Monitoring and Adaptive Management; and discussed in the co-lead agencies' RODs, as appropriate.

5.1.2 Avoidance and Minimization Measures

This section describes avoidance and minimization measures that were incorporated as a component of the proposed MOs, as well as the decision framework used to identify which effects need mitigation.

The co-lead agencies would avoid and minimize impacts to the environment by implementing BMPs (such as minimizing ground disturbance) and industry standards, as required, to comply with applicable federal and state regulations.

Generalized avoidance or minimization actions, standard BMPs, and industry standards that would likely be required for the proposed MOs are listed below. The list provided below is not intended to be complete; rather, it reflects the most predictable actions that would be implemented as integral components of the MOs. Other, site-specific avoidance and minimization actions may be identified and discussed in any future NEPA documents.

Standard BMPs would include the following:

- Use water and other dust suppressants to control fugitive dust and minimize erosion during construction.
- Develop and implement storm water prevention, erosion and sediment control, and spill prevention control and countermeasure plans.
- Implement secondary containment for fuel and hazardous chemicals used in conjunction with construction and operational implementation of measures.
- Adhere to fish passage guidelines during in-water work and construction of ladders, weirs, and other in-water structures and coordinate with NOAA Fisheries and the U.S. Fish and Wildlife Service if ESA-listed species are impacted.
- Implement dam safety requirements for construction and operation of new structures associated with Federal hydroelectric projects (term used to encompass a dam, reservoir, and all associated infrastructure).
- Implement standard fish handling techniques to minimize stress, and acquire the necessary federal and state scientific take permits for fish handling.
- Minimize spread and establishment of invasive species by implementing control measures for construction equipment.

5.1.3 Conservation Recommendations per Fish and Wildlife Coordination Act of 1934

In developing mitigation for the effects of the alternatives, the co-lead agencies also considered the conservation recommendations included in the U.S. Fish and Wildlife Service's (USFWS) Fish and Wildlife Coordination Act Report (CAR). The Fish and Wildlife Coordination Act (FWCA) of 1934, as amended (16 U.S.C. §§ 661–667e) provides authority for USFWS and NMFS involvement in evaluating impacts to fish and wildlife from proposed water resource development projects and requires them to provide conservation recommendations for the project. The draft CAR is included in Appendix U and provides analysis of effects of the alternatives, landscape findings, and conservation recommendations. The USFWS will be preparing a final CAR with emphasis on the Preferred Alternative for inclusion in the final EIS. Coordination between the co-lead agencies and the USFWS is ongoing for the final CAR.

5.1.4 Affected Resources

Mitigation measures were developed to offset impacts to affected resources that are protected by Federal laws, regulations, and Executive Orders, such as the following:

- Waters of the U.S. - Clean Water Act and EO 11990 Protection of Wetlands
- Threatened and endangered species -Endangered Species Act and Lacey Act
- Raptors, waterfowl, and migratory birds -Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act

- Tribal, Cultural and Historic Resources - Native American Graves Protection and Repatriation Act and National Historic Preservation Act
- Invasive Species -Executive Order (EO) 13751 – Invasive Species
- Floodplains -EO 11988 – Floodplain Management

Additional information describing these regulations and others relevant for this EIS can be found in Chapter 8.

5.2 DECISION FRAMEWORK AND SELECTION PROCESS

Mitigation measures were proposed as comments received during the public scoping period and by technical teams during evaluation of the alternatives. These preliminary mitigation features were further developed, compared, and then vetted through a robust selection process. The process started with the co-lead agencies, with input from cooperating agencies on the technical teams, considered potential mitigation measures from scoping comments and the technical teams' expertise. Then, the co-lead agencies used the decision framework (described below) to identify if mitigation was warranted based on the adverse effects of implementing a measure in the MOs and an evaluation of the severity of the impact on a resource. The areas of analysis were divided into four regions (regions A, B, C, D) to access regional and localized impacts. During the last round of the selection process, those screened mitigation measures were matched to mitigate adverse effects based on ability to reduce specific impacts. They were then further developed, refined, and screened, which resulted in the proposed mitigation as shown in Section 5.4.

Mitigation was only developed for adverse impacts; if an action resulted in negligible effects or the effect was beneficial, then no additional mitigation was proposed. For resources with minor effects, the co-lead agencies generally practice avoidance where practical through operations and implement BMPs, but did not propose taking additional mitigation actions. For purposes of meeting compliance with different federal laws, regulations, and EOs, the co-lead agencies have proposed mitigation measures, where appropriate, even if effects are minor, such as for wetland impacts. Conversely, if a proposed operational or structural measure would result in a moderate or major impact to any resource, then a range of mitigation measures were developed to address the impacted resource or resources. To differentiate among minor, moderate, and major effects as described in Section 3.1, the effect descriptors were used to evaluate the intensity of the impact in relation to significance (see 40 C.F.R. § 1508.27). The rationale for why an effect is considered to fall under one of the preceding intensity descriptors is included in each resource section and summarized in Chapter 3.

The full suite of proposed mitigation measures were assessed based on five criteria developed by the co-leads with cooperating agencies input, which helped to identify the likelihood that a measure would be adopted by the co-lead agencies:

Category type: in-kind and in-place mitigation measures were preferred over out-of-kind or out-of-place measures.

Effectiveness: a qualitative assessment of the mitigation measure's effectiveness in reducing the impact from the alternative.

Scale: a qualitative assessment of the spatial (i.e., site-specific or regional) and temporal scale (i.e., short-term or long-term, seasonal or annual, or temporary or permanent) of the mitigation measure relative to the severity and duration of the impact.

Feasibility: a qualitative assessment of the feasibility of implementing a measure based on technical and economic factors. For example, a mitigation measure may not be feasible if there are other technical actions that would effectively reduce the severity or duration of impact. Similarly, if the expense of implementing a measure would be unreasonable, then the measure would not be feasible.

Jurisdiction: an assessment of the co-lead agencies' jurisdiction or authority to implement the measures

Finally, the suite of proposed mitigation measures were evaluated to determine if each measure would fully reduce or minimize the impact or if residual impacts would exist after implementation. The co-lead agencies identified where effects would remain after implementing the mitigation measure. The full suite of prescreened mitigation measures are available in Appendix R - Mitigation, Monitoring and Adaptive Management, Part 3.

5.2.1 Existing Programs That Include Mitigation Under The No Action Alternative

Under the No Action Alternative, mitigation currently being implemented would continue. With implementation of any of the proposed MOs, there are nine mitigation programs that the co-lead agencies currently implement that would be incorporated, with certain modifications, in the respective alternatives. These mitigation programs are the Bonneville Power Administration (Bonneville) Fish and Wildlife Program (F&W Program), the Lower Snake River Compensation Plan, the U.S. Army Corps of Engineers' (Corps') Columbia River Fish Mitigation Program, U.S. Bureau of Reclamation's (Reclamation) Columbia River Tributary Habitat Program, the Federal Columbia River Power System Cultural Resources Program, Predator Management, Invasive Species Management, Pest Management Programs, and Nutrient Supplementation Program. Outside of the specific mitigation measures that have been identified in the CRSO EIS, changes to mitigation programs, like the Bonneville F&W Program, are not being made through this EIS process. Rather, for example, future program adjustments for the Bonneville F&W Program would be made in consultation with the region through Bonneville's budget-making processes and other appropriate forums and consistent with existing agreements. In determining appropriate mitigation measures to implement, the co-lead agencies considered the extent to which mitigation is already occurring or planned under the No Action Alternative.

In their management and operation of the Columbia River System, Bonneville, the U.S. Army Corps of Engineers, and the Bureau of Reclamation have together fulfilled the other primary fish and wildlife mitigation mandate in the Northwest Power Act, providing fish and wildlife "equitable treatment" with the other congressionally authorized purposes of the FCRPS (16 USC

§ 839b(h)(11)(A)(i)). Since the 1990s, the federal agencies have overhauled system operations and infrastructure, achieving juvenile dam passage survival that meets or exceeds performance standards of 96% and 93% for spring and summer migrants respectively,[1] a marked improvement as compared to when Congress passed the Act and the estimated average juvenile mortality at each mainstem dam and reservoir project was 15%–20% with losses recorded as high as 30%.[2] Travel time improved for yearling Chinook and juvenile steelhead through the system, even in low flow years such as 2015,[3] and total In-River survival has improved for migrating juvenile salmon and steelhead. Comparing two time periods reported in NOAA's reach study[4], (1997–2007 and 2008–2016), there has been a 10% survival increase for hatchery and wild sockeye salmon, a 2% increase in hatchery and wild Chinook (4% for wild), and a 25% survival increase for hatchery and wild steelhead (13% for wild).

5.2.1.1 Bonneville Power Administration Fish and Wildlife Program

The Bonneville F&W Program funds hundreds of projects each year to mitigate the impacts of the development and operation of the federal hydropower system on fish and wildlife. Bonneville began this program to fulfill mandates established by Congress in the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act), 16 USC § 839b(h)(10)(A), to protect, mitigate, and enhance fish and wildlife affected by the development and operation of the FCRPS. Each year Bonneville funds projects with many local, state, tribal, and federal entities to fulfill its Northwest Power Act fish and wildlife responsibilities and to implement offsite mitigation actions listed in various Biological Opinions for ESA-listed species. Offsite protection and mitigation actions typically address impacts to fish and wildlife not caused directly by the CRS, but they are actions that can improve the overall conditions for fish to help address uncertainty related to any residual adverse effects of CRS management. For example, the Bonneville F&W Program funding improves habitat in the mainstem as well as tributaries and the estuary, builds hatcheries and boosts hatchery fish production, evaluates the success of these efforts, and improves scientific knowledge through research. This work is implemented through annual contracts, many of which are associated with multi-year agreements like the Columbia River Basin Fish Accords, the Accord extensions, or wildlife settlements.

HABITAT ACTIONS

Bonneville works with states, tribes, and watershed groups to protect, mitigate, and enhance spawning and rearing habitat, targeting factors that limit fish survival throughout the Columbia River Basin. Bonneville has funded hundreds of projects across the basin to restore natural

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1 See Endangered Species Act Federal Columbia River Power System 2016 Comprehensive Evaluation – Section 1, at 17, t.2 (Jan. 2017).

2 See Nw. Res. Info. Ctr. v. Nw. Power Planning Council, 35 F.3d 1371, 1374 (9th Cir. 1994) (citing the U.S. General Accounting Office, Impacts and Implications of the Pacific Northwest Power Bill, at 22 (Sept. 4, 1979)).

3 2016 Comprehensive Evaluation at page 20.

4 James R. Faulkner, Daniel L. Widener, Steven G. Smith, Tiffani M. Marsh, and Richard W. Zabel. 2017. Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs, 2016. Report of research for Bonneville Power Administration, Contract 40735, Project 199302900.

stream channels, reconnect estuarine tidal channels, enhance flow volume and timing, expand cold water refuges and open access to habitat (www.cbfish.org). These habitat improvement actions provide both near-term and long-term benefits, including those that will help address the effects of climate change. Actions that improve connectivity and stream flow will provide a buffer against the effects of climate change.

In addition to habitat improvement actions, Bonneville works with willing landowners to protect land by putting it under permanent conservation easement to further support habitat and fish conservation in the short and long term.

HATCHERY ACTIONS

Bonneville constructed and now funds the operation and maintenance of over 20 compensation, conservation, and supplementation hatchery programs throughout the Columbia and Snake River basins to preserve, rebuild, and reduce extinction risk for ESA-listed fish species as well as to meet Northwest Power Act objectives to protect, mitigate, and enhance fish and wildlife affected by the FCRPS. The conservation hatchery programs help rebuild and enhance the naturally reproducing ESA-listed fish in their native habitats using locally-adapted broodstock, while maintaining genetic and ecologic integrity, and supporting harvest where and when consistent with conservation objectives. These hatchery programs include captive propagation for critically endangered Snake River sockeye, Snake River spring/summer Chinook supplementation, Snake River fall Chinook supplementation, reintroduction of spring Chinook in the Okanagan Basin, coho reintroduction and supplementation in the Mid and Upper Columbia basins, reconditioning of Mid and Upper Columbia and Snake River steelhead kelts, Kootenai River White sturgeon, burbot and westslope cutthroat trout.

PREDATION

Bonneville's F&W Program funds efforts to address the mortality of ESA-listed and non-listed fish caused by predators including birds, fish, and mammals. Certain types of fish in rivers are voracious consumers of juvenile salmon and steelhead. Predation by introduced fish species in reservoirs is also a concern. Other predators are known to consume substantial numbers of adult spring Chinook salmon and winter steelhead below Bonneville Dam and injure adult fish that migrate upstream. Bonneville funds projects to reduce the impact of these predator species on native fish.

LAMPREY

Several lamprey species, both anadromous and resident, are native to the Columbia River Basin, which historically supported productive populations. Much of the research and mitigation effort in the Basin is currently focused on the anadromous Pacific Lamprey due to its cultural importance to tribes and vital role in the ecosystem. At present Bonneville funds six lamprey projects to improve our understanding of Pacific Lamprey status and limiting factors, implement high-priority habitat restoration actions, increase populations through reintroduction and translocation efforts, and conduct artificial propagation research with plans to release hatchery juveniles in select areas pending an environmental assessment.

WILDLIFE MITIGATION FOR CONSTRUCTION, INUNDATION, AND OPERATIONS

When the CRS dams were built and the reservoirs behind them filled, they inundated about 308,996 acres, much of it important fish and wildlife habitat. To calculate the area affected by FCRPS development—dam construction and inundation by the reservoirs behind them—Bonneville relied on either the amounts agreed upon in negotiated mitigation agreements with state and tribal entities or the loss assessments prepared by Federal, state, and tribal wildlife managers.[5]

To date, Bonneville has implemented wildlife habitat projects on over 689,000 acres to address the impact of the development of the FCRPS, many of which were permanently acquired for wildlife habitat. Bonneville also provides operations and maintenance funding for these projects.

The loss assessments relating to dam construction and inundation considered all habitat losses up to and including full reservoir pool levels. As such, mitigation for those losses can also serve to address the effects of reservoir operations on wildlife habitat, to the extent that such operational impacts occur below full pool level.

While much of the mitigation work has been implemented through annual contracts, Bonneville and its partners negotiated "settlement agreements" to complete the wildlife mitigation for construction and inundation impacts, and some operational impacts, for Dworshak, Libby, Hungry Horse Projects and part of the impacts from the Albeni Falls Dam. These settlements allowed Bonneville and the affected states or tribes to agree on an appropriate amount of mitigation to be done and the funding or other consideration Bonneville would provide.

- ***Albeni Falls Dam.*** In the 2018 Albeni Falls Dam Wildlife Mitigation Agreement, Bonneville and the State of Idaho established that 14,087 acres had already been mitigated through the efforts of the state and three tribes (6,617 acres were impacted as a result of the construction and inundation of Albeni Falls dam).[1] In addition, Bonneville agreed to fund the State of Idaho to protect and enhance 1,279 acres of wetland habitat at the Clark Fork Delta and an additional 99 acres at the Priest River Delta to address the upriver effects of Albeni Falls operations. This is in addition to the 624 acres of wetland protected and enhanced on the Clark Fork Delta by IDFG, which was funded by Bonneville through a letter agreement in 2012.

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5 Bonneville funded but did not control the production of wildlife habitat loss assessments by wildlife managers in the mid-1980s and early 1990s. These documents, also called "Brown Books," are on file with Bonneville. The Brown Books generally reflect the acres inundated by the FCRPS as determined by the surface area of the reservoirs created behind each dam. See, e.g., U.S. Fish and Wildlife Service, Wildlife Impact Assessment Bonneville, McNary, The Dalles, and John Day Projects (Oct. 1990).

- ***Dworshak Dam***. The 1992 Dworshak wildlife mitigation agreement with the State of Idaho and the Nez Perce Tribe, frequently referred to as the "Dworshak Settlement," mitigated the impacts to wildlife from developing that dam estimated at 16,970 acres.[6] To determine acreage protected, Bonneville relied on the Dworshak Wildlife Agreement reports from the tribe. The tribe's 2018 annual report indicates it has purchased 7,576 acres and still has over $9.5 million remaining in its mitigation fund established under the agreement.[7] The State of Idaho also has a $3 million fund provided by Bonneville to manage the 60,000 acre Peter T. Johnson Unit of the Craig Mountain Wildlife Management Area (formerly known as Craig Mountain), which Bonneville purchased and transferred to Idaho.[8] All told, Bonneville has already funded 67,576 acres of mitigation for Dworshak Dam.
- ***Montana Dams.*** As with Dworshak, Bonneville addressed the construction and inundation mitigation for Libby and Hungry Horse dams wildlife using a comprehensive long-term agreement. To determine acreage protected, Bonneville relied on reports from Montana Fish, Wildlife, and Parks. Under the 1989 Montana Wildlife Mitigation Trust Agreement,[9] Montana has protected or enhanced 272,104 acres[10] (substantially more than the Council's program called for, which was a total of 55,837 acres for Libby and Hungry Horse dams split between 29,171 acres of enhancement and 26,666 acres of protection).[11]

5.2.1.2 Lower Snake River Compensation Plan

Congress authorized the Lower Snake River Compensation Plan (LSRCP) as part of the Water Resources Development Act of 1976 (90 Stat. 2917) to offset fish and wildlife losses caused by construction and operation of the four lower Snake River dams. A major component of the authorized plan was the design and construction of fish hatcheries and satellite facilities. The U.S. Corps of Engineers and Bonneville implement separate portions of this program.

U.S. Corps of Engineers' Lower Snake River Compensation Plan

The Corps' LSRCP includes construction of fish hatcheries and acclimation facilities in Idaho, Oregon, and Washington. In addition, the Corps developed over 23,000 acres of land as wildlife habitat (shrub-steppe and riparian) to replace habitat that was inundated and to provide fishing and hunting access.

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6 Crediting Forum, Final Report 3.
7 Nez Perce Tribe, Dworshak Wildlife Mitigation Annual Report (2018) (on file with Bonneville).
8 Idaho Dept. of Fish and Game, Craig Mountain Wildlife Management Area 2014-2023 Wildlife Management Plan 9 (Dec. 2014), https://idfg.idaho.gov/sites/default/files/2014-2023-CraigMtnWMA-Plan-Final.pdf
9 Montana Fish, Wildlife and Parks, Montana's Wildlife Mitigation Settlement (Power Point presented to Bonneville by MFWP wildlife managers on Nov. 19, 2013) (on file with Bonneville).
10 Montana Fish, Wildlife and Parks, Montana Wildlife Mitigation Program FY 2019, 1 (Oct. 2, 2019).
11 See, Council, 1987 Columbia River Basin Fish and Wildlife Program § 1000 138–39 tbl.4, https://www.nwcouncil.org/media/6843101/1987Program.PDF; see also, Montana Fish, Wildlife and Parks, Program for Mitigating Wildlife Impacts Caused by construction of Libby and Hungry Horse Dams: Five-Year Operating Plan 3 (July 1, 2009) (citing Yde and Olsen (1984)), http://fwp.mt.gov/fwpDoc.html?id=53780 [hereinafter Program for Libby and Hungry Horse].

BONNEVILLE'S LOWER SNAKE RIVER COMPENSATION PLAN

In addition to the hatchery operations that are funded through its F&W Program, Bonneville directly funds the U.S. Fish and Wildlife Service (USFWS) for annual operations and maintenance of the LSRCP fish hatcheries and facilities. The LSRCP hatcheries and satellite facilities produce and release more than 19 million salmon, steelhead, and resident rainbow trout as part of the program's mitigation responsibility. The 25 LSRCP hatcheries and satellite facilities are operated by Idaho Fish and Game (IDFG), Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), USFWS, the Nez Perce Tribe (NPT), Confederated Tribes of the Umatilla River (CTUIR), and Shoshone-Bannock Tribes (SBT). LSRCP would be continued, consistent with the NAA, under all of the MOs except for MO3.

5.2.1.3 U.S. Corps of Engineers' Columbia River Fish Mitigation Program

The Columbia River Fish Mitigation Program (CRFM) is the Corps' construction account for studying, designing, and constructing new anadromous fish passage improvements at CRS dams. Nearly all fish passage improvements required for compliance with past Biological Opinions issued by the NMFS have been constructed, and few new anadromous fish improvements requiring construction have been identified. Therefore it is assumed that for CRS dams, requirements for new construction will be completed within the next 10 years.

Examples of CRFM funded activities include installing turbine intake screens and bypass systems, modifying spillways (e.g., flow deflectors, surface spill weirs, and modified surface spill structures), and installing improved fish passage turbines. Additional modifications to fish ladders have also been underway to increase passage of adult lamprey, including the installation of specialized lamprey passage structures at Bonneville, The Dalles, and McNary dams.

5.2.1.4 Bureau of Reclamation's Columbia River Tributary Habitat Program

Reclamation has a Columbia-Snake salmon program to help meet its ESA obligations for the Grand Coulee and Hungry Horse projects. The program funds, designs, and implements tributary habitat improvements in specified Columbia River sub-basins, and also funds avian predation management.

5.2.1.5 Direct Funding Agreements with the Corps and Reclamation

In addition to Bonneville's fish and wildlife mitigation program described above, there are also fish and wildlife mitigation costs that are direct funded by Bonneville to the Corps and Reclamation for mitigation activities, such as hatchery operations, fish stocking, elk habitat maintenance, cultural resource compliance and others.

5.2.1.6 Federal Columbia River Power System Cultural Resource Program

The co-lead agencies implement the Federal Columbia River Power System Cultural Resource Program (Cultural Resource Program) (Bonneville 2019) to comply with Section 106 of the NHPA.

When a historic property is adversely affected by a Federal undertaking, agencies consult with consulting parties to seek ways to avoid, minimize, or mitigate for the adverse effects. To effectively manage historic properties within the study area (see Chapter 1 for map), the co-lead agencies developed the Cultural Resource Program in 1997 to address compliance with Section 106 for the undertaking that resulted from the System Operation Review (SOR) EIS – the operation and maintenance of the Federal Columbia River Power System for the multiple congressionally authorized project purposes. Activities implemented as part of the program are guided by the 2009 Systemwide Programmatic Agreement for the Management of Historic Properties Affected by the Multipurpose Operations of Fourteen Projects of the Federal Columbia River Power System (Systemwide PA) (Bonneville 2009). Through the Cultural Resources Program and the Systemwide PA, the co-lead agencies also partner with other Federal agencies, states, and tribal technical staff who specialize in Columbia River Plateau archaeology, historic and cultural importance to tribes, the built environment, and other cultural resources to share information and assist in defining priorities and solutions to appropriately manage cultural resources in the study area.

Under the Systemwide PA, the Cultural Resources Program manages historic properties through a standard process of surveys, evaluation, assessments, and resolution of adverse effects. In addition, the program evaluates potential historic properties to determine if they are eligible for listing in the National Register of Historic Places. Annual operation and maintenance activities affect some of the historic properties. Operations and maintenance can affect cultural resource sites and areas of traditional importance, sometimes exposing artifacts that could potentially be looted or vandalized. The PA assesses the effects from changes in configuration, and operations and maintenance activities, and develops options to resolve adverse effects. Through the assessment of effects, the program can monitor the status of site conditions and fund limited law enforcement activities, where appropriate.

If a cultural resource is eligible for listing in the National Register of Historic Places, the Cultural Resource Program works with the consulting parties to determine how to prioritize activities to mitigate the adverse effects. Examples of mitigation include protection and restoration; bank stabilization for erosional areas; data recovery, and analysis; public education through the production of brochures, exhibits, interpretive trails, or presentations; and creative offsite mitigation. Offsite mitigation options can include, but are not limited to rehabilitating structures that have a cultural tie to the impacted areas or funding educational opportunities and activities for tribal members related to cultural practices tied to particular properties.

The existing Cultural Resource Program would be carried forward and funded under the No Action Alternatives, MO1, MO2, and MO4 for continued archaeological monitoring through the Columbia River study area. Mitigation for MO3 is discussed below. Activities implemented under MO1, MO2, and MO4 could include the continued periodic use of drones and satellites to document changes through time in sites. Activities include monitoring for erosion and other site formation processes; providing opportunities for public education to increase awareness about the importance, value, and need for protecting archaeological sites; increasing signage across the study area to support public education and awareness where appropriate; data recovery, and other various forms of mitigation activities to address effects to Traditional Cultural Properties and historic properties of religious or cultural importance to tribes.

5.2.1.7 Predation Management

Existing avian and pinniped predator management programs are in place and would continue with implementation of any of the MOs. The co-lead agencies would continue implementing existing avian predator management actions in the lower Snake and Columbia Rivers and the existing pinniped predator management program in the lower Columbia River. Predator management actions are both in-place and out-of-place, and are intended to mitigate for impacts to juvenile and adult fish that are adversely impacted by high TDG concentration during migration, but the mitigation does not address elevated TDG itself. TDG concentrations would remain unchanged under these mitigation measures. The number of fish impacted by spill operations would decrease as a result of predator management actions.

5.2.1.8 Invasive Species and Pest Management Programs

The co-lead agencies currently plan and continue to implement invasive species management on Federal lands within the study area to detect, manage, and control nuisance and invasive species, including animals, plants, or other organisms. Invasive species can hinder or otherwise adversely affect navigation, hydropower generation, flood risk management, water supply, water quality, fish and wildlife habitat, and recreational activities (e.g., Corps 2017, 2019; Reclamation 2019). Management activities include biological, chemical, and mechanical methods as part of integrated management programs to control both terrestrial and aquatic pests.

5.2.1.9 Nutrient Supplementation Programs

The co-lead agencies currently plan and continue to implement three existing programs to improve water quality and enhance fisheries in the study area. One program is implemented in Dworshak Reservoir, the second is implemented downstream of Libby in the Kootenai River, and the third is in Kootenay Lake. These plans would continue with implementation of any MO.

The Dworshak Reservoir Nutrient Restoration Project is implemented by the Corps and Idaho Department of Fish and Game in Dworshak Reservoir to restore ecological function, improve water quality and enhance fisheries (Idaho Department of Fish and Game 2018). Construction of the dam blocked upstream fish migration on the North Fork Clearwater River, depleting nutrients upstream of the dam. Results from a pilot project implemented between 2007 and 2010 demonstrated that supplementing the reservoir with additional nitrogen balanced the ratio of nutrients and improved overall ecological function. In 2017, the nutrient supplementation project was incorporated into reservoir operations and maintenance, and water quality is regularly monitored to ensure the program beneficially supports water quality, plankton communities, and fish.

Funded by Bonneville and implemented by tribal and state partners, the Kootenai River Nutrient Enhancement Program mitigates for a loss of nutrients in the river to benefit resident fish, including Kootenai River White Sturgeon (*Acipenser transmontanus*) and bull trout (*Salvelinus confluentus*), by supplementing the river with phosphorous and nitrogen. This action is intended to support aquatic invertebrate production and contribute to the food web to support fish and other aquatic organisms. (Kootenai River Ecosystem Final Environmental Assessment, June 2005). Nutrients are trapped in the Libby Reservoir, depleting concentrations in the Kootenai River and reducing overall productivity in the river. Nutrient concentrations become increasingly diluted downstream of the dam. The program is planned to continue until the summer of 2026. Continuation of the program would occur following evaluation of conditions, research, and monitoring results.

Additionally, the Kootenay Lake Ecosystem Project provides an annual addition of nutrients to the south arm of Kootenay Lake to increase biological productivity and restore native fish populations. The nutrient additions promote zooplankton abundance, an important food source for kokanee, and important food item for adult and juvenile Kootenai white sturgeon. Under this program Bonneville funds the British Columbia Ministry of Forests, Lands, and Natural Resource Operations to add nutrients and monitor from June through August using boat-mounted applicator tanks. This project began in 2004, and complements another nutrient supplementation program also implemented by British Columbia on the North Arm of the Kootenay Lake. Details of this program may be found in Bonneville’s Environmental Assessment for the Kootenai River Ecosystem Project (2005, 2012).

5.3 CONSIDERATIONS FOR ESA COMPLIANCE

Compliance measures for the No Action Alternative were described in Chapter 2. The Preferred Alternative is currently being coordinated for consultation with the USFWS and NMFS under the Endangered Species Act. Results of consultation may change, supplement, or remove measures previously carried forward in the No Action Alternative. Chapter 7 addresses those measures added for the ESA compliance of the Preferred Alternative. Should MO1, MO2, MO3, or MO4 be selected as the Preferred Alternative, it would require additional analysis through consultation with USFWS and NMFS, and may include, as appropriate, more or less ESA measures to be compliant with the ESA.

5.4 POTENTIAL MITIGATION FOR ALTERNATIVES

This section describes the additional mitigation measures identified by the co-lead agencies for impacts to resources from each of the MOs. Each MO includes a summary table of potential mitigation the co-lead agencies would take if that MO were to be implemented. The sections are organized according to region, resource, or subject area. Additional information about mitigation measures that were considered but were screened or not selected for further consideration can be found in Appendix R - Monitoring and Adaptive Management. The list of mitigation measures for the Preferred Alternative will be updated after public review of the draft EIS and included as a comprehensive list in the final EIS.

5.4.1 Mitigation Measures for Multiple Objective Alternative 1

The additional mitigation measures proposed for MO1 address impacts to water quality, anadromous and resident fish, vegetation, wildlife, wetlands, and floodplains, and navigation and transportation. Impacts to these resources are described fully in Chapter 3, Chapter 4, and Chapter 6. Effects to cultural resources would be addressed by continuing to implement the existing Cultural Resource Program discussed in Section 5.2.1.6. For MO1, there would be no impacts requiring additional mitigation for flood risk management, aesthetics, noise, water supply, recreation or cultural resources, as there are negligible impacts. Although power and transmission have moderate adverse effects compared to the No Action Alternative, mitigation actions are discussed within the Chapter 3 Power and Transmission section.

5.4.1.1 Water Quality

MO1 would have negligible effects to water quality in Region A, B, and D and therefore no additional mitigation is warranted. In Region C, a measure is proposed to address public health concerns as described below. In Region C and D, total dissolved gas (TDG) would increase. Mitigation for effects of this TDG increase to fish is proposed in the Anadromous Fish Mitigation section.

The co-lead agencies propose mitigation in Region C to limit impacts to water quality. Elevated water temperatures in the lower Snake River during the summer months could increase algal growth, which decreases water quality and poses health risks in recreational areas. To help ameliorate impacts to water quality and public health to those recreating, the co-lead agencies will either initiate monitoring or increase the existing monitoring at recreational areas in Region C for algal growth. If monitoring indicates the presence of toxic algal blooms, then public advisories would be posted in recreational areas to minimize risks to the public. This proposed mitigation is not intended to reduce algal growth, but is intended to assist in protecting the public.

5.4.1.2 Anadromous Fish

The co-lead agencies are not proposing any mitigation measures in Regions A or B (upstream of Chief Joseph) for impacts to anadromous fish because there are no anadromous fish above Chief Joseph Dam. One new measure is proposed for Region C and D for TDG impacts. No other additional mitigation is proposed for anadromous fish. Ongoing programs for anadromous fish in Regions B (below Chief Joseph), C, and D would continue, including habitat projects and fish hatchery programs for salmon and steelhead discussed above in Section 5.2.1. Examples of these projects are discussed below.

NEW MITIGATION ACTIONS

In Region C and D, concentrations of TDG would increase because of spill measures implemented as part of MO1. If it is observed that conditions in the project tailrace are impeding upstream passage of adult salmon and steelhead or actionable TDG impacts to fish are observed, the co-lead agencies would implement performance standard spill operations until the situation is remedied. These real-time decisions are made in the Regional Forum. These operations are of short duration, and as-needed, to resolve the passage issues.

EXAMPLES OF CONTINUING PROGRAMS WITH MO1

Below Chief Joseph Dam, ongoing activities for anadromous fish would continue, including habitat improvement actions in the tributaries and the Columbia River estuary for juvenile salmon and steelhead species, and fish hatchery programs as discussed in the examples below.

In Region B, the Confederated Tribes of the Colville Reservation operate the Chief Joseph Hatchery on the Colville Reservation below Chief Joseph Dam, releasing smolts to increase the abundance of adult summer/fall and spring Chinook to the Okanogan River and Columbia River mainstem above the Okanogan River confluence. This is for conservation and harvest purposes, and assists in re-establishing a fourth population of UCR spring Chinook in the Okanogan River Basin through reintroduction of an experimental population under the ESA.

In Region C, Bonneville F&W Program-funded hatchery programs include the captive propagation for critically endangered Snake River sockeye, Snake River spring/summer Chinook supplementation, Snake River fall Chinook supplementation and the reconditioning of Snake River steelhead kelts. Further, the Springfield Hatchery, located near American Falls, Idaho, was constructed to address recovery objectives for ESA-endangered Snake River Sockeye Salmon.

In Region D, Bonneville F&W Program-funded hatchery programs include coho reintroduction and supplementation in the Mid-Columbia and reconditioning of Mid-Columbia steelhead kelts.

Throughout Regions C and D, the Bonneville F&W Program annually funds tributary habitat improvement actions for ESA-listed anadromous stocks, such as Snake River steelhead distinct population segment, Snake River spring/summer Chinook salmon evolutionary significant unit, and the Middle Columbia steelhead distinct population segment. Further, in Region D, co-lead agencies would continue to implement habitat restoration actions in the Columbia River Estuary. These actions primarily focus on the restoration of disconnected tidally influenced floodplain ecosystems for all juvenile salmonids and steelhead species in order to provide greater opportunity, access, and capacity for juvenile salmonid and steelhead rearing conditions. Additionally, in Region D, there are numerous actions to benefit Pacific lamprey, including projects like the Pacific Lamprey Conservation Initiative and the Tribal Pacific Lamprey Restoration Plan, which have been developed to improve understanding of Pacific Lamprey status and limiting factors, and implement high-priority habitat restoration actions.

5.4.1.3 Resident Fish

Under MO1, the co-lead agencies propose mitigation measures for adverse effects to resident fish in Region A near Bonners Ferry, Idaho and at Hungry Horse reservoir; and in Regions B for at Lake Roosevelt. No additional mitigation is proposed in Regions C or D because implementing MO1 results in minor adverse effects, occurs temporarily, or does not rise to the level of severity warranting additional mitigation. Ongoing actions as described in Section 5.2.1 for resident fish, such as bull trout and sturgeon in Regions A, B, C, and D, would continue. A few examples of those actions are discussed below.

Collectively, the measures for MO1 affect seasonal water surface elevations and flows, and the co-lead agencies do not expect a perceptible change to habitat conditions for resident fish. In Region B, MO1 would adversely affect the abundance of non-native species, such as smallmouth bass (*Micropterus dolomieu*) and walleye (*Sander vitreus*). Decreasing the reproductive success of these populations would support increased survival of ESA-listed species such as salmon and steelhead below Chief Joseph Dam. For these reasons, and the adverse effects are to non-native species, the co-lead agencies are not proposing additional mitigation.

NEW MITIGATION ACTIONS

To address impacts of MO1 in Region A, the co-lead agencies propose planting cottonwood trees at Bonners Ferry, Idaho, to improve habitat and floodplain connectivity to benefit ESA-listed Kootenai River White Sturgeon and bull trout. Similar to the proposed mitigation for vegetation, wildlife, wetlands, and floodplains, expanding the quantity and distribution of wetland habitats and increasing floodplain connectivity along the Kootenai River could help address seasonal impacts at Bonners Ferry from the *December Libby Target Elevation* measure. High winter levels could decrease the recruitment and long-term survival of cottonwood trees adjacent to the river when seeds and saplings are swept downstream during winter flows. While implementation of this MO negligibly effects these resources relative to the No Action, the co-lead agencies propose to plant 1-2 gallon cottonwoods near Bonners Ferry to improve habitat and floodplain connectivity, which would benefit ESA-Listed Kootenai River White Sturgeon by providing a food source. This would complement ongoing habitat actions already being taken in the region. This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would further minimize any negative effects.

Mitigation measures for the fish impacts of Libby dam are coordinated with adjacent tribal, state, and provincial governments. Programs like the Libby Dam Fisheries Mitigation and Implementation Plan (Montana Fish Wildlife and Parks et al. 1998) seek to enhance hydropower-affected fish stocks in the Montana portion of the Kootenai Watershed consistent with white sturgeon, bull trout, westslope cutthroat trout and redband trout conservation needs and requirements. This program implements and evaluates habitat enhancement to alleviate limiting factors to native species including projects to protect or enhance spawning, rearing, and over-wintering habitats. Additionally, since 2010, BPA has funded the Kootenai

Tribe of Idaho (KTOI) to manage and implement habitat restoration measures within the Kootenai River downstream of Libby Dam. These habitat restoration actions have increased active floodplain, increased river pool depths, reduced erosion, and provided increased complexity and velocities to aid in the survival and potential reproduction of Kootenai River White Sturgeon and potentially benefit for the native salmonid populations as well. In addition to their habitat work, KTOI operates the Kootenai Tribal sturgeon hatchery and the Tribal Twin Rivers sturgeon and burbot hatchery facility, which was constructed in 2014. These facilities have preserved sturgeon genetic and demographic diversity and have pioneered culture techniques for burbot.

Under Bonneville's Fish and Wildlife Program, Bonneville funds the Confederated Salish and Kootenai Tribes and the State of Montana to assess population level effects of CRS operations on native fishes, implements habitat improvement, habitat conservation, and fish passage actions, and quantifies and reduces the effects of non-native aquatic species on native fishes for impacts from Hungry Horse Dam.

MO1 lowers water surface elevations and creates seasonal drawdowns in the Hungry Horse reservoir, adversely affecting bull trout migration in late the summer and early fall. As reservoir elevations decline, fish passage conditions at the mouth of spawning tributaries prohibit fish migration into spawning tributaries. Under these conditions, bull trout are more susceptible to angling and predation pressures due to a lack of sufficient cover while they hold until conditions are passable. This also causes delays in migration which result in an overall decrease in productivity. To offset these effects, the co-lead agencies propose installing structural components like woody debris and vegetation at the mouth of tributaries, such as Wounded Buck, Sullivan, Wheeler, and Bunker Creeks, to stabilize channels and increase cover for migrating fish. These actions would improve habitat conditions for bull trout and minimize impacts from fluctuating water levels on the reservoir. This mitigation action would also increase the survival of outmigrating juveniles and increase production of terrestrial and aquatic invertebrates. Considering the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs with this proposed mitigation component, adverse effects are anticipated to be reduced to negligible.

In Region B, changes in elevation would leave current habitat in Lake Roosevelt dewatered and expose new areas that could be appropriate for gravel spawning habitat. The co-lead agencies would develop additional spawning habitat at Lake Roosevelt to minimize adverse effects to resident fish. The co-lead agencies propose to place appropriate gravel for spawning habitat at locations up to 100 acres along reservoir and tributaries. Prior to placement, the co-lead agencies would conduct site surveys post operations of an alternative to determine where to site spawning habitat at Lake Roosevelt for burbot, kokanee, and redband rainbow trout.

EXAMPLES OF CONTINUING PROGRAMS WITH MO1

There are numerous ongoing actions to benefit resident fish. Under Bonneville's Fish and Wildlife Program, Bonneville funds the Confederated Salish and Kootenai Tribes and the State of Montana to assess population level effects of CRS operations on native fishes, implements habitat improvement, habitat conservation, and fish passage actions, and quantifies and reduces the effects of non-native aquatic species on native fishes for impacts from Hungry Horse Dam. Part of the mitigation work for Hungry Horse Dam involves fish production at two small hatcheries in northern Montana. Bonneville funds Creston National Hatchery's production of juvenile westslope cutthroat trout and juvenile rainbow trout for stocking in Montana waters. Bonneville also funded the construction of Sekokini Springs Isolation Facility for spawning, rearing, isolation, and release of genetically unique westslope cutthroat trout stocks originating from wild parent stocks. Mitigation actions for the fish impacts of Libby dam are coordinated with adjacent tribal, state, and provincial governments. Programs like the Libby Dam Fisheries Mitigation and Implementation Plan (Montana Fish Wildlife and Parks et al. 1998) seek to enhance hydropower-affected fish stocks in the Montana portion of the Kootenai Watershed consistent with white sturgeon, bull trout, westslope cutthroat trout, and redband trout conservation needs and requirements. This program implements and evaluates habitat enhancement to alleviate limiting factors to native species including projects to protect or enhance spawning, rearing, and over-wintering habitats. Additionally, since 2010, BPA has funded the Kootenai Tribe of Idaho (KTOI) to manage and implement habitat restoration measures within the Kootenai River downstream of Libby Dam. These habitat restoration actions have increased active floodplain, increased river pool depths, reduced erosion, and provided increased complexity and velocities to aid in the survival and potential reproduction of Kootenai River White Sturgeon and potentially benefit for the native salmonid populations as well. In addition to their habitat work, KTOI operates the Kootenai Tribal sturgeon hatchery and the Tribal Twin Rivers sturgeon and burbot hatchery facility, which was constructed in 2014. These facilities have preserved sturgeon genetic and demographic diversity and have pioneered culture techniques for burbot.

Bonneville's F&W Program provides funding to the Kalispel Tribe to develop and implement a resident fish mitigation program for the impacts from Albeni Falls Dam. This work includes improving bull trout habitat within the basin. Additional priorities are to restore habitats for westslope cutthroat trout, and maintain the suppression effort on non-native predator and competitive fish species within the Pend Oreille Basin. Finally, through the 2018 Albeni Falls Dam Wildlife Mitigation Agreement, Bonneville and the State of Idaho to protect and enhance 1,378 acres to address operational impacts of Albeni Falls Dam on wildlife.[12] Much of this work focuses on the Clark Fork Delta and restoration of riparian habitat and the reestablishment of wetland plant communities, which will also benefit resident fish species.

In Region C, Bonneville F&W-funded projects with the Nez Perce Tribe in the Lochsa watershed are working to improve habitat for resident fish. Idaho Department of Fish and Game are also improving habitat for Yellowstone cutthroat trout. Riparian, wetland, and instream habitat restoration in Regions C and D that targets anadromous fish or wildlife species also can improve habitat conditions for resident fish species.

[12] Northern Idaho Memorandum of Agreement Between the State of Idaho and the Bonneville Power Administration for Wildlife Habitat Stewardship and Restoration section II.C.3, page 6 (2018) (on file with Bonneville).

5.4.1.4 Vegetation, Wildlife, Wetlands, and Floodplains

Under MO1, the co-lead agencies propose mitigation measures in Region A along the Kootenai River. This mitigation measure would help address impacts to vegetation, wildlife, wetland, and floodplain habitats. Collectively, the measures for MO1 affect seasonal water surface elevations, but the co-lead agencies expect a minor to negligible perceptible change to habitat conditions, wetlands, and floodplains.

While the *Predator Disruption Operations* and *Increased Forebay Range Flexibility* measures may cause temporary effects to wetlands in Region D, specifically in Lake Umatilla or Lake Celilo, no mitigation is proposed as the effects are not expected to result in perceptible changes to wetland habitats. Similarly, while MO1 would result in a minor to negligible seasonal decrease in water surface elevations in the Columbia River estuary downstream of Bonneville Dam, the effects would not perceptibly change wetland or estuary habitat conditions. Therefore, no additional mitigation is proposed for impacts from MO1 in the Columbia River estuary.

As a result, no additional actions are proposed for Region B, C, or D. Ongoing actions for impacts to vegetation and wildlife in Regions A, B, C, and D would continue, including protection and enhancement of wildlife habitat as discussed in the examples below.

NEW MITIGATION ACTIONS

In Region A, the co-lead agencies propose two mitigation measures to help address impacts to vegetation. First, the co-lead agencies propose updating and implementing an invasive species management plan to offset the impacts from implementing the *Modified Draft at Libby* measure. With this measure, lower summer reservoir elevations at Libby would increase the exposure of mudflats during the growing season, which could increase spread and establishment of invasive species along the shoreline. To address this concern, the co-lead agencies would update existing management plans and implement them where warranted. Existing Invasive Species management programs were described above in Section 5.2.1.8 for the No Action Alternative.

Implementing the *December Libby Target Elevation* measure could decrease seasonal water surface elevations during the growing season. Additionally, the *December Libby Target Elevation measure* could result in higher winter flow and decrease the recruitment and long-term survival of black cottonwood trees (*Populus balsamifera* ssp. *trichocarpa*) adjacent to the river when seeds and saplings are swept downstream during winter flows. This measure could adversely affect wetland quality, quantity, and distribution along the Libby reservoir and the Kootenai River. To mitigate these effects, the co-lead agencies proposed planting approximately 100 acres of forested and scrub-shrub wetland habitat for the loss of these forests and support vegetation succession. This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible. This expansion of wetland habitats along the Kootenai River would also help ameliorate seasonal impacts at Bonners Ferry, Idaho.

EXAMPLES OF CONTINUING PROGRAMS WITH MO1

In Region A, Bonneville addressed the construction and inundation mitigation for Libby and Hungry Horse dams wildlife using a comprehensive long-term agreement. To determine acreage protected, Bonneville relied on reports from Montana Fish, Wildlife, and Parks. Under the 1989 Montana Wildlife Mitigation Trust Agreement,[13] Montana has protected or enhanced 272,104 acres[14] (the Council's program called for a total of 55,837 acres for Libby and Hungry Horse dams split between 29,171 acres of enhancement and 26,666 acres of protection).[15] In the 2018 Albeni Falls Dam Wildlife Mitigation Agreement, Bonneville and the State of Idaho established that 14,087 acres had already been mitigated through the efforts of the state, the Kalispel Tribe, Kootenai Tribe of Idaho, and the Coeur D'Alene Tribe (6,617 acres were impacted as a result of the construction and inundation of Albeni Falls dam).[16] In addition, Bonneville agreed to fund the state to protect and enhance an additional 1,378 acres to fully address operational impacts of Albeni Falls Dam on wildlife.[17] Bonneville also agreed to fund the State of Idaho to protect and enhance 1,279 acres of wetland habitat at the Clark Fork Delta and an additional 99 acres at the Priest River Delta to address the upriver effects of Albeni Falls operations. This is in addition to the 624 acres of wetland protected and enhanced on the Clark Fork Delta by Idaho Department of Fish and Game (IDFG), which was funded by Bonneville through a letter agreement in 2012.

In Region B, Bonneville funds the Colville Tribes' wildlife mitigation efforts, which are focused on projects in the Hellsgate Game Reserve on the Colville Reservation. Under a 2008 agreement between Bonneville and the Colville Tribes, the Colville Tribes have acquired almost 4,000 acres, completed over 54,000 acres of invasive/noxious weed control measures, engaged in extensive boundary fence monitoring (over 270 miles), and modified fencing for reintroduced pronghorn antelope.

In Region C, Bonneville funds acquisition and management of wildlife mitigation lands under the 1992 Dworshak Wildlife Mitigation Agreement with the State of Idaho and the Nez Perce Tribe. Bonneville has provided the State of Idaho $3 million to manage the 60,000 acre Peter T. Johnson Unit of the Craig Mountain Wildlife Management Area (formerly known as Craig

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13 Montana Fish, Wildlife and Parks, Montana's Wildlife Mitigation Settlement (Power Point presented to Bonneville by MFWP wildlife managers on Nov. 19, 2013) (on file with Bonneville).

14 Montana Fish, Wildlife and Parks, Montana Wildlife Mitigation Program FY 2019, 1 (Oct. 2, 2019).

15 See, Council, 1987 Columbia River Basin Fish and Wildlife Program § 1000 138–39 tbl.4, https://www.nwcouncil.org/media/6843101/1987Program.PDF; see also, Montana Fish, Wildlife and Parks, Program for Mitigating Wildlife Impacts Caused by construction of Libby and Hungry Horse Dams: Five-Year Operating Plan 3 (July 1, 2009) (citing Yde and Olsen (1984)), http://fwp.mt.gov/fwpDoc.html?id=53780 [hereinafter Program for Libby and Hungry Horse].

16 Northern Idaho Memorandum of Agreement Between the State of Idaho and the Bonneville Power Administration for Wildlife Habitat Stewardship and Restoration section II.C, page 5 (2018) (on file with Bonneville).

17 Northern Idaho Memorandum of Agreement Between the State of Idaho and the Bonneville Power Administration for Wildlife Habitat Stewardship and Restoration section II.C.3, page 6 (2018) (on file with Bonneville).

Mountain), which Bonneville purchased and transferred to Idaho. The Nez Perce Tribe has purchased 7,576 acres of wildlife mitigation lands and has over $9.5 million remaining in its mitigation fund under the agreement.

In Region D, the Confederated Tribes of the Umatilla Indian Reservation secured and now manage the 8,768 acre Rainwater project, the 5,937 acre Iskulpa project, and the 2,765 acre Wanaket wildlife area located just above McNary Dam. Further, the 34,000 acre Pine Creek Conservation Area in Wheeler County, Oregon is owned and managed as wildlife habitat by the Confederated Tribes of the Warm Springs Reservation.

5.4.1.5 Navigation and Transportation

The co-lead agencies are not proposing any mitigation measures in Regions A, C, and D for navigation and transportation because the measures implemented as part of MO1 would have negligible effects on these resources as discussed in Chapter 3, and therefore no additional mitigation was warranted.

In Region B, the Inchelium-Gifford Ferry would go out of service for longer durations, up 9 more days in wet years than the No Action Alternative, when operational measures at Grand Coulee cause the draft for flood risk management to begin sooner. The effect would isolate tribal members in the community of Inchelium, and while the effect is temporary, it would affect the potential days this community can use the ferry and their ability to reach emergency and medical services and supplies. As a result, mitigation is proposed to extend the ramp at the Inchelium-Gifford Ferry so that it is available at lower water elevations in Lake Roosevelt. This would reduce the effects to negligible effects, and may be moderately beneficial comparative when compared to the No Action Alternative.

5.4.1.6 Cultural Resources

In Region A and B, there could be moderate to major adverse effects to cultural resources from an increase in number of acre-days that archaeological resources would be exposed. Region A and B would use Cultural Resource Program funding for activities such as archaeological site and traditional cultural property monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other alternative mitigation to address impacts to TCPs. This mitigation measure, when considered with the existing FCRPS Cultural Resource Program, would work to continue minimizing any adverse effects to negligible (Table 5-1).

Table 5-1. Mitigation Summary for MO1

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Water Quality	Region C: Moderate adverse effects from water temperatures can create increased algal growth due to high August water temperatures in the Lower Snake River Projects. This can be a public safety issue for water recreation.	On the Lower Snake River Increased harmful algal bloom monitoring at recreational areas; if algal blooms produce toxins, post public advisories at recreational areas with to protect the public.	Reduction of potential health impacts through public notification to reduce exposure would help to reduce effects to negligible.
Anadromous Fish	Regions C and D: Moderate adverse effect from increased spill levels, which create turbulence and eddies below the dams resulting in delays to adult passage.	Temporary extension of performance standard spill levels in coordination with the Regional Forum to assist fish migration.	Performance Standard Spill is effective in passing adult fish and delays in passage would be negated, resulting in negligible effects.
Resident Fish - ESA Kootenai River White Sturgeon	Region A: The current flow regime at Libby has made establishment of riparian vegetation difficult to sustain young stands of cottonwoods - major contributors to food web for Sturgeon. This results in moderate localized effects. While this MO would not exacerbate these effects above the No Action, it is an ongoing problem.	Plant 1-2 gallon cottonwoods near Bonners Ferry to improve habitat and floodplain connectivity, which would benefit ESA-Listed Kootenai River White Sturgeon by providing a food source. This would complement ongoing habitat actions already being taken in the region.	This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible.
Resident Fish – ESA Bull Trout	Region A: Drawdowns cause low water elevations at time of Bull Trout migration, which could make it difficult to enter spawning tributaries and make Bull Trout more susceptible to angling/predation. Negligible to Moderate adverse effect.	On the Hungry Horse Reservoir, install structural components like woody debris, and plant vegetation at the tributaries (Sullivan and Wheeler Creeks, possibly more) to stabilize channels, increase cover for migrating fish, and improve the varial zone.	Considering the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs and the proposed mitigation component, this would minimize any negative effects to negligible.
Resident Fish - Burbot, Kokanee, and Redband Rainbow Trout	Region B: Changes in elevation would leave current habitat dewatered and expose new potential areas appropriate for developing additional gravel spawning habitat.	Develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. Determine post-operations where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband rainbow trout to inform where mitigation is needed. Place appropriate gravel (spawning habitat) at locations up to 100 acres along reservoir and tributaries.	This action is in addition to the Bonneville program that addresses current habitat restoration in Lake Roosevelt and would compensate for additional effects of the new action. Exact sites and acreage would be determined post-alternative implementation.
Vegetation, Wildlife,	Region A and B: Exposure of mudflats and barren soils during the spring months could result in minor effects to native habitats by	In Region A, update and implement Invasive Plant Management Plan for the shoreline at	Recruitment of native plant communities in wetlands and

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Wetlands & Floodplains	establishment of non-native, invasive plant species.	Libby. Region B mitigation includes habitat for fish mitigation (see Resident Fish)	floodplains to preclude establishment of non-native plants.
Vegetation, Wildlife, Wetlands & Floodplains	Region A: Conversion of wetland to upland habitat in May through summer months (off-channel habitat) has adverse effects on wildlife phenology and fecundity (inverts, amphibian eggs, flycatchers, bats). Effects are minor and would occur seasonally.	On Kootenai River downstream of Libby: Plant native wetland and riparian vegetation up to ~100 acres along river.	This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible
Navigation & Transportation	Region B: Inchelium-Gifford Ferry (transportation for Tribal community of Inchelium) will go out of service for longer durations and isolate community members. This could be a moderate adverse effect that results in public safety concerns.	Extend the ramp at the Inchelium-Gifford Ferry on Lake Roosevelt so that it is available at lower water elevations.	Extending the ramp would eliminate additional effects to the community, potentially beneficial effect from the No Action condition. There would be no effects to public safety or environmental justice with this mitigation measure.
Cultural Resources	Region A and B: Major adverse effects from increase in number of acre-days that archaeological resources would be exposed.	Use the Cultural Resource Program funding for activities such as resource monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other alternative mitigation to address impacts to TCPs.	This mitigation measure, when considered with the existing FCRPS Cultural Resource Program in addition to this measure, would work to continue minimizing any negative effects to negligible.

5.4.2 Mitigation Measures Proposed for Multiple Objective Alternative 2

The mitigation measures proposed for MO2 address impacts to water quality, resident fish, vegetation, wildlife, wetlands, and floodplains, navigation and transportation, recreation, and cultural resources. These impacts are described fully in Chapter 3, Chapter 4, and Chapter 6. There would be no adverse impacts requiring additional mitigation for flood risk management, visual aesthetics, noise, or water supply, as there are no to negligible effects as compared to the No Action Alternative. Power and Transmission overall would experience major beneficial effects from MO2, and would not require mitigation for this resource. Impacts to cultural resources would be addressed by continuing to implement the existing Cultural Resource Program discussed in Section 5.2.1.6.

5.4.2.1 Water Quality

The co-lead agencies are proposing mitigation in Region A for MO2 for impacts to water quality. Effects to water quality in Regions B, C, and D are minor adverse effects that would not result in measurable differences to water quality within the study area. As a result, no additional mitigation is proposed in Region B, C, and D.

In Region A, the effects to water quality are negligible to minor adverse. The co-lead agencies propose to continue supplementing nutrients, nitrogen, and phosphorous at Libby and to initiate a similar nutrient supplementation program at Hungry Horse to aid in replacing primary and secondary biological productivity that result from reservoir drawdowns and higher flushing rates. A similar program is currently implemented at Dworshak with success, improving overall reservoir productivity. In addition to impacts to water quality, the benefits from this mitigation action would support resident fish populations, including ESA-listed bull trout. Monitoring and adaptive management actions would be necessary to ensure nutrients do not become imbalanced, which could lead to harmful algal blooms that dominate the system.

5.4.2.2 Anadromous Fish

The co-lead agencies are not proposing any mitigation measures in Regions A, B, C, or D to mitigate for impacts to anadromous fish. There are no anadromous fish above Chief Joseph Dam in Regions A and B. In Regions C and D, the measures implemented as part of MO2 could have minor beneficial to moderate adverse effects, predicated on the differing modeling results. Ongoing programs for anadromous fish in Regions B (below Chief Joseph dam), C, and D would continue, including habitat projects and fish hatchery programs for salmon and steelhead discussed above in Section 5.2.1.

5.4.2.3 Resident Fish

Under MO2, the co-lead agencies propose additional mitigation measures in Region A at Bonners Ferry, Idaho, and at tributaries on Hungry Horse Reservoir. In Region B, C, and D, the co-lead agencies do not expect a perceptible change to habitat conditions and measures would have negligible effects. No additional mitigation is proposed in Region B, C, and D. Ongoing programs for resident fish in Regions A, B, C, and D would continue, including projects and fish hatchery programs for westlope cutthroat trout, kokanee salmon and rainbow trout discussed above in Section 5.2.1.

In Region A, the co-lead agencies propose planting cottonwood trees at Bonner's Ferry, Idaho, similar to the proposal under MO1, to improve habitat and floodplain connectivity to benefit ESA-listed Kootenai River White Sturgeon and bull trout. Similar to the proposed mitigation for vegetation, wildlife, wetlands, and floodplains, expanding the quantity and distribution of wetland habitats and increasing floodplain connectivity along the Kootenai River could help address seasonal impacts at Bonners Ferry from the *December Libby Target Elevation* measure. High winter levels could decrease the recruitment and long-term survival of cottonwood trees adjacent to the river when seeds and saplings are swept downstream during winter flows. While implementation of this MO negligibly effects these resources relative to the No Action Alternative, the co-lead agencies propose to plant 1-2 gallon cottonwoods near Bonners Ferry to improve habitat and floodplain connectivity for the benefit ESA-Listed Kootenai River White Sturgeon by providing a food source. This would complement ongoing habitat actions already being taken in the region. This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would further minimize any negative effects.

Additional mitigation from the ongoing habitat programs carried out in the No Action Alternative proposed by the co-lead agencies to benefit bull trout includes installing structural components like woody debris and vegetation at the mouth of tributaries on the Hungry Horse Reservoir, such as Wounded Buck, Sullivan, Wheeler, and Bunker Creeks, to stabilize channels and increase cover for migrating fish. These actions would improve habitat conditions for bull trout and minimize impacts from fluctuating water levels on the Hungry Horse Reservoir. This mitigation action would also increase the survival of outmigrating juveniles and increase production of terrestrial and aquatic invertebrates. In addition, the construction of bank-channel habitat for juvenile bull trout on the Flathead River would help address impacts to fish and aquatic invertebrates from high winter flows out of Hungry Horse. These measures, when taken collectively across 15 tributaries in the Hungry Horse Reservoir, would help address impacts to ESA-listed bull trout caused by implementing MO2 at Hungry Horse. Considering the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs with this proposed mitigation component, adverse effects are anticipated to be reduced to negligible.

In Region B, the co-lead agencies would develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. The co-lead agencies propose to place appropriate gravel for spawning habitat at locations up to 100 acres along reservoir and tributaries. Prior to placement, the co-lead agencies would conduct site surveys post operations of alternative to determine where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband rainbow trout is needed for construction of spawning habitat. This would build on the 2019 program Bonneville funded, already in year one of a three year study to determine if modifications in Lake Roosevelt refill would impact resident fish access to spawning habitat.

5.4.2.4 Vegetation, Wildlife, Wetlands, and Floodplains

Under MO2, the co-lead agencies propose to implement additional mitigation measures in Region A to offset impacts to vegetation, wildlife, wetlands, and floodplains. No additional mitigation measures are proposed for Regions B, C, and D as the measures in MO2 would not result in measurable or perceptible changes to habitat conditions, and have negligible to minor effects. These negligible effects to vegetation, wildlife, wetlands, and floodplains do not warrant mitigation. However, ongoing actions for impacts to vegetation and wildlife in Regions A, B, C, and D would continue as under No Action Alternative, including protection and enhancement of wildlife habitat as described in Section 5.2.1.

In Region A, mitigation measures would help address impacts to vegetation and wildlife habitat from implementing the *December Libby Target Elevation* measure. This measure potentially decreases quality and quantity of wetland habitats in Libby and Hungry Horse Reservoirs by decreasing water surface elevations and increasing the establishment of invasive species by increasing the quantity and distribution of mudflats and duration of exposure. As a result of these changes, invasive species could spread and become established in new or larger areas throughout the reservoirs. To address this potential effect, the co-lead agencies would prepare invasive species and pest management plans where they do not currently exist or update the existing invasive species management plans and implement the plans where warranted.

Downstream of Libby Dam, lower water levels on the Kootenai River during the growing season would affect the quality and quantity of forested and scrub-shrub wetlands adjacent to the river. To help mitigate existing wetlands being converted to drier, upland habitat types, the co-lead agencies propose planting approximately 100 acres of forested and scrub-shrub wetland vegetation. This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible. This expansion of wetland habitats along the Kootenai River would also help ameliorate seasonal impacts at Bonners Ferry, Idaho.

5.4.2.5 Navigation and Transportation

The co-lead agencies are not proposing any mitigation measures in Regions A, C, and D under MO2 for navigation and transportation because the measures implemented as part of this alternative would have negligible effects on these resources.

Similar to MO1, the Inchelium-Gifford Ferry in Region B would go out of service for longer than the No Action Alternative durations when operational measures at Grand Coulee draft the reservoir deeper. To help ameliorate effects to the tribal community at Inchelium, including their ability to reach emergency and medical services and supplies, the co-lead agencies propose extending the ramp at the Inchelium-Gifford Ferry so that it is available at lower water elevations in Lake Roosevelt. This would reduce the effects to negligible effects, and may be moderately beneficial comparative when compared to the No Action Alternative.

5.4.2.6 Recreation

The co-lead agencies are not proposing any mitigation measures in Regions A, B, and D under MO2 for recreation as the measures implemented as part of this alternative would have negligible effects on this resource.

In Region C, the co-lead agencies propose mitigation to offset impacts to recreation at Dworshak State Park near Freeman Creek in Idaho. The *Slightly Deeper Draft for Hydropower* measure implemented under MO2 to increase flexibility in power generation would lower water levels in April when this park facility is used by hunters and sport fishers. The boat ramp becomes inaccessible at lower water levels in April at the beginning of turkey hunting season and bass fishing season. Terrain and road access make the Dworshak State Park one of the most heavily used boat ramps in the middle reservoir area outside of the traditional (i.e., summer and fall) recreation seasons. To offset these moderately adverse effects to recreational hunters and fishers, the co-lead agencies propose extending the boat ramp approximately 26 feet to maintain access to the reservoir during the early spring.

5.4.2.7 Cultural Resources

In Region A, B, and C, there could be moderate to major adverse effects to cultural resources from an increase in number of acre-days that archaeological resources would be exposed. Region A, B, and C the Cultural Resource Program funding would be increased for activities such as archeological site and traditional cultural property monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other alternative mitigation to address impacts to TCPs. This mitigation measure, when considered with the existing FCRPS Cultural Resource Program, would work to continue minimizing any negative effects to negligible (Table 5-2).

Table 5-2. Mitigation Summary of MO2

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Water Quality	Region A: At Hungry Horse, the drawdown in summer impacts primary and secondary biological productivity that result from reservoir drawdowns and higher flushing rates.	Initiate a nutrient supplementation program at Hungry Horse.	This measure would improve the food source and reduce adverse effects to negligible.
Resident Fish – ESA Kootenai River White Sturgeon	Region A: The current flow regime at Libby has made establishment of riparian vegetation difficult to sustain young stands of cottonwoods - major contributors to the food web for Sturgeon. This results in moderate localized adverse effects. While this MO would not exacerbate these impacts in the No Action, it is an ongoing problem.	Plant 1-2 gallon cottonwoods near Bonners Ferry to improve habitat and floodplain connectivity, which would benefit ESA-Listed Kootenai River White Sturgeon by providing a food source. This would complement ongoing habitat actions already being taken in the region.	This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible.
Resident Fish – ESA Bull Trout	Region A: Drawdowns cause low water elevations at time of Bull Trout migration, which could make it difficult to enter spawning tributaries and make Bull Trout more susceptible to angling/predation. Negligible to Moderate adverse impact.	On the Hungry Horse Reservoir, install structural components like woody debris, and plant vegetation at the tributaries (Sullivan and Wheeler Creeks, possibly more) to stabilize the channels, increase cover for migrating fish, and improve the varial zone.	This mitigation measure, when considered with the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs, minimizes any negative effects to negligible.
Resident Fish - Burbot, Kokanee, and Redband Rainbow Trout	Region B: Changes in elevation would leave current habitat dewatered and expose new potential areas appropriate for developing additional gravel spawning habitat.	Develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. Determine post-operations where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband rainbow trout to inform where mitigation is needed. Place appropriate gravel (spawning habitat) at locations up to 100 acres along reservoir and tributaries.	This action is in addition to the Bonneville program that addresses current habitat restoration in Lake Roosevelt and would compensate for additional effects of the new action. Exact acreage would be determined post-implementation.

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Vegetation, Wildlife, Wetlands & Floodplains	Region A: Conversion of wetland to upland habitat in May through summer months (off-channel habitat) has adverse effects on wildlife phenology and fecundity (inverts, amphibian eggs, flycatchers, bats). Effects are minor and would occur seasonally.	On Kootenai River downstream of Libby: Plant native wetland and riparian vegetation up to ~100 acres along river.	This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program would minimize any negative effects to negligible.
Vegetation, Wildlife, Wetlands & Floodplains	Region A and B: Exposure of mudflats and barren soils during the spring months could result in minor effects to native habitats by establishment of non-native, invasive plant species.	In Region A, update and implement Invasive Plant Management Plan for the shoreline at Libby. Region B mitigation includes habitat for fish mitigation (see Resident Fish).	Recruitment of native plant communities in wetlands and floodplains to preclude establishment of non-native plants.
Navigation & Transportation	Region B: Inchelium-Gifford Ferry (transportation for Tribal community of Inchelium) will go out of service for longer durations and isolate community members. This would be a moderate adverse effect that results in public safety concerns.	Extend the ramp at the Inchelium-Gifford Ferry on Lake Roosevelt so that it is available at lower water elevations.	Extending the ramp would eliminate additional effects to the community, potentially beneficial effect from the No Action condition. There would be no effects to public safety or environmental justice with this mitigation measure.
Recreation	Region C: Changes in water levels would make the Dworshak State Park (Freeman Creek) boat ramp inaccessible for 30 days in the month of April, the start of turkey hunting season and early bass fishing season. Because of the steep terrain and limited road access at Dworshak, this boat ramp is heavily used by recreators, especially hunters and fishermen, outside of the traditional recreation season. The alternative results in minor impacts to recreation.	Extend the boat ramp at Dworshak State Park (Freeman Creek) to make it accessible in April, when it is used by hunters and fishermen.	The extension of the Dworshak State Park boat ramp would eliminate the impact to boat ramp users.
Cultural Resources	Region A and B: Major adverse effects from increase in number of acre-days that archaeological resources would be exposed.	Region A, B, and C increase Cultural Resource Program funding for activities such as resource monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other mitigation to address impacts to TCPs.	This mitigation measure, when considered with the existing FCRPS Cultural Resource Program, in addition to this measure would work to continue minimizing any negative effects to negligible.

5.4.3 Mitigation Measures Proposed for Multiple Objective Alternative 3

The mitigation measures proposed for MO3 address impacts to water quality, anadromous and resident fish, vegetation, wildlife, wetlands, and floodplains, navigation and transportation, cultural resources and public safety. These effects are described fully in Chapter 3, Chapter 4, and Chapter 6. No mitigation is proposed for flood risk management or noise, as effects are negligible. While effects to power and transmission, water supply and navigation are major adverse effects, no feasible mitigation has been identified. In some cases, mitigation can be completed by public and private entities. Recreation would major adverse effects; however change in types of usage would alleviate some of these effects. Cultural resources in Region C would experience a major adverse effect. In Region D, mitigation is proposed using the existing PA; however, a new programmatic agreement with Tribes would be required to carry out 106 responsibilities on the lower Snake River properties in the interim, until such a time that the deauthorized project lands are transferred to new ownership. These real-estate transactions would require their own review and are outside the scope of this EIS. They would be initiated concurrent with the engineering and design work for implementing the breaching actions.

5.4.3.1 Water Quality

The co-lead agencies are not proposing any mitigation measures in Regions A, B, or D to mitigate for impacts under MO3 for impacts to water quality because the measures implemented as part of this alternative would have negligible effects, the severity of impact is low, and the effect would occur infrequently. Several mitigation actions would be taken by the co-lead agencies to further define sediment and dissolved oxygen effects in Region C for the time of dam removal and up to 7 years while the system flushes sediments and stabilizes. A few additional mitigation actions are recommended to be taken by other entities prior to breaching actions, as described below.

Because of limited data to determine the exact magnitude of water quality impacts from breaching the dams on the lower Snake River, effects in Chapter 3 are described as a range from low to most severe anticipated scenarios. If MO3 is selected for implementation, additional data collection and monitoring would be required during engineering and detailed project design, including sediment sampling and analysis to determine sediment oxygen demand, monitoring of the bio-accumulation of contaminants in sediment and fish tissues, and any potential hazard for human health. The co-leads would conduct these studies to investigate more accurately the impacts of water quality and specifically, dissolved oxygen to aquatic organisms and fish. The co-lead agencies would coordinate with state and Federal resource agencies to determine the best way to minimize any impacts to water quality. Some potential options could include aeration, dilution from upstream sources (e.g., the North Fork Clearwater River), or chemical treatment (e.g., peroxide dosing). During the design phase, timing of the dam breaching would be coordinated with the U.S. Fish and Wildlife Service and NMFS, and other regulatory agencies, to determine the appropriate work window to minimize construction-related effects for water quality and fish. If necessary, a tiered NEPA document would be prepared to disclose any impacts not contained within this EIS and site-specific impacts associated with the construction (removal) of the dam infrastructure.

Additionally, several mitigation actions are recommended to be carried out by others with responsibilities and authorities to remediate contaminated sediments and ground water. These contaminants are not caused by the actions taken by the co-lead agencies, but could be mobilized by implementing MO3. The co-lead agencies identified the potential re-suspension of contaminated sediments in Region C that contain bioaccumulative compounds such as dioxins, pesticides, mercury, and others. The suspension and downstream deposition of contaminated sediments could expose fish and invertebrate populations to new, higher levels of contaminants for several years following implementation. The co-lead agencies do not have authorities for removing in-stream contaminated sediments, and have not identified a feasible way to avoid mobilization. To offset this impact and any associated impacts to bioaccumulation in fish and other aquatic species, other entities could remove or cap contaminated sediment "hot spots" in lower Snake River prior to implementing the *Breach Snake Embankments* measure.

In addition to contaminated sediments, the co-lead agencies identified there would be effects to groundwater flows from changes in river flow and substantial decreases in reservoir elevations in Region C. Combined, this could cause movement from polluted sources of groundwater near Lewiston, Idaho. The movement of groundwater could pollute neighboring systems and potentially enter the lower Snake River. If this is selected as the Preferred Alternative, prior to implementing the *Breach Snake Embankments* measure, the co-lead agencies would recommend responsible entities of contaminated groundwater sources provide the following one or more mitigation measures: installing groundwater cutoff walls or treatment curtains along areas of known groundwater contamination, pumping and treating groundwater to prevent flows from entering the river, and/or remediating known contamination areas. Additional actions include redefining National Pollutant Discharge Elimination System permits. Containing or remediating contaminated groundwater areas would reduce polluted inputs into lower Snake River following implementation of MO3, and any associated impacts to fish and other aquatics, wildlife, and public safety.

5.4.3.2 Anadromous Fish

The co-lead agencies are not proposing any mitigation measures in Regions A or B for impacts to anadromous fish because there are no anadromous fish in Regions A or B. As described below, mitigation measures are proposed for Regions C for MO3 for short-term impacts. Monitoring for real time operations adjustments is proposed in Region D because for minor effects to anadromous fish in this region. Ongoing actions for impacts to anadromous fish in Regions B (below Chief Joseph Dam), C and D would continue as under No Action Alternative, including habitat and hatchery projects as described in Section 5.2.1.

In Region C, the co-lead agencies propose constructing a new trap and haul facility at McNary and conduct at least two years of trap-and-haul operations for Snake River fish (Chinook salmon, Sockeye, Steelhead) to allow removal and transport of these fish from the lower Snake

River prior to implementing the *Breach Snake Embankments* measure. Removing the dam embankments would result in temporary however major adverse effects to water quality, including high levels of turbidity and suspended sediments between Lower Granite and Ice Harbor. Fish collected at trap and haul facilities would be transported by truck to a release point upstream of the affected area. While the effect of this mitigation measures does not offset the impact of degraded water quality conditions that directly impact in-river survival of fish during the initial phase of implementation, or aid other non-listed fish or aquatic organisms adversely affected by MO3, the mitigation measure reduces the number of targeted fish impacted by the alternative.

Additionally, the co-lead agencies propose raising additional hatchery fish to offset two lost year classes prior to start of breach on the Lower Snake River. The timing of dam breaching would occur during migration for Snake River Chinook, upper Columbia River fall Chinook, and upper Snake River sockeye, which could result in the mortality of 20 to 40 percent of these populations. Low concentrations of dissolved oxygen would impact survival of fish at Little Goose and Lower Monumental during the first phase of demolition, potentially removing an entire generation or year class of migrating Snake River fall Chinook and upper Snake River sockeye from the system. These additional hatchery fish should provide a safety replacement of those populations potentially adversely affected during the short-term construction.

In Region D, concentrations of TDG could increase as a result of spill measures implemented as part of MO3. If it is observed that conditions in the tailrace are impeding upstream passage of adult salmon and steelhead or actionable TDG impacts to fish are observed, the co-lead agencies would implement performance standard spill operations until the situation is remedied. These real-time decisions are made in the Regional Forum. These operations are of short duration, as needed, to resolve the passage issues.

5.4.3.3 Resident Fish

Under MO3, the co-lead agencies propose mitigation measures in Region A at Bonners Ferry, Idaho along the Kootenai River and at Hungry Horse. In Region B, mitigation is proposed in Lake Roosevelt. In Region C, mitigation for impacts to fish access to mouths of Tucannon Tributary due to short-term impacts to both resident and anadromous species is proposed. No mitigation is proposed in Region D because implementing MO3 results in minor effects to resources, and the effect does not rise to the level of severity warranting mitigation. Ongoing actions as described in Section 5.2.1 for resident fish, such as bull trout and sturgeon in Regions A, B, C, and D, would continue.

In Region A, the co-lead agencies propose actions similar to the proposed mitigation measures for MO1 and MO2. Specifically, planting cottonwoods along the Kootenai River at Bonners Ferry would mitigate adverse effects to ESA-listed Kootenai River white sturgeon from the loss of wetland habitat and floodplain connectivity. In addition, installing structural components like woody debris and planting vegetation around the upper 10 feet of the reservoir and at the mouths of spawning tributaries would stabilize the channels, increase cover for migrating fish, and improve habitat conditions to offset impacts to resident fish, including ESA-listed bull trout, from reservoir fluctuations, seasonal drawdowns, and fewer days at full pool, which collectively result in a reduction in habitat quality and benthic productivity supporting the food web at Hungry Horse. This mitigation measure, when added with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any adverse effects to negligible.

To offset effects to bull trout in the Hungry Horse Reservoir, the co-lead agencies propose a mitigation measure to improve habitat conditions for bull trout. MO3 lowers water surface elevations in the reservoir and increases summer outflows. As reservoir elevations decline, fish passage conditions at the mouth of spawning tributaries prohibit fish migration into spawning tributaries. Under these conditions, bull trout are more susceptible to angling and predation pressures due to a lack of sufficient cover while they hold until conditions are passable. This also causes delays in migration which result in an overall decrease in productivity. To mitigate these effects, the co-lead agencies propose installing structural components like woody debris and vegetation at the mouth of tributaries, such as Wounded Buck, Sullivan, Wheeler, and Bunker Creeks, to stabilize channels and increase cover for migrating fish. These actions would improve habitat conditions for bull trout and minimize impacts from fluctuating water levels on the reservoir. This mitigation action could also increase the survival of outmigrating juveniles and increase production of terrestrial and aquatic invertebrates. Considering the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs with this proposed mitigation component, adverse effects are anticipated to be reduced to negligible.

In Region B, the co-lead agencies would develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. The co-lead agencies propose to place appropriate gravel for spawning habitat at locations up to 100 acres along reservoir and tributaries. Prior to placement, the co-lead agencies would conduct site surveys post operations of the alternative implementation to determine where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband rainbow trout is needed for construction of spawning habitat. This would build on the 2019 program Bonneville funded, already in year one of a three year study to determine if modifications in Lake Roosevelt refill would affect resident fish access to spawning habitat.

In Region C, the co-lead agencies propose modifying the channel at the mouth of the Tucannon River, a tributary of the Snake River, to offset adverse impacts to upstream fish passage following implementation of the *Breach Snake Embankments* measure. Implementing this measure, in associated with other measures in MO3, would disconnect the Tucannon River from the Snake River until high flows create a stable, fish passable channel for bull trout. To mitigate for this temporary loss of connectivity, the co-lead agencies propose constructing a channel to support year-round connectivity at the confluence of the two rivers during bull trout migration.

Prior to implementing the *Breach Snake Embankments* measure, the co-lead agencies propose mitigating effects to bull trout and white sturgeon on the Snake River from a temporary adverse effect, but with long-lasting consequences. MO3 would reduce forage fish and invertebrates resulting from poor water quality during and immediately after dam breaching. Dam breaching would create lethal concentrations of suspended sediments, turbidity, and low dissolved oxygen between Lower Granite and Ice Harbor, resulting in widespread loss of white sturgeon, the forage fish they feed on, and other aquatic organisms. To mitigate for these effects to white sturgeon, the sturgeon would be trapped in the lower Snake River and relocated upriver to Hells Canyon or locations below McNary on the Columbia River. For avoiding adverse effects to bull trout, their abundance in the lower Snake River is low after fall migration. Implementation of the *Breach Snake Embankments* measure would be coordinated to occur during low water conditions in the fall and winter to minimize adverse effects to this species.

5.4.3.4 Vegetation, Wildlife, Wetlands, and Floodplains

Under MO3, the co-lead agencies propose to implement mitigation measures in Regions A, C, and D to offset adverse effects to vegetation, wildlife, wetlands, and floodplains. No mitigation measures are proposed for Region B because implementing measures associated with MO3 would result in negligible impacts to these resources. In Region A, the *December Libby Target Elevation*, *Modified Draft at Libby*, and *Sliding Scale at Libby and Hungry Horse* measures affect seasonal water surface elevations. In Regions C and D, the *Breach Snake Embankments* and *Increased Forebay Range Flexibility* measures influence water surface elevations and result in changes to vegetation and habitat conditions. Many of the major adverse effects are short-term, with long-term negligible effects to both major beneficial and major adverse effects in Region C. Ongoing actions for impacts to vegetation and wildlife in Regions A, B, C, and D would continue as under No Action Alternative, including protection and enhancement of wildlife habitat as described in Section 5.2.1.

In Region A, mitigation measures would mitigate effects to vegetation and wildlife habitat from implementing the *December Libby Target Elevation* measure. This measure potentially decreases quality and quantity of wetland habitats in Libby by decreasing water surface elevations and increasing the establishment of invasive species by increasing the quantity and distribution of mudflats and duration of exposure. As a result of these changes, invasive species could spread and become established in new or larger areas throughout the reservoir. To address this potential effect, the co-lead agencies would prepare invasive species and pest management plans where they do not currently exist or update the existing invasive species management plans and implement the plans where warranted.

The *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures would result in a conversion of wetland habitats to upland habitats along the Kootenai River from a seasonal decrease in water surface elevations. To offset this impact, the co-lead agencies propose planting approximately 100 acres of native wetland vegetation along the Kootenai River to restore wetland habitats similar to the proposals described under MO1.

Breaching the four lower Snake River dams would significantly decrease water surface elevations on the lower Snake River, as well as mobilize sediments to deposit in downstream portions of the river channel and along the shoreline. These actions would have a major adverse effect to existing upland, wetland, and aquatic vegetation, reducing the quality, quantity, and distribution of habitats in Region C. To offset these effects, mitigation proposed would be to replant approximately 13,000 acres of arid, upland native vegetation on newly exposed soils and approximately 1,500 acres of emergent and forested, scrub-shrub wetland habitat adjacent to the new surface elevations of the lower Snake River.

Additionally, in Region D the co-lead agencies propose approximately 155 acres of emergent and forested scrub-shrub wetland habitats on the Columbia River downstream of the confluence with the Snake River would be planted to comply with CWA regulations. On the 155 acres, newly deposited sediments would be excavated to maintain the hydrologic conditions necessary to support wetland habitats. Twenty-three of the 155 acres would be planted with wetland vegetation. For consideration of mitigation to cultural resources, the planting plans would be developed to incorporate proposed tule (*Schoenoplectus acutus*) restoration and other culturally significant vegetation. The plant list used for restoration activities would be the existing list developed through coordination with regional tribes under the existing Cultural Resource Program.

5.4.3.5 Navigation and Transportation

MO3 would result in moderate to major effects to navigation and transportation in Regions B and C.

In Region B, the Inchelium-Gifford Ferry would be out of service two additional days in the wet years than the No Action Alternative. While this is a minor change, limiting access to medical and emergency service is a significant risk. The co-lead agencies propose extending the ramp at the Inchelium-Gifford Ferry to provide service at lower water elevations on Lake Roosevelt, similar to what is proposed for MO1 and MO2.

In Region C, MO3 would result in a complete loss of commercial navigation on the lower Snake River. Conditions on the lower Snake River after implementing the *Breach Snake Embankments* measure would not support commercial navigation, and could not be feasibly mitigated. Other entities could take actions and/or build infrastructure to change their transportation modes or connect to the navigation system at a different point on the river.

In Region D, at the confluence of the lower Snake River as described in the River Mechanics Section 3.3.3.5, there would be increased sediment passing from the lower Snake River into the Columbia River. During the two year construction period, beginning with breaching and drawdown of the upper two projects, modeling indicates that sediment volumes and concentrations passing out of the lower Snake River would be elevated immediately following draw-down, and for the two years that follow as the system transitions from reservoirs to run of river. After the near-term period, there would be an estimated period of two to seven years where lower Snake River would continue moving higher volumes of sediment. Over the long-term the lower Snake River is expected to eventually reach a new quasi-equilibrium condition and largely pass incoming sediment loads. This sediment load will cause a short term major adverse effect to the navigation channel.

Based upon these changing sediment patterns and timing, dredging operations within the McNary pool (Wallulla Reservoir) and at the confluence of the lower Snake River would need to increase substantially to keep the channel operational. . Sediment relocation and deposition is expected to occur within the federal navigation channel and on the left bank of Lake Wallulla. The mitigation proposal is to dredge to maintain this reach of the federal navigation channel. Likewise, public and private port facilities both near the confluence of the lower Snake River and on the left bank of Lake Wallula would need to conduct sequential dredging in order to avoid interruptions in service and maintain access to the navigation channel. Dredging mitigation for maintaining the federal navigation channel would be a Corps expense, while dredging to maintain port facilities and access to the federal navigation channel would not.

Dredging operations are expected to remain similar to No Action in the remaining reach of the Columbia navigation channel.

NON-FEDERAL TRANSPORTATION INFRASTRUCTURE

In evaluating the feasibility of implementing MO3 and breaching the four dams on the lower Snake River, the co-lead agencies also evaluated impacts to transportation infrastructure not associated with the Federal projects, but crucial infrastructure for the region. The following is a brief description of additional actions that would be needed to mitigate effects on regional transportation infrastructure.

Bridge piers on the lower Snake River would experience a permanent change in water velocity, and higher seasonal flows would increase scour and cause erosion around bridge piers. The co-lead agencies propose armoring piers of up to 25 bridges to protect them from increased erosion due to the *Breach Snake Embankments* measure.

In addition to bridge piers, approximately 80 miles of railroad and highway embankments would need to be armored to protect them from erosion resulting from higher water velocities and higher flows through existing drainage structures and culverts. Of the 80 miles identified, approximately 45 miles are constructed of engineered fill which would be exposed to river flows at lower river elevations. These locations are the highest risk for failure, posing a risk to public safety, and would require additional evaluation to identify the appropriate modification to maintain stability.

5.4.3.6 Recreation

Although moderate effects are anticipated to recreation resources in Region C, the co-lead agencies are not proposing any mitigation for recreation with implementation of MO3. In Regions A, B, and most of D, measures implemented as part of this alternative would have negligible effects on this recreational resource and no mitigation is warranted.

In Region C and upper reach of Region D, major adverse effects to water based recreation and water accessibility would occur. Existing recreational activities in the lower Snake River would transition from lake to river recreation following implementation of the *Breach Snake Embankments* measure under MO3. As a result of this measure, water surface elevations on the lower Snake River and extending into the Columbia River confluence would drop significantly, disconnecting boat ramps from the river at Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. Sediment deposition in the lower portion McNary Reservoir would decrease accessibility to existing marinas, parks, and access channels in Lake Wallula. While overall beneficial effects would occur for those activities related to river and faster flowing water-activities, reservoir-type activities would cease. The major adverse effects to recreation are from lack of boat ramps accessibility from federal lands. The co-lead agencies would no longer operate project lands for recreation after the projects are de-authorized. Recreational sites could be modified in the future as project land is transferred through real estate actions. In other areas below Ice Harbor bordering the Region C and D, local entities could extend public boat ramps to maintain water accessibility.

5.4.3.7 Water Supply

In Region C, and potentially Region D around the confluence of the lower Snake River, MO3 would have adverse effects to incidental irrigation. Currently and in the No Action Alternative, water is available from the pools of these facilities and from groundwater that results from the pools. The pumps that supply this water would no longer be operational once the dams were breached. The effect is nearby groundwater elevations could be substantially impacted. Additionally, M&I pumps in the Lewiston area would also likely be adversely effected, along with other small M&I uses along the river, as groundwater would have the potential to drop by the entire height of the dams, i.e., up to 100 feet. This would affect all well users in the region. Chapter 3 analyzes the social and economic effects of implementing this measure. The co-lead agencies would not mitigate for these impacts to water users. However, private and public entities could extend intake pumps, ground water wells, or other infrastructure. .

5.4.3.8 Cultural Resources

In Region A, there is a moderate to major adverse effects to cultural resources from an increase in number of acre-days that archaeological resources would be exposed. In Region A, an increase Cultural Resources Program funding for activities such as archeological site and traditional cultural property monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other mitigation is proposed to address impacts to TCPs. This mitigation measure, when considered with the existing FCRPS Cultural Resource Program, would work to continue minimizing any negative effects to negligible.

In Regions B, no additional mitigation, as compared to the No Action Alternative, is proposed and the existing Cultural Resource Program and System-wide PA would continue to be implemented.

In Region C, there would be major adverse effects to cultural resources due to an extensive increase in the archeological resources that would be exposed as part of dam breaching. Following implementation of the *Breach Snake Embankments* measure, over 350 known cultural resources would be exposed or accessible after the reservoirs on the lower Snake River are drawn down. The scale of protecting and monitoring these sites, as well as recovering data, would exceed the existing Cultural Resource Program. Given this, the co-lead agencies would prepare and implement a new programmatic agreement to avoid, minimize, and mitigate impacts to these locations, sites, and resources.

Mitigation specific to dam breaching would include law enforcement patrols of exposed areas along 150 river miles to deter looting until vegetation is re-established, reseeding 14,000 acres with native species, irrigation to stimulate plant growth in 10 locations, archaeological monitoring of exposed sites to identify issues that need quick remediation, and conducting Section 106 of the NHPA compliance activities. The new PA would cover activities for an interim period, up to ten years for cultural resource management, until federal properties are disposed.

Additional mitigation measures proposed in Region C include implementing the Historic American Building Survey and Historic American Engineering Record programs to document historic places, infrastructure, and landscape features prior to implementation of MO3 measures associated with dam breaching. During dam breach, security fencing and signs would be installed to prevent access, a public outreach campaign would be developed and implemented to document and excavate exposed sites that are in danger of loss, and collect artifacts for museum curation or repatriation to Tribes under NAGPRA.

In Region D, sediment deposition along the shorelines of the Columbia River in the McNary Reservoir would affect the distribution of wetland plant communities critical to traditional cultural practices. For example, tule plant communities in Lake Wallula would be buried due to sediment deposition following breach of Ice Harbor Dam. This cultural resource would be unavailable in Lake Wallula for several years until vegetation is reestablished following implementation of MO3. The co-lead agencies propose implementing mitigation measures consistent with the existing Cultural Resource Program to restore tule habitat at alternate sites in Region D as described in the vegetation, wildlife, wetlands, and floodplains section above.

5.4.3.9 Public Safety

In evaluating the feasibility of implementing MO3 and breaching the four dams on the lower Snake River, the co-lead agencies identified additional actions to maintain safety that would be needed to mitigate effects from changes in river conditions with implementing the *Breach Snake Embankments* measure. In Region C, gas lines that cross the Snake River near Lyons Ferry would need to be modified to withstand the higher velocities and scour due to breach. The co-lead agencies would coordinate these modifications prior to implementing the MO3 breach (Table 5-3).

Table 5-3. Mitigation Summary of MO3

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Anadromous Fish	Regions D: Moderate adverse effect from increased spill levels, which create turbulence and eddies below the dams resulting in delays to adult passage.	Temporary extension of performance standard spill levels in coordination with the Regional Forum	Performance Standard Spill is effective in passing adult fish and delays in passage would be negated, resulting in negligible effects.
Anadromous Fish	Region C: Breaching the lower Snake River dams would have major short-term adverse effects. Breaching would create lethal river conditions (turbidity and suspended sediment, low dissolved oxygen) which would cause major effects to Snake River anadromous fish populations in the short-term.	Construct a trap-and-haul facility at McNary and conduct at least two years of trap-and-haul operations for Snake River fish (Chinook salmon, Sockeye, Steelhead) to allow removal and transport of these fish from the lower Snake River prior to breaching.	Trapping and transport of affected fish populations would lower effects to the Snake River anadromous fish populations. When implemented with other anadromous fish mitigation measures for MO3, this action would contribute to lowering impacts from major to minor.
Anadromous Fish	Region C: Breaching the lower Snake River dams would create major adverse short-term effects from high levels of turbidity/suspended sediment from Lower Granite Dam to Ice Harbor Dam during fall fish migration. This could result in mortality of 20-40% of the populations. Very low dissolved oxygen levels caused by dam breaching would result in fish mortality in the lower Snake River, with considerable impacts to year class of fall migrating fish.	Raise additional hatchery fish to help to address two lost year classes of anadromous fish, prior to the initiation of each phase of breaching (2 phases) of the lower Snake River dams.	Raising additional hatchery fish would help to lower the negative impacts of dam breaching to lower Snake River anadromous fish populations. When implemented with other anadromous fish mitigation measures for MO3, this action would contribute to lowering impacts from major adverse effect to minor adverse effect.
Resident Fish – ESA Kootenai River White Sturgeon	Region A: The current flow regime at Libby has made establishment of riparian vegetation difficult to sustain young stands of cottonwoods - major contributors to food web for Sturgeon. This results in moderate localized adverse effects. While this MO would not exacerbate these effects in the No Action, it is an ongoing problem.	Plant 1-2 gallon cottonwoods near Bonners Ferry to improve habitat and floodplain connectivity, which would benefit ESA-Listed Kootenai River White Sturgeon by providing a food source. This would complement ongoing habitat actions already being taken in the region.	This mitigation measure, when considered with the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible.
Resident Fish – ESA Bull Trout	Region A: Drawdowns cause low water elevations at time of Bull Trout migration, which could make it difficult to enter spawning tributaries and make	On the Hungry Horse Reservoir install structural components like woody debris, and plant vegetation at the tributaries (Sullivan and Wheeler Creeks, possibly	This mitigation measure, when considered with the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
	Bull Trout more susceptible to angling/predation. Negligible to Moderate adverse impact.	more) to stabilize the channels, increase cover for migrating fish, and improve the varial zone.	of Montana programs, minimizes any negative effects to negligible.
Resident Fish - Burbot, Kokanee, and Redband Rainbow Trout	Region B: Changes in elevation would leave current habitat dewatered and expose new potential areas appropriate for developing additional gravel spawning habitat.	Develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. Determine post-operations where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband rainbow trout to inform where mitigation is needed. Place appropriate gravel (spawning habitat) at locations up to 100 acres along reservoir and tributaries.	This action is in addition to the Bonneville program that addresses current habitat restoration in Lake Roosevelt and would compensate for additional effects of the new action. Exact acreage would be determined post-implementation.
Resident & Anadromous Fish	Region C: Breaching the lower Snake River Dams would result in major short-term adverse effects from reservoir drawdown. These conditions could make the Tucannon River (a tributary of the Snake River) delta inaccessible to Bull Trout, salmon and steelhead, inhibiting their access to spawning habitat.	Modify the Tucannon River channel at the delta to allow bull trout, salmon, and steelhead passage after Snake River water elevations decrease from breaching.	This mitigation measure would provide access to the Tucannon River and could reduce and minimize anticipated adverse short-term effects from major to minor for Tucannon River populations.
Resident Fish – White Sturgeon	Region C: Breaching the lower Snake River dams would create major adverse short-term effects from high levels of turbidity/suspended and very low dissolved oxygen levels in the river. This could result in mortality for sturgeon and the forage fish they feed on. Although sturgeon are not ESA-listed, they are important to regional tribes and sport fishers.	On the Snake River, trap –and-haul White Sturgeon from impacted areas prior to dam breaching. Relocate trapped sturgeon to locations in Hells Canyon on the Snake River, and downstream of McNary project on the Columbia River.	Relocation of White Sturgeon from the lower Snake River prior to breaching could lower impacts of breaching to the overall population, and moving effects from major to minor.
Vegetation, Wildlife, Wetlands & Floodplains	Region A: Operations at Libby Dam will affect wetland vegetation along the Kootenai River and could cause conversion of wetland habitat to upland habitat. This could cause impact to wildlife. Moderate adverse effects would occur seasonally.	On Kootenai River downstream of Libby: Plant native wetland and riparian vegetation up to ~100 acres along river.	Considering the existing Bonneville-funded Kootenai River Habitat Restoration Program, would minimize any negative effects to negligible.

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Vegetation, Wildlife, Wetlands & Floodplains	Region A: Exposure of mudflats and barren soils could result in establishment of non-native, invasive plant species, a moderate, adverse effect.	Update and implement the existing Invasive Plant Management Plan at Libby to prevent establishment of invasive plant species.	Implementation of this mitigation measure would minimize adverse effects from moderate to negligible.
Vegetation, Wildlife, Wetlands & Floodplains	Region C: Lowering of the water table associated with breaching could have a major adverse effect by conversion of plant communities to non-native, invasive plant communities.	Develop and implement a planting plan to restore arid, native plant communities on approximately 13,000 acres of lands along the lower Snake River.	Implementation of this measure to restore native plant communities would reduce major adverse effects to minor to negligible.
Vegetation, Wildlife, Wetlands & Floodplains	Region C: Breaching the lower Snake River dams would expose approximately 13,800 acres of shoreline, creating major negative effects to wetland and riparian plant communities.	Develop and implement a planting plan for approximately 1500 acres of wetland and riparian species along the exposed shorelines.	Implementation of this measure to restore native plant communities would reduce major adverse effects to minor to negligible.
Vegetation, Wildlife, Wetlands & Floodplains	Region C: Breaching the lower Snake River dams would result in sediment deposition, causing major adverse impacts for wetlands downstream of Ice Harbor dam.	Develop and implement a restoration plan for approximately 155 acres of wetlands downstream of Ice Harbor. The plan may include excavation of sediments deposited after breaching.	Implementation of this measure to restore native plant communities would reduce major adverse effects to minor to negligible.
Navigation & Transportation	Region B: Inchelium-Gifford Ferry (transportation for Tribal community of Inchelium) will go out of service for longer durations and isolate community members. This would be a moderate adverse effect that results in public safety concerns.	Extend the ramp at the Inchelium-Gifford Ferry on Lake Roosevelt so that it is available at lower water elevations.	Extending the ramp would eliminate additional effects to the community, potentially beneficial effect from the No Action condition. There would be no effects to public safety or environmental justice with this mitigation measure.

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Navigation & Transportation	Region C: Breaching the lower Snake River Dams would result in higher water velocities, increasing scour around bridge piers and creating a major adverse effect to transportation and public safety.	Armor piers of up to 25 bridges to protect them from erosion caused by higher velocity flows in the river after breaching.	Armoring bridge piers would reduce the effects from higher water velocities from major adverse effect to negligible.
Navigation & Transportation	Region C: Breaching the lower Snake River dams will result in higher water velocities in the river, increasing erosion of road and railroad embankments and higher flows through drainage structures and culverts, creating a major adverse effect to transportation and public safety.	Armor approximately 80 miles of railroad and highway embankments previously designed or constructed by the Corps to protect them from erosion caused by the breaching measure.	Armoring road and railroad embankments would reduce the effects to public safety and transportation infrastructure from higher water velocities from major adverse effect to negligible.
Navigation & Transportation	Region D: At the breaching of the lower Snake River dams would cause sediment to deposit in the federal navigation channel in the lower Snake River near the confluence with the Columbia River in the upper part of McNary Reservoir.	At the confluence of the lower Snake River in Region D the Corps would dredge the Federal navigation channel post breaching and until the river equilibrium is achieved, as needed, to maintain the federal channel.	With a series of dredging actions, the effects to the federal channel in Region D should be minimized to negligible.
Cultural Resources	Region A and B: Major adverse effects from increase in number of acre-days that archaeological resources would be exposed.	In Region A and B, an increase to the Cultural Resource Program funding for activities such as resource monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other mitigation to address impacts to TCPs.	This mitigation measure, when considered with the existing FCRPS Cultural Resource Program, in addition to this measure would work to continue minimizing any negative effects to negligible.

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Cultural Resources	Region C: Drawdown of the reservoirs on the lower Snake River caused by dam breaching would result in the exposure of over 350 known cultural resources.	Develop a new Programmatic Agreement under the existing FCRPS Cultural Resource Program for cultural resources exposed in the four reservoir areas.	Implementation of this measure would help to reduce major adverse effects to minor effects.
Public Safety	Region C: Breaching the lower Snake River dams would create high water velocities that could increase scour conditions that would damage existing gas pipelines that cross the lower Snake River near Lyons Ferry. This could cause a major adverse effect to utilities, contribute to an interruption in service, and pose public safety effects.	After breaching the lower Snake River dams, the gas lines would need to be modified to withstand the velocities due to breach.	Implementation of this measure would reduce the effects from higher water velocities from major adverse effect to negligible and maintain utility and public safety.

5.4.4 Mitigation Measures for Multiple Objective Alternative 4

The mitigation measures proposed for MO4 address impacts to water quality, anadromous and resident fish, vegetation, wildlife, wetlands, and floodplains, and navigation and transportation. There would be no mitigation proposed for flood risk management, water supply, noise, or visual, as these effects are minor adverse to negligible. While power and transmission would experience a major adverse effect, no feasible mitigation has been identified. Mitigation considerations for power and transmission are discussed within Chapter 3 - Power and Transmission section. Effects are fully described in Chapter 3, Chapter 4, and Chapter 6. For MO4, effects to cultural resources would be addressed by continuing to implement the existing Cultural Resource Program discussed in Section 5.2.1.6.

5.4.4.1 Water Quality

In MO4, the co-lead agencies are only proposing additional mitigation for water quality in Region A. In Region B, the measures cause negligible effects. In Regions C and D implementation of measures would have negligible to major adverse effect to elevation in TDG, which would have mitigation under anadromous fish. The co-lead agencies would need to comply with updated water quality standards under the CWA.

In Region A, the effects to water quality are negligible to minor. However, the co-lead agencies propose to continue supplementing nutrients, nitrogen, and phosphorous at Libby and initiate a similar nutrient supplementation program at Hungry Horse to offset impacts to primary and secondary biological productivity that result from reservoir drawdowns and higher flushing rates similar to MO2.

Mitigation is also proposed at Albeni Falls to offset impacts from the *McNary Flow Target* measure, which results in warmer water temperatures that support increased growth of macrophytes or other aquatic plants (e.g., Eurasian water milfoil [*Myriophyllum spicata*]). Increased macrophyte density decreases overall water quality, habitat quality, and inhibits accessibility for recreation. The co-lead agencies propose implementing and expanding an existing invasive aquatic plan removal program to offset impacts to water quality, wildlife habitat, and recreation.

5.4.4.2 Anadromous Fish

The co-lead agencies are not proposing any mitigation measures in Regions A or B for impacts to anadromous fish because there are no anadromous fish in these regions. Effects to fish in Region C and D varies from minor adverse effects to major beneficial effect, depending on the species and the predictions of separate models. Additional mitigation measures are proposed for Regions C and D for MO4. Ongoing actions for impacts to anadromous fish in Regions B (below Chief Joseph Dam), C and D would continue as under No Action Alternative, including habitat and hatchery projects as described in Section 5.2.1.

Similar to MO1, in Region C and D, concentrations of TDG increase as a result of the juvenile spill passage measures implemented as part of MO1. To limit increased TDG concentrations and adverse effects to anadromous fish during upstream passage, the co-lead agencies propose implementing performance spill operations consistent with the No Action Alternative to increase upstream passage opportunities for adult salmon and steelhead. If it is observed that conditions in the tailrace are impeding upstream passage of adult salmon and steelhead or actionable TDG impacts to fish are observed, the co-lead agencies would implement performance standard spill operations until the situation is remedied. These real-time decisions are made in the Regional Forum. These operations are of short duration, as needed, to resolve the passage issues.

An additional mitigation action in Region C is a proposed to modify the raceway at Little Goose dam to reduce TDG concentrations. Incorporate infrastructure that promotes water de-gassing decreases TDG exposure during fish collection for juvenile salmon and steelhead. As a result of this action, fish would be transported in water with lower TDG compared to river conditions, mitigating adverse effects associated with spill operations, and increasing overall survival for fish throughout the lower Columbia and Snake Rivers.

5.4.4.3 Resident Fish

Under MO4, the co-lead agencies propose mitigation measures in Regions A, B, and C. No additional mitigation is proposed in Region D as implementing MO4 results in minor effects that do not rise to the level of severity warranting mitigation. Ongoing actions as described in Section 5.2.1 for resident fish, such as bull trout and sturgeon in Regions A, B, C, and D, would continue. Implementing MO4 would results in increased outflows from the Hungry Horse Reservoir which reduces the availability of zooplankton, phytoplankton, and other aquatic invertebrates for bull trout in late summer. Additionally, in MO4, the impact from the McNary Flow Target measure on food resources for bull trout is severe in wet and average water years, but extremely severe in dry years. The co-lead agencies propose installing structural components like woody debris and planting vegetation at Hungry Horse reservoir to stabilize channels, increase cover for migrating fish, and improve habitat conditions. These actions would offset impacts to bull trout from reservoir fluctuations and seasonal drawdowns during spring and fall migration, and improve availability of food production and fish passage into spawning streams similar to the proposals in MO1, MO2, and MO3. Considering the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs with this proposed mitigation component, adverse effects are anticipated to be reduced to negligible.

In Region B, the co-lead agencies would develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. The co-lead agencies propose to place appropriate gravel for spawning habitat at locations up to 100 acres along reservoir and tributaries. Prior to placement, the co-lead agencies would conduct site surveys post operations of the alternative implementation to determine where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband rainbow trout is needed for construction of spawning habitat. This would build on the 2019 program Bonneville funded, already in year one of a three year study to determine if modifications in Lake Roosevelt refill would impact resident fish access to spawning habitat.

5.4.4.4 Vegetation, Wildlife. Wetlands, and Floodplains

The co-lead agencies propose no mitigation measures for Region A, B, C, or D as implementing MO4 would result in minimal to negligible effects when considering ongoing programs in the No Action. The ongoing actions for impacts to vegetation, wildlife, wetlands, and floodplains for Regions A, B, C, and D would continue, including protection and enhancement of wildlife habitat as described in Section 5.2.1.

In Region A, the McNary Flow Target measure decreases water surface elevations in Lake Pend Oreille. As a result of decreased water surface elevations, wetland habitats could become drier and the opportunity for non-native, invasive species to become established on exposed mudflats would increase. To help address these potential impacts offset impacts to wetlands, the co-lead agencies would use the existing programs at Albeni Falls and Lake Pend Oreille to address potential effects in this region.

5.4.4.5 Navigation and Transportation

The co-lead agencies are not proposing any mitigation measures in Regions A under MO4 for navigation and transportation because the measures implemented as part of this alternative would have negligible effects on these resources.

In Region B, the co-lead agencies propose extending the boat ramp at the Inchelium-Gifford Ferry to provide service at lower water elevation on Lake Roosevelt similar to MO1 and MO2.

In Regions C and D, the *Spill to 125 Percent TDG* operational measure and lower tail waters would increase shoaling in the navigation channel of the lower Snake and Columbia Rivers and would adversely affect navigation. In order to maintain the navigation channel and reduce adverse effects to negligible, proposed mitigation includes increasing the frequency and total volume of dredging at John Day, McNary, Ice Harbor, Lower Monument, and Lower Granite at a 4 -7-year interval. Higher spill volumes combined with tailrace conditions could also result in infrastructure damage and shoaling. Regular monitoring of the tailrace would take place to determine if additional mitigation to install coffer cells at Lower Monumental, Little Goose, McNary, and John Day would be needed. Coffer cells would dissipate energy during high spill operations, which would support movement of sediment in the navigation channel, thereby maintaining navigational capacity and river transportation. These measures would increase overall maintenance costs for the projects, but would reduce the adverse effects to negligible.

5.4.4.6 Recreation

The co-lead agencies are not proposing any mitigation measures in Regions A, B, C, or D under MO4 for recreation as the measures implemented as part of this alternative are minor adverse to negligible effects, and temporary.

In Region A, deep drafts to Lake Pend Oreille to meet the *McNary Flow Target* would lower lake elevations, creating inability to use these boat ramps during periods of time in low water years. To mitigate for these occasional, short-term effects, local entities could extend public and private boat ramps to reach new surface elevations similar to usage in the No Action Alternative.

In Region B, the co-lead agencies considered extending boat ramps at several recreational access locations in Lake Roosevelt to maintain accessibility. The *McNary Flow Target* measure decreases water surface elevations above Grand Coulee, which would reduce accessibility at numerous existing boat ramps when they become disconnected from the lake, including Evans, Hawk Creek, Marcus Island, Napoleon Bridge, and North Gorge. However, because recreation would be impacted fewer than 10 days per calendar year, the co-lead agencies determined that the severity of impact is minor and temporary, and the effect does not warrant mitigation.

5.4.4.7 Cultural Resources

In Region A, B, and C, there is a moderate to major adverse effects to cultural resources from an increase in number of acre-days that archaeological resources would be exposed. In Region D, there is a major adverse effect to cultural resources from an increase in number of acre-days that archaeological resources would be exposed. Effects in Regions A, B, C, and D could be mitigated by increasing Cultural Resource Program funding for activities such as archeological site and traditional cultural property monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other mitigation to address impacts to TCPs. These mitigation measures, when considered with the existing FCRPS Cultural Resource Program, would work to continue minimizing any adverse effects to negligible (Table 5-4).

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Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
Water Quality	Region A: Lower lake levels at Albeni Falls could make near shore areas more difficult to access due to greater macrophyte and periphyton growth (e.g. Eurasian water milfoil). This is estimated to be a negligible to minor effect.	Implement and expend the existing Invasive Aquatic Plant Removal program at Albeni Falls.	Implementation of this mitigation measure, combined with ongoing programs, would reduce effects to negligible.
Water Quality	Region A: At Hungry Horse, the drawdown in summer affects primary and secondary biological productivity that result from reservoir drawdowns and higher flushing rates.	In Region A, initiate a nutrient supplementation program at Hungry Horse Reservoir.	This measure would improve the food source and reduce adverse effects to negligible.
Anadromous Fish	Regions C and D: Moderate adverse effect from increased spill levels, which create turbulence and eddies below the dams resulting in delays to adult passage.	Temporary extension of performance standard spill levels in coordination with the Regional Forum	Performance Standard Spill is effective in passing adult fish and delays in passage would be negated, resulting in negligible adverse effects.
Anadromous Fish	Region C: Water in the Little Goose raceway is expected to have high TDG due to higher spill levels. This could have major adverse effects to transported fish.	Modify the Little Goose Raceway infrastructure to de-gas the water in the raceway during collection for transport. This would allow the fish to be transported in water with lower TDG than that in the river.	Implementation of this measure would reduce major adverse effects from TDG to transported fish negligible.
Resident Fish – ESA Bull Trout	Region A: Drawdowns cause low water elevations at time of Bull Trout migration, which could make it difficult to enter spawning tributaries and make Bull Trout more susceptible to angling/predation. Negligible to Moderate adverse impact.	On the Hungry Horse Reservoir install structural components like woody debris, and plant vegetation at the tributaries (Sullivan and Wheeler Creeks, possibly more) to stabilize the channels, increase cover for migrating fish, and improve the varial zone.	This mitigation measure, when considered with the existing Bonneville-funded Confederated Salish and Kootenai Tribes and State of Montana programs, minimizes any negative effects to negligible.
Resident Fish - Burbot, Kokanee, & Redband Rainbow Trout	Region B: Changes in elevation would leave current habitat dewatered and expose new potential areas appropriate for developing additional gravel spawning habitat.	Develop additional spawning habitat at Lake Roosevelt to minimize impacts to resident fish. Determine post-operations where to site spawning habitat augmentation at Lake Roosevelt for burbot, kokanee, and redband	This action is in addition to the Bonneville program that addresses current habitat restoration in Lake Roosevelt and would compensate for additional effects of the new action.

Resource	Impact	Proposed Mitigation Action	Effects After Mitigation
		rainbow trout to inform where mitigation is needed. Place appropriate gravel (spawning habitat) at locations up to 100 acres along reservoir and tributaries.	Exact acreage would be determined post-implementation.
Navigation & Transportation	Region B: Inchelium-Gifford Ferry (transportation for Tribal community of Inchelium) will go out of service for longer durations and isolate community members. This would be a moderate adverse effect that results in public safety concerns.	Extend the ramp at the Inchelium-Gifford Ferry on Lake Roosevelt so that it is available at lower water elevations.	Extending the ramp would eliminate additional effects to the community, potentially beneficial effect from the No Action condition. There would be no effects to public safety or environmental justice with this mitigation measure.
Navigation & Transportation	Regions C and D: High spill, combined with tailrace conditions could result in infrastructure damage and more frequent O&M of navigation channel at projects.	Regular monitoring of tailrace conditions will be conducted. If any discovery of adverse or damaging effects, install coffer cells at Lower Monumental, Lower Granite, McNary, and John Day to dissipate energy from higher spill levels.	Installation of coffer cells could reduce adverse effects to the tailrace and navigation channel from constant high spill to negligible.
Navigation & Transportation	In Region C & D, high spill volumes and lower tail water increase scour, creating sediments and filling of the navigation channel. This is a moderate adverse impact to navigation.	Monitoring of scour and infill at John Day, McNary, Ice Harbor, Lower Monumental, and Lower Granite projects and increase dredging maintenance, as needed to maintain navigation channel. This is predicted to be needed every 4-7 years.	Increasing the routine maintenance frequency and for total volume of dredging would reduce these navigation impacts to negligible.
Cultural Resources	Region A and B: Major adverse effects from increase in number of acre-days that archaeological resources would be exposed.	Region A, B and C increase Cultural Resource Program funding for activities such as resource monitoring (pedestrian and drone use), reservoir and river bank stabilization, data recovery, public education awareness, protective signage, and other alternative mitigation to address impacts to TCPs.	This mitigation measure, when considered with the existing FCRPS Cultural Resource Program in addition to this measure, would work to continue minimizing any negative effects to negligible.

5.5 MONITORING AND ADAPTIVE MANAGEMENT

Monitoring and adaptive management address sources of uncertainty, steer project implementation and maintenance to ensure that the intended project benefits are attained, and documents project effects for communication to participants and stakeholders. When effectiveness monitoring indicates that projects or mitigation measures do not effectively address an impacted resource, mitigation measures can be adaptively managed to improve effectiveness. For the purposes of this EIS, adaptive management is defined as a structured and iterative process to reduce uncertainty over time. Monitoring mitigation measures can incorporate elements of adaptive management if monitoring results indicate a change is needed to more fully offset impacts to an impacted resource.

5.5.1 Monitoring Strategy

A monitoring plan would be developed to address an individual measure of the preferred alternative, or a group of similar measures throughout the study area. The co-lead agencies would prepare a monitoring plan which specifies the following:

- The intended goal or goals of the project or measure
- Objectives for measuring the progress toward the goal(s)
- Any uncertainties involved with the implementation or the body of knowledge supporting the implementation of the proposed action
- The strategy for implementing the project or program
- The process of evaluating project success and the metrics used to evaluate success

The co-lead agencies would prepare an appropriate monitoring and adaptive management plan prior to implementation of the preferred alternative. The plan would identify what data are needed to assess project effectiveness, as well as the method and frequencies of monitoring the project after implementation or construction. If mitigation does not adequately address impacts to an affected resource, or is ineffective at meeting the goal, then adaptive management would be used to assess and implement changes to achieve the intended goal of the mitigation action. If significant changes to the project or program cannot be adequately addressed through operational changes described in this EIS, a supplemental NEPA evaluation may needed.

Monitoring requirements included as part of project-specific permits would be developed in consultation with the appropriate Federal or state agencies as the preferred alternative advances through any applicable permitting process. For example, projects requiring coordination with state agencies to prepare erosion and stormwater control plans would include monitoring to ensure projects maintain water quality. The specific monitoring requirements would be identified in the permit or authorization from the state agency and the co-lead agencies' monitoring plan would incorporate these requirements as part of project implementation. Monitoring plans typically include biological monitoring to evaluate fish and invertebrate presence and abundance, as well as harmful aquatic organisms and toxic algal blooms. Monitoring could also include water and sediment chemistry to assess changes in water and sediment quality and toxicity. Monitoring plans can also be developed to assess sediment erosion and deposition to evaluate changes to channel structure and flow characteristics, which can be used to assess fish and wildlife habitat.

5.5.2 Adaptive Management

Adaptive management is often defined as a structured and iterative process to improve the decision-making process while allowing for uncertainty during implementation. Adaptive management is intended to reduce uncertainties through monitoring the effectiveness of a project in mitigating adverse impacts and using monitoring results to determine if changes are needed to improve project implementation. In general, adaptive management is used to improve the process that leads to more effective, strategic, and beneficial projects.

Integrating adaptive management into the decision-making process enables managers to address uncertainties associated with implementation of an individual project or a comprehensive program. The co-lead agencies have incorporated lessons learned from monitoring previous projects implemented in the study area and conducting research to improve the proposed measures and MOs. The co-lead agencies would integrate adaptive management into future planning, implementation, and monitoring for projects implemented under the preferred alternative to ensure relevant, high-quality information is available and used during the decision-making process.

Furthermore, by integrating an adaptive management strategy into the monitoring plan, the co-lead agencies would accomplish the following goals:

- Ensure collaborative decision-making processes are maintained through cooperation with regional stakeholders, tribes, and other Federal and state government agencies
- Ensure monitoring and research results are implemented as intended
- Ensure data are collected, analyzed, and documented in a manner that promotes review and integration of any lessons learned to influence future management decisions
- Ensure there is flexibility in implementation of projects or programs that allows for adjusting methods to achieve success in meeting project or program objectives

A component of the monitoring and adaptive management plan would specify the performance standard or success criteria used to determine overall project performance. In addition, the trigger for adaptively managing project implementation would be identified in the monitoring and adaptive management plan. The monitoring and adaptive management plan would also identify the minimum timeframe necessary to evaluate project success, as well as when monitoring tasks are complete and would cease. If monitoring results are not returning useful information to determine project success, the monitoring and adaptive management plan would specify timeframes for reviewing monitoring results and the process by which the co-lead agencies would modify monitoring efforts or project implementation.

CHAPTER 6 - CUMULATIVE EFFECTS

6.1 INTRODUCTION

Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) requires an assessment of cumulative effects. CEQ defines a cumulative effect as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 Code of Federal Regulations § 1508.7). This section describes the methods for identification of cumulative actions and presents the results of the cumulative effects analysis.

6.1.1 Analysis Approach

The cumulative action analysis methods are based on the policy guidance and methodology originally developed by CEQ (1997a). This method includes identifying affected resources and direct/indirect effects, establishing the geographic and temporal boundaries of the analysis, identifying applicable cumulative actions, and analyzing the cumulative effects.

The *Environmental Consequences* sections of Chapter 3 present the direct and indirect effects of the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS) Multiple Objective Alternatives (MOs) on each resource's affected environment as presented in the *Affected Environment* sections of Chapter 3. The resource conditions described in those sections account for the effects to resources related to past and present actions. Chapter 6, *Cumulative Effects*, further considers the cumulative effects of each alternative combined with reasonably foreseeable future actions and conditions. Climate change, for example, can be considered an effect of past, present, and future actions that may have a cumulative effect on certain resources in the analysis area. The effects of climate change on all affected resources (indirect, direct, and cumulative) are analyzed and discussed in detail in Chapter 4.

6.1.2 Geographic and Temporal Scope

The geographic boundary for each resource considered in this cumulative effects analysis is referred to as the cumulative impact analysis area (CIAA). The CIAA follows the geographic boundaries of direct and indirect effects for each resource identified in Chapter 3 unless noted otherwise under specific resources.

The temporal boundaries for cumulative effects in this analysis have three components—past, present, and future. In this analysis, past cumulative effects have been discussed in the *Affected Environment* sections of Chapter 3, insofar as they are relevant to effectively describing the existing condition for each resource. Conversely, present and reasonably foreseeable future actions are included in this chapter if they are expected to overlap in space and time with the scope of this EIS, which unless otherwise noted is, for temporal purposes, approximately 25 years into the future.

6.1.3 Identification of Past, Present, and Reasonably Foreseeable Future Actions

6.1.3.1 Past Actions

The effects of past actions are reflected in the resource descriptions under each resource in the *Affected Environment* sections of Chapter 3, which describes the existing condition for each resource. According to CEQ, a cumulative effects analysis may assess past actions in the project area by focusing on the "current aggregate effects of past actions without delving into the historical details of individual past actions" (CEQ 2005). The effects of all past actions do not need to be identified for the cumulative impact analysis. That said, a summary of past actions in the CIAA is described in the following section with regard to Columbia River Basin aquatic species (including fish), aquatic invertebrates, and their habitats, which have been particularly vulnerable to past anthropogenic (human-caused) pressures.

Human uses and development have had substantial influences on the CIAA for nearly all of the resources analyzed. Human presence in the Columbia and Snake River Basins dates back more than 16,000 years, to a time when the Columbia River was the dominant contributor of food, water, and transportation for humans. Within the analysis area, aquatic, riparian, and floodplain habitat have been changed throughout history, including habitat loss, modification, degradation, and restoration. This includes modification of the hydrograph since pre-dam conditions. Before dams existed in the basin, the hydrograph was that of a natural riverine system. Hundreds of miles of riverine habitat have been converted to slack water reservoirs along the mainstem Columbia and Snake Rivers (Ebel et al. 1989).

In general, relevant past cumulative actions that have affected aquatic species and other wildlife include construction and operation of dams, levees, and other river infrastructure; dredging and sediment management; commercial and recreational fishing harvest; invasive species; floodplain development; water pollution; logging and mining; water withdrawals to support human development; and agricultural, urban, and transportation corridor development. These actions have had adverse effects throughout their implementation, including direct mortality to species and habitat loss and degradation. Examples of the various ways that habitat can be lost and/or degraded include the creation of fish passage barriers, overharvest and overconsumption of aquatic species, introduction of invasive and predatory species, flow modifications, water temperature variability, and water pollution.

Relevant past cumulative actions also include the voluntary actions and Federal- and state-mandated actions of private and public parties to create positive and offsetting effects for affected aquatic species and other wildlife. These include but are not limited to hatcheries and fisheries management; predation management; hydro operations and asset management; water quality management; and habitat, conservation, and land management.

Appendix E provides a glimpse into the host of actors and actions engaged in these and other activities affecting salmon and steelhead in and around the Columbia, Snake, and Willamette Rivers from 2010 to 2019. During this time, over 400 formal and formal programmatic biological opinions (BiOps) were issued by NMFS to govern salmon and steelhead protection. The BiOps vary widely in the scope of effects, required analyses, responsible parties, and required actions. They also provide concrete examples of how the co-lead agencies' ability to successfully carry out mitigation responsibilities depends on a myriad of other actors and actions upstream, downstream, and inland from mitigation activities.

6.1.3.2 Ongoing and Present Actions

Present actions are typically ongoing activities that have already been incorporated into the affected environment for each resource. Presently, influencing factors on the Columbia and Snake Rivers are the dams that provide hydroelectric power, flood risk management (FRM), navigation (including commercial and cruise lines), recreation, timber and logging industry, non-point source pollution, and municipal and industrial (M&I) water supply. Ongoing and present actions also include the exercise of existing Federal and state environmental regulatory authorities and mechanisms. The EIS alternatives analysis broadly assumes existing laws, policies, agency jurisdictions, rulings, BiOps, etc., will remain in place for their stated duration (see Appendix E for the last 10 years of formal and formal programmatic NMFS BiOps for salmon and steelhead on the Columbia, Snake, and Willamette Rivers).

Likewise, the adequacy and health of existing regional coordination, alignment, and planning actions will not be assessed for the purposed of this EIS, but nonetheless merits mention for context. The United States and Canada began negotiations in 2018 to modernize the Columbia River Treaty regime. The negotiations are currently ongoing, therefore any potential effects on the environment that may result from that effort are not reasonably foreseeable. Notable efforts are also underway to create more integrated and regional approaches to salmon and steelhead challenges that require collaboration across Federal, state and Tribal Government jurisdictions (e.g., Columbia Basin Partnership Taskforce). Anticipated future effects of these activities are included where applicable herein, and cumulative effects are analyzed where reasonably foreseeable future actions exist.

6.1.3.3 Reasonably Foreseeable Future Actions

RFFAs are considered in the cumulative effects analysis for each resource in this chapter. RFFAs are proposed activities that could cause similar effects in the same space and time as the MOs, but that are proposed by an outside entity. RFFAs are not yet implemented. In order to be deemed reasonably foreseeable, RFFAs must typically be budgeted for and included under formal proposals or decisions (such as an official agency decision document or a county land use plan). RFFAs include proposed and planned developments, actions, and trends related to population growth; agriculture (including timber and logging industry); urban development; climate change; power generation (including operations and maintenance activities); new transmission lines; existing transmission maintenance activities; environmental management, laws, and policies; fisheries management; and the maintenance and operation of the Columbia River System (CRS), as well as other Federal and private dams and river infrastructure.

6.2 CUMULATIVE ACTIONS SCENARIO

This section lists resources analyzed in the direct and indirect analysis in Chapter 3, *Affected Environment and Environmental Consequences*, where only minor direct and indirect effects were identified in Chapter 3 and little to no cumulative actions were identified. A summary of actionable RFFAs and potentially affected resources are provided in Table 6-1 and Table 6-2, and discussed throughout the remainder of the chapter.

In addition, there are numerous reasonably foreseeable future trends, planning efforts, programs, proposals, projects, and new legislation within the Columbia River Basin that overlap in space and time and are therefore additive in impact when combined with those effects from the MOs. Primarily, these cumulative actions and trends are focused on the management of fish and wildlife (primarily fish), environmental management, water quality management, industrial and agricultural developments, population growth in the region, energy development, and operations and maintenance of existing Federal and non-Federal dams and other river infrastructure. These are listed in Table 6-1 below with a key used for identification in certain portions of the chapter.

Table 6-1. Reasonably Foreseeable Future Actions and Trends

RFFA ID	RFFA Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses
RFFA3	New and Alternative Energy Development
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization
RFFA5	Federal and State Wildlife and Lands Management
RFFA6	Increase in Demand for New Water Storage Projects
RFFA7	Fishery Management
RFFA8	Bycatch and Incidental Take
RFFA9	Bull Trout Passage at Albeni Falls
RFFA10	Ongoing and Future Habitat Improvement Actions for Bull Trout
RFFA11	Resident Fisheries Management
RFFA12	Fish Hatcheries
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement
RFFA14	Lower Columbia River Dredged Material Management Plan
RFFA15	Snake River Sediment Management Plan
RFFA16	Seli'š Ksanka Qlispe'(SKQ) Dam (Formerly Kerr Dam) Operations
RFFA17	Invasive Species
RFFA18	Marine Energy and Coastal Development Projects
RFFA19	Climate Change
RFFA20	Clean Water Act–Related Actions
RFFA21	Idaho Power Hells Canyon Complex Mercury Contamination Issues/Remediation
RFFA22	Idaho Power Hells Canyon Complex Temperature Issues
RFFA23	Mining in Reaches Upstream of CRSO Dams

RFFA ID	RFFA Description
RFFA24	Hanford Site
RFFA25	Columbia Pulp Plant
RFFA26	Middle Columbia Dam Operations

The specific actions and trends are further described under each heading below.

RFFA1 – Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development. Human populations are increasing primarily in urban metropolitan areas with smaller increases in rural areas. This increase is expected to continue until at least 2030 (Independent Scientific Advisory Board [ISAB] 2007b). Population increases in the Columbia River Basin are projected to continue although there is a wide range of estimates of the specific number. Projections to 2040 of population growth rates for the interior Columbia River Basin range from 0.3 percent per year to 1.6 percent per year. Lackey et al. (2006) concluded that if the largely migration-driven population growth continues unabated, it will result in a threefold to sevenfold increase in the population in the Columbia River Basin region. In Washington and Oregon, many acres of forestlands are being converted to residential and commercial development, a trend that is expected to continue.

Agricultural land is also being converted to nonagricultural uses. Like forestland, an important factor influencing the conversion of agricultural land is the increase in land prices driven by population growth. Urban development causes marked changes in the physical, chemical, and ecological characteristics of stream ecosystems, which are in most cases detrimental to native fish and wildlife. The rate of exurban (area just beyond denser suburbs) development also seems to be increasing. This type of development tends to result in degraded habitat for fish and wildlife through direct habitat conversion and loss. Human population growth and development can be expressed as potential causes of increases in discharges of pollutants in stormwater runoff from residential, commercial, industrial, agricultural, recreational, and transportation land uses.

A variety of population-driven factors external to the Columbia River Basin can also cause effects within the basin. International trade through shipping has led to modifications to the lower river and estuary. Future channel deepening and other port modifications may result in increasing numbers of ships and cargo tonnage on the river. Globalization of trade may have contributed to the loss of some industries within the Columbia River Basin, such as aluminum, and will continue to affect resource-based industries. Increased volumes of materials, especially hazardous goods and fuels that power trains, vessels, and trucks, are moved through the Columbia River Basin in response to the demands of a growing population. With increased movement of goods via all three modes, more accidents and spills are likely. Mining, logging, trade, and transportation projects also influence the hydrology, water quality, and use of the CRS.

RFFA2 – Water Withdrawals for Municipal, Agricultural, and Industrial Uses. Freshwater withdrawals for domestic, industrial, commercial, and public uses are increasing, whereas withdrawals for irrigation purposes are decreasing due to the conversion of agricultural lands to residential areas. Freshwater withdrawals for domestic and public uses are projected to increase by 71 to 85 percent by 2050. Freshwater withdrawals for irrigation are projected to decline but will be more than offset by increases in withdrawals for public, domestic, industrial, and commercial uses (ISAB 2007b). Increased withdrawals have large implications for instream flow and for maintenance of riparian and aquatic habitats for fish and wildlife. New water withdrawals are typically subject to regulatory restrictions.

Many tributaries in the Columbia River Basin are substantially depleted by water diversions. In 1993, state, tribal, and conservation group experts estimated that 80 percent of 153 Columbia tributaries had low flow problems, of which two-thirds were caused, at least in part, by irrigation withdrawals (Oregon Water Resources Department [OWRD] 1993). The surface/live flows of some tributaries in Oregon are already fully appropriated by state regulators (OWRD 2019). The Northwest Power and Conservation Council showed similar problems in many Idaho, Oregon, and Washington tributaries (NW Council 1992). Diminished tributary stream flows have been identified as an important limiting factor for most species in the Columbia River Basin upstream of Bonneville Dam (National Marine Fisheries Service [NMFS] 2007). Tributary water diversions are expected to continue in the future over the study period.

RFFA3 – New and Alternative Energy Development. Numerous wind, solar, and natural gas energy projects in the Columbia River Basin that have yet to be constructed are either under review or have been approved for construction. A full listing of applications and their statuses are available from state energy departments such as the Oregon Department of Energy and the Washington State Energy Office. Some of the larger future projects that overlap with the CRSO EIS include:

- Bakeoven Solar Project in Wasco County, Oregon
- Mist Underground Natural Gas Storage Facility in Columbia County, Oregon
- Nolin Hills Wind Power Project in Umatilla County, Oregon
- Desert Claim Wind Power Project in Kittitas County, Washington
- Golden Hills Wind Project in Sherman County, Oregon
- Whistling Ridge Energy Wind Development in Skamania County, Washington
- Montague Wind Power Facility in Gilliam County, Oregon
- Summit Ridge Wind Farm in Wasco County, Oregon
- Ella Wind Project, in Morrow County, Oregon
- Jordan Butte Wind Project, in Gillam County, Oregon
- Troutdale Grid Energy Storage, in Multnomah County, Oregon

RFFA4 – Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization. A basinwide trend exists within the Columbia River Basin toward increased use of renewable energy and reduced greenhouse gas (GHG) emissions. There is potential for an increase in lack-of-market/lack-of-turbine-capacity involuntary spill, which could lead to higher total dissolved gas (TDG) levels. Conversely, decarbonizing and electrifying transportation and other sectors could reduce involuntary spill from lack-of-market spill. This trend is expected to continue into the future, largely because it is being driven by multiple legislative factors designed to induce long-term change, including the following:

- Washington Clean Energy Transformation Act
- Federal Affordable Clean Energy Rule
- Oregon Clean Electricity and Coal Transition Plan
- Federal Cleaner Trucks Initiative
- Electric vehicle use and government incentive programs
- State and municipal emissions GHG reductions targets
- Coal power plant retirements
- Renewable Energy Portfolio Standards, including adjacent states and provinces

RFFA5 – Federal and State Wildlife and Lands Management. Throughout the study area, there are numerous national wildlife refuges and other public lands managed for the benefit of wildlife and other public uses. In regard to wildlife refuges, the analysis assumes that the state agencies and the U.S. Fish and Wildlife Service would continue to implement management activities consistent with management area and refuge goals and agency policies for the benefit for fish and wildlife. Federal and state-owned wildlife lands are detailed in Section 3.6.2.3. There are numerous other parcels of land that are managed for a multitude of uses, such as resource extraction (logging, mining, etc.), recreation, grazing, and conservation. The way that these lands are managed in the study area can have cumulative effects when added to the actions proposed in this EIS. In particular, water management, soil management, vegetation management, and fire management can have important additive effects, which could be beneficial or adverse depending on the nature of the management action.

RFFA6 – Increase in Demand for New Water Storage Projects. A general trend of increased water storage needs in the Columbia River Basin is projected to continue to encourage new water storage projects. However, new water storage projects are typically subject to state and federal regulatory requirements prior to being approved. Some of the larger future projects that overlap with the CRSO EIS include the following:

- Switzler Reservoir Water Storage Project: The reservoir would have a peak storage capacity of approximately 44,000 acre-feet through construction of a concrete-faced rockfill dam approximately 325 feet in height and located approximately 1.1 miles upstream of the confluence of the Switzler drainage with the Columbia River. This project would be located in Benton County, Washington, just across the Columbia River from Hermiston, Oregon.

- Goldendale Closed Loop Pumped Storage Facility: The proposed Goldendale Energy Project No. 14861 is a closed-loop pumped storage hydropower facility proposed by FFP Project 101, LLC. The proposed lower reservoir would be off-stream of the Columbia River at John Day Dam, located on the Washington (north) side of the Columbia River at River Mile 215.6. The project would be located approximately 8 miles southeast of Goldendale in Klickitat County, Washington. The proposed project would use off-peak energy (i.e., energy available during periods of low electrical demand) to pump water from the lower reservoir to the upper reservoir and generate energy by passing the water from the upper to the lower reservoir through generating units during periods of high electrical demand.

RFFA7 – Fishery Management. Pacific Salmon Fishery Management Plans are commercial-harvest fisheries plans that are prepared by the Pacific Fishery Management Council (PFMC) and are implemented and enforced by the NMFS in Federal waters (e.g., 3 to 200 miles offshore). The main salmon species that PFMC manages are Chinook, coho, and pink salmon. NMFS promulgates regulations for how many salmon can be caught offshore based on these PFMC plans. PFMC, including NMFS, is examining ways to better manage the catch of salmon in offshore ocean waters. Currently, PFMC has established a Southern Resident Killer Whale Workgroup to reassess the effects of Federal ocean salmon fisheries on Southern Resident killer whales and to potentially recommend conservation measures or management that better limit fisheries effects on Chinook salmon in Federal waters. The workgroup is comprised of representatives from West Coast tribes; the states of California, Idaho, Oregon, and Washington; PFMC; and NMFS. The workgroup is scheduled to provide recommendations for ocean salmon fisheries management via a final report to PFMC members in March 2020. Such recommendations (e.g., time and area ocean salmon fishing closures) could result in a benefit for anadromous species and Southern Resident killer whales.

Another important fishery management plan is the 2018–2027 *United States v. Oregon* Management Agreement. The purpose of the agreement is to rebuild weak runs to full productivity and fairly share the harvest of upper river runs between treaty Indian and non-treaty fisheries in the ocean and Columbia River Basin. As a means to accomplish this purpose, the parties use habitat protection authorities, enhancement efforts, artificial production techniques, and harvest management.

RFFA8 – Bycatch and Incidental Take. This refers to incidental take or bycatch of fish species such as bull trout by recreational anglers and incidental take of eulachon by shrimp fishing. Bycatch and incidental take are forecast to continue alongside recreational and commercial fishing.

RFFA9 – Bull Trout Passage at Albeni Falls. The proposed action is to construct an upstream “trap and haul” fish passage facility at Albeni Falls Dam; downstream passage will occur through the spillway and powerhouse. Once bull trout enter the trap and are captured, they will be sorted from non-target species for transport via truck to a release location approximately 5 miles upstream of the dam. Non-target species will either be returned below Albeni Falls Dam, be routed directly to the forebay upstream of the dam, or euthanized by the resource managers. The construction schedule assumes a 2-year construction period centered on two low-flow periods required for installation and removal of the cofferdam systems. The implementation time frame is uncertain, because it requires an appropriation of funding, but this action is considered reasonably foreseeable during the time period of analysis given the continued support of the project by the U.S. Army Corps of Engineers (Corps). The Corps continues to demonstrate capability for this project during the annual budget process.

RFFA10 – Ongoing and Future Habitat Improvement Actions for Bull Trout. A common goal among these actions is the improvement of aquatic habitat and water quality to benefit native salmonids, especially bull trout. Overlap varies, but these actions are generally ongoing. A comprehensive list of activities that contribute to the recovery of bull trout in the Columbia River Recovery Unit and Lake Pend Oreille area is not available because of the multitude of federal, state, tribal, and non-governmental organizations that conduct activities in the region. Some of the important activities that are ongoing or have been recently completed within the region are as follows:

- Construction of upstream fish passage facility at Box Canyon Dam (construction began in 2016, facility expected to be operational in 2019; Pend Oreille Public Utility District)
- Lake trout removal in Lake Pend Oreille (Idaho Department of Fish and Game)
- Tributary habitat restoration, enhancement, and passage
- Kalispel resident fish project (Kalispel Natural Resources Department)
- Non-native species suppression projects, such as the Kalispel Tribe Non-Native Fish Suppression Project in Pend Oreille River
- Road abandonment and bank stabilization (Kalispel Natural Resources Department)
- Bull trout research and monitoring
- Genetic inventory of bull trout in the Pend Oreille River subbasin (Kalispel Natural Resources Department)
- Mainstem Pend Oreille River water quality
- Temperature total maximum daily load (TMDL) implementation for the Pend Oreille River (Washington Department of Ecology and stakeholders)
- Water quality monitoring (Kalispel Natural Resources Department)

RFFA11 – Resident Fisheries Management. The state and tribal fish and game agencies manage, for recreational, ceremonial, and subsistence, fisheries in the Columbia River Basin and regulate private and public hatchery releases. The agencies modify and publish recreational fishing regulations on an annual basis. Currently, recreational anglers may not target bull trout in most areas, but may incidentally catch and release bull trout. Other resident fisheries include kokanee and burbot in the upper basin.

RFFA12 – Fish Hatcheries. In addition to hatcheries already considered under the No Action Alternative, there are more than 100 other hatchery programs funded through different sources and operated by federal entities, tribes and tribal entities, state agencies, and/or public utility districts. Many of these hatchery programs are intended to mitigate for lost habitat, for mortality of juvenile and adult fish, and/or other effects related to the existence and operation of Federal and non-Federal dams. It is anticipated that the co-lead agencies and other entities would continue to fund the operation and maintenance of most existing hatchery programs, except perhaps for MO3 that are associated with the operation of the lower Snake dams under the Lower Snake Compensation Plan.

There are numerous hatcheries in the Columbia River Basin that focus on conservation of rare species and/or maintaining the abundance of recreational species. Hatchery programs in the Columbia River Basin are implemented to augment harvest, to help conserve a population, or for both purposes. Of the 177 hatchery programs in the Columbia River Basin, 62 (35 percent) are funded wholly or in part by the Mitchell Act. NMFS, part of NOAA within the U.S. Department of Commerce, currently distributes Mitchell Act appropriations to the operators of these 62 hatchery programs that annually produce more than 63 million fish. The most common species produced are fall Chinook salmon, coho salmon, and spring Chinook salmon in the lower Columbia River and fall Chinook salmon, spring Chinook salmon, and summer steelhead in the interior Columbia River. Chum salmon, sockeye salmon, and summer Chinook salmon are the least common species produced. The hatchery programs' geographic scope includes rivers, streams, and hatchery facilities where hatchery origin salmon and steelhead occur or are anticipated to occur in the Columbia River Basin, as well as the Snake River and all other tributaries of the Columbia River. The program area also includes the Columbia River estuary and plume.

RFFA13 – Tribal, State, and Local Fish and Wildlife Improvement. These actions include non-Federal habitat actions supported by state and local agencies, tribes, environmental organizations, and private communities. Projects supported by these entities focus on improving general habitat and ecosystem function or species-specific conservation objectives. Actions and programs contributing to these benefits include, but are not limited to, growth management programs, various stream and riparian habitat projects, watershed planning and implementation, acquisition of water rights for instream purposes and sensitive areas, instream flow rules, stormwater and discharge regulation, TMDL implementation, tribal activities to improve Pacific lamprey passage, and hydraulic project permitting.

RFFA14 – Lower Columbia River Dredged Material Management Plan (DMMP). Currently, an integrated DMMP and EIS is being developed due to the need for additional placement locations with sufficient capacity to maintain the congressionally authorized, deep draft, Federal navigation channel for the next 20 years. The deep draft, Federal navigation channel extends from River Mile 3 to 105.5 of the lower Columbia River. The forecasted average annual dredging needed to maintain the lower Columbia River Federal Navigation Channel is currently 6.5 million cubic yards (mcy) (130 mcy total over 20 years). Existing dredged material placement sites were assessed in a Preliminary Assessment and found to have insufficient capacity for the next 20 years. The plan is also evaluating needs for future upland and in-water placement of dredged material, as well as construction and repair of channel training features. It is assumed that potentially affected resources from the new DMMP would be identified and analyzed in the integrated EIS. The following measures would be evaluated:

- Beneficial use of dredged material
- In-water placement of dredged material
- Shallow water placement of dredged material
- Shoreline placement of dredged material
- Upland placement of dredged material
- Pile dikes
- Other channel training features

RFFA15 – Snake River Sediment Management Plan. The Snake River Sediment Management Plan is intended to maintain the lower Snake River projects by managing, and preventing if possible, sediment accumulation in areas of the lower Snake River reservoirs that interfere with the authorized purposes. The selected alternative from the Snake River Plan provides a suite of all available dredging, system management, and structural sediment management measures for the Corps to use to address sediments that interfere with the existing authorized project purposes of the lower Snake River projects. The Snake River Sediment Management Plan is anticipated to be implemented under all of the MOs with the exception of MO3 due to dam breaching. The following measures are available under the lower Snake River projects:

- Navigation-objective reservoir operation (on temporary basis until dredging is implemented)
- Navigation channel and other dredging
- Dredging to improve conveyance capacity
- Beneficial use of dredged material
- In-water placement of dredged material
- Upland placement of dredged material
- Reservoir drawdown to flush sediments (drawdown)
- Reconfigure affected facilities
- Relocate affected facilities
- Raise Lewiston levees to manage flood risk
- Bendway weirs

- Dikes and dike fields
- Agitation to resuspend sediments
- Trapping upstream sediment (in reservoir)

RFFA16 – Seli'š Ksanka Qlispe' Dam (formerly Kerr Dam). Operations of the Seli'š Ksanka Qlispe' Dam (SKQ) dam primarily affect habitat downstream in the lower Flathead River and cause entrainment of fish out of Flathead Lake. A matrix of RFFAs as relates to potentially affected resources is provided in Table 6-2.

RFFA17 – Invasive Species Management. Non-native and invasive plants and animals are currently damaging biological diversity and ecosystem integrity across the Columbia River Basin and within the study area. Aquatic species are of particular concern because they spread rapidly and can quickly alter the function of an ecosystem. Throughout the study area, the co-lead agencies, as managers of the lands and waters within their jurisdiction, are involved with cooperative weed management efforts, invasive species prevention and eradication, and vegetation treatments. Common invasive species and the types of effects they have on the environment are described in Section 3.6.2.2.

RFFA18 – Marine Energy and Coastal Development Projects. Coastal development occurs along the Pacific Northwest coastline. Potential effects include vessel strikes from increased shipping traffic, noise from increased vessel traffic, and non-point source pollution from coastal areas (e.g., stormwater runoff). During the past two decades, there has been growing interest in developing sites to explore wave and tidal energy technologies along the West Coast, especially along Oregon and Washington where wave energy potential is the highest in the lower 48 states (Bedard 2005). Examples of such tidal energy projects in planning stages are the Pacific Marine Energy Test Center – South Energy Test Site Wave Test Center of the Oregon coast and the Admiralty Inlet Tidal Energy Project in Puget Sound. These technologies, depending on where they are located, could include effects via entrainments of fish, collisions with marine mammals (e.g., orcas), and obstruction of migration routes for salmonids and marine mammals. In addition, there has been growing interest in developing liquid natural gas (LNG) terminals in coastal areas. Construction and operation of LNG terminals (including effects resulting from LNG shipping traffic) would affect resources within the ocean environments. Leaks, spills, explosions, and release of contaminants could impair water quality or cause physical effects to fish, marine mammals, and other wildlife. It is noted that any tidal energy or LNG projects are speculative at this time but are potentially feasible within the temporal scope of this analysis. Other actions could potentially affect marine mammals, including quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor.

RFFA19 – Climate Change. Chapter 4 provides a detailed assessment of the potential effects of climate change on the Columbia River Basin, including the results of a 4-year research project completed by the University of Washington and Oregon State University, with resource support and technical expertise provided by the River Management Joint Operating Committee

(RMJOC) agencies (Corps, Bonneville Power Administration [Bonneville], and U.S. Bureau of Reclamation). The RMJOC-II report (2018) found the following for the 2020 to 2049 time period (referred to as the 2030s):

- Temperatures in the region have already warmed about 1.5 degrees Fahrenheit since the 1970s. Temperatures are expected to warm another 1 to 4 degrees Fahrenheit by the 2030s.
- Warming in the region is likely to be greatest in the interior with a greater range of possible outcomes. Less pronounced warming is projected near the coast.
- Future precipitation trends are more uncertain, but a general upward trend is likely for the rest of the twenty-first century, particularly in the winter months. Already dry summers could become drier.
- Average winter snowpacks are very likely to decline over time as more winter precipitation falls as rain instead of snow, especially on the U.S. side of the Columbia River Basin.
- By the 2030s, higher average fall and winter flows, earlier peak spring runoff, and longer periods of low summer flows are very likely. The earliest and greatest streamflow changes are likely to occur in the Snake River Basin, although that is also the basin with the greatest modeling uncertainty.
- The incidence of large forest fires has increased since the early 1980s and is projected to continue increasing as temperatures rise. Wildfire alters the land surface and can have strong influences on runoff generation, vegetation dynamics, erosion and sediment transport, and ecosystem processes. Strong seasonality and dependence on spring snowmelt positions the basin to be at risk for increased fires due to the effects of climate change.

The RMJOC-II report (2018) concludes, "…such precipitation increases, along with a warming climate, could have profound implications on both the magnitude and seasonality of future streamflows for hydroregulation operations and planning."

RFFA20 – Clean Water Act–Related Actions. In addition to maintaining or improving water quality through numerous smaller permitting actions, there are also a number of ongoing specific actions related to Clean Water Act (CWA) compliance that are anticipated to maintain or improve water quality. Some of the important efforts include the following:

- Columbia-Snake River Water Temperature TMDL – The U.S. Environmental Protection Agency (EPA) is working with the States of Oregon, Idaho, and Washington; the Columbia River Basin tribal governments; Federal agencies; public utility districts; and industrial and municipal dischargers to develop a temperature TMDL for the Columbia and lower Snake Rivers. The TMDL is focused on sources of heat that contribute to temperature impairments in the Columbia and lower Snake Rivers.

- Idaho Power Hells Canyon Complex Water Quality Certification and Settlement Agreement – Water quality certification for the Idaho Power Hells Canyon Complex (Brownlee, Oxbow, and Hells Canyon Dams on the Snake River in the southern part of Hells Canyon along the Oregon-Idaho border) were issued in mid-2019. The certifications, meant to ensure compliance with water quality standards, include actions aimed at improving fish habitat and water quality in the Snake River and its tributaries. In addition to habitat restoration and fish placement, operational improvements will aim to cool water in the river for spawning and increased survival. These operational changes could have a cumulative beneficial effect on lower Snake River water quality temperatures. For example, Idaho Power will operate Brownlee Dam to reduce the temperature of water released from the dam, which is expected to reduce stress on all fish and aquatic life.

RFFA21 – Idaho Power Hells Canyon Complex Mercury Contamination Issues/Remediation. The Hells Canyon Complex has legacy mercury contamination and atmospheric deposition that is currently being studied. Research suggests that the dams combined with certain water quality conditions may be creating an environment that is efficient at converting inorganic mercury to methylmercury. Based on recent data collected, methylmercury concentrations and mercury in the form of methylmercury found in both sediments and deeper in the water column are substantially elevated compared to other natural waters and reservoirs in Idaho, Oregon, and Washington. Methylmercury concentrations in fish tissue generally increase downstream through the Hells Canyon Complex, followed by a decrease downstream of Hells Canyon Dam toward the confluence of the Snake and Salmon Rivers (USGS 2016). Remediation actions are possible to overlap in time and space with the CRS, but it is unclear at this point of what the timing and extent of remediation would be. As stated in the Hells Canyon Complex Section 401 certification, "the downstream effect of the methyl mercury values will be evaluated if a pump system or any temperature control structure that accesses Brownlee Reservoir hypolimnion water is proposed."

RFFA22 – Idaho Power Hells Canyon Complex Temperature Issues. There are known temperature water quality standard exceedances caused in the fall coming out of the HCC. Brownlee Reservoir drafts also have potential to exceed desired temperatures during summer migration.

RFFA23 – Mining in Reaches Upstream of CRS Dams. Canadian mining operations continue to increase, creating water quality problems in the U.S. rivers downstream due to the discharge of heavy metals such as arsenic, cadmium, mercury, and lead. In a case brought by the Confederated Tribes of the Colville Reservation (Colville Tribes), the U.S. Court of Appeals for the Ninth Circuit recently held that Canadian mining company Teck is responsible for discharging thousands of tons of heavy metals that have flowed downstream into Washington State and Lake Roosevelt. There are also ongoing remediation projects related to mining on the Spokane arm of Lake Roosevelt, including the Midnight Mine cleanup.

RFFA24 – Hanford Site. The Hanford Site is a former nuclear production facility located along the Columbia River near Richland, Washington, upstream of the confluence with the Snake River. Cleanup of the Hanford Site started in 1989 and is anticipated to continue.

RFFA25 – Columbia Pulp Plant. This straw pulp plant was recently constructed in Lyons Ferry near Starbuck, Washington. The company's start-up process began in October 2019, and the company expects to reach full commercial production midyear in 2020. Once in full service, it will process 140,000 tons of straw per year, taking what has historically been a waste product and turning it into pulp used to make paper and other products, such as specialty papers, tissue, and packaging products. The plant employs around 100 persons. In addition to producing pulp from straw and alfalfa, it is expected to produce up to 95,000 tons per year of lignin and sugar, which can be used for transportation and agricultural purposes such as deicing, dust control, and spray adjuvants. Columbia Pulp selected this location because it is one of the densest wheat-farming regions in North America, and states that it has growth plans for the future, saying that further mills might be built in the region. The site is a minor source of air emissions. It will not funnel any wastewater back into the water table. The mill uses natural gas and co-generates its own steam and electricity.

RFFA26 – Middle Columbia Dam Operations. These dams include the five middle Columbia River dams between Chief Joseph Dam and the Snake River confluence. Changes in flows from the middle Columbia River dams affect power generation and aquatic species and their habitat on the lower river. All five dams have fish passage structures and fish passage survival rates are similar to CRS dams.

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Table 6-2. Reasonably Foreseeable Future Actions and Potentially Affected Resources Matrix

RFFA ID	Hydrology and Hydraulics	River Mechanics	Water Quality	Anadromous Fish	Resident Fish	Wildlife	Vegetation, Wildlife, Wetlands, and Floodplains *	Power and Transmission	Air Quality and GHG	Power and Transmission	Flood Risk Management	Navigation and Transportation	Recreation	Fisheries	Water Supply	Environmental Justice	Visual Resource	Noise	Fisheries	Cultural Resources	Indian Trust Assets, Tribal Perspectives, and Tribal Interests	Environmental Justice
RFFA1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RFFA2	X	X	X	X	X	X	X	-	-	X	X	X	X	X	X	X	-	-	X	X	X	X
RFFA3	X	-	X	X	X	X	X	X	X	X	X	-	-	-	-	X	X	X	-	X	X	X
RFFA4	X	-	X	-	-	X	X	X	X	X	X	-	-	-	-	X	-	X	-	X	X	X
RFFA5	-	X	-	X	X	X	X	-	X	-	-	-	-	X	-	X	-	-	X	X	X	X
RFFA6	X	X	-	X	X	X	X	-	-	-	X	-	X	-	X	X	-	-	-	X	X	X
RFFA7	-	-	-	X	X	X	X	-	-	-	-	-	X	X	-	X	-	-	X	-	X	X
RFFA8	-	-	-	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-
RFFA9	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	X	-	-	X	X	X	X
RFFA10	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	X	-	-	X	X	X	X
RFFA11	-	-	-	-	X	-	-	-	-	-	-	-	X	X	-	-	-	-	X	-	X	X
RFFA12	-	-	-	X	X	X	X	-	-	X	-	-	X	X	-	X	-	-	X	X	X	X
RFFA13	-	-	-	X	X	X	X	-	-		-	-	X	X	-	X	-	-	X	X	X	X
RFFA14	-	X	X	X	X	X	X	-	-	-	-	X	X	-	-	X	-	-	-	-	X	X
RFFA15	-	X	X	X	X	X	X	-	-	-	-	X	-	-	-	X	-	-	-	X	X	X
RFFA16	X	-	-	-	-	-	X		-	X	-	-	-	-	-	X	-	-	-	-	X	X
RFFA17	-	-	-	X	X	X	X	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X
RFFA18	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	X	-	-	X	-	X	X
RFFA19	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X
RFFA20	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X
RFFA21	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
RFFA22	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
RFFA23	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X
RFFA24	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X
RFFA25	-	-	X	-	-	-	X	-	-	-	-	-	-	-	X	-	X	X	-	X	X	X
RFFA26	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X

* For Vegetation, Wildlife, Wetlands, and Floodplains: Not every RFFA affects each resource; please see Resource section below for more information.
** For Indian Trust Assets, Tribal Perspectives, and Tribal Interests: Not every RFFA affects each resource; please see Resource section below for more information

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6.3 CUMULATIVE EFFECTS ANALYSIS

This section identifies affected resources; briefly summarizes their direct and indirect effects as analyzed in Chapter 3; identifies applicable cumulative actions and trends that may be additive; and, finally, analyzes the potential cumulative effects to the resources.

6.3.1 Analyses

6.3.1.1 Hydrology and Hydraulics

RFFAs with potential to affect the hydrology and hydraulics in the CIAA are listed in Table 6-3 along with a description of the effects of these actions.

Table 6-3. Reasonably Foreseeable Future Actions Relevant to Hydrology and Hydraulics

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	Overall, there would be an adverse cumulative effect from reduced availability of water from increased demand and thus consumptive use. Increased consumer demands for power could change the shape of hydropower generation patterns.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	Overall, there could be an adverse cumulative effect from reduced availability of water from increased demand. Increased demands for power could change the shape of hydropower generation from existing patterns.
RFFA3	New and Alternative Energy Development	Increased generation from wind, solar, and natural gas projects could decrease the demand for average hydropower generation, though wind and solar projects would increase the demand for hydropower flexibility. Changes in generating resources and new transmission line projects would shift power flows through the transmission system.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	There would be possible adverse effects due to the potential for an increase in lack-of-market/lack-of-turbine-capacity spill, which could lead to higher TDG levels. Conversely, decarbonizing and electrifying transportation and other sectors could reduce involuntary spill from lack of market.
RFFA6	Increase in Demand for New Water Storage Projects	With new storage projects there would be potential changes to the timing of delivery and quantity of water in different locations.
RFFA19	Climate Change	In general, there is potential for higher average fall and winter flows, earlier peak spring runoff, and longer periods of low summer flows in the Columbia River Basin. A detailed description of the potential effects on hydrology and hydraulics from climate change is presented in Section 4.2.1.

Humans require water for urban, rural, commercial, industrial, and agricultural development. As land development intensifies, so will the demands for water. Water withdrawals will in turn increase to support these uses. Continuous population growth in the Columbia River Basin will therefore place increased demands and heighten competition for limited water supplies (ISAB 2007b). The effects of increasing water demand will be exacerbated by climate change effects on the quantity and temperature of summer stream flows in many subbasins (ISAB 2007a). Hurd et al. (1999) conclude that consumptive uses of water in the western United States are relatively vulnerable to climate change. They note that intensive water use is associated with intensive development. In the Columbia River Basin, curtailment of consumptive water uses in favor of instream uses is possible, especially if the watershed is susceptive to drought and extreme events (ISAB 2007a). Increases in surface water use are expected to be accompanied by increases in groundwater use from rural development. Increased ground or surface water withdrawals could be required by state or federal laws to offset their effect by conserving water or providing storage water during times it is beneficial to the waterbody.

Energy development as part of a trend of increased use of new and alternative energy sources (such as wind, solar, and natural gas projects) also has the potential to impact hydrology and hydraulics by shifting electric power consumption demands and thus changing the nature of flows that are associated with hydropower production.

The general trend in increased water storage needs in the Columbia River Basin also has the potential to impact hydrology and hydraulics through impoundment of additional water in the future, making less water available downstream.

NO ACTION ALTERNATIVE

There could be substantial effects to hydraulics and hydrology (changes from existing condition) under the No Action Alternative from cumulative actions such as climate change. However, the contribution of the No Action Alternative to these combined cumulative effects would be negligible on its own, because the No Action Alternative operations do not appreciably change the hydrology and hydraulics in the Columbia River Basin from the existing conditions as described in Chapter 3. The existing condition is strongly influenced by the construction and operation of numerous dams—both Federal and non-Federal—that were authorized and built throughout the basin for flood control, hydropower, fish and wildlife conservation, navigation, recreation, irrigation, municipal and industrial water supply, and water quality.

MULTIPLE OBJECTIVE ALTERNATIVE 1

RFFAs with the potential to contribute cumulative effects to hydrology and hydraulics are described in Table 6-3. The direct and indirect effects of MO1 compared to the No Action Alternative are summarized in Table 6-4.

Table 6-4. Hydrology and Hydraulics Direct/Indirect Effects from Multiple Objective Alternative 1 Compared to the No Action Alternative

Project	MO1
Libby	At the Libby project, there would be higher water levels in the summer through December and lower levels in April. There would also be higher releases from Libby for much of the winter, but lower releases in December, May, and August.
Hungry Horse	At Hungry Horse, there would be lower water levels for most months in average and below-average water years. There would also be a reduction in releases for most of the year except for higher releases in the summer.
Grand Coulee	At Grand Coulee, there would be lower water levels from December through April, increased outflow in December, and decreased outflow from February through September.
Dworshak	At Dworshak, there would be changes in late summer releases with increases in June, July, and September, and a decrease in August.
Lower Snake River	In the lower Snake River projects, there would be higher elevations from April through August and increase in flows in June, July, and September.
Lower Columbia River	At the John Day project, there would be higher elevations in April through May. There would also be increased flows in December and decreased flows from February through September. There would be lower winter peak flows below Bonneville Dam.

At Libby, higher water levels in the reservoir in the summer may partially be offset by projected decreased volumes of water in the summer from cumulative actions, including climate change.

At Hungry Horse, projected lower water levels in the reservoir and a general reduction in releases may be partially offset by higher winter and spring water volumes from climate change, but exacerbated in the summer by decreased volumes of water from cumulative actions, such as new water uses.

At Grand Coulee, lower reservoir elevations in the spring may be offset by increased spring runoff as a consequence of climate change. Reduced summer flows, on the other hand, could be reduced even further as a result of cumulative actions, such as increasing water withdrawals. At Dworshak, increased releases in late summer could offset lower summer base flows; however, the lower flows in August may be lower when considered in light of the effects of cumulative actions.

In the lower Snake River projects, slightly higher reservoir elevations in the spring may be even higher when combined with cumulative effects. However, predicated higher reservoir elevations may be reduced in summer months because of lower water volumes from cumulative actions.

In the lower Columbia River projects, higher April, May, and December flows may be increased further by higher climate change–related spring flows and winter flows. Decreased February to September flows may be even lower with the addition of the effects of cumulative actions.

Combined with the effects of the cumulative actions identified in Table 6-3, there could be moderate effects (changes from No Action Alternative) under MO1 in circumstances where

MO1 causes higher volumes in the winter and spring and lower volumes of water in the summer.

MULTIPLE OBJECTIVE ALTERNATIVE 2

RFFAs with the potential to contribute to cumulative effects to hydrology and hydraulics are described in Table 6-3. The direct/indirect impacts of MO2 compared to the No Action Alternative are summarized in Table 6-5.

Table 6-5. Hydrology and Hydraulics Direct/Indirect Effects from Multiple Objective Alternative 2 Compared to the No Action Alternative

Project	MO2
Libby	At Libby, there would be higher water levels in the summer through October; the reservoir would be lower in November and December and from January through April in drier years. There would also be higher flows in November through December and lower releases from January through May, and in August.
Hungry Horse	At Hungry Horse, there would be lower water levels for most months in average and below-average water years. There would be a reduction in releases for most of the year except in August and September.
Grand Coulee	At Grand Coulee, the reservoir would be lower from December through May in wet and dry years and deeper in September. Flows below the dam would be higher in December and lower in February for average years and higher in wet years. There would be lower flows from March through August.
Dworshak	Deeper drafts from January through April; increases in flow in January and February; less flows in March and April
Lower Snake River	In the Lower Snake River there would be increased flows (but in normal operating range).
Lower Columbia River	There would be variations in McNary and John Day flows and lower winter peak flows below Bonneville Dam.

At Libby, higher water levels in the reservoir in the summer may be partially offset by projected decreased volumes of incoming water in the summer from cumulative actions, such as climate change. Projected lower reservoir levels in drier years in the winter and spring may also be partially offset by higher winter and spring runoff due to climate change. Higher outflows in November and December may be increased by higher winter and spring runoff, and periods of lower releases in the summer may be made lower by the effects of climate change, including lower summer inflows, combined with other cumulative actions. At Hungry Horse, projected lower water levels in the reservoir and a general reduction in releases may be partially offset by higher incoming winter and spring water volumes from climate change, but exacerbated in the summer by decreased volumes of inflows from cumulative actions.

At Grand Coulee, deeper drafts from December through May in wet and dry years may be even deeper due to increased winter and spring runoff. Lower flows in the summer may be even lower from the effects of the cumulative actions.

At Dworshak, deeper drafts from January through April and increased flows in January and February may both be more extreme as a result of an increase in winter and spring runoff. The effects of lower flows in March and April may be partially offset by increased spring runoff.

In the lower Columbia River projects, lower winter peak flows below Bonneville Dam may be partially offset by higher winter runoff.

Combined with the effects of the RFFAs on hydrology and hydraulics, there could be moderate effects (changes from the No Action Alternative) under MO2 in circumstances where MO2 causes higher volumes of water in the winter and spring and lower volumes of water in the summer.

MULTIPLE OBJECTIVE ALTERNATIVE 3

RFFAs with the potential to contribute to cumulative effects to hydrology and hydraulics are described in Table 6-3. The direct/indirect effects of MO3 compared to the No Action Alternative are summarized in Table 6-6.

Table 6-6. Hydrology and Hydraulics Direct/Indirect Effects from Multiple Objective Alternative 3 Compared to the No Action Alternative

Project	MO3
Libby	At Libby, there would be higher water levels in the reservoir in summer through October and the reservoir would be deeper in November through April in drier years. There would be higher flows below the dam in November and December and lower releases in January through May and August.
Hungry Horse	At Hungry Horse, there would be lower water levels in the reservoir for most months in average and below average water years. There would be a reduction in releases from the dam for most of the year except for August and September.
Grand Coulee	At Grand Coulee, water levels in the reservoir would be higher in winter. Flows below the dam would be higher in November and December and lower from April through September.
Lower Snake River	There would be substantial fluctuations in elevations—up to a 100-foot decrease in the Lower Snake River. Flows would increase with drawdown, and then after breach is complete, flows would return to natural river-like flows.
Lower Columbia River	In the lower Columbia River, John Day would continue to operate at full pool.

At Libby, higher water levels in the reservoir in the summer and fall may partially offset decreased volumes of water in the summer resulting from cumulative actions, including climate change. Lower releases and therefore greater storage in January and May due to MO3 may partially offset decreased volumes of water due to cumulative actions.

At Hungry Horse, projected lower water levels in the reservoir and a general reduction in releases may be partially offset by higher winter and spring water volumes from climate change, but exacerbated in the summer by decreased volumes of water from cumulative actions.

At Grand Coulee, higher water levels in the reservoir in winter may be increased further through increased winter precipitation due to climate change.

Combined with the effects of the cumulative actions identified in Table 6-3, there could be moderate cumulative effects (changes from the No Action Alternative) on hydrology and hydraulics under MO3 in circumstances where MO3 causes higher volumes of water in the winter and spring and lower volumes of water in the summer. Volume shifts are due to changes in storage project operations. MO3 has major direct and indirect effects to hydraulics and hydrology from the breach of the Snake River dams. These changes would be the largest influence on hydrology and hydraulics in this area rather than cumulative actions.

MULTIPLE OBJECTIVE ALTERNATIVE 4

RFFAs with the potential to cause cumulative effects to hydrology and hydraulics are described in Table 6-3. The direct/indirect effects of MO4 compared to the No Action Alternative are summarized in Table 6-7.

Table 6-7. Hydrology and Hydraulics Direct/Indirect Effects from Multiple Objective Alternative 4 Compared to the No Action Alternative

Project	MO4
Libby	At Libby, there would be higher reservoir water levels in summer through December in above average precipitation years, but lower water levels in below average years. Below the dam, there would be higher releases in winter and July, but lower releases in December, April, and May.
Hungry Horse	At Hungry Horse, there would be lower reservoir water levels (10 to 15 feet) in the drier half of years. There would be reduced releases below the dam most of year, except for higher releases from July through September.
Albeni Falls	Lake Pend Oreille would be up to 2.7 feet lower in summer months during dry years.
Grand Coulee	Water levels in Lake Roosevelt would be 5 to 8 feet lower during drawdown (December through March) and during refill (May through June), and larger decreases (up to 20 feet) in July and August during low water years. Most months have a reduction in releases from the dam, except December and January, and the drier half of years in May through July.
Lower Snake River	Water levels would be higher during minimum operating pool (MOP) from April to August. Under MO4, MOP starts and ends earlier than in the No Action Alternative.
Lower Columbia River	Water levels at Lake Umatilla would be slightly lower, with other projects at substantially lower elevations. There would be increased flows in December and January with decreases in February and November, except from May through July in dry years. There would be lower winter peak flows below Bonneville Dam.

At Libby, higher water levels in the reservoir in the summer during average years may partially be offset by projected decreased volumes of water in the summer from cumulative actions, including climate change. Higher releases in winter may be increased due to an increase in winter and spring runoff resulting from climate change.

At Hungry Horse, projected lower water levels in the reservoir and a general reduction in releases may be partially offset by higher winter and spring water volumes from climate change and exacerbated in the summer by decreased volumes of water from cumulative actions. Behind Albeni Falls Dam in Lake Pend Oreille, a decrease in elevation up to 2.7 feet in the summer months during dry years would be further exacerbated by lower summer volumes due to the effects of cumulative actions. Cumulative actions would have a similar effect at Grand Coulee, where water levels are also projected to be lower under MO4.

In the lower Snake and lower Columbia River projects, winter flows may be higher, during some years, but spring flows are more likely to be lower, except in dry years when storage projects draft additional water. Recovery of the additional draft may be harder in the future due to climate change, increased water withdrawals, and other cumulative actions that reduce the amount of water. Combined with the effects of the cumulative actions identified in Table 6-3 and climate change, there could be moderate cumulative effects (changes from the No Action Alternative) under MO4 in circumstances where MO4 causes lower spring flows.

6.3.1.2 River Mechanics

RFFAs with potential to affect the geomorphology and sediment transport in the CIAA are listed in Table 6-8 along with a summary of the effects of these actions.

Table 6-8. Reasonably Foreseeable Future Actions Relevant to Geomorphology and Sediment

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be reduced availability of water from increased development. More frequent or more severe drawdowns (or both) could lead to increased head-of-reservoir sediment mobilization and shoreline exposure/erosion. An increase in development projects has the potential to increase sediment input during construction and operation.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	Overall, there is potential for reduced availability of water from increased demand. More frequent or more severe drawdowns (or both) could lead to increased head-of-reservoir sediment mobilization and shoreline exposure/erosion.
RFFA5	Federal and State Wildlife and Lands Management	Public land management practices can influence the type and amount of sediment entering the system.
RFFA6	Increase in Demand for Water Storage Projects	An increase in water storage projects in the upper Columbia River Basin has the potential to trap additional sediment.
RFFA14	Lower Columbia River Dredged Material Management Plan	This project maintains the federally authorized navigation channel by removing accumulated sediment and depositing it in upland locations or other locations in the river. Other measures, such as channel training device construction, are potentially available.
RFFA15	Snake River Sediment Management Plan	This project maintains the federally authorized navigation channel by removing accumulated sediment and depositing in upland locations or other locations in the river. Other measures such as reservoir drawdowns are potentially available.

RFFA ID	RFFA Description	Impact Description
RFFA19	Climate Change	Changes in climate have the potential to influence erosion, transport of sediment, and sediment deposition. More frequent or more severe drawdowns could lead to increased head-of-reservoir sediment mobilization and shoreline exposure/erosion. A detailed description of the potential effects on geomorphology and sediment transport from Climate Change is presented in Section 4.2.2.
RFFA20	Clean Water Act–Related Actions	Minimizes sediment inputs in areas sensitive to sedimentation through continuation of stormwater permit actions for construction projects and programs related to reducing non-point sources of excess sediment.
RFFA23	Mining Upstream of CRS Dams	Similar to other development projects, mining projects have the potential to increase sediment input during construction and operations.

Land use and precipitation are important drivers for sediment erosion and yield into the river system. Land use is anticipated to follow similar patterns as currently experienced, with discrete population centers in some areas, but with a large portion of the watershed held as public lands. Sources of sediment such as agricultural fields are expected to continue cultivation in a manner similar to current conditions. There is a potential for lower availability of water in the summer from the effects of future human development and water withdrawals combined with the effects of climate change. This effect has the potential to increase the instances of reservoir drawdowns that could leave reservoir deltas exposed during high-flow periods. In these instances, the upper layer of reservoir deltas would be eroded and transported farther into the reservoir, potentially increasing turbidity and downstream sediment deposit thickness. Changes in storage project elevations or changes to the flow of water and sediment into a reservoir can result in changes to head-of-reservoir erosion and deposition patterns. Changes in the hydraulic conditions within run-of-river reservoirs and river reaches can change the ability of the river to transport sediment high in the water column, potentially changing the size of material passing through or settling in a run-of-river reservoir or free-flowing reach. Lower summer flows due to future water demand and climate change could exacerbate changes in sediment transport character of affected reaches.

New agricultural, industrial, mining, and commercial and rural construction projects have the potential to increase the amount of sediment inputs into the system. The effects from these types of projects would continue to be minimized through CWA–related permitting actions. The general trend in increased water storage needs in the Columbia River Basin also has the potential to affect sediment transport through impoundment of additional water in the future, resulting in less available sediment downstream. Large-scale sediment management projects in the Snake River and lower Columbia River would lessen the impact of excess sedimentation in these reaches through sediment removal and placement actions.

NO ACTION ALTERNATIVE

Combined with the effects of the RFFAs and climate change, there would likely be additional effects to sediment processes (changes from existing condition) under the No Action

Alternative. As discussed in Section 3.3.3.2, the effects of the No Action Alternative do not appreciably change the geomorphology and sediment processes, or the closely related hydrology and hydraulics, of the CRS from the existing conditions.

MULTIPLE OBJECTIVE ALTERNATIVE 1

RFFAs with the potential to contribute to cumulative effects to geomorphology and sediment transport are described in Table 6-8. The direct/indirect impacts of MO1 compared to the No Action Alternative are summarized in Table 6-9.

Table 6-9. Multiple Objective Alternative 1 Direct/Indirect Effects Compared to the No Action Alternative

Location	MO1
Storage Projects (Libby, Hungry Horse, Albeni Falls, Grand Coulee, John Day, Dworshak)	There would be negligible change (from existing conditions) in head-of-reservoir sediment mobilization with the exception of the Columbia River entering Lake Roosevelt. There is a small change in depositional patterns with temporary head-of-reservoir deposits shifting downstream caused by the Winter System FRM Space measure at Grand Coulee. There would be negligible change in trap efficiency and shoreline exposure.
Run-of-River Reservoirs and Free-Flowing Reaches (Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, Bonneville)	There would be negligible change in potential for sediment to pass run-of-river reservoirs and free-flowing reaches with the exception of lower Clearwater River above the Snake River confluence. There is potential for a small decrease in the amount of sediment passing the Clearwater River at the Snake-Clearwater confluence due to the Modified Dworshak Summer Draft measure operation. There would be negligible change in processes that supply, transport, and deposit sediment in the system, with the exception of Lake Roosevelt upper reach on the Columbia River. There is potential for a small amount of coarsening of bed sediment at the head of Lake Roosevelt caused by the Winter System FRM Space measure at Grand Coulee. There would be negligible change in the overall geomorphic character of the rivers. There would be less than 1 percent change from the No Action Alternative in the average annual volume of sediment deposited in the Snake River and Columbia River navigation channel.

At storage projects, direct and indirect effects to sediment processes would be negligible except for the Columbia River entering Lake Roosevelt. There is a minor effect in depositional patterns with temporary head-of-reservoir deposits shifting downstream caused by the Winter System FRM Space measure at Grand Coulee. There could be increases in drawdowns in the future from the effects of climate change and increased demand for water that could cause detectable changes to sediment processes at other storage projects and could increase the small changes in reservoir sediment mobilization at Grand Coulee.

In run-of-river projects and river reaches, there would be negligible effects in sediment processes except for potential small decreases in the amount of sediment passing the Clearwater River at the Snake River confluence. Similar to storage projects, there is potential for cumulative actions such as climate change and increased water withdrawals that could increase these effects in the future and cause detectable effects to sediment processes in other run-of-river projects and river reaches.

It is unknown to what magnitude climate change, increased demand for water, and other cumulative actions identified in Table 6-8 may impact future sediment processes. However, given that MO1 effects are predicted to be minor or negligible, the contribution to these cumulative effects from MO1 would likely not be substantial. Combined with the effects of the cumulative actions and climate change, there could be increased effects under MO1 in circumstances where MO1 is projected to cause minor changes on its own, and there could be detectable changes where MO1 is currently projected to cause negligible effects.

MULTIPLE OBJECTIVE ALTERNATIVE 2

RFFAs with the potential to contribute to cumulative effects to sediment processes are described in Table 6-8. The effects of MO2 compared to the No Action Alternative are summarized in Table 6-10.

Table 6-10. Direct/Indirect Effects of Multiple Objective Alternative 2 Compared to the No Action Alternative

Location	MO2
Storage Projects (Libby, Hungry Horse, Albeni Falls, Grand Coulee, John Day, Dworshak)	There would be a negligible impact to erosion or deposition processes and patterns at the head of storage project reservoirs, except at Dworshak Reservoir, where there is a minor impact to depositional patterns with temporary head-of-reservoir deposits shifting downstream. There would be negligible change in trap efficiency and shoreline exposure, except at Dworshak Reservoir, where there is a minor change in shoreline exposure from lower reservoir levels.
Run-of-River Reservoirs and Free-Flowing Reaches (Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, Bonneville)	There would be negligible change in potential for sediment to pass run-of-river reservoirs and free-flowing reaches. There would be negligible change in processes that supply, transport, and deposit sediment in the system with the exception of a small amount of fining of bed sediment in the reach of the Flathead River immediately upstream of SKQ Reservoir, and a small amount of coarsening of bed sediment at the head of Grand Coulee Reservoir. There would be negligible change in the overall geomorphic character of the rivers. There would be less than 1 percent change from the No Action Alternative in average annual volume of sediment deposited in the Snake River and Columbia River navigation channel.

At storage projects, direct and indirect effects to sediment processes would be negligible, except at Dworshak Reservoir, where there are potential small changes in deposition with head-of-reservoir deposits shifting downstream and small changes in shoreline exposure. There could be increases in drawdowns in the future from the effects of climate change and increased demand for water that could cause detectable changes to sediment processes at other storage projects and could increase the extent of changes in reservoir sediment mobilization and reservoir shoreline exposure at Dworshak.

In run-of-river projects and river reaches, there would be negligible change in sediment processes except for potential small amount of fining of bed sediments in the Flathead River upstream of SKQ Reservoir, and a small amount of coarsening at the head of Grand Coulee. Similar to storage projects, there is potential for cumulative actions such as climate change and increased water withdrawals could increase these effects in the future and cause detectable effects to sediment processes in other run-of-river projects and river reaches.

It is unknown to what magnitude climate change, increased demand for water, and other cumulative actions identified in Table 6-8 may impact future sediment processes. However, given that MO2 effects are predicted to be small or negligible, it is likely the contribution of MO2 to the overall cumulative effect would not be substantial. Combined with the effects of the cumulative actions and climate change, there could be increased effects in conjunction with MO2 in circumstances where MO2 is projected to cause minor changes on its own, meaning there could be detectable changes where MO2 is currently projected to cause negligible effects.

MULTIPLE OBJECTIVE ALTERNATIVE 3

RFFAs with the potential to contribute to cumulative effects to geomorphology and sediment processes are described in Table 6-8. The direct/indirect effects of MO3 compared to the No Action Alternative are summarized in Table 6-11.

Table 6-11. Direct/Indirect Effects of Multiple Objective Alternative 3 Compared to the No Action Alternative

Location	MO3
Storage Projects (Libby, Hungry Horse, Albeni Falls, Grand Coulee, John Day, Dworshak)	There would be negligible change in erosion or deposition processes and patterns at the head of storage project reservoirs. There would be negligible change in trap efficiency and shoreline exposure.

Location	MO3
Run-of-River Reservoirs and Free-Flowing Reaches (Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, Bonneville)	There would be little change in the potential for sediment to pass run-of-river reservoirs and free-flowing reaches, except for the Snake River from the upstream extents to Lower Granite Reservoir downstream to the Columbia River and the Clearwater River backwatered by Lower Granite Reservoir. There could be large temporary increases in the size and amount of sediment passing these reaches caused by dam breach. There could also be large temporary increases in the amount of sediment passing from the Snake River into the Columbia River from the Snake River confluence downstream. Current processes that supply, transport, and deposit sediment in the system will continue at historical rates except at the Snake River from the upstream extents to Lower Granite Reservoir downstream to the Columbia River and the Clearwater River backwatered by Lower Granite Reservoir. There is potential for a large amount of coarsening of bed sediment through these reaches. There is also potential for a large increase in the amount of material depositing in McNary Reservoir. The bed material size would be fine in the short term and coarsen in the long term due to upstream dam breach. There would be negligible change in width-to-depth ratios except for the Snake River from the upstream extents to Lower Granite Reservoir downstream to the Columbia River and the Clearwater River backwatered by Lower Granite Reservoir. There would be a major impact in geomorphic character in these reaches with the river becoming much shallower relative to its wetted width because of dam breach. Navigation maintenance is assumed to stop on the Snake River due to dam breach. There would be a 1 percent decrease from the No Action Alternative in average annual volume of sediment depositing in the lower Columbia River.

There would be negligible changes at storage projects from implementation of MO3. In run-of-river projects and river reaches, there would be a negligible change in sediment processes except for potentially large effects from dam breach on the lower Snake River. The effects from dam breaching would be major and would be the largest influence on sediment process effects.

It is unknown to what degree climate change, increased demand for water, and other cumulative actions may impact future sediment processes. However, given that MO3 effects are predicted to be major in some reaches, the cumulative effect would likely be major in areas impacted by dam breach. Combined with the effects of the cumulative actions and climate change, there could be increased effects than those previously described in Chapter 3 under MO3.

MULTIPLE OBJECTIVE ALTERNATIVE 4

RFFAs with the potential to contribute to cumulative effects to geomorphology and sediment processes are described in Table 6-8. The effects of MO4 compared to the No Action Alternative are summarized in Table 6-12.

Table 6-12. Effects of Multiple Objective Alternative 4 Compared to No Action Alternative

Location	MO4
Storage Projects (Libby, Hungry Horse, Albeni Falls, Grand Coulee, John Day, Dworshak)	There would be a negligible change in erosion or deposition processes and patterns at the head of storage project reservoirs, except at the Columbia River and Spokane River entering Grand Coulee Reservoir, where there is potential for a small change in depositional patterns with temporary head-of-reservoir deposits shifting downstream. There is also potential for a small change in head-of-reservoir sediment mobilization with deposits becoming coarser in the Columbia River entering John Day Reservoir. There would be a negligible change in trap efficiency and shoreline exposure, except at Hungry Horse Reservoir, where there is potential for a small change in shoreline exposure.
Run-of-River Reservoirs and Free-Flowing Reaches (Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, Bonneville)	There would be negligible change in potential for sediment to pass run-of-river reservoirs and free-flowing reaches except the Columbia River upstream of Kettle Falls, Washington, to the U.S.-Canada border, where there is potential for a small increase in the amount of sediment passing through the upper reach of Lake Roosevelt. There would be negligible change in the processes that supply, transport, and deposit sediment in the system except at the Columbia River between Grand Coulee Dam and the U.S.-Canada border, where there is potential for a small amount of bed sediment coarsening in Lake Roosevelt and reaches upstream to the border. There is also potential for a small amount of sediment coarsening in the Snake River downstream of Ice Harbor, the Columbia River from the Snake River confluence to Wallula, Washington, the Columbia River at the upstream end of John Day reservoir, and the Columbia River between John Day Dam and Skamania, Washington. The estimated average annual volume of sediment depositing in the Snake River navigation channel and lower Columbia River would be less than a 1 percent change from the No Action Alternative.

Small changes in head-of-reservoir sediment deposition at the Columbia River and Spokane River entering Grand Coulee Reservoir and the Columbia River entering John Day Reservoir may be exacerbated by the effects of cumulative actions and climate change if additional reservoir drawdowns occur in the future. Similarly, changes in shoreline exposure at Hungry Horse may increase. Minor effects in the processes that supply, transport, and deposit sediment in the system as described in Table 6-12 may also increase.

It is unknown to what degree climate change, increased demand for water, and other cumulative actions may impact future sediment processes. However, given MO4 effects are predicted to be small or negligible, it is likely the contribution of MO4 to the cumulative effect to geomorphology and sediment transport would not be substantial. Combined with the effects of the cumulative actions and climate change, there could be increased effects than those previously described in Chapter 3.

6.3.1.3 Water Quality

RFFAs with potential to affect the water quality in the CIAA are listed in Table 6-13 along with a description of the effects of these actions.

Table 6-13. Reasonably Foreseeable Future Actions Relevant to Water Quality

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be adverse effects from increased volumes of pollution in response to a growing population, as human population growth brings potential increases in discharges of pollutants in stormwater runoff from residential, commercial, industrial, agricultural, recreational, and transportation development.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There could be adverse effects from increased volumes of water withdrawals for domestic, industrial, commercial, and public uses. Increased withdrawals have implications for instream water temperatures, which is typically the cause of adverse effects by increasing water temperature.
RFFA3	New and Alternative Energy Development	There would be possible adverse effects due to the potential for an increase in lack-of-market/lack-of-turbine-capacity spill, which could lead to higher TDG levels.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	There would be possible adverse effects due to the potential for an increase in lack-of-market/lack-of-turbine-capacity spill, which could lead to higher TDG levels. Conversely, decarbonizing and electrifying transportation and other sectors could reduce involuntary spill from lack-of-market spill.
RFFA14	Lower Columbia River Dredged Material Management Plan	In-water and shoreline placement of dredged materials, as well as construction associated with channel training structures, may affect water quality by releasing suspended sediments into the water column and increased turbidity. Effects could be minimized by sediment removal best management practices.
RFFA15	Snake River Sediment Management Plan	Dredging effects on water quality could include the release of suspended sediments into the water column and increased turbidity. Effects could be minimized by sediment removal best management practices.
RFFA19	Climate Change	There would be possible adverse effects from increased air surface temperatures resulting in increased water temperatures. In addition, there is potential for higher winter and spring volumes and lower summer volumes of Columbia River Basin water. Refer to section 4.2.3 for more information.
RFFA20	Clean Water Act–Related Actions	This would likely result in the potential to maintain or improve water quality.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA21	Idaho Power Hells Canyon Complex Mercury Contamination Issues/Remediation	This could result in remediation and cleanup actions, as well as lead to a reduction or elimination of fish consumption advisories for mercury in fish tissue, but it is unclear what the timing and extent of remediation would be.
RFFA22	Idaho Power Hells Canyon Complex Temperature Issues	There would likely be ongoing adverse effects due to temperature threshold exceedances in the fall.
RFFA23	Mining in Reaches Upstream of CRS Dams	There would be ongoing adverse effects to both water quality and fish (tissue contamination) due to the release of contaminants downstream from mining activities that are occurring upstream.
RFFA24	Hanford Site	This could result in remediation and cleanup actions, but it is unclear what the timing and extent of remediation would be.
RFFA25	Columbia Pulp Plant	This could increase potential adverse effects due to chemical discharges, water use, and spills.

Direct and indirect effects to water quality as a result of the effects analysis in Chapter 3 are listed in Table 6-13 along with a description of the effects.

Water quality issues in the Columbia River Basin are linked to water temperature, TDG, and contaminants suspended in both water and sediment. In general, cumulative impact concerns within the CIAA related to water quality are dominated by actions that increase the additive effects of increasing air surface temperatures, which in turn increases water surface temperatures. The main influencing factor in increasing temperatures in the basin is climate change. These temperature effects are described in detail in Chapter 4. In summary, under all MOs including the No Action Alterative, air temperature is projected to continue an ongoing warming trend, resulting in higher temperatures throughout the Columbia River Basin over the study period.

Climate change also is very likely to increase the higher winter and spring volumes and lower summer volumes of water runoff throughout the Columbia River Basin. Fall water temperatures are likely to remain warmer for longer. Warmer air temperatures combined with projected decreased summer and fall flow volume could lead to increased riverine and reservoir surface water temperatures. This could exacerbate algal and nutrient problems, cyanobacterial blooms, microbial activity at swim beaches, increase pH, or reduce dissolved oxygen within the region’s reservoirs and river reaches. This warming could also increase the prevalence of invasive species (Table 6-14).

Table 6-14. Summary of Direct and Indirect Effects to Water Quality

Region	MO1	MO2	MO3	MO4
A (Libby)	There is potential for a small increase in TDG downstream of Libby Dam, too warm river water temperatures in winter, and in-reservoir and downstream river water temperatures being colder in the spring/early summer.	There is potential for reduced reservoir productivity and river water temperatures downstream of Libby Dam being warmer in the winter.	Same as MO2	There is potential for a small increase in TDG downstream of Libby Dam, too warm river water temperatures in winter, downstream river water temperatures colder in the spring/early summer, and reduced reservoir productivity.
A (Hungry Horse)	No change from NAA	There is potential for reduced reservoir productivity.	Same as MO2	Same as MO2
A (Albeni Falls)	No change from NAA	No change from NAA	No change from NAA	There is potential for greater amounts of macrophyte and periphyton growth (reduced water quality).
B (Grand Coulee)	Elevated turbidity is possible due to greater reservoir fluctuations. There could be increased mercury methylation from longer reservoir drawdowns. Reduced dissolved oxygen is expected in the reservoir near the Spokane River confluence. Water temperatures downstream of Grand Coulee are expected to be similar to NAA, with conditions that exceed water quality standards in late summer and fall. These warm conditions are likely to be exacerbated by climate change, with a longer period of warm water conditions and likely higher maximum temperatures.	Same as MO1	Same as MO1	Same as MO1
B (Chief Joseph)	In-reservoir and downstream water temperatures would likely be warmer in some summers.	Same as MO1	Same as MO1	Same as MO1

Region	MO1	MO2	MO3	MO4
C (Dworshak)	Water temperatures downstream of Dworshak would likely be warmer in August to provide cooling to the Lower Snake River.	Decreased spill discharges could create lower amounts of TDG downstream of Dworshak Dam.	No change from NAA	No change from NAA
C (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor)	Water temperatures downstream of Dworshak would likely be warmer in August to provide cooling to the lower Snake River. Increased harmful algae blooms are possible due to high August water temperatures.	No change from No Action	High suspended sediment could create reduced and/or anoxic conditions in Lower Monumental Reservoir under the first year of dam breaching. Dam breaching would resuspend contaminants and increase the biological uptake of contaminants. Contaminated groundwater flows may increase pollution in the lower Snake River once embankments have been breached. Warmer early summer in-river water temperatures are expected.	Higher TDG
D (Four Lower Columbia River Projects)	No change from NAA	No change from NAA	No change from NAA	No change from NAA

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Water quality issues in the Columbia River Basin are linked to water temperature, TDG, and contaminants suspended in both water and sediment. In general, cumulative impact concerns within the CIAA related to water quality are dominated by actions that increase the additive effects of rising air surface temperatures, which in turn increases water surface temperatures. In general, there are minimal cumulative effects in the basin related to TDG that are not short term and/or minimal. Contaminant pollution from both new and legacy sources are expected to create additive concerns within the basin, in particular when sediments are disturbed, or water surface level fluctuations occur.

The main influencing factor in increasing temperatures in the basin is climate change. These temperature effects are described in detail in Chapter 4. In summary, under all MOs, including the No Action Alterative, air temperature is projected to continue an ongoing warming trend, resulting in higher temperatures throughout the Columbia River Basin over the study period.

Climate change also is very likely to increase the higher winter and spring volumes and lower summer volumes of water runoff throughout the Columbia River Basin. Fall water temperatures are likely to be higher and remain warmer for longer. Warmer air temperatures combined with projected decreased summer and fall flow volume could lead to increased riverine and reservoir surface water temperatures. This could exacerbate algal and nutrient problems, cyanobacterial blooms, and microbial activity at swim beaches; increase pH; and reduce dissolved oxygen within the region’s reservoirs and river reaches. This warming could also increase the prevalence of invasive species.

In terms of TDG, there are few additive effects expected within the CIAA. It is possible that the increase in renewable energy development and a reduction in reliance on fossil fuel energy sources could also lead to higher spill (at times when hydropower is taken offline or ramped down to accommodate increasing wind and solar energy, for example). In this case, increasing TDG levels could result. That said, it is unknown how often this would occur or the magnitude of the effect.

Within the Columbia River Basin, sediment and water quality vary by location. The uppermost end of the system, such as the area near Hungry Horse Dam, tends to have fewer human influences and thus less pollution. As one moves downstream to more populous areas, sediment pollution is more common, reflecting the land uses occurring in proximity to the reservoir or river reach. Polluted runoff enters the CIAA from adjacent urban, agricultural, and industrial areas as a result of the use of chemicals, pesticides, fertilizers, and herbicides, as well as via contaminants from both historical and new mining and industrial areas, and natural sources, such as mercury in volcanic soils. The contaminants of concern can be detected in sediment, the water column, and aquatic organisms and include metals, arsenic, mercury, PCBs, dioxins, pesticides, and other organic compounds (mostly from human sources). In addition, some reservoirs and reaches, such as Lake Roosevelt and the lower Snake River, have known sediment and water pollution problems related to past industrial discharges and legacy contaminant issues that have not been remediated, as well as new discharges from new mining upstream.

Under all MOs, these polluted releases are expected to continue, resulting in additional pollutant loads moving through the river and reservoir system, carried by water and in fine sediments and eventually dispersing downstream through the dams to the riverbeds and the estuary. It is possible that remediation of known contaminated sites will occur; however, at present, this is not reasonably foreseeable to occur and, even if it does occur, may be offset by future increases in mining or other land use changes that disturb soils. New and continued releases of mining-related contaminants such as mercury (which then gets converted to methylmercury) are expected to continue and perhaps even increase under all MOs, especially in Lake Roosevelt as elevated mercury contamination from mining activities upstream is expected to continue over the planning period.

NO ACTION ALTERNATIVE

Under the No Action Alternative, as described above, increasing temperatures are expected to continue to play a large role in terms of additive effects to water quality. Continued and increased pollutant and nutrient loading is expected, due in large part due to population growth, which increases agricultural, industrial, and urban runoff. Continued pollutant and nutrient loading are expected in the lower Snake and Columbia Rivers due to farming activities, industry, and urban and agricultural runoff. Mining-related contaminants such as mercury into Lake Roosevelt are also expected to continue and perhaps increase. Thus, it is expected that the current water quality impairments would continue under the No Action Alternative and could perhaps worsen. It is possible that remediation of known contaminated sites will occur; however, at present, this is not reasonably foreseeable to occur and, even if it does occur, may be offset to some degree by future increases in mining or land use changes that disturb soils.

Under the No Action Alternative, winter flows and the frequency of winter flood events are projected to increase in the mainstem and lower Columbia River because of climate change. This could lead to increases in TDG through the winter and early spring due to increased involuntary spill. The lower Columbia River contains a variety of human-sourced compounds, including metals and organic compounds. Portions of the reach from The Dalles to Bonneville Dams are on the Washington or Oregon CWA 303(d) lists for high pH and/or dissolved oxygen. Additionally, some portion of all four reservoirs contain other water quality impairments that manifest as fish advisories or TMDLs for mercury, PCBs, and dioxins. These issues are expected to persist under the No Action Alternative, because changes to the CWA and remediation actions are not at this point reasonably foreseeable.

Under the No Action Alternative, decreases in summer flow volumes through the dams on the lower Snake River are expected. The water quality characteristics of the lower Snake River are largely influenced by the local and upstream flows and the inflowing upper Snake River. This includes temperatures exiting the Hells Canyon Complex out of Brownlee Reservoir that exceed water quality standards, creating cumulative temperature effects during summer migration on the lower Snake River. In addition, legacy naturally occurring, and atmospheric deposition of mercury, and other contaminant issues in the Hells Canyon Complex continue to affect the quality of water flowing into the lower Snake River. Adverse conditions could increase potential contaminants in the lower Snake River from the Hells Canyon Complex via selective intake structures.

Over the study period, the Hells Canyon Complex relicensing process (certified in 2019) will likely influence future CRS operations, including Dworshak Dam water releases. The certifications, meant to ensure compliance with water quality standards, include actions aimed at improving fish habitat and water quality in the Snake River and its tributaries. In addition to habitat restoration and fish placement, operational improvements will aim to cool water in the river for spawning and increased survival. Cooling water from Dworshak Reservoir is routinely used by the co-lead agencies to mitigate the influx of warm water into the lower Snake River. Under the new certification, however, Idaho Power will operate Brownlee Dam to reduce the temperature of water released from the dam, which is expected to reduce stress on all fish and aquatic life. This could also relieve some of the actions co-lead agencies currently take to mitigate for high temperatures coming out of the Hells Canyon Complex through Dworshak releases. These combined operational changes could have a cumulative beneficial effect on lower Snake River water quality temperatures.

Winter flows and the frequency of winter flood events are projected to increase in the lower Snake River and at Dworshak Reservoir under the No Action Alternative. In response to this change, Dworshak Dam could store and evacuate inflow volumes for system winter flood events more frequently than during the historical period. The projected higher volumes and variability in flows could result in increased spill leading to increased TDG from lack-of-market and lack-of-turbine-capacity spill and turbidity during winter months. During spring, the freshet is projected to occur earlier, resulting in an earlier fill period for Dworshak Reservoir and higher outflows in April, which could result in higher TDG in spring and increased reservoir productivity.

Under the No Action Alternative for Grand Coulee and Chief Joseph, periods of higher temperatures have the potential to occur earlier in the year and last for longer durations than historically. This could exacerbate algal, nutrient, pH, and dissolved oxygen issues. In the spring, water temperatures could warm earlier in the year because of the projected increase in air temperature. Grand Coulee creates a lagged effect on downstream seasonal water temperature change because the outflow temperature is less than inflow. This thermal lagging from the dam is likely to persist under projected climate change conditions. Flow volume is projected to increase during winter months, which could result in higher outflows and higher spill. Increased inflow and spill volume is likely to result in higher TDG than historical levels during winter. In the summer, TDG could be decreased as a result of projected lower flow volumes.

Under the No Action Alternative, nutrients or pollution would remain relatively low in Hungry Horse Reservoir. It is expected that coal production in the Kootenai River watershed above Libby Dam will continue to increase as it has over the past 20 years. This increase will lead to greater selenium and nitrate loadings into Lake Koocanusa and the Kootenai River downstream of Libby Dam. Under the No Action Alternative, the additive effects of higher winter flows and runoff anticipated under climate change may cause suspended solids (nutrients, selenium) to move farther down into the reservoir and downstream of Libby Dam in the Kootenai River. Runoff in combination with an expected increase in coal production is expected to increase pollutants in both the reservoir and the river. The continued increase in nitrate loadings to Lake Koocanusa could make the lake susceptible to increased algal blooms, including potential nuisance species, under the No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 1

In general, water temperature responses at Hungry Horse and Chief Joseph projects under MO1 are expected to be similar to the No Action Alternative. Overall negligible water quality effects are anticipated for Regions A, B, and D, with the exception of major reductions in TDG below Grand Coulee Dam in Region B. Minor increase in spill and associated TDG levels are expected at Libby Dam due to the project's draft and refill operations.

There are no changes to operations expected at Albeni Falls Dam under MO1, so the water quality in Lake Pend Oreille and the Pend Oreille River is expected to remain unchanged and reflect conditions as described in the No Action Alternative (see Table 6-15). In Region C under MO1, moderate adverse effects to water temperature and negligible effects to TDG and other water quality parameters would likely occur.

Table 6-15. Water Quality Direct/Indirect Effects from Multiple Objective Alternative 1 Compared to the No Action Alternative

Region	MO1
A (Libby)	Effects are expected to be similar to the No Action Alternative, with the exception of a minor increase in spill and associated TDG levels at Libby Dam due to the project's draft and refill operations.
A (Hungry Horse)	Effects are expected to be similar to the No Action Alternative.
A (Albeni Falls)	Effects are expected to be similar to the No Action Alternative.
B (Grand Coulee)	Effects are expected to be similar to the No Action Alternative, with the exception of major reductions in TDG below Grand Coulee Dam in Region B. Increased seasonal water surface elevations are anticipated to result in an increased amount of mercury that is converted to methylmercury upon rewatering of shorelines. Methylmercury is the more toxic form of mercury that bioaccumulates in fish tissue.
B (Chief Joseph)	Effects are expected to be similar to the No Action Alternative.
C (Dworshak)	Effects are expected to be similar to the No Action Alternative.
C (Lower Snake River)	The Dworshak Temperature Control measure results in significantly higher water temperature than NAA in August and early September. These effects are greatest at Lower Granite and decrease downstream.
D (Lower Columbia River)	Effects are expected to be similar to the No Action Alternative.

Under MO1, slightly higher water temperatures would be expected in the lower Snake River during August due to the Modified Dworshak Summer Draft measure. Under MO1, cool water would be discharged into the lower Snake River from June 21 to August 1. This measure results in substantially higher water temperatures than No Action Alternative in August and early

September. These effects are greatest at Lower Granite and decrease downstream. This measure could exacerbate potential warming water temperatures from Climate Change.

At Grand Coulee, increased seasonal water surface elevations are anticipated to result in an increased amount of mercury that is converted to methylmercury upon rewatering of shorelines. Methylmercury is the more toxic form of mercury that bioaccumulates in fish tissue. This could be exacerbated over the study period if more inflows of mercury into Lake Roosevelt were to occur due to RFFA23, Mining in Reaches Upstream of CRS Dams.

In addition, increases in spill and associated TDG levels at Libby Dam are anticipated due to the project's draft and refill operations. It is not well understood how RFFAs could cumulatively affect this condition, whether adverse or beneficial. Major reductions in TDG below Grand Coulee do not have associated cumulative effects.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Cumulative effects to water quality from MO2 are described in Table 6-16 and discussed in the text below. In general, water temperature response at Grand Coulee, Chief Joseph, and Albeni Falls projects and in the Lower Snake River are expected to be similar to the No Action Alternative. In Region A, negligible to minor improvements to water quality would occur. In Region B, negligible water quality effects would occur, with the exception of major reductions in TDG below Grand Coulee Dam. In Region C, moderate to minor increases in summer water temperatures would occur, while in Region D water temperature effects would be negligible. In Regions C and D, frequency of exceeding state TDG water quality standards would decrease.

Table 6-16. Water Quality Direct/Indirect Effects from Multiple Objective Alternative 2 Compared to the No Action Alternative

Region	MO2
A (Libby)	There would likely be adverse effects due to higher outflows, potentially resulting in suspended solids moving farther down into the reservoir and downstream of Libby Dam, and increased downstream water temperature.
A (Hungry Horse)	The Slightly Deeper Draft for Hydropower measure would allow for greater operational flexibility and results in deeper winter drawdowns at Hungry Horse Reservoir. This, in turn, reduces spring outflows and spill in some cases. As a result, the number of days that TDG below the dam is greater than 110 percent under MO2 is expected to be lower than the No Action Alternative in most years.
A (Albeni Falls)	Effects are expected to be similar to the No Action Alternative.
B (Grand Coulee)	Effects are expected to be similar to the No Action Alternative, with the exception of major reductions in TDG below Grand Coulee Dam.
B (Chief Joseph)	Effects are expected to be similar to the No Action Alternative.
C (Dworshak)	Beneficial negligible decreases in TDG are expected at Dworshak in addition to colder water temperatures from April through June, alongside moderate to minor increases in summer water temperatures.
C (Lower Snake River)	Decreases in TDG levels are expected, alongside moderate to minor increases in summer water temperatures.
D (Lower Columbia River)	Decreases in TDG levels are expected.

Hungry Horse would experience deeper winter drawdowns under MO2. This, in turn, could reduce spring outflows and spill, thereby potentially reducing TDG below the dam to lower than No Action Alternative levels in most years.

Under MO2, a deeper drawdown of Libby Reservoir may help to mitigate for higher inflows anticipated in the winter as a result of climate change. However, deeper reservoir drafts and higher outflows may result in suspended solids (nutrients, selenium) moving farther down into the reservoir and downstream of Libby Dam, and increased downstream water temperatures in the Kootenai River. This, combined with the additive effects of mining and coal extraction upstream, would likely adversely affect contaminant levels in Libby Reservoir and the Kootenai River. In addition, there would be a slight decrease in TDG releases from Grand Coulee dam in average flow years.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Cumulative effects to water quality from MO3 are described in Table 6-17 and discussed the text below.

Table 6-17. Water Quality Direct/Indirect Effects from Multiple Objective Alternative 3 Compared to the No Action Alternative and Multiple Objective Alternatives 1 and 2

Region	MO3
A (Libby)	Similar to MO2, a deeper drawdown of Libby Reservoir may help to mitigate for higher inflows anticipated in the winter under climate change. However, deeper reservoir drafts and higher outflows may result in suspended solids (nutrients, selenium) moving farther down into the reservoir and downstream of Libby Dam, as well as increased downstream water temperatures.
A (Hungry Horse)	Effects are expected to be similar to MO1.
A (Albeni Falls)	Effects are expected to be similar to the No Action Alternative.
B (Grand Coulee)	Effects are expected to be similar to the No Action Alternative.
B (Chief Joseph)	Effects are expected to be similar to the No Action Alternative.
C (Dworshak)	Effects are expected to be similar to the No Action Alternative.
C (Lower Snake River)	Major short-term adverse impact on water quality due to the mobilization of sediment during dam breaching. Long-term beneficial effect on water quality in Region C, including major reductions in TDG and fall water temperatures. MO3 is expected to result in warmer water temperature in the spring and increased air temperatures under climate change could exacerbate this impact.
D (Lower Columbia River)	Minor reductions in fall water temperatures are expected as compared to the No Action Alternative. Moderate short-term adverse effect on water quality, particularly in McNary Reservoir due to the mobilization of sediment during dam breaching. Long-term negligible to minor beneficial effect on water quality in Region D.

The primary water quality concern under MO3 from dam breach is the exposure of chemical contaminants that have been contained in reservoir sediment. Chemicals of concern include total DDT, dioxin, manganese, and un-ionized ammonia. DDT could potentially affect the biological system, and un-ionized ammonia concentrations may exceed EPA water quality criteria for the protection of aquatic life. This, combined with the additive effects of legacy contaminant issues upstream, would likely increase contaminant levels in the lower Snake and Columbia Rivers, culminating in a larger impact to sediment contamination in the McNary reservoir. This will likely be higher in the short term following breach and continue intermittently with high-flow events that reach areas that were previously mud flats. Breach of the lower Snake River dams would result in sediment being transported downstream to the McNary forebay, particularly in the years immediately following dam breach (near term). As a result, near-term, adverse effects associated with the sediment transport would be expected in the McNary Reservoir. Dissolved oxygen, light attenuation, phytoplankton, zooplankton, and productivity would likely be depressed, while total suspended solids, turbidity, nutrients, organics, and metals would likely increase.

Under MO3, elevated river TDG due to dam spill operations would not occur. An initial reduction of primary and secondary production is likely to occur while suspended solids are concentrated and turbidity is elevated. As compared to the No Action Alternative, MO3 is expected to result in warmer water temperature in the spring, similar water temperatures in the summer, and cooler water temperatures in the fall with the overall duration of warm water reduced. Furthermore, the shallower free flowing river condition of MO3 will lead to greater diurnal fluctuations in water temperature, including nighttime cooling. Daily low temperatures (occurring at night) are projected to warm faster than daily high temperatures. The effects of projected increasing nighttime temperatures could reduce nighttime cooling of the river. Cumulatively, increased air temperatures under climate change could exacerbate this impact. In addition, the river would likely cool more at night, providing more refuge for fish. These temperature changes could be adverse or beneficial depending on the season or time of day. In the case of beneficial effects (such as nighttime temperature drops), the additive cumulative sources of heat in the Columbia River Basin (such as climate change) would have less of an impact under MO3, resulting in less of a need to draft Dworshak to add cold water to the system. In the case of adverse effects (such as daytime temperature increases), the additive sources of heat in the basin could make it harder to cool the river in times of extreme heat under MO3. This would encourage early (starting in July) Dworshak water temperature management to mitigate warming in the lower Snake River.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Cumulative effects to water quality from MO4 are described in Table 6-18 and discussed the text below.

Table 6-18. Water Quality Direct/Indirect Effects from Multiple Objective Alternative 4 Compared to the No Action Alternative and Multiple Objective Alternative 1

Region	MO4
A (Libby)	Reduced productivity is expected in the reservoir. This operation and resultant impact may increase in frequency as streamflow volumes are likely to shift to occur earlier in the year and late spring/summer flow declines (Section 4.1.2.4).
A (Hungry Horse)	Effects are expected to be similar to MO1.
A (Albeni Falls)	Effects are expected to be similar to the No Action Alternative.

Region	MO4
B (Grand Coulee)	Effects are expected to be similar to MO1, with the exception of major reductions in TDG below Grand Coulee Dam. Water temperatures downstream of Grand Coulee are expected to continue to exceed water quality standards in late summer and early fall, which could be exacerbated in dry years.
B (Chief Joseph)	Effects are expected to be similar to MO1.
C (Dworshak)	Increased TDG is expected in this part of the river.
C (Lower Snake River)	Increased TDG is expected in this part of the river.
D (Lower Columbia River)	Increased TDG is expected in this part of the river.

Under MO4, in low water years, the *McNary Flow Target* measure would allow the following maximum releases: 534,000 acre-feet from Libby, 232,000 acre-feet from Hungry Horse, 234,000 acre-feet from Albeni Falls, and 1 million acre-feet from Grand Coulee. These releases would in turn result in lower reservoir elevations at each project, which could reduce productivity in the reservoir and impact fish growth. As a result of the additive effect of climate change, this operation may need to increase in frequency as streamflow volumes are likely to shift to occur earlier in the year and as late spring/summer flow declines. Water temperatures downstream of Grand Coulee are expected to continue to exceed water quality standards in late summer and early fall, and this could be exacerbated in dry years by the early release of flows and missed refill due to the *McNary Flow Target* measure. Cumulative effects such as climate change would only increase air surface temperatures in this region, thus increasing water temperatures as well.

6.3.1.4 Anadromous Fish

RFFAs with potential to impact anadromous fish in the CIAA are listed in Table 6-19 and Table 6-20, along with a summary of the effects of these actions.

Table 6-19. Reasonably Foreseeable Future Actions Relevant to Anadromous Fish

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be an adverse effect from loss of riparian habitat and fragmentation through new development projects.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There could be an overall adverse effect from reduced availability of water from increased demand. In addition, tributaries that are substantially depleted by water diversions will continue to be an important limiting factor for most species in the Columbia River Basin upstream of Bonneville Dam.
RFFA3	New and Alternative Energy Development	There could be a possible adverse effect from increase in lack-of-market or lack-of-turbine-capacity spill in the future and higher TDG levels if shifting away from hydropower to other sources occurs.
RFFA5	Federal and State Wildlife Lands Management	Land management practices are anticipated to continue to include watershed improvement projects that can benefit fish.
RFFA6	Increase in Demand for New Water Storage Projects	There is potential for adverse effects from changes to timing, delivery, and quantity of water in different locations from new storage projects.
RFFA7	Fishery Management Plans	The goal of Pacific Salmon Fishery Management Plans is to better manage catch of salmon in ocean waters offshore. This could lead to a trend of beneficial effects to salmon numbers by reducing commercial catch for these species. The *United States v. Oregon* Fishery Management Agreement has the overall goal of rebuilding weak runs to full productivity through habitat protection authorities, enhancement efforts, artificial production techniques, and harvest management. Implementation of this agreement could lead to a trend of beneficial effects to target species.
RFFA8	Bycatch and Incidental Take	Bycatch of Endangered Species Act (ESA)–listed species and incidental take would continue to have an adverse effect.
RFFA12	Fish Hatcheries	Hatcheries would continue to benefit overall anadromous populations that are increased through stocking. There are also adverse effects that would continue to occur from interactions between hatchery and naturally reproduced fish.
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement	New tribal, state, and local fish and wildlife improvement projects are projected to restore, maintain, create, or enhance fish and wildlife habitat. Many of these projects are focused on benefiting anadromous species.
RFFA14	Lower Columbia River Channel Improvement Plan	In-water and shoreline placement of dredged materials, as well as construction associated with channel training structures, may temporarily disrupt aquatic habitat.
RFFA15	Snake River Sediment Management Plan	Dredging effects on fish are generally localized and include possible entrainment, increased turbidity, noise, and changes to habitat such as substrate and depth. Effects on salmonids would continue to be minimized by conducting work during the approved in-water work period when many fish species are at lower densities.

RFFA ID	RFFA Description	Impact Description
RFFA17	Invasive Species	There is a projected increase in northern pike and other species that prey on salmonids. Non-native fishes such as walleye, smallmouth bass, and channel catfish are also present in slower-moving areas throughout the Columbia River Basin.
RFFA19	Climate Change	Projected changes in air temperature, precipitation, hydrology and stream temperature have adverse implications for the freshwater, estuarine, and marine environments of many fish species in the Pacific Northwest. For salmon and steelhead in the Columbia River Basin, climate change may affect the timing of spawning, emergence, and migration; cause changes in growth and development; increase predation rates; increase ocean temperatures; and affect the availability of critical habitat. These biological changes could impact species productivity and abundance. A detailed description of the potential effects on anadromous fish from Climate Change is presented in Section 4.2.3.
RFFA20	Clean Water Act–Related Actions	CWA-related permitting and actions related to temperature and other water quality parameters would continue to benefit anadromous species.
RFFA22	Idaho Power Hells Canyon Complex Temperature Issues	There is potential for temperature effects during summer migration if Brownlee Reservoir is drafted.
RFFA23	Mining in Reaches Upstream of CRS Dams	There would be potential adverse effects due to pollutants and bioaccumulation.
RFFA26	Middle Columbia Dam Operations	Passage rates are similar to CRS dams, however, Columbia River salmon, steelhead, and lamprey must pass these five additional dams before they reach other tributaries.

1047 **Table 6-20. Direct and Indirect Effects on Anadromous Species Compared to the No Action Alternative**

Fish Type	MO1	MO2	MO3	MO4
Upper Columbia Salmon and Steelhead	Effects would be similar to the No Action Alternative. Structural and operational measures designed to provide incremental improvements in juvenile survival and adult returns would have negligible to minor benefits based on fish modeling results.	Lower spill would, generally increase travel time, transportation, and the number of powerhouse encounters for outmigrating juveniles. CSS model results show major adverse effects while NOAA LCS model results show minor adverse effects to juvenile survival and adult abundance. There would also be lower TDG exposure.	There would be negligible to minor beneficial effects due to increases in juvenile survival and adult returns with fewer powerhouse encounters. There would also be slightly higher TDG exposure.	CSS model results show major beneficial effects while NOAA LCS model results show moderate adverse effects to juvenile survival and adult abundance. There would also be higher TDG exposure, which may also reduce passage success of adults.

Fish Type	**MO1**	**MO2**	**MO3**	**MO4**
Snake River Salmon and Steelhead	Effects would be similar to the No Action Alternative. Structural and operational measures would provide incremental, small improvements and the fish models show negligible to minor benefits. The Modified Dworshak Summer Draft measure intended to improve thermal conditions for adults would result in adverse water temperatures and reduce adult migration success.	There would be decreases in juvenile survival metrics based on reduced spill during downstream passage. Adult abundance may vary depending on latent mortality assumptions. Adult abundance results vary by model; minor increases if more transported fish contributes to higher returns or major decreases due to more powerhouse encounters and reduced ocean survival. There would also be lower TDG exposure.	Snake River anadromous species would experience short-term, major adverse effects immediately post-breath, then major beneficial effects after sediment movement returns to No Action Alternative levels.	CSS model results show major beneficial effects while NOAA LCS model results show moderate adverse effects to juvenile survival and adult abundance. There would be higher TDG exposure with increased spill, which may also reduce passage success of adults.
Other Anadromous Fish	There would be minor adverse effects to chum salmon. There would be minor beneficial effects to lamprey from expanding the network of lamprey passage structures. Eulachon, shad, and green sturgeon effects would be similar to the No Action Alternative.	There would be decreased overall juvenile survival. There would be moderate adverse effects to chum salmon, minor beneficial effects to lamprey, and minor adverse effects to Eulachon and green sturgeon. There would also be lower TDG exposure.	Effects to coho and chum salmon would be similar to the No Action Alternative. There would be minor adverse effects to eulachon and green sturgeon. There would be minor beneficial effects to lamprey.	There would be lower chum flows and survival. Minor adverse effects to eulachon and green sturgeon would occur. There would be minor beneficial effects to lamprey

NO ACTION ALTERNATIVE

As described in Section 3.5.5.2, a variety of factors, including project structures, surface passage modifications, natural mortality, and predation affect juvenile migration and survival at the lower Columbia River and lower Snake River Projects. Adult migration is affected by dam passage, predation, and temperature and flow conditions. The measures in the No Action Alternative are not expected to change these factors, although temperature and flow conditions under the No Action Alternative may be impacted by climate change and other actions.

There are a number of cumulative actions that could have beneficial and adverse effects to anadromous species under the No Action Alternative as described in Table 6-20.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 creates small overall improvements for upper Columbia River salmon and steelhead and Snake River salmon and steelhead through structural measures and flow modifications. In the future, these improvements may be offset by projected changes in flows and temperature. Under MO1, there would also be adverse effects to Snake River salmon and steelhead from the Dworshak flow measure, which would limit the ability of the CRS to mitigate high temperature inflows, resulting in temperature increases later in the summer. Flows for chum salmon would be met in 2 percent less years than the No Action Alternative. The most influential effect of MO1 on Columbia River sockeye would be the substantial reduction in nesting habitat for the birds that prey on outmigrating juvenile fish. There would be an incremental benefit to lamprey from lamprey measures. Mitigation measures under MO1 include temporary extension of performance standard spill levels which would reduce effects from increased spill levels in Regions C and D. Cumulative actions that have the potential to further reduce water levels in the future, such as population growth and development, water withdrawals, new storage projects, and climate change, could increase adverse effects identified from the Dworshak measure and could increase the number of years that chum salmon flows are not met, but it is uncertain to what degree. In addition, there are a number of other cumulative actions that could have beneficial and adverse effects to anadromous species in the basin under MO1 as described in Table 6-19. Considering the beneficial effects of MO1 combined with other actions with the goal of improving conditions for anadromous species in the Columbia River Basin, it is anticipated that there would be a cumulative benefit to anadromous species with MO1 contributing to these beneficial effects. These cumulative benefits are uncertain, however, because the effects of environmental factors such as climate change could have adverse effects to anadromous species that would outweigh benefits from measures in MO1 and other cumulative actions intended to benefit anadromous species, such as tribal, state, and local fish and wildlife improvement projects.

MULTIPLE OBJECTIVE ALTERNATIVE 2

MO2 includes structural measures to improve survival of juvenile salmon and steelhead, but lower spill would, generally speaking, increase travel time and the number of powerhouse encounters for juvenile outmigrants. Anadromous juveniles outmigrating in the Snake River would be transported at a higher rate than under the No Action Alternative, which could result in more reaching Bonneville Dam sooner than in-river fish. Depending on ocean survival dynamics, more or less adults could return, and returning adults would likely have higher rates of straying and migration delays due to higher rates of transported juveniles. There would also be decreased juvenile steelhead and salmon survival in the middle and lower Columbia River reaches and minor adverse effects to eulachon and green sturgeon. However, the lower spill may decrease steelhead kelt survival but would lower TDG overall. Juvenile sockeye salmon would experience lower survival during outmigration in the river than under the No Action Alternative. The most important change for Columbia River sockeye from MO2 is the potential for transportation of juveniles, which can improve short-term survival of juveniles but may have adverse consequences when they return as adults. Additionally, higher temperatures compared to the No Action Alternative would have additional adverse effects for adults.

Similar to MO1, cumulative actions that have the potential to further increase temperatures and reduce water levels in the future, such as population growth and development, water withdrawals, new storage projects, and climate change, could increase adverse effects identified due to hydropower measures and decreased spill, but it is uncertain to what degree. Some of these adverse effects could be partially offset by other actions that have the goal of benefiting anadromous species as identified in Table 6-19. Overall, because MO2 has predominantly adverse effects to anadromous species, when combined with adverse effects from cumulative actions, it is anticipated that there could be a substantial adverse cumulative impact under MO2.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Under MO3, modeling results indicate there would be minor increases in juvenile survival and adult returns and fewer powerhouse encounters for upper Columbia River salmon and steelhead. MO3 would involve breaching the lower Snake projects, which would end juvenile fish transportation at the collector projects, and would also have effects on both juvenile outmigration and adult upstream migration. Hatchery fish production in the basin would be reduced with the elimination of the Snake River Compensation Plan hatcheries. With the breaching of Snake River dams, there would no longer be the commitment to mitigate for those dams, so the hatchery programs funded by the Lower Snake River Compensation Plan would no longer produce smolts. These fish account for 80 to 90 percent of all juvenile Snake River fish passing CRS projects. COMPASS and CSS models do not account for this dramatic reduction in juvenile fish production. Adverse effects from increased spill levels would be minimized through performance standard spill in Region D and adverse effects from dam breaching in Region C would be minimized by trapping and transporting affected populations and raising additional hatchery fish to address fish lost from dam breaching. Modification of the Tucannon River channel at the delta would minimize anticipated passage effects to anadromous fish on the Tucannon River due to breaching. Breaching of the lower Snake River dams would have downstream benefits to sockeye salmon related to turbidity and reducing predation plus added safety in numbers for outmigrating juveniles. There would also be minor increases in middle and lower Columbia River salmon and steelhead. Coho and chum salmon would experience effects similar to the No Action Alternative, and there would be minor adverse effects to eulachon and green sturgeon. Considering the beneficial effects of MO3 combined with other actions with the goal of improving conditions for anadromous species in the Columbia River Basin as described in Table 6-19, it is anticipated that there would be a cumulative benefit to anadromous species under MO3, with MO3 dam breaching on the lower Snake River contributing to these beneficial effects. The degree of cumulative benefits is uncertain, however, there are other factors such as climate change (higher water temperatures, decreased in-river water flow, etc.) that could have adverse effects to anadromous species that outweigh benefits from measures in MO3 and other actions intended to benefit anadromous species.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Under MO4, for upper Columbia River salmon and steelhead, there would be minor increases in juvenile survival and adult returns, shorter travel time, and fewer powerhouse encounters from increased spill. However, there would be higher TDG exposure. For Snake River salmon and steelhead, there would be increased juvenile survival and much higher TDG exposure. There would also be increased juveniles in the middle and lower Columbia River. There would be lower chum salmon flows and survival, and temperature effects for lamprey in the middle Columbia River. The most notable adverse effects of this MO for Snake River sockeye would be increased nesting habitat for predatory birds and greater TDG exposure. There could be an increase in northern pike spreading downstream in the Columbia River due to increased entrainment out of Lake Roosevelt. Under MO4 there would be a temporary extension of performance standard spill in Regions C and D that would minimize adverse effects from increased spill levels. In Region C, the Little Goose raceway infrastructure would be modified to minimize effects from higher spill levels. Benefits to upper Columbia River and Snake River fish due to increased spill may be partially offset by adverse effects from cumulative actions that reduce water levels, such as climate change and increased future water withdrawals, but it is uncertain to what extent. These same actions may increase adverse effects on chum salmon, sockeye salmon, and lamprey. Considering the beneficial effects of MO4 combined with other actions with the goal of improving conditions for anadromous species in the Columbia River Basin as described in Table 6-19, it is anticipated that there would be a cumulative benefit to anadromous species under MO4 possibly with the exception of lamprey and chum salmon. The degree of cumulative benefits is uncertain, however, because there are also other factors, such as climate change, that could have adverse effects to anadromous species that outweigh benefits from measures in MO4 and other actions intended to benefit anadromous species.

6.3.1.5 Resident Fish

RFFAs with potential to impact resident fish in the CIAA are listed in Table 6-21 along with a summary of the effects of these actions.

1165 **Table 6-21. Reasonably Foreseeable Future Actions Relevant to Resident Fish**

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be an adverse effect from loss of riparian habitat, fragmentation, and water pollution through new development projects.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There could be an overall adverse effect from reduced availability of water from increased demand. In addition, tributaries that are substantially depleted by water diversions will continue to be a major limiting factor for most species in the Columbia River Basin upstream of Bonneville Dam.
RFFA3	New and Alternative Energy Development	There would possibly be an adverse effect from increase in lack-of-market/lack-of-turbine-capacity spill in the future and higher TDG levels if shifting away from hydropower to other sources occurs.
RFFA5	Federal and State Wildlife Lands Management	Land management practices are anticipated to continue to include watershed improvement projects that can benefit fish.
RFFA6	Increase in Demand for New Water Storage Projects	Potential adverse effects from changes to timing, delivery, and quantity in different locations.
RFFA7	Fishery Management Plans	The goal of Pacific Salmon Fishery Management Plans is to better manage catch of salmon in ocean waters offshore. This could lead to a trend of beneficial effects to salmon numbers by reducing commercial catch for these species. The *United States v. Oregon* Fishery Management Agreement has the overall goal of rebuilding weak runs to full productivity through habitat protection authorities, enhancement efforts, artificial production techniques, and harvest management. Implementation of this agreement could lead to a trend of beneficial effects to target species.
RFFA8	Bycatch and Incidental Take	Bycatch of ESA-listed species and incidental take would continue to have an adverse effect.
RFFA9	Bull Trout Passage at Albeni Falls	The proposed action is to construct an upstream “trap and haul” fish passage facility at Albeni Falls; downstream passage will occur through the spillway and powerhouse.
RFFA10	Ongoing and Future Habitat Improvement Actions for Bull Trout	A common goal among these plans is the improvement of aquatic habitat and water quality to benefit native salmonids, especially bull trout.
RFFA11	Bull Trout Fisheries Management	The state fish and game agencies manage fisheries in the Columbia River Basin and regulate private and public hatchery releases. The agencies modify and publish recreational fishing regulations on an annual basis. Currently, recreational anglers may not target bull trout in most areas but may incidentally catch and release bull trout.

RFFA ID	RFFA Description	Impact Description
RFFA12	Fish Hatcheries	Hatcheries would continue to benefit resident fish populations that are increased through stocking. There would also be continued adverse effects from interactions between hatchery-produced and naturally reproduced fish.
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement	New tribal, state, and local fish and wildlife improvement projects are projected to restore, maintain, create, or enhance fish and wildlife habitat. Many of these projects are focused on resident species of concern.
RFFA14	Lower Columbia River Dredged Material Management Plan	Channel training and in-water and shoreline placement of dredged materials may temporarily disrupt aquatic habitat.
RFFA15	Snake River Sediment Management Plan	Dredging effects on fish are generally localized and include possible entrainment, increased turbidity, noise, and changes to habitat such as substrate and depth. Effects on fish would continue to be minimized by conducting work during the approved in-water work period.
RFFA16	SKQ Dam Operations	Adverse effects to bull trout would continue to occur from entrainment through SKQ Dam out of Flathead Lake.
RFFA17	Invasive Species	Non-native fishes such as northern pike, walleye, smallmouth bass, and channel catfish would continue to be present in reservoirs and slower-moving riverine areas throughout the Columbia and Snake River Systems.
RFFA19	Climate Change	Potential effects of climate change, such as warmer air temperatures and changes to hydrology, could have effects on the ecosystem. Warming air temperatures coupled with changing rainfall amounts and timing affects soil conditions, plant communities, insects, and wildlife. A warming climate could affect the distribution and abundance of many resident fish, increasing the range of some species while reducing the range of others.
RFFA20	Clean Water Act–Related Actions	CWA-related permitting and actions related to temperature and other water quality parameters would continue to benefit fish.
RFFA22	Idaho Power Hells Canyon Complex Temperature Issues	There is potential for temperature effects during summer migration.
RFFA23	Mining in Reaches Upstream of CRS Dams	There would be potential adverse effects due to pollutants and bioaccumulation.

Table 6-22 below provides a summary of direct and indirect effects identified for resident fish.

Table 6-22. Summary of Direct and Indirect Effects to Resident Fish from Alternatives

Region	MO1	MO2	MO3	MO4
Region A Resident Fish	In the Kootenai area, there would be mixed benefits to food production in the reservoir and minor adverse effects to burbot and Kootenai River White Sturgeon. In the Hungry Horse area, there would be minor to moderate adverse effects from changes in reservoir elevations and outflows to bull trout and other native fish, food availability, the varial zone, fish entrainment, and habitat. Effects in the Lake Pend Oreille basin would be similar to the No Action Alternative.	In the Kootenai area, there would be minor adverse effects to riparian and sturgeon recruitment, however, there would be a minor beneficial increase to river habitat for bull trout and other native fish. In the Hungry Horse area, there would be moderate to major adverse effects to food availability, the varial zone, entrainment, and habitat. In the Lake Pend Oreille basin, there would be reduced entrainment risk.	In the Kootenai area, there would be moderate adverse effects to food availability and minor adverse riparian and sturgeon recruitment effects; however, there would be a minor beneficial increase to river habitat for bull trout and other native fish. In the Hungry Horse area, there would be minor to moderate adverse effects to bull trout, food availability, the varial zone, entrainment, and habitat. Effects in the Lake Pend Oreille basin would be similar to the No Action Alternative.	In the Kootenai area, there would be minor beneficial effects to the riparian habitat; however, there would be a minor to moderate adverse effects to reservoir habitat and tributary access. In the Hungry Horse area, there would be moderate to major adverse effects to bull trout, food availability, the varial zone, entrainment, and habitat (especially in dry years). In the Lake Pend Oreille basin, there would be minor adverse effects to riparian and reservoir habitat and tributary access (especially in dry years).
Region B Resident Fish	There would be minor to moderate effects in Lake Roosevelt to bull trout and other resident fish including increased entrainment and varial zone effects. Overall effects in river reaches would be similar to the No Action Alternative except for minor reduction in sturgeon recruitment.	There would be moderate adverse effects in Lake Roosevelt such as increased entrainment and varial zone effects. River effects and sturgeon recruitment would be similar to No Action Alternative.	There would be minor adverse effects to sturgeon above Lake Roosevelt and minor adverse effects due to entrainment of Lake Roosevelt fish. In the McNary reservoir there would be increased sturgeon recruitment and connectivity. There would be minor short-term adverse effects from breaching the four lower Snake River dams.	There would be moderate to major adverse effects in Lake Roosevelt, such as increased entrainment and varial zone effects (especially in dry years). Sturgeon recruitment would be similar to the No Action Alternative.

Region	**MO1**	**MO2**	**MO3**	**MO4**
Region C Resident Fish	Minor increases in water temperature in August would favor non-native fish (Dworshak Summer Draft measure) and result in minor adverse effects to native species, otherwise effects would be similar to the No Action Alternative.	There would be minor to moderate adverse entrainment effects to Dworshak bull trout and kokanee. Snake River fish would have increased mortality during dam passage but would be exposed to lower TDG.	There would be moderate to major adverse short-term construction effects from dam breaching. There would be a major beneficial effect to bull trout and white sturgeon, due to reconnection of fragmented populations and increased spawning habitat for white sturgeon.	There would be a minor to moderate adverse effects, due to higher TDG exposure.
Region D Resident Fish	Effects would be similar to the No Action Alternative with negligible adverse effects to flows and water temperatures and potential stranding of white sturgeon larvae.	Effects to Bull trout and other resident fish would be similar to the No Action Alternative.	Effects to Bull trout and other resident fish would be similar to the No Action Alternative.	There would be a minor to moderate adverse effects, due to higher TDG exposure.

NO ACTION ALTERNATIVE

As described in Section 3.5.5.2, the effects of the No Action Alternative are anticipated to be similar in nature to the existing conditions. Resident fish species would continue to be impacted by the dams and their operations as described in the *Affected Environment* section of Chapter 3. There are a number of cumulative actions that could both beneficially and adversely affect resident species under the No Action Alternative as described in Table 6-21.

MULTIPLE OBJECTIVE ALTERNATIVE 1

In Region A, MO1 causes a reduced food supply, higher entrainment, and varial zone adverse effects in Hungry Horse Reservoir, and higher summer flows reduce habitat for resident fish in the Flathead River. To minimize these effects there would be vegetation planting and structural habitat components installed around Hungry Horse Reservoir. In the Kootenai River, there would be a minor increase in bull trout and redband rainbow trout and westslope cutthroat trout river habitat. Mitigation measures implemented under MO1, including cottonwood planting near Bonners Ferry, would minimize adverse effects to Kootenai River White Sturgeon. In Region B, there would be increased entrainment and reduced productivity in Lake Roosevelt and increased stranding of kokanee and burbot eggs along with affects to redband rainbow trout from lower water levels. To minimize these effects, additional spawning habitat at Lake Roosevelt would be identified and established. In Region C, warmer temperatures from Dworshak would adversely impact native fish and benefit non-native warmwater fish. In Region D, a drop in the John Day reservoir could strand larvae. Overall, cumulative actions that have the potential to further reduce water levels in the future, such as population growth and development, water withdrawals, new storage projects, and climate change, could increase adverse effects identified, but it is uncertain to what degree. Adverse cumulative effects would be partially offset by actions that have the goal of benefitting resident species as identified in Table 6-22. Mitigation actions under MO1 intended to benefit resident species, as identified in Chapter 5, could further offset adverse cumulative effects.

MULTIPLE OBJECTIVE ALTERNATIVE 2

In Region A, MO2 causes reduced food supply and increased winter entrainment at Hungry Horse. Winter habitat in the Flathead River would be substantially reduced. In the Kootenai River, there would be a decrease in spring freshets and sturgeon river habitat. There would be an increase in bull trout and redband and westslope cutthroat trout river habitat. These effects would be minimized by planting cottonwoods near Bonners Ferry and vegetation planting and installation of structural habitat components around Hungry Horse Reservoir. In Region B at Lake Roosevelt, there would be adverse effects similar to those described for MO1. These effects would be minimized by identifying and developing additional spawning habitat at Lake Roosevelt. In Region C, there would be increased entrainment of kokanee and reduced survival of fish through the turbines. Similar to MO1, actions that have the potential to further reduce water levels in the future, such as population growth and development, water withdrawals, new storage projects, and climate change, could increase adverse effects identified due to hydropower measures, but it is uncertain to what degree. There are also other factors that could have unquantified adverse effects to resident species as described in Table 6-21. Adverse cumulative effects would be partially mitigated by actions that have the goal of benefitting resident species as identified in Table 6-21. Mitigation actions intended to benefit resident species, as identified in Chapter 5, could further offset adverse cumulative effects.

MULTIPLE OBJECTIVE ALTERNATIVE 3

In Region A, effects of MO3 at Hungry Horse Dam and Pend Oreille River would be similar to the No Action Alternative. These effects would be minimized by vegetation planting and installation of habitat structures around Hungry Horse Reservoir, and cottonwood planting near Bonners Ferry. In the Kootenai River, there would be minor increases in lake productivity and habitat. There would be an increase in bull trout river habitat and westslope and redband cutthroat habitat. In Region B at Lake Roosevelt, there would be adverse effects due to increased entrainment and reduced productivity, but there would also be decreased stranding of kokanee and burbot eggs. These effects would be minimized by identifying and developing additional spawning habitat at Lake Roosevelt. In Region C on the Snake River, there would be short-term construction effects from dam breaching, but long-term beneficial effects shifting to more native fish with conversion of reservoirs to river habitat. Adverse effects would be minimized by modifying the Tucannon River channel to improve passage and haul and trap of white sturgeon on the Snake River in areas impacted by dam breaching. In Region D, the higher John Day reservoir provides more habitat for sturgeon but could strand larvae, and the lower May and June flows could increase predation. Overall, considering the beneficial effects of MO3 combined with other actions with the goal of improving conditions for resident species in the Columbia River Basin as described in Table 6-21, it is anticipated there would be a cumulative benefit to resident species under MO3 with dam breaching on the lower Snake River contributing substantially to these beneficial effects. The degree of cumulative benefits is uncertain, however, because the effects of environmental factors such as climate change could have larger adverse effects to resident species in the future. There are also other factors that could have unquantified adverse effects to resident species as described in Table 6-22.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Under MO4, there would be reduced food supply, higher entrainment, and varial zone adverse effects at Hungry Horse. These effects would be minimized by vegetation planting and installation of habitat structures around Hungry Horse. The high summer flows would reduce habitat in the Flathead River. At Lake Pend Oreille, lower reservoir elevations limit access to tributaries and reduce shallow habitat. On the Kootenai River, there would be minor decreases in bull trout lake and river habitat. There would also be a decrease in redband and westslope cutthroat trout river habitat. In Region B at Lake Roosevelt, there would be major increases in entrainment and reduced productivity. There would be large increases in stranding of kokanee and burbot eggs and large varial zone effects to redband rainbow trout and kokanee. These effects would be minimized by identifying and developing additional spawning habitat at Lake Roosevelt. Northern pike invasion downstream into the Columbia River would likely increase due to higher entrainment risk of northern pike. In Region C, higher TDG would affect bull trout and other resident fish. In Region D, TDG would be higher at all dams, and drawdowns at lower Columbia River reservoirs could reduce habitat. Actions that have the potential to further reduce water levels in the future, such as population growth and development, water withdrawals, new storage projects, and climate change, could increase adverse effects identified due to hydropower measures, but it is uncertain to what degree. There are also other factors that could have adverse effects to resident species as described in Table 6-22. Adverse cumulative effects would be partially offset by actions that have the goal of benefitting resident species as identified in Table 6-22. Mitigation actions intended to benefit resident species, as identified in Chapter 5, could further offset adverse cumulative effects.

6.3.1.6 Vegetation, Wildlife, Wetlands, and Floodplains

RFFAs with potential to impact vegetation, wetlands, wildlife, and floodplains in the CIAA are listed in Table 6-23 along with a summary of the effects of these actions. The table is followed by a description of cumulative effects of the different MOs by region. Effects from the No Action Alternative are expected to be similar to existing conditions as described in Section 3.6.3.2.

Table 6-23. Reasonably Foreseeable Future Actions Relevant to Vegetation, Wildlife, Wetlands, and Floodplains

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be an adverse effect from loss of habitat and fragmentation and increased water use leading to reduced instream flows through new development projects potentially affecting floodplain inundation timing.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There would be an adverse effect from less available water in the future that may lead to conversion of wetland habitat into drier habitat types and reduced instream flow potentially affecting floodplain inundation timing.
RFFA3	New and Alternative Energy Development	There is a potential loss of habitat from new construction projects. Wind turbines can also impact birds, bats, and insects.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	There would be possible adverse effects due to the potential for an increase in lack of market/lack of turbine capacity spill, which could lead losses in vegetation, wetland, and floodplains that could adversely affect wildlife.
RFFA5	Federal and State Wildlife Lands Management	Continued public ownership of land and land management for fish and wildlife purposes is projected to be beneficial by maintaining native habitat types and wetlands on these lands.
RFFA6	Increase in Demand for New Water Storage Projects	New water storage projects have the potential to inundate riparian vegetation, creating an adverse impact and reduced instream flow potentially affecting floodplain inundation timing.
RFFA7	Pacific Salmon Management Plans	Plan implementation may have a beneficial impact to orcas, sea lions, avian predators, and other wildlife that eat salmon and steelhead.
RFFA12	Fish Hatcheries	May have a beneficial impact to orcas, sea lions, avian predators, and other wildlife that eat salmon and steelhead.
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement	New tribal, state, and local fish and wildlife improvement projects are projected to restore, maintain, create, or enhance native vegetation types and wetlands and, potentially, have beneficial effects on floodplains if the projects enhance floodplain function.
RFFA14	Lower Columbia Dredged Material Management Plan	There would be a localized adverse effect on plankton and benthic organisms during dredging operations.
RFFA15	Snake River Sediment Management Plan	There would be a localized adverse effect on plankton and benthic organisms during dredging operations.
RFFA16	SKQ Dam Operations	SKQ operations can have the adverse effect of limiting cottonwood regeneration in the river below the Dam.
RFFA17	Invasive Species	Invasive plants are currently damaging biological diversity and ecosystem integrity across the Columbia River Basin. They are on a trajectory to increase and can outcompete and cause displacement of native plants.

RFFA ID	RFFA Description	Impact Description
RFFA18	Marine Energy and Coastal Development Projects	Coastal development has the potential effects include non-point source pollution from coastal areas (e.g., stormwater runoff) that would affect vegetation, wetlands, wildlife and floodplains.
RFFA19	Climate Change	Potential effects of climate change, such as warmer air temperatures and changes to hydrology, could have adverse effects on the ecosystem, including effects to vegetation, wetlands, and floodplains. Warming air temperatures coupled with changing rainfall amounts and timing affects soil conditions, plant communities, insects, and wildlife.
RFFA25	Columbia Pulp Plant	There would be a potential localized adverse effect through loss of vegetation and wetlands in the project area.

1265 Table 6-24 below provides a summary of direct and indirect effects identified for vegetation, wetlands, wildlife, and floodplains.

1266 **Table 6-24. Vegetation, Wetlands, Wildlife, and Floodplains Direct and Indirect Effects Summary**

Region	MO1	MO2	MO3	MO4
Region A				
Vegetation, Wetlands, Wildlife, and Floodplains	There would be some areas of habitat conversion to drier types at Lake Koocanusa and the Kootenai River which could impact wildlife supported by wetland habitats. The current probability of inundation for the existing active floodplains would continue.	There would be an overall negligible effect under MO2 compared to the No Action Alternative. Notable effects include an expanded drawdown zone at Lake Koocanusa, and lower outflow from Libby Dam and Hungry Horse in the spring. The current probability of inundation for the existing active floodplains would continue.	There would be some areas of habitat conversion to drier types at Lake Koocanusa. There is potential for effects to grebes downstream of Albeni Falls Dam from changes in water surface elevations. Floodplain effects would be the same as for MO1.	There would be an expansion of barren areas in Lake Koocanusa and Hungry Horse Reservoirs which would cause a loss of wetland structure and extent. Same as MO1 for floodplains.

Region	**MO1**	**MO2**	**MO3**	**MO4**
Region B				
	Large decrease in water surface elevation at Lake Roosevelt which would cause a shift to upland habitats and cause an overall minor adverse effect to wildlife supported by wetland habitats. The current probability of inundation for the existing active floodplains would continue.	There would be minor effects to wildlife on Lake Roosevelt from decreasing reservoir elevations. The current probability of inundation for the existing active floodplains would continue.	There would be little to no effect to the quantity, quality, and distribution of habitats under MO3. Floodplain effects would the same as for MO1.	Lower reservoir elevations at Grand Coulee and Chief Joseph during the majority of the growing season would result in a shift to upland plant communities in some areas. Same as MO1 for floodplains.
Region C				
Riparian, Wetlands, Aquatic, Invasive Vegetation and Floodplains	There would be a larger barren area at Dworshak Reservoir that could cause drying of amphibian eggs. Portions of the Clearwater River would experience a marginal increase inundation in June and July which would be a benefit to amphibians and birds. Overall, MO1 would have minor (Dworshak) and negligible (lower Snake River) changes in vegetation, habitat, and wildlife. The current probability of inundation for the existing active floodplains would continue.	There would be drying of shoreline habitat and larger barren areas in Dworshak Reservoir. Floodplain effects would the same as for MO1.	There would be short-term perched tributaries from dam breaching. There would be a long-term conversion of deep water to wetland islands and mudflats, and conversion/erosion of riparian habitat and increased exposed sediments. Floodplain effects would be negligible across the basin, with the exception of the Snake River below Dworshak Dam, where the floodplain would ultimately return to a more natural condition with major beneficial effects on floodplain values.	Negligible change from the No Action Alternative. Floodplain effects would the same as for MO1.

Region	MO1	MO2	MO3	MO4
Region D				
Riparian, Wetlands, Aquatic, Invasive Vegetation and Floodplains	Changes would be within the natural variability and daily fluctuations would be similar to the No Action Alternative. Overall negligible effect compared to the No Action Alternative. The current probability of inundation for the existing active floodplains would remain unchanged from current conditions in most of the basin, with minor reductions in inundation frequency below Bonneville Dam and below John Day Dam (for MO4), which could have minor effects on floodplain benefits in those reaches.	Negligible change from the No Action Alternative. Floodplain effects would the same as for MO1.	There would be increased sediment deposition after dam breaching which could support development of new wetlands. Floodplain effects would be negligible across the basin.	There would be an increase in mudflats and drying of wetlands regionwide due to decreased reservoir elevations on the lower Columbia River reaches above Bonneville Dam during the growing season. The current probability of inundation for the existing active floodplains would remain unchanged from current conditions in most of the basin, with minor reductions in inundation frequency below John Day Dam (for MO4), which could have minor effects on floodplain benefits in those reaches.

Regions A and B. Under MO1 and MO4, some areas of habitat conversion to drier types, and some loss of wetland spatial extent and structure are possible in areas affected by lower water levels due to deeper drafts. Under MO3 there could be increased exposure of mudflats that would result in establishment of invasive plant species. RFFAs that could potentially decrease the amount of water in the future, such as increased development and associated water withdrawals, climate change, and increases in future storage projects, would increase this effect. These cumulative actions would also increase habitat conversion, potential for increased colonization of invasive species and the expansion of barren areas in reservoirs, loss of wildlife access, and increase invasive species. These effects are also associated with lower water levels due to the MOs, which can lead to adverse effects to floodplain inundation timing. Adverse effects from the MOs and from cumulative actions would be partially offset by habitat improvement projects such as Federal and state wildlife land management and tribal, state, and local fish and wildlife improvements. Mitigation actions intended to benefit wildlife and vegetation as well as wetlands, as identified in Chapter 5, such as vegetation planting and updating and implementing invasive species plans, could further offset adverse cumulative effects in Region A. Overall, under all of the Alternatives there would be both beneficial and adverse cumulative effects to vegetation, wetlands, wildlife, and negligible and minor effects to floodplains in Regions A and B.

Region C. In Region C, drying of shoreline habitat and larger barren areas in Dworshak Reservoir are caused by deeper drafts for hydropower under MO1 and MO2. This adverse effect would be increased by the same cumulative actions described for Regions A and B. MO3 would cause adverse effects to wetlands along the existing shorelines, particularly at tributary inflow locations due to major decreases in water levels. In the long term, dam breaching would convert deep water to a riverine environment with wetlands, islands, mudflats, riparian habitat, and exposed sediments and shoreline. Additionally, after breaching the four lower Snake River dams, the floodplain would ultimately return to a more natural condition with major beneficial effects on floodplain values. Mitigation actions implemented under MO3, such as vegetation planting, and updating and implementing invasive species plans would minimize adverse effects from dam breaching. Similar to Regions A and B, habitat improvement programs and projects have the potential to positively affect vegetation, floodplains, and wildlife in this region. Overall, there would be both beneficial and adverse cumulative effects to vegetation, wetlands, wildlife, and floodplain values under all of the Alternatives in Region C, with major long-term beneficial effects to floodplains after breaching the four lower Snake River dams under MO3.

Region D. In Region D, there would be minor reductions in floodplain inundation frequency below Bonneville Dam for MO1 and MO2, and John Day under MO4, but negligible effects would occur under MO3. In Region D, there would be negligible direct and indirect effects and negligible cumulative effects under MO1 and MO2 in comparison to the No Action Alternative.

Under MO3, there would be substantial changes with drawdown of reservoirs, dam breaching, and mobilization of sediment. Sediment mobilization immediately following dam breach lasting 2 to 7 years would result in notable changes, including sediment deposition in Lake Wallula above McNary Dam and suspended washload moving through the downstream projects to the estuary at the Pacific Ocean. Additional sediment deposition in Region D could create conditions favorable for establishment of new wetlands. Cumulative actions that have the goal of increasing wetland habitat could add to this beneficial effect.

Under MO4, the drawdown to MOP measure would have effects on wetland habitat as a function of decreased reservoir elevations on the lower Columbia River reaches above Bonneville Dam during the growing season. RFFAs that could potentially decrease the amount of water in the future (as identified under Regions A and B) could cause additional loss of wetlands and an increase in mudflats. Cumulative actions that have the goal of increasing wetland habitat could partially offset this effect by creating new wetlands.

Major cumulative floodplain effects, arising primarily from past human development actions and water withdrawals, would be expected to continue into the future, with potential minor adverse contributions to cumulative floodplain effects from MO1, MO2, and MO4.

6.3.1.7 Power and Transmission

RFFAs with potential to impact the power or transmission or both in the CIAA are listed in Table 6-25, along with a description of the effects of these actions.

The planned retirement of several coal-plants in the region affect power and transmission. For transmission, changes in generation affect the flow of power across different transmission paths in the Federal transmission system. The impact to power stems from the fact that power generation from Federal and non-federal projects are shared through a wholesale spot-market. Thus, the Federal and non-federal power supply are used to serve the regional demand for power. If hydropower generation is reduced in some of the alternatives, then non-federal power might be used to serve some of Bonneville's load obligation. However, the retirement of additional coal plants reduces the availability of non-Federal power. For power and transmission effects analysis, the cumulative effects of other non-Federal hydroelectric projects and projected scenarios for coal power plant retirements are captured within the analysis of direct and indirect effects. The power analysis in Section 3.7 assesses both CRS hydropower and the reliability of regional power supply. The extent of future coal plant retirements was a key factor influencing the direct and indirect effects analysis. This is because the availability of coal-fired power plants to serve regional demand for power (primarily by the region's investor-owned utilities) influenced how effectively replacement power resources could compensate for lost hydropower generation, and the base analysis relied on base case coal retirement assumptions formed in 2017. Two scenarios – one being more coal plant retirements based on updated information and one being the retirement of all coal plants in the region – provided an understanding of the differences between the CRSO EIS alternatives and costs of zero-carbon replacement portfolios via modeling the difference in coal plant retirements into the future. See Section 3.7 for more information.

Table 6-25. Reasonably Foreseeable Future Actions Relevant to Power and Transmission

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	Population growth and development would likely result in an increased demand for power; but it is uncertain how or by what entity that need would be met.
RFFA3	New and Alternative Energy Development	Increased generation from wind, solar, and natural gas projects could decrease the demand for average hydropower generation, though wind and solar projects would increase the demand for hydropower flexibility. Changes in generating resources and new transmission line projects would shift power flows through the transmission system.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	This combination could adversely affect Bonneville's ability to assure an adequate, efficient, economical and reliable power supply to its firm power customers. Changes in generating resources and the loads would shift power flows through the transmission system. Increased renewable development and associated transmission may result in more difficulty of facility siting.
RFFA19	Climate Change	Changes in temperature, precipitation, snowpack, and streamflow would likely adversely affect hydropower generation and load in the Columbia River Basin, increase the potential for wildland fire, which could impact transmission, and increased uncertainty in the magnitude of hydropower generation. Refer to section 4.2.5 for more information.

Table 6-26 below provides a summary of direct and indirect effects identified for Power and Transmission.

Table 6-26. Summary of Direct and Indirect Effects to Power and Transmission (Power & Transmission Effects are Columbia River Basin-wide)

MO1	MO2	MO3	MO4
Hydropower generation from the CRS projects would decrease by about 130 aMW (roughly enough to power 100,000 households annually). The FCRPS, which includes the CRS, would lose 290 aMW of firm power available for long-term, firm power sales to preference customers under critical water conditions. There would be a potential for reduced winter hydropower production flexibility and lost energy production May - September due to increased juvenile fish passage spill, additional water supply withdrawals, and the modified Dworshak summer draft measure. The reduction in power generation would reduce power system reliability, requiring replacement power resources (about 1,200 MW of solar power or 560 MW of single-cycle natural gas turbines under the base case) that could cost up to $160 million per year. A small amount of increased transmission congestion on some paths, particularly some west-to-east (such as Hemingway to Summer Lake) and north-to-south paths would occur.	Hydropower generation from the CRS projects would increase by 450 aMW (roughly enough to power 360,000 households annually), and the FCRPS would gain 370 aMW of firm power available for long-term firm power sales. This would improve power system reliability and reduce electricity costs. Several power measures would substantially increase within-day flexibility allowing for integrating higher amounts of renewable generation. Shifts in transmission congestion would occur on some paths, particularly some west-to-east, depending on runoff conditions.	Hydropower generation from the CRS projects would decrease by 13%, or 1,100 aMW (roughly enough to power 900,000 households annually). Within-day flexibility would be substantially reduced. The FCRPS would lose 730 MW of firm power available for long-term firm power sales. The reduction in generation would reduce power system reliability, requiring replacement power resources (about 1,120 MW of combined cycle natural gas turbines or about 2,250 MW of solar power resources, 1,125 MW battery, and 600 MW of demand response) in the base case analysis. To replace the lost flexibility and generating capability of the Lower Snake River projects that would be lost under MO3, and additional resources beyond the 2,250 MW of solar power and battery storage would be required. The loss of hydropower generation at Ice Harbor would require that a transmission reinforcement project be in place prior to breaching of the dams. Transmission congestion hours for some north-to-south paths could increase under some runoff conditions and there would be an improvement in congestion hours on some west-to-east paths.	Hydropower generation from the CRS projects would decrease by 16%, or 1,300 aMW (roughly enough to power 1 million households annually). The FCRPS would lose 870 MW of firm power available for long-term firm power sales. The large decrease in hydropower generation from increased spill and other measures would reduce within-day flexibility, flexibility that would be useful for integrating wind and solar generation. The reduction in generation (especially from spill and the August reduction from the McNary Flow Augmentation measure) would reduce power system reliability, resulting in risks of power shortages in about one in every three years. To restore reliability would require replacement power resources (about 3,240 MW of single-cycle natural gas turbines or about 5,000 MW of solar power resources and 600 MW demand response) in the base case analysis. Transmission congestion hours for some north-to-south paths could increase under some runoff conditions and there would be an improvement in congestion hours on some west-to-east paths.

NO ACTION ALTERNATIVE

For power and transmission under the No Action Alternative the following RFFAs follow a theme of increased demand for hydropower generation and/or flexibility effects: Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development; New and Alternative Energy Development; and Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization. New generation resources would affect both Federal and non-Federal generation likely in similar ways. Some of the generation would be in Bonneville's balancing area and some would be in non-Federal balancing areas. Generally, an increase in variable renewables added to the power mix (renewable integration) could place additional strain on the hydropower system if using the inherent flexibility in hydropower to integrate and follow renewable resources. Hydropower is considered a base load resource, which means that its firm energy and capacity production is used to supply electric power to meet the retail loads of the region's utilities. Because renewables are not considered base load resources but rather intermittent generating plants due to their unpredictable external fuel availability (such as wind and sunlight), they rely on base load generating resources to ramp up or down in response to their changing power generation. Because of the trends related to emissions reductions in the region, base load generating resources such as coal-fired power plants are being retired, and the likelihood of new natural gas plants being built to replace the retired plants is presently unlikely. As a whole, the region would have more variable generation with more need for flexibility from the base-load resources like hydropower and existing gas-fired power plants.

Increasing use of variable renewable energy sources, changes in energy usage patterns, and population growth may shift flow patterns on the transmission system. Bonneville would continue to meet its transmission system reliability requirements but may experience shifts in regional congestion patterns or need to add reinforcements to accommodate changes in power generation or loads beyond that identified in the planning base cases captured within the analysis of direct and indirect effects for power and transmission. Additionally, as more variable renewable energy sources are developed, the competition for locations to site new generation and transmission could increase, which could increase costs and environmental effects.

The increased mix of renewables could substantially change the regional import and export of power, for instance, by changing hourly demands, but it is uncertain how these demands would be met. Meeting demand would depend on where future resources are brought online. There may be a need for reserves that the hydro system may attempt to provide. There would likely be an increased need for within day/within hour hydropower generation flexibility (unless there are other sources of base load generation, which is unlikely because of the move toward a carbon-free energy sector in the region). This could adversely affect Bonneville's ability to meet its overarching obligation to assure an adequate, efficient, economical, and reliable power supply to its firm power customers.

The cumulative effects to power and transmission resources as a result of climate change include the potential for less or more hydropower production, because changes in temperature, precipitation, snowpack, and streamflow would likely impact hydropower generation and load in the Columbia River Basin. Climate change could have substantial effects on hydropower; however, an uncertainty exists as to the annual and monthly magnitude of effects to hydropower generation in the region. Projected increasing temperatures would likely also impact loads and would affect non-Federal utilities similarly to the effect on Federal load.

In addition, the additive effects from the increase in wildland fire as a result of climate change could have potential effects to system reliability. Maintenance costs could increase if transmission lines are lost due to fires.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Hydropower decreases from the CRS projects would require replacement resources to return the region to the No Action Alternative LOLP of 6.6 percent. The reduced spring generation and winter hydropower production flexibility from MO1 could cause a decrease in amounts of renewable generation integration supported by the CRS projects or require greater amounts of replacement resources to replace the energy and some of the peaking ability of the hydropower system causing upward rate pressure.

Cumulative effects from RFFA1, RFFA3, RFFA4, and RFFA20, in combination with the power and transmission effects analyzed under MO1 are expected to be similar to that of the No Action Alternative. Regional utilities would be similarly impacted by the cumulative effects from RFFA1, RFFA3, and RFFA4 with upward rate pressure. If the region did not acquire additional resources to replace the reduction in hydropower generation, while loads and need for renewable resources are growing, then there would be an increase in the risk of power shortages (blackouts). Bonneville would continue to meet its transmission system reliability requirements, but may experience shifts in regional congestion patterns or need to add reinforcements to accommodate changes in power generation or loads beyond that identified in the planning base cases captured within the analysis of direct and indirect effects for power and transmission.

The cumulative effects to power and transmission resources as a result of climate change include the potential for less or more hydropower production, because changes in temperature, precipitation, snowpack, and streamflow would likely affect hydropower generation and load in the Columbia River Basin. Projected changes from climate change are likely to affect generation under MO1 relative to the No Action Alternative roughly the same on an annual basis.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Hydropower increases from the CRS projects would increase power and system reliability. Other non-Federal regional hydropower projects would experience similar winter trends in hydropower generation to the CRS projects but would not be affected from changing spill at the CRS projects. The regional hydropower system (including these non-CRS projects) under MO2 would generate 14,000 aMW in an average water year. This represents a 3 percent increase in power generation relative to the No Action Alternative.

The increase in average and peak hydropower generation as well as increases in hydropower flexibility from various measures in MO2 would allow for higher amounts of renewable generation integration than under the No Action Alternative. This would decrease the cumulative effects from RFFA1, RFFA3, RFFA4, and RFFA20. As the LOLP (risk of power shortages) under MO2 would be lower than the No Action Alternative, no replacement resources would be needed, and no new interconnections or reinforcements would be required to add to the effects associated with the RFFAs.

The cumulative effects to power and transmission resources as a result of climate change would likely affect generation under MO2 relative to the No Action Alternative roughly the same on an annual basis.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Major hydropower decreases from the CRS projects would decrease power and system reliability, which would require large amounts of replacement resources. Breaching the four lower Snake River dams would shift some flexibility requirements onto the remaining hydropower facilities - and some to other generation sources - decreasing the flexibility available to integrate renewable generating sources. Other non-Federal regional hydropower generation would not be impacted by the breach directly. However, the reduction in CRS project hydropower by over 10 percent would require large amounts of new capacity to bring the LOLP of MO3 to the No Action Alternative level. This would likely cause upward rate pressure and would affect the market price for power.

As more variable renewable energy sources are being developed in the region under RFFA1, RFFA3, RFFA4, and RFFA20, available siting locations for generating resources and transmission lines could decrease. The lack of available siting locations would be exacerbated when combined with the large amount of resources needed to bring LOLP back to No Action Alternative levels under MO3. The use of less suitable sites would increase costs and environmental effects associated with the variable renewable energy and transmission development.

In the summer, major cumulative effects from climate change with longer periods of low flows could exacerbate the loss in hydropower generation from lower Snake River dams, contributing to substantial reliability concerns of MO3. These RFFAs could also alter power generation and usage patterns which may further shift transmission flow patterns and associated regional congestion patterns or reinforcement needs.

The cumulative effects to power and transmission resources as a result of climate change are likely to affect generation under MO3 relative to the No Action Alternative roughly the same on an annual basis.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Major hydropower decreases in generation from the CRS projects would decrease power, and system reliability would require large amounts of replacement resources. The decreased generation would decrease the flexibility available to integrate renewable generating sources. Other non-Federal regional hydropower generation would not be impacted by increased spill, but would be impacted by the change in outflows from the headwater projects, such as the flow change to meet McNary flow augmentation that shifts generation into the spring and out of late summer with potentially high regional loads, causing upward rate pressure.

Cumulative effects from RFFA1, RFFA3, RFFA4, and RFFA20, in combination with the power and transmission effects analyzed under MO4, are expected to be similar to that of MO3. However, MO4 reduces generation even more than MO3, thus further increasing demand for existing hydropower and leaning more on non-federal generation in the region, thus exacerbating the potential for declines in system reliability, particularly in August. With this larger reduction in CRS generation under MO4, there would be a greater potential cumulative impact associated with variable renewable energy development siting in the region.

As more variable renewable energy sources are being developed in the region, available siting locations for generating resources and transmission lines could decrease. The lack of available siting locations would be exacerbated when combined with the large amount of resources needed to bring LOLP back to No Action Alternative levels under MO4. The use of less suitable sites would increase costs and environmental effects associated with the variable renewable energy and transmission development.

In the summer, when the loss of generation from higher spill requirements contributes to substantial reliability concerns, major cumulative effects from climate change could exacerbate the decrease in potential generation with longer periods of low flows over summer. These RFFAs could also alter power generation and usage patterns which may further shift transmission flow patterns and associated regional congestion patterns or reinforcement needs.

The cumulative effects to power and transmission resources as a result of climate change are likely to affect generation under MO4 relative to the No Action Alternative roughly the same on an annual basis.

6.3.1.8 Air Quality and Greenhouse Gases

RFFAs with potential to impact air quality and GHGs in the CIAA are listed in Table 6-27, along with a description of the effects of these actions.

Table 6-27. Reasonably Foreseeable Future Actions Relevant to Air Quality and Greenhouse Gases

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	As the population grows and development increases, it would likely result in an additive adverse effect of increased GHG and air pollutant emissions.
RFFA3	New and Alternative Energy Development	A beneficial impact would likely be seen from the likelihood of reduced GHG and air pollutant emissions. However, generation could be replaced by gas or renewable sources If it is replaced by gas, then there could be increased emissions.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	A beneficial impact would likely be seen from the likelihood of reduced GHG and air pollutant emissions. However, generation could be replaced by gas or renewable sources. If it is replaced by gas, then there could be increased emissions.
RFFA5	Federal and State Wildlife and Lands Management	This would likely result in an additive adverse effect of GHG, air pollutant emissions (including particulate matter from wildland fire).
RFFA19	Climate Change	Potential increase in wildfires could increase GHG and air pollutant emissions, and reduce overall air quality. Reference section 4.2.6 for more information.

Table 6-28 below provides a summary of direct and indirect effects identified for air quality and GHGs under the Action Alternatives as compared to the No Action Alternative. Impacts under the No Action Alternative are such that regional emissions are likely to be reduced over time due to current trends in decarbonization.

Section 3.8.3 explains that the primary driver of potential future air pollutants and GHG emissions in the CIAA are directly related to anticipated future changes in power generation sources and transportation methods in the Pacific Northwest. Of the scenarios contemplated as reasonably foreseeable, all identified a trend toward increasing renewable generation sources while simultaneously reducing fossil fuels generation sources across the region. In addition, cleaner vehicle technologies are expected to continue the current trend of bringing electric and low-emission automobiles to market. This is a result of regional emissions reduction targets, economic incentives and tax breaks, and recently enacted Federal and state laws.

Because of this, the overall cumulative forecast over the analysis timescale for both air quality and GHG emissions are an improvement in air quality and a reduction in GHG emissions. This is because, as the burning of fossil fuels decreases, so do the emissions of criteria air pollutants and GHGs. The No Action Alternative, MO1 (with renewable replacement power resources), and MO2 showed a decrease in air pollutants and GHG emissions. Cumulative impacts could increase the beneficial effects to air quality and GHG found under those alternatives. However, under MO3 and MO4, as well as MO1 with fossil-fuel replacement power resources, the direct and indirect analysis showed an increase in air pollutants and GHG emissions due to decreases in hydropower generation, so it is possible that the cumulative impacts could potentially offset the adverse effects found under those alternatives.

Table 6-28. Summary of Direct and Indirect Effects to Air Quality and Greenhouse Gases

Region	MO1	MO2	MO3	MO4
All Regions	Air quality and GHG emissions would most likely be improved due to increased reliance on renewable resources and a reduction in fossil fuel generation (assuming zero-carbon resource replacement). If conventional least-cost resources, specifically gas-fired generation, replace reduced hydropower generation, then GHG emissions would likely increase slightly and air quality would be slightly degraded.	Minor beneficial air quality and GHG emissions effects from increased hydropower generation, with the exception of minor short-term adverse effects to air quality in Region C near Dworshak Dam.	Overall, effects of MO3 on GHG emissions would be moderate and adverse over the short and long term due to reduced hydropower generation, even assuming resources replacing hydropower are zero-carbon resources (i.e., solar power) and increased truck traffic to replace barge navigation. Addition minor and adverse effects over the short term due to construction activities including dam breaching.	Long-term, moderate, adverse effects on air quality and GHG emissions from increased fossil fuel power generation, even assuming resources replacing hydropower are zero-carbon resources (i.e., solar power). Short-term minor adverse effects to air quality and GHG emissions from construction activities and potential fugitive windblown dust near Hungry Horse.
A (Albeni Falls, Libby and Hungry Horse)	No change from No Action Alternative.	Increased hydropower generation could reduce regional fossil fuel power generation and improve air quality as well as reduce GHG emissions.	No change from No Action Alternative.	There is a small potential for short-term windblown fugitive dust emissions that cause adverse human health effects to occur during reservoir drawdowns. Short-term, minor, adverse effects from localized construction activities at Libby and Hungry Horse.
B (Grand Coulee and Chief Joseph)	No change from No Action Alternative.	Increased hydropower generation could reduce regional fossil fuel power generation and improve air quality as well as reduce GHG emissions.	No change from No Action Alternative.	No change from No Action Alternative.

Region	MO1	MO2	MO3	MO4
C (Dworshak, Lower Granite, Little Goose, Lower Monumental & Ice Harbor)	No change from No Action Alternative.	Increased hydropower generation could reduce regional fossil fuel power generation and improve air quality with reduced greenhouse gas emissions. Potential for seasonal, long-term, localized windblown dust from exposed sediments associated with reduced reservoir water surface elevation at Dworshak.	Potential increases in windblown dust from construction activities (on road and non-road) during dam breaching and from exposed river sediment in the lower Snake River region post-dam breaching. Increases in GHG and air pollutant emissions would occur from construction vehicles and equipment during breaching and increased truck transport of goods no longer shipped by barge. Breaching the lower Snake River Dams would require replacement of lost power generation and flexible capacity. Generation could be replaced by gas or renewable sources. If it is replaced by gas, then there could be increased emissions. However, even if zero-carbon renewable resources were used as replacements, GHG emissions would still likely increase because existing coal and gas fired generation could increase generation leading to elevated GHG and air pollutant emissions.	Hydropower generation would decrease substantially and require replacement of lost power generation. Generation could be replaced by gas or renewable sources. If it is replaced by gas, then there could be increased emissions. However, even if renewable sources were used as replacements, greenhouse gas emissions would still increase because existing coal and gas fired generation could increase leading to elevated emissions. Short-term air quality effects from construction and exposed sediments would most likely be localized to the project site during construction at Little Goose, Lower Monumental and Ice Harbor Dams.

Region	MO1	MO2	MO3	MO4
D (McNary, John Day, The Dalles & Bonneville)	Multiple structural projects at McNary may result in PM and other air pollutant emissions nearby an existing maintenance area for PM emissions, though the increased emissions are unlikely to exceed de minimis standards and risk the attainment status of this maintenance area.	Increased hydropower generation could reduce regional fossil fuel power generation and improve air quality with reduced GHG emissions.	Increase in GHG and air pollutant emissions from increased truck transport of goods no longer shipped by barge. Hydropower generation would decrease resulting in increased generation from existing gas and coal plants resulting in increased GHG and air pollutant emissions.	Hydropower generation would decrease resulting in increased generation from existing gas and coal plants resulting in increased GHG. Short-term air quality effects, including potential windblown dust (PM) and other pollutants that cause adverse health effects from construction and exposed sediments would most likely be localized to the project site during construction at McNary, The Dalles and Bonneville Dams.

ALL ALTERNATIVES

As described in Section 3.8.2, the Pacific Northwest generally has good air quality, with relatively few airsheds failing to attain ambient air quality standards, and recent air pollutant emission trends from the electricity generation and transportation sectors (the sources most relevant to this analysis) continue to improve under the No Action Alternative and MOs. Oregon requires coal resources to be eliminated from retail rates by 2030 and the Oregon legislature has been considering a cap-and-trade program to reduce GHG emissions across multiple sectors. Washington recently passed legislation eliminating costs associated with coal resources from retail rates by 2025 and requiring retail electricity sales to be GHG neutral by 2030, which overlap the CIAA.

For air quality and GHGs, under the No Action and Action Alternatives, a recurring theme surfaced regarding the additive effects of cleaner air and carbon reduction in the region as a result of the following cumulative effects: New and Alternative Energy Development; Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions; and Federal and State Lands Management. Generally, an increase in renewable energy sources being added to the power mix, the retirement of coal fired power plants, the low likelihood of new natural gas plants being built, the proliferation of the use of electric cars and potentially hydrogen fuel cells, as well as potential conservation measures would all result in the beneficial additive effect of cleaner air in the CIAA (lower emissions of particulates, pollutants, and GHGs). Federal and State Lands Management could either worsen or improve the cumulative outcomes of population growth and wildland fires, depending on the nature of the management action(s).

Reasonably foreseeable future actions associated with Climate Change; Federal and State Lands Management; and Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development could degrade air quality and increase GHGs for the No Action Alternative and MOs. These actions increase the likelihood that existing stagnant atmosphere could be worsened, thereby increasing summer ozone concentrations over time in the Columbia River Basin. In addition, wildland fires fueled by projected changes to climate (Section 4.1.2.6) and increased population growth could become an increasing source of particulate matter emissions, thus degrading air quality adverse and also increasing GHGs across the basin. Federal and State Lands Management could either worsen or improve the cumulative outcomes of population growth and wildland fires, depending on the nature of the management action(s). However, the cumulative impact of a reduction in fossil fuels described above could combat these effects somewhat by curtailing emissions of ozone precursors, particulate matter, and GHGs.

NO ACTION ALTERNATIVE

Cumulative effects applicable to the No Action Alternative are detailed in the "all alternatives" summary above, and are most similar to the cumulative impacts under MO1 (with zero-carbon replacement power resources) and MO2. Air pollutants from power generation would be reduced from current levels under the No Action Alternative, assuming a continued reduction in coal generation over time. Additional clean fuel standards could lead to a decrease in emissions associated with transportation and navigation activities. The No Action Alternative includes nine project-specific structural measures that have the potential to generate air pollutant emissions from use of construction equipment. Under the base case for the No Action Alternative, predicted regional emissions would be relatively steady or reduced relative to 2016 levels over time, reflecting continued generation from coal and natural gas resources, constant hydropower, and new regional renewable power.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Cumulative effects applicable to MO1 are detailed in the "All Alternatives" summary above, and the cumulative impacts under MO1 with zero-carbon replacement power resources are most similar to those found under the No Action and MO2. Decreased hydropower generation under MO1 could result in an increased reliance on, and associated air pollutant and GHG emissions from, existing fossil fuel plants. In addition, if additional fossil-fuel power resources replaced the decreased hydropower generation air quality could be degraded and GHG emissions increase. Air quality degradation would most likely occur in areas in the CIAA where existing fossil fuel plants are concentrated.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Cumulative effects applicable to MO2 (aside from RFFA 3 and RFFA4) are detailed in the "All Alternatives" summary above, and the cumulative impacts under MO2 are most similar to those found under the No Action Alternative and MO1 with zero-carbon replacement power resources. MO2 increases hydropower generation over the No Action Alternative, which could potentially reduce GHGs. Though climate change may slightly reduce that difference, MO2 would still be beneficial to air quality relative to the No Action Alternative by reducing reliance on fossil fuel power plants. MO2 includes a relatively low level of construction activity given no new power generation resources would be needed to meet regional demand for power, which minimizes the effects of RFFAs 3 and 4 (New and Alternative Energy Development and Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization). In Region C, potential exists for seasonal, localized fugitive dust emissions at Dworshak over the long term due to reduced water levels during reservoir drawdown. However, these emissions would not be near or within existing nonattainment or maintenance areas and may be mitigated by watering exposed sediment and limiting vehicle use in the exposed sediment areas (BMPs and/or mitigation).

MULTIPLE OBJECTIVE ALTERNATIVE 3

Cumulative effects applicable to MO3 are detailed in the "All Alternatives" summary above, and the cumulative impacts under MO3 are most similar to those found under MO4.

Exposed riverbed along the Snake River would increase potential for fugitive dust (PM) emissions in Region C and would occur adjacent to an existing maintenance area for PM (Wallula), risking the ability of this area to maintain adherence to NAAQS for PM. Overall, the effects of MO3 on air quality would most likely be moderate and adverse over the short and long term, primarily in Regions C and D. Fugitive dust increases under MO3 could be exacerbated by the following RFFAs: Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development; Federal and State Wildlife and Lands Management; Federal and State Lands Management; and Climate Change. That said, the use of BMPs or mitigation measures to control fugitive dust could minimize the direct and indirect impacts of these activities, thus reducing or eliminating the cumulative effects.

The reduction in hydropower generation under MO3 could increase the need for additional power resources. While the type (i.e., mix of renewables and natural gas) and location of additional power resources is uncertain, the analysis identifies increased power generation from fossil fuels, including both coal and natural gas, even under the zero-carbon resource replacement portfolio, degrading air quality and increasing GHG emissions. This is because the magnitude and timing of the reduction in hydropower generation would occur in particular times seasonally or daily (e.g., during peak demand) during which flexible resources would need to increase generation in order to maintain reliability (i.e., to meet the demand for power and avoid blackouts). Based on currently available technology, other renewable resources (e.g., solar and wind) are intermittent; that is, they are not always able to be dispatched on demand because they are reliant on external factors, such as sun exposure or wind speed. Therefore, these sources of renewable generation must be used alongside other flexible (dispatchable) resources to maintain system reliability. With less clean hydropower to provide this flexible resource, the region would likely rely more on fossil-fuel-based resources, such as coal and natural gas, to balance renewable generation. Increased GHG emissions associated with modal shifts in freight transport from barge to relatively high emissions rail and truck would be long-term and adverse under MO3, which would conflict with the trend of decarbonization and increased electrical vehicle use described in RFFA4.

Overall, effects of MO3 on GHG emissions would be moderate and adverse over the short and long term due to construction activities, modal shifts to truck transportation and increased fossil-fuel power generation. Short term adverse effects to air quality would occur due to construction and potential fugitive windblown dust. That said, the use of BMPs or mitigation measures could reduce the direct and indirect impacts of these activities, thus reducing or eliminating the cumulative impacts.

MULTIPLE OBJECTIVE ALTERNATIVE 4

Cumulative effects applicable to MO4 are detailed in the “All Alternatives” summary above, and the cumulative impacts under MO4 are most similar to those found under the MO3. The reduction in hydropower generation under MO4, combined with climate change (which could also reduce regional hydropower generation by reducing available water), could increase the need for additional power resources. While the type (i.e., mix of renewables and natural gas) and location of additional power resources is uncertain, if natural gas were added, it would further degrade air quality relative to the No Action Alternative. Similar to MO3, even if zero-carbon power resources were added GHG emissions would increase and air quality would likely be degraded. This is because the magnitude and timing of the reduction in hydropower generation would occur in particular times seasonally or daily (e.g., during peak demand) during which flexible resources would need to increase generation in order to maintain reliability (i.e., to meet the demand for power and avoid blackouts). With less clean hydropower to provide this flexible resource, the region would likely rely more on fossil-fuel-based resources, such as coal and natural gas, to balance renewable generation.

Short-term air quality effects from construction activities and exposed sediments would most likely be localized to the project site during construction of additional powerhouse surface passage routes at Little Goose, Lower Monumental, McNary, The Dalles, Bonneville and Ice Harbor. Construction activities at McNary and Ice Harbor Dams are close to the Wallula maintenance area for PM10, however BMPs or mitigation measures could reduce the direct and indirect impacts of these activities.

6.3.1.9 Flood Risk Management

RFFAs with potential to impact flood risk management in the CIAA and a summary of their potential impact are listed in Table 6-29. Effects to Flood Risk Management from the No Action Alternative are expected to be similar to existing conditions as described in Section 3.9.4.2.

Table 6-29. Reasonably Foreseeable Future Actions Relevant to Flood Risk Management

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	As the population grows and development increases, it is possible that additional structures and populations may be located in flood-prone areas.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There would be an overall reduced availability of water from increased demand. Increased demands for power could change the shape of generation from existing patterns.
RFFA3	New and Alternative Energy Development	Increased generation from wind, solar, and natural gas projects could decrease the demand for average hydropower generation, though wind and solar projects would increase the demand for hydropower flexibility. Changes in generating resources and new transmission line projects would shift power flows through the transmission system.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	There would be possible adverse effects due to the potential for an increase in lack of market/lack of turbine capacity spill, which could lead to higher total dissolved gas (TDG) levels. Conversely, decarbonizing and electrifying transportation and other sectors could reduce involuntary spill from lack-of-market.
RFFA6	Increase in Water Storage Projects	There would be potential changes to timing of delivery and quantity of water in different locations.
RFFA19	Climate Change	In general, there would be potential for higher winter and spring volumes and lower summer volumes. Refer to section 4.2.7 for more information.

The Flood Risk Management analysis (Section 3.9) evaluated the MOs to determine if there would be a change in flood hazards faced by communities, property, infrastructure or levees in the Columbia River Basin under each of the alternatives. Anticipated future flood risk under the

No Action Alternative is anticipated to be consistent with current conditions. Under MO1, MO2, MO3, and MO4, decreases in flood risk may occur in some areas, especially Region D under MO1, MO2, and MO4. New and alternative energy sources or the increasing use of renewable energy sources may change the timing and patterns of flows in the CRS. Actions outside of the alternatives, such as climate change (higher winter and spring runoff) and population growth and development, may adversely impact flood risk in the future as noted in Table 6-29, but there would be no adverse cumulative effect under any of the alternatives because none of the alternatives would cause direct or indirect adverse effects to flood risk management. It is possible that actions such as increases in water storage projects and lower overall water levels in the summer from climate change combined with benefits noted for MO1 through MO4 could have a cumulative benefit to flood risk management.

6.3.1.10 Navigation and Transportation

RFFAs with potential to impact navigation and transportation in the CIAA and a summary of their potential impact are listed in Table 6-30.Conditions under the No Action Alternative are expected to be similar to those described in the existing conditions presented in Section 3.10.3.2.

Table 6-30. Reasonably Foreseeable Future Actions Relevant to Navigation and Transportation

RFFA ID	RFFA Description	Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	As the population grows and development increases, it is possible that there could be an increased demand for transportation of goods on the navigation channel.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There would be a reduced availability of water from increased demand.
RFFA14	Lower Columbia River Dredged Material Management Plan	There would be a beneficial effect from removal of accumulated sediment in the navigation channel.
RFFA15	Snake River Sediment Management Plan	There would be a beneficial effect from removal of accumulated sediment in the navigation channel.
RFFA19	Climate Change	Navigation and transportation could be affected by climate change through its effects on seasonal patterns and variability of streamflow and consequences for riverbed profiles. Refer to section 4.2.8 for more information.

Anticipated future navigation and transportation under the No Action Alternative is anticipated to be consistent with current conditions. Direct and indirect effects of the other alternatives are listed below in Table 6-31.

Future higher spring runoff volumes due to climate change could increase the direct and indirect effects of the alternatives on the Inchelium-Gifford Ferry operations at Lake Roosevelt, but it is not known to what extent. Mitigation actions identified in Chapter 5 would include extending the ramp at the Inchelium-Gifford Ferry to minimize this impact. None of the other cumulative actions identified for navigation are expected to impact navigation in the upper

Columbia River Basin. Alternatives would have negligible effects to navigation on the lower Columbia River and lower Snake River, except MO3 and MO4 There are no anticipated discernable cumulative effects to navigation on the lower Columbia and lower Snake Rivers except under MO3. Mitigation actions under MO3 would include armoring piers on a limited amount of bridges and armoring a limited amount of railroad and highway embankments that could minimize adverse effects to infrastructure due to an increase in flow velocities. Loss of the Federal Navigation Channel in Region D at the confluence of the lower Snake and Columbia Rivers would require additional dredging actions. Mitigation actions under MO4 would also include monitoring of tailrace conditions in Regions C and D to determine if structure modifications are necessary to reduce damages and increased dredging as needed due to shoaling caused by higher spill levels. Under MO3, navigation on the lower Columbia River could be adversely affected by projected overall lower water levels in the summer due to climate change and increased water demand in the future. Continued dredging in the lower Columbia River would continue to offset the effects of sedimentation in this reach. Under MO3, commercial navigation on the lower Snake River would be effectively eliminated by dam breaching, and it is anticipated that dredging operations would cease in this reach.

Table 6-31. Summary of Direct and Indirect Effects to Navigation

Location	MO1	MO2	MO3	MO4
Upper Columbia River Basin	There would be a reduction in Inchelium-Gifford Ferry Operations for an additional 9 days in wet years.	Same as MO1	There would be a reduction in Inchelium-Gifford Ferry Operations for an additional 2 days in wet years.	Same as MO1
Lower Columbia River	Negligible change from the No Action Alternative.	Negligible change from the No Action Alternative.	Commercial Navigation on the Columbia River shallow segment would be adversely affected at ports above McNary Dam due to sedimentation for 2 to 7 years. Some river ports on the Columbia River would experience a large volume increase. Cruise line operations would be curtailed and may stop. Loss of the Federal Navigation Channel in Region D at the confluence of the lower Snake and Columbia Rivers would require additional dredging actions.	High spill combined with tailrace conditions could result in increased infrastructure damage.
Lower Snake River	Negligible change from the No Action Alternative.	Negligible change from the No Action Alternative.	Commercial Navigation would be eliminated at four lower Snake River projects. All ports on the Snake River would be inaccessible without dredging. Shipping costs would increase and would vary widely depending on location. There would be elimination of access for commercial cruise operations.	High spill combined with tailrace conditions could result in increased infrastructure damage.

6.3.1.11 Recreation

RFFAs with potential to impact recreation in the CIAA and a summary of their potential effects are listed in Table 6-32.

Table 6-32. Reasonably Foreseeable Future Actions Relevant to Recreation

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be an overall reduced availability of water from increased demand. Increased demands for power that could change shape of generation.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	There would be an adverse impact through reduced availability of water from increased demand.
RFFA6	Increase in Demand for New Water Storage Projects	There would be a beneficial impact through increased opportunity for reservoir-based recreation, possible adverse impact through reduction in river-based recreation.
RFFA7	Fishery Management Plans	The goal of Pacific Salmon Management plans is to better manage catch of salmon in ocean waters offshore. This could lead to a trend of beneficial effects to salmon numbers by reducing commercial catch for these species. The U.S. v Oregon Fishery Management Agreement has the overall goal of rebuilding weak runs to full productivity through habitat protection authorities, enhancement efforts, artificial production techniques and harvest management. Implementation of this agreement could lead to a trend of beneficial effects to target species important to recreational anglers.
RFFA11	Resident Fisheries Management	The state and tribal fish and game agencies manage, for recreational, ceremonial, and subsistence, fisheries in the Columbia River Basin and regulate private and public hatchery releases. The agencies modify and publish recreational fishing regulations on an annual basis. Currently, recreational anglers may not target bull trout in most areas but may incidentally catch and release bull trout. Other resident fisheries include Kokanee and Burbot in the upper basin.
RFFA12	Fish Hatcheries	There would be a beneficial effect from increasing fish populations through stocking.
RFFA13	Tribal, State, and Local Fish and Wildlife Management	New Tribal, State, and Local fish and wildlife improvement projects are projected to restore, maintain, create, or enhance fish and wildlife habitat. Many of these projects are focused on benefiting anadromous species.
RFFA14	Lower Columbia River Dredged Material Management Plan	There would be a beneficial effect from removal of accumulated sediment in the navigation channel.
RFFA19	Climate Change	Recreational opportunities could be impacted by climate change primarily by changing seasonal access for in-water activities. Climate change effects to other resources, for instance, fish and wildlife, could also affect recreational opportunities. Refer to section 4.2.9 for more information.

Future recreation under the No Action Alternative is anticipated to be consistent with current conditions as described in Section 3.11.3.2. Direct and indirect effects of the MOs are listed below in Table 6-33.

Table 6-33. Summary of Direct and Indirect Effects to Recreation

Location	MO1	MO2	MO3	MO4
Regions A and B	Overall effects of MO1 on recreational visitation are anticipated to be negligible to minor in the region. Effects to the quality of fishing, hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under MO1 would be negligible.	There would be a minor reduction in reservoir visitation at Lake Roosevelt, Hungry Horse, and Lake Koocanusa. There would be adverse effects to fishing quality in the region and minor adverse effects to the quality of hunting, wildlife viewing, swimming, and water sports in the region.	There would be negligible to minor reductions in reservoir visitation at Hungry Horse and Lake Koocanusa. There would be negligible adverse effects to fishing quality and to the quality of hunting, wildlife viewing, swimming, and water sports in the region.	There would be a minor reduction in reservoir visitation at Hungry Horse and Lake Koocanusa. There would be minor adverse effects to the quality of hunting, wildlife viewing, swimming, and water sports in the region.
Region C	Overall effects of MO1 on recreational visitation are anticipated to be negligible to minor in the region. Effects to the quality of fishing, hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under MO1 would be negligible.	There would be a minor reduction in reservoir visitation at Dworshak. There would be minor adverse effects to fishing quality, the quality of hunting, wildlife viewing, swimming, and water sports in the region.	There would be a potentially large reduction in reservoir visitation at the four lower Snake River Projects, but potential increases in river visitation. Adaptation to the new river environment is likely over time. There would be short-term adverse effects to the quality of hunting, wildlife viewing, swimming, and water sports.	There would be no reduction in reservoir visitation. There would be negligible to minor adverse effects to the quality of hunting, wildlife viewing, and swimming, and water sports at river recreation sites in the region.
Region D	Overall effects of MO1 on recreational visitation are anticipated to be negligible to minor in the region. Effects to the quality of fishing, hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under MO1 would be negligible.	There would be no reduction in reservoir visitation. There would be negligible to minor adverse effects to fishing quality, quality of hunting, wildlife viewing, swimming, and water sports in the region.	There would be potentially large reductions in reservoir visitation at Lake Wallula (McNary) due to sedimentation over 2 to 7 years with adaptation likely over time. There would be potential short-term adverse effects to the quality of hunting, wildlife viewing, swimming, and water sports.	There would be no reductions in reservoir visitation and minor benefits to the quality of hunting, wildlife viewing, swimming, and water sports in the region.

Regions A and B. For each of the alternatives, negligible to small reductions in reservoir visitation at Lake Roosevelt, Hungry Horse, and Lake Koocanusa are driven by reduced boat ramp accessibility for some periods of time during the year. An overall reduced volume of available water from increased demand and from the effects of climate change, causing lower summer runoff volumes, has the potential to cumulatively increase these negligible to minor adverse effects under the MOs, especially during the summer.

Adverse effects to fishing quality, hunting, wildlife viewing, swimming, and other water sports in the upper basin under MO2, MO3, and MO4 are caused by changes in reservoir elevations (mainly lower reservoir elevations) and river flows and associated water quality, water temperatures, and bird, wildlife, and fish habitat. Similar to visitation, the overall reduced volumes of water that could result from climate change in summer and from increased water demand due to development could cumulatively increase these adverse effects in the future. These same cumulative actions have the potential to decrease the minor benefits anticipated under MO1.

An increase in water storage projects in the upper basin would be considered beneficial to reservoir-based recreation, but it could adversely affect river-based recreation in these areas. Fish propagation and stocking are anticipated to continue under each of the MOs, providing a benefit to recreation under all of the MOs through maintained or improved fish populations.

Region C. Under MO1 and MO2, there would be negligible to minor reductions in reservoir visitation at Dworshak, while under MO4 there would be no reductions in reservoir visitation in the lower Snake River. The small reductions in MO1 and MO2 are caused by lower water levels making boat ramps temporarily inaccessible. Extending the boat ramp at Dworshak State Park to make it accessible in April would minimize adverse recreational effects for fishermen under MO2. Cumulative actions that also lower water levels, such as climate change and increased withdrawals, would likely increase this effect. Under MO3, there is a potentially large reduction in visitation at the four lower Snake River projects due to dam breach and sedimentation for 2 to 7 years. After the river stabilizes, there would be benefits to river-based recreation that could be increased from cumulative actions such as fishery management and decreased from cumulative actions such as climate change, water withdrawals, and population growth and development. Adaptation to the new river environment over time would benefit river-based recreation, but would be a complete loss of reservoir-based recreation.

Similar to the lower Columbia River, minor effects to the quality of hunting, wildlife viewing, swimming, water sports, and fishing under MO1, MO2, and MO4 are caused by changes in reservoir elevations and river flows and associated water quality, water temperatures, and fish and wildlife habitats as described in detail in Chapter 3. Effects from cumulative actions would be the same as described for the lower Columbia River. Under MO3, there would be short-term adverse effects to the quality of recreation caused by the dam breach and sedimentation. After the river stabilizes, there would be benefits to river-based recreation that could be increased from cumulative actions such as fishery management and decreased from cumulative actions such as climate change, water withdrawals, and population growth and development.

Region D. There would be no effects to visitation under the MOs except for MO1 and MO3. There would be a minor impact to visitation under MO1 from reduced reservoir levels. The contribution of cumulative actions would be the same as described for the upper basin. MO3 would cause a potentially large reduction in reservoir visitation at Lake Wallula (McNary) due to sedimentation over 2 to 7 years following dam breaching.

Minor beneficial changes would be increased through continued fish propagation and stocking (e.g. the U.S. v Oregon Fish Management Plan), and Pacific Salmon Management Plans for recreational fishing, and dredging, which would continue to provide a benefit through maintaining the navigation channel for boating. Minor adverse effects would be increased by the effects of climate change and increased future water withdrawals due to population growth and development.

6.3.1.12 Water Supply

RFFAs with the potential to impact water supply are primarily those that result in additional water surface elevation changes and increased sedimentation in the CIAA and are listed in Table 6-34, along with a description of the effects of these actions.

Table 6-34. Reasonably Foreseeable Future Actions Relevant to Water Supply

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	As the population grows and development increases, adverse effects may result from increased demands and heightened competition for limited water supplies. There could be reduced availability of water from increased development. An increase in development projects has the potential to increase sediment input during construction and operation.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	Overall, there is potential for reduced availability of water from increased demand. Adverse effects result from heightened competition for limited water supplies, including ongoing non-federal tributary-based water diversions.
RFFA6	Increase in Demand for New Water Storage Projects	With new storage projects there would be potential changes to the timing of delivery and quantity of water in different locations.
RFFA19	Climate Change	In general, there is potential for higher average fall and winter flows, earlier peak spring runoff, and longer periods of low summer flows in the Columbia River Basin.
RFFA25	Columbia Pulp Plant	This could increase potential adverse effects due to chemical discharges, water use, and spills.

Anticipated future water supplies under the No Action Alternative are anticipated to be consistent with current conditions. Direct and indirect effects of the MOs are listed below in Table 6-35.

Table 6-35. Summary of Direct and Indirect Effects to Water Supply

Region	MO1	MO2	MO3	MO4
A (Libby, Hungry Horse, Albeni Falls)	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.
B (Grand Coulee, Chief Joseph)	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.
C (Dworshak, Four Lower Snake River Projects)	No change from No Action Alternative.	No change from No Action Alternative.	Approximately 48,000 acres would no longer be irrigated from the reservoirs behind the Lower Snake Dams, 9,000 acre-feet of M&I delivery would likely be impacted, and approximately 63 wells may be adversely impacted by dropping water levels due to breach of lower Snake River dams.	No change from No Action Alternative.
D (Four Lower Columbia River Projects)	No change from No Action Alternative.	No change from No Action Alternative.	Small, private pumps may receive fine sediment that may impact pump filters and require more frequent maintenance due to these measures: Breach Snake Embankments, Lower Snake Infrastructure Drawdown, and Drawdown Operating Procedures.	No change from No Action Alternative.

Effects to water supply resources are primarily related water surface elevation and sedimentation because pumping from the river requires water elevations to be above the pumps, and the pumps need to be bringing in clean enough water to not clog the pumps. Effects to water supply resources are primarily related water surface elevation and sedimentation because pumping from the river requires water elevations to be above the pumps, and the pumps need to be bringing in clean enough water to not clog the pumps. Therefore, most cumulative effects would be associated with similar effects (changes to water surface elevation or releases of sediment that could affect pump operations).

Under all alternatives, climate change has the potential to impact current water supply practices for both surface and groundwater users. This is because reductions in summer and fall surface water stream flows may reduce the amount of available surface water supply. The decreased ability to rely on surface water could cause some water users to rely more on groundwater, thus impacting groundwater supplies through increased pumping by users to meet need. In addition, the decrease in snowpack and higher intensity winter storms as a result of climate change may exacerbate this issue by decreasing the surface water available to facilitate groundwater recharge. On the mainstem Columbia and Snake Rivers, the vast majority of water diversions for irrigation and municipal and industrial water supply are captured in the direct and indirect effects section, because these diversions are part of the alternatives. However, the cumulative effects of smaller, tributary-origin water diversions are not part of the alternatives and are therefore cumulative actions. The cumulative effects of tributary water diversions added to Federal water diversions are expected to continue in the future over the study period under all alternatives and will adversely affect water supply into the future by removing water supplies before they reach the mainstem of the Columbia and Snake Rivers, which is where the vast majority of federal water diversions occur.

NO ACTION ALTERNATIVE

As described in the cumulative effects analysis for hydrology and hydraulics (Section 6.3.1.1), Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development in the Columbia River Basin is expected to drive the conversion of existing agricultural lands to nonagricultural uses. This is true of all alternatives.

The Columbia River Basin Project delivers 70,000 acre-feet of municipal and industrial water to project contractors. Some cities and industries divert water from the river system, but these diversions are small to the point of being immeasurable when compared to the total flow in the system. In the future, due to population growth, it is reasonably foreseeable that municipal and industrial water withdrawals will increase, whereas currently they are concentrated on or near the Lower Granite and McNary reservoirs.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 does not have any measures that would affect the ability to deliver water to meet current water supply. As a result of climate change, water supply uses that rely on live/natural flow water rights for delivery may experience increased shortage in the summer or fall as flows decrease during this period. Changes to operations should not affect live/natural flow distributions because they are generally premised on the legal principle of prior appropriation.

MULTIPLE OBJECTIVE ALTERNATIVE 2

MO2 does not have any measures that would affect the ability to deliver water to meet current water supply. Water flowing into Lake Roosevelt could be impacted by climate change, both in volume and timing. However, it will likely not impact water supply deliveries for the Columbia Basin Project because existing water users have senior water rights when compared to most other uses at Lake Roosevelt, and the flow and timing changes will not impact those deliveries.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 includes measures to breach dams on the lower Snake River, where water is diverted for irrigation in Washington. These measures are *Breach Snake Embankments, Lower Snake Infrastructure Drawdown,* and *Drawdown Operating Procedures*. Currently and in the No Action Alternative, water is provided out of the reservoirs of these facilities and groundwater that results from the reservoirs. The pumps that supply this water would no longer be operational once the dams are breached and the nearby groundwater elevations could be substantially lowered by MO3. As a result, approximately 48,000 acres would no longer be irrigated from the reservoirs behind the lower Snake River dams, affecting approximately 9,000 acre-feet of M&I

delivery. In addition, approximately 63 wells may be impacted by dropping water levels due to breaching of lower snake dams.

In terms of cumulative effects, it is largely uncertain as to where population growth and additional water withdrawals for municipal, agricultural, and industrial uses would occur in the CIAA in the future. If these activities were to occur in Region C (in the vicinity of Dworshak, Lower Granite, Little Goose, Lower Monumental and Ice Harbor), such as in the Tri-Cities of Pasco, Richland, and Kennewick, Washington, additive adverse effects would likely result from increased demands and heightened competition for limited water supplies (water supply shortages, particularly for M&I). Since 2000, the population of the Tri-Cities metropolitan area increased approximately 50 percent, adding just over 90,000 people. The area's projected 10-year growth rate is 12 percent (Washington Office of Financial Management 2019). Future potential water shortages could stress this growing area's ability to deliver water to residents and industry.

It is possible under MO3 that existing water supply intakes in the McNary and John Day reservoirs impacted during periods of breach could be cumulatively impacted by the increase in frequency of wildland fire due to climate change (which could increase sedimentation in the river). The same exacerbation of sediment loads could also be cause by mining upstream of dams and population growth, urban, and rural development. Depending on the nature of land use management practices, sediment loads could either add cumulatively to increased sedimentation or reduce sediment to offset other effects. Lastly, Clean Water Act-related actions could also offset increased sediments due to efforts to reduce sediment in the river. It is also possible that mitigation may be applied under MO3 to minimize and perhaps eliminate these potential sedimentation-related effects (see Chapter 5).

Additive cumulative effects from climate change are not expected to differ from the No Action Alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 4

MO4 does not have any measures that would affect the ability to deliver water to meet current water supply. Effects are similar to the No Action Alternative.

6.3.1.13 Visual Resources

RFFAs with the potential to impact visual are primarily those that result in changes to visual resources in the CIAA and are listed in Table 6-36, along with a description of the effects of these actions.

Table 6-36. Reasonably Foreseeable Future Actions Relevant to Visual Resources

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There could be potential additive visual effects due to change in the viewshed from human population growth, which brings potential permanent modifications from residential, commercial, industrial, agricultural, recreational, and transportation development.
RFFA3	New and Alternative Energy Development	There could be potential additive visual effects due to the permanent change in the viewshed from construction or deconstruction of energy infrastructure.
RFFA12	Fish Hatcheries	There would be possible adverse effects due to construction and operations of fish hatcheries near the dams effecting the viewer's experience. The construction and operations of fish hatcheries would adversely affect sensitive viewers.
RFFA25	Columbia Pulp Plant	This would be additive visual effects due to the permanent change in the viewshed from the installation of the pulp plant, which is located in Lyons Ferry downstream of Little Goose Dam and upstream of Lower Monumental Dam.

Anticipated future effects to visual resources under the No Action Alternative are anticipated to be consistent with current conditions. Direct and indirect effects of the MOs are listed below in Table 6-37.

Table 6-37. Summary of Direct and Indirect Effects to Visual Resources

Region	MO1	MO2	MO3	MO4
A (Libby, Hungry Horse, Albeni Falls)	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.	Moderate effects on sensitive viewers from operational measures that result in reservoir drawdowns. Minor effects from structural measures. Sensitive viewers may be affected.
B (Grand Coulee, Chief Joseph)	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.	Moderate-to-major effects from operational measures that result in reservoir drawdowns. Minor effects from structural measures. Sensitive viewers may be affected.

Region	MO1	MO2	MO3	MO4
C (Dworshak, Four Lower Snake River Projects)	Minor overall effect from changes in the seasonal timing and duration of effects from operational measures. Minor-to-moderate effects from structural measures. Sensitive viewers may be affected.	Minor overall effect from changes in the seasonal timing and duration of effects from operational measures. Minor-to-moderate effects from structural measures. Sensitive viewers may be affected.	Breaching the lower Snake River dams would result in a major visual quality effect. Depending on the viewer's perspective, this change could be beneficial or adverse. Sensitive viewers may be affected.	Minimal change from No Action Alternative.
D (Four Lower Columbia River Projects)	Minor overall effect from changes in the seasonal timing and duration of effects from operational measures. Minor-to-moderate effects from structural measures. Sensitive viewers may be affected.	Minor overall effect from changes in the seasonal timing and duration of effects from operational measures. Minor-to-moderate effects from structural measures. Sensitive viewers may be affected.	Minor effect from structural measures. Sensitive viewers may be affected.	Minimal change from No Action Alternative.

Visual impairments associated with construction or modification of facilities are anticipated under various MOs. Overall, the effects from the alternatives in combination with past, present, and reasonably foreseeable future actions are expected to result in minor cumulative effects to visual resources, except for effects associated with MO3 and MO4.

MULTIPLE OBJECTIVE ALTERNATIVE 1

MO1 does not contain measures that would substantially affect the viewshed, and therefore any cumulative impact from the RFFAs listed above would be negligible. Overall, the operational and structural measures under MO1 would have a similar effect as under the No Action Alternative. There would be a moderate effect to visual quality from new fish-passage structures and minor effect from modifications of existing structures in Region D and the lower Snake River projects in Region C, but overall, the effects from MO1 would be minor.

MULTIPLE OBJECTIVE ALTERNATIVE 2

MO2 would have a similar effect on visual quality to sensitive viewers as under the No Action Alternative. In addition, no substantial reasonably foreseeable cumulative effects are expected in the CIAA over the analysis period. Therefore, no cumulative effects are anticipated under this alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 3

The most substantial effects were identified in Region C from breaching the lower Snake River projects. In particular, local residents and visitors would experience viewshed changes due to losses of lake-like characteristics and a return to free-flowing river characteristics under MO3 in the vicinity of the existing reservoirs in the lower Snake River. For the structural measures, there would be major alterations to the viewshed associated with the dam breaching in Region C. Viewers would see the loss of earthen embankments and some associated project infrastructure. There would be a loss of lake-like characteristics in the lower Snake River with the addition of a free-flowing river. Overall, the visual effect of dam breaching would be moderate to major. Depending on the viewer's perspective, this change could be beneficial or adverse.

These effects would occur in relatively isolated areas without residences immediately nearby. Ongoing land-based activities would continue under all of the alternatives, but it is unclear how much new development would be expected after the breach of the four lower Snake River dams in MO3, for instance.

The Columbia Pulp Plant could potentially increase adverse effects due to visual changes associated with the newly constructed pulp plant, which is located in Lyons Ferry downstream of Little Goose Dam and upstream of Lower Monumental Dam in Region C.

Taken together, the impact to visual quality from dam breaching under MO3 in Region C, when added to other past, present, and reasonably foreseeable future actions affecting the viewshed such as the Columbia Pulp Plant and other land-based development trends, could result in cumulative effects on visual quality.

MULTIPLE OBJECTIVE ALTERNATIVE 4

The McNary flow target measure drafts the storage projects in Region A and B for fish flows in the lower basin. These drawdowns would result in a substantial effect to visual quality on a seasonal basis. At Lake Koocanusa and Hungry Horse Reservoir, these effects would occur in relatively isolated areas without residences immediately nearby, therefore the likelihood of adding to the cumulative effects to visual quality is negligible. There is the potential for new residential and commercial development near both Lake Pend Oreille and Lake Roosevelt. The drawdowns would add to the cumulative effects to visual resources at these two locations, but it is unclear how much new development would occur.

6.3.1.14 Noise

RFFAs with the potential to impact noise in the CIAA and are listed in Table 6-38, along with a description of the effects of these actions.

Table 6-38. Reasonably Foreseeable Future Actions Relevant to Noise

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	There would be adverse effects from increased volumes of noise as human population growth brings potential increases in background noise from residential, commercial, industrial, agricultural, recreational, and transportation development and activities.
RFFA3	New and Alternative Energy Development	There would be possible adverse effects due to construction or deconstruction of new and old energy infrastructure.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	There would be possible adverse effects due to construction and operations of renewable energy sources (i.e., wind turbines).
RFFA25	Columbia Pulp Plant	This could increase potential adverse effects due to noise associated with operating the pulp plant, which is located in Lyons Ferry downstream of Little Goose Dam and upstream of Lower Monumental Dam.
RFFA26	Middle Columbia Dam Operations	There would be possible adverse effects due to ongoing noise from operations and maintenance activities.

Anticipated future effects to noise under the No Action Alternative are anticipated to be consistent with current conditions. Direct and indirect effects of the MOs are listed below in Table 6-39.

Table 6-39. Summary of Direct and Indirect Effects to Noise

Region	MO1	MO2	MO3	MO4
A (Libby, Hungry Horse, Albeni Falls)	Negligible and minor effect, similar to the No Action Alternative.	Negligible and minor effect.	Negligible and minor effect, similar to the No Action Alternative.	No change from No Action Alternative.
B (Grand Coulee, Chief Joseph)	Negligible and minor effect, similar to the No Action Alternative.	Negligible and minor effect.	Negligible and minor effect, similar to the No Action Alternative.	No change from No Action Alternative.
C (Dworshak, Four Lower Snake River Projects)	Negligible and minor effect, similar to the No Action Alternative.	Negligible and minor effect.	Short-term effects resulting from breaching the four lower Snake River dams will result from construction activities during the two years following the signing of the ROD. This noise could temporarily exceed state noise standard levels at nearby residences. Overall, construction noise would result in moderate noise effects for nearby residents. Once beaching work is complete, local noise levels would be lower than under the No Action Alternative because operations and maintenance would cease at those project sites. Increased rail and vehicle traffic would likely result in a minor change to noise levels long-term.	No change from No Action Alternative.
D (Four Lower Columbia River Projects)	Negligible and minor effect, similar to the No Action Alternative.	Negligible and minor effect.	Negligible and minor effect, similar to the No Action Alternative.	No change from No Action Alternative.

Noise associated with construction or modification of facilities are mostly short-term in duration. Ongoing activities, such as operation of motor vehicles and farming would continue under all of the alternatives. No effects to noise are anticipated from climate change (see Section 4.2). Overall, the effects from the alternatives in combination with past, present, and reasonably foreseeable future actions would result in little to no cumulative effects to noise, except for those associated with MO3.

MULTIPLE OBJECTIVE ALTERNATIVE 1

There would be negligible to minor effects to noise levels from operational measures. The effect of the proposed MO1 structural measures on ambient sound levels at the lower Snake River projects in Region C and Lower Columbia River projects in Region D would be similar to the No Action Alternative and would be a minor effect. In addition, no substantial reasonably foreseeable cumulative effects are expected in the CIAA over the analysis period. Therefore, no cumulative effects are anticipated under this alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 2

There would be a negligible to minor effect to noise levels from structural and operational measures under MO2. In addition, no substantial reasonably foreseeable cumulative effects are expected in the CIAA over the analysis period. In addition, no substantial reasonably foreseeable cumulative effects are expected in the CIAA over the analysis period. Therefore, no cumulative effects are anticipated under this alternative.

MULTIPLE OBJECTIVE ALTERNATIVE 3

The primary noise effects in this EIS would occur under MO3 and would be related to substantial structural changes to the four lower Snake River projects. These effects would occur in relatively isolated areas without residences immediately nearby. Short-term effects resulting from breaching the four lower Snake River dams will result mainly from the construction activities during the two years following the signing of the ROD. This noise could temporarily exceed state noise standard levels at nearby residences, but construction noise related to dam breaching would result in moderate noise effects, particularly for nearby residents. Once beaching work is completed, the local noise levels would be lower than under the No Action Alternative because operations and maintenance would cease at those project sites. In the long term, increased rail and vehicle traffic would likely result in a minor change to noise levels.

There could potentially be adverse effects from increased volumes of noise as human population growth brings potential increases in background noise from residential, commercial, industrial, agricultural, recreational, and transportation development and activities in Region C. However, it is unclear how much new development would be expected after the breach of the four lower Snake River dams in MO3.

The Columbia Pulp Plant could potentially increase adverse effects due to noise associated with operating the pulp plant, which is located in Lyons Ferry downstream of Little Goose Dam and upstream of Lower Monumental Dam in Region C, however, any cumulative effects would be short-term, as they would only occur during dam breach.

MULTIPLE OBJECTIVE ALTERNATIVE 4

There would be a negligible to minor effects to noise levels from structural and operational measures under MO4. In addition, no substantial reasonably foreseeable cumulative effects are expected in the CIAA over the analysis period. Therefore, no cumulative effects are anticipated under this alternative.

6.3.1.15 Fisheries and Passive Use

RFFAs with the potential to impact fisheries resources in the CIAA are listed in Table 6-40, along with a description of the effects of these actions.

Table 6-40. Reasonably Foreseeable Future Actions Relevant to Fisheries

RFFA ID	RFFA Description	Impact Description
RFFA 1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	Adverse effects would occur from loss of riparian habitat and fragmentation through new development projects.
RFFA 2	Water Withdrawals for Municipal, Agricultural, Industrial Uses	Overall there would be an adverse effect from reduced availability of water from increased demand.
RFFA 5	Federal and State Wildlife Lands Management	Land management practices are anticipated to continue to include watershed improvement projects that can benefit fish.
RFFA 7	Fishery Management Plans	The goal of Pacific Salmon Management plans is to better manage catch of salmon in ocean waters offshore. This could lead to a trend of beneficial effects to salmon numbers by reducing commercial catch for these species. The U.S. v Oregon Fishery Management Agreement has the overall goal of rebuilding weak runs to full productivity through habitat protection authorities, enhancement efforts, artificial production techniques and harvest management. Implementation of this agreement could lead to a trend of beneficial effects to target species.
RFFA 8	Bycatch and Incidental Take	Bycatch of ESA-listed species and incidental take would continue to have an adverse effect.
RFFA 9	Bull Trout Passage at Albeni Falls	The proposed action is to construct an upstream “trap and haul” fish passage facility at AFD; downstream passage will occur through the spillway and powerhouse.
RFFA 10	Ongoing and Future Habitat Improvement Actions for Bull Trout	A common goal among these projects is the improvement of aquatic habitat and water quality to benefit native salmonids, especially bull trout.

RFFA ID	RFFA Description	Impact Description
RFFA 11	Resident Fisheries Management	The state and tribal fish and game agencies manage, for recreational, ceremonial, and subsistence, fisheries in the Columbia River Basin and regulate private and public hatchery releases. The agencies modify and publish recreational fishing regulations on an annual basis. Currently, recreational anglers may not target bull trout in most areas, but may incidentally catch and release bull trout. Other resident fisheries include Kokanee and Burbot in the upper basin.
RFFA 12	Fish Hatcheries	Hatcheries would continue to benefit anadromous populations that are increased through stocking.
RFFA 13	Tribal, State, and Local Fish and Wildlife Improvement	New Tribal, State, and Local fish and wildlife improvement projects are projected to restore, maintain, create, or enhance fish and wildlife habitat. Many of these projects are focused on benefiting anadromous species.
RFFA 17	Invasive Species	There would be a continuing trend towards increases in Northern Pike and other species that prey on salmonids. Non-native fishes such as walleye, smallmouth bass, and channel catfish are present in the slower moving areas throughout the CRS as well.
RFFA18	Marine Energy and Coastal Development Projects	There would be adverse effects to anadromous fish, due to collisions with marine mammals (e.g., orcas), and obstruction of migration routes for salmonids and marine mammals.
RFFA 19	Climate Change	Potential effects of climate change, such as warmer air temperatures and changes to hydrology, could have adverse effects on the ecosystem. Warming air temperatures coupled with changing rainfall amounts and rainfall timing could affect soil conditions, plant communities, insects, and fish.

Based on the results of the anadromous and resident fish analyses it is assumed that under the No Action Alternative commercial and subsistence catch would be consistent with current conditions. Direct and indirect effects of the other alternatives are listed in the below Table 6-41

Under all of the alternatives, the extent to which changes in the abundance of various fish populations result in changes in fisheries is driven by fishery management decisions that determine how much, when, and by whom fish can be caught. Due to the complexity of fishery management, it is not possible to predict changes in fishery management that may result from changes in fish abundance. The direct effects to fish species are presented in sections 3.5. Direct effects to fisheries are presented in section 3.15. As noted in Table 6-19 and Table 6-21, there are numerous cumulative actions that could both beneficially and adversely affect species important to commercial fishing and subsistence and ceremonial purposes. Climate changes, including warming air temperatures coupled with changing rainfall amounts and rainfall timing, could affect soil conditions, plant communities, insects, and fish. Based on the potential effects of the alternatives and cumulative actions, the potential for beneficial cumulative effects to commercial fishing, subsistence fishing, and ceremonial use would be most likely under MO3 and MO4. The potential for adverse cumulative effects would be highest under MO2. MO1 and the No Action Alternative would likely have similar effects (Table 6-41).

Table 6-41. Direct and Indirect Impact Summary for Fisheries

Impact Type	MO1	MO2	MO3	MO4
Social Welfare Effects	There would be negligible changes in commercial salmon fisheries. There would be minor to moderate adverse effects due to warmer summer water temperatures, reduced flows, increased entrainment, and increased TDG, which could have effects to resident fish and related ceremonial and subsistence fishing.	MO2 may result in adverse effects to Upper Columbia Spring Chinook, Snake River Spring and Summer Chinook, Upper Columbia Steelhead, Mid-Columbia Steelhead, Columbia River Sockeye, Snake River steelhead, Snake River sockeye, and Snake River coho.	MO3 may benefit Upper Columbia Spring Chinook, Snake River Spring and Summer Chinook, Upper Columbia Steelhead, Mid-Columbia Steelhead, Columbia River Sockeye, Snake River steelhead, Snake River sockeye, and Snake River coho.	MO4 may benefit Upper Columbia Spring Chinook and Snake River Spring and Summer Chinook. The overall effect to Snake River steelhead, sockeye, and coho is expected to be beneficial.
Regional Economic Effects	There would be negligible changes in commercial salmon fisheries.	MO2 may result in some adverse regional economic effects.	MO3 may benefit the regional economy through increases in commercially important fish populations.	MO4 may benefit the regional economy through increases in commercially important fish populations.
Other Social Effects	There would be negligible other social effects.	MO2 may adversely affect some commercially important and ceremonial and subsistence fish populations.	MO3 may beneficially affect some commercially important and ceremonial and subsistence fish populations.	MO4 may beneficially affect some commercially important and ceremonial and subsistence fish populations.

6.3.1.16 Cultural Resources

RFFAS with the potential to impact cultural resources are primarily those that would result in an increase in ground disturbance or reservoir level fluctuations in the study area and are listed in Table 6-42, along with a description of the effects of these actions.

Table 6-42. Reasonably Foreseeable Future Actions Relevant to Cultural Resources

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	Population growth could result in ground disturbance and an increase in human presence on the landscape, which could increase the chances of exposure, erosion, and looting of archaeological sites.
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	Increasing water withdrawals could increase the chances of exposure and erosion of archaeological sites through reservoir level fluctuations.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA 3	New and Alternative Energy Development	Increasing ground disturbance and/or reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	Increasing ground disturbance and/or reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites.
RFFA5	Federal and State Wildlife and Lands Management	Public land management practices can influence ground disturbance, and therefore could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action. Bank stabilization and stormwater runoff management projects, for example, are intended to decrease erosion, which could benefit the preservation of archaeological sites.
RFFA6	Increase in Demand for Water Storage Projects	Any new water storage projects could increase ground disturbance or reservoir level fluctuations, and therefore could increase or decrease the chances of exposure, erosion, and looting of archaeological sites.
RFFA9	Bull Trout Passage at Albeni Falls	Ground disturbance from construction of a fish passage facility at Albeni Falls could increase the chances of exposure, erosion, and damage of archaeological sites. Any modifications to historic structures could fall under Section 106 compliance, thus affecting cultural resources.
RFFA10	Ongoing and Future Habitat Improvement Actions for Bull Trout	Any ground disturbance from habitat modifications from restoration efforts could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action. Bank stabilization projects are intended to decrease erosion, which could benefit the preservation of archaeological sites. Modifications to historic structures as a result of constructing a fish passage facility at Box Canyon Dam could fall under Section 106 compliance, thus affecting cultural resources.
RFFA12	Fish Hatcheries	Any ground disturbance from new hatchery development or maintenance of existing hatchery facilities could increase the chances of exposure, erosion, and damage of archaeological sites
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement	Non-federal actions to improve habitat and regulate stormwater discharges could increase or decrease the chances of exposure, erosion, and looting of archaeological sites.
RFFA15	Snake River Sediment Management Plan	Removal of accumulated sediment in the navigation channel, depositing it in upland locations, and changing reservoir levels to accommodate dredging could increase the chances of exposure, erosion, loss, looting and damage of archaeological sites.
RFFA17	Invasive Species Management	Weed management efforts, invasive species prevention and eradication, and vegetation treatments could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA19	Climate Change	Changes in flow could affect lake levels as a result of climate change. These changes could substantially exacerbate the probability of exposure, erosion, and loss of archaeological sites due to fluctuating runoff timing, intensity, and duration. This would apply to both high and low flows, and operational responses to changing conditions. Refer to section 4.2.15 for more information.
RFFA24	Hanford Site	Any ground disturbance from clean-up efforts could increase the chances of exposure, erosion, and looting of archaeological sites.
RFFA25	Columbia Pulp Plant	Any ground disturbance from construction of the facility could increase the chances of exposure, erosion, and looting of archaeological sites.

Anticipated future cultural resource concerns under the No Action Alternative are anticipated to be consistent with current conditions. Direct and indirect effects of the MOs are listed below in Table 6-43.

Table 6-43. Summary of Direct and Indirect Effects to Cultural Resources

Region	MO1	MO2	MO3	MO4
A (Libby, Hungry Horse, Albeni Falls)	Increased exposure of archaeological resources at Hungry Horse, leading to increased erosion, recreational effects, and possible looting.	Increased exposure of archaeological resources at Hungry Horse and Libby.	There is potential for a small increase in exposure of archaeological resources by reservoir fluctuation and increased flows.	There is potential for a small increase in exposure of archaeological resources.
B (Grand Coulee)	Increased archaeological exposure by 10%, leading to increased erosion, recreational effects, and possible looting. Reservoir elevation changes increase in frequency by 32%, increasing the rate at which erosion occurs.	Increased archaeological exposure by 13%. Reservoir elevation changes increase in frequency by 26%.	High draft rate events increase from an average of 5.8 times a year to above 6.3 times a year, leading to increased potential for slumping and other kinds of mass wasting.	Increased archaeological exposure by 47%. Reservoir elevation changes increase in frequency by 24%. High draft rate events increase the same as MO3.
B (Chief Joseph)	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.	No change from No Action Alternative.

Region	MO1	MO2	MO3	MO4
C (Dworshak)	High draft rate events increase from an average of 2 times a year to above 4 times a year.	Increased archaeological exposure by 13%. Amplitude of reservoir elevation changes (from max to min) increase by 28%, leading to increased erosion.	No change from No Action Alternative.	No change from No Action Alternative.
C (Four Lower Snake River Projects)	No change from No Action Alternative.	No change from No Action Alternative.	A drawdown rate of 2 feet per day leads to slumping and mass wasting of post-reservoir sediments on archaeological sites. Invasive weeds could take over exposed soils leading to the development of a post-reservoir plant community that does not resemble pre-reservoir conditions. This would diminish the integrity of exposed TCPs. Existing plants may fail to propagate over areas exposed by removal of reservoir due to lack of water. Lack of plant cover would lead to accelerated erosion of archaeological resources. Exposure of archaeological sites due to removal of reservoir waters could lead to increased looting. Exposure of sandy areas along rivers leads to increase vehicle traffic on the former bed of the reservoir, which leads to rutting and damage to exposed sites. Breaching leads to the dismantling of (eligible) historic structures.	No change from No Action Alternative.

Region	MO1	MO2	MO3	MO4
D (Four Lower Columbia River Projects)	Negligible change from No Action Alternative.	Negligible change from No Action. Alternative.	Release of accumulated sediment from Lower Snake River dam breaching overwhelms some wetlands, affecting distribution of plant communities that are critical to some TCPs (such as tule).	Increased archaeological exposure by 23% in John Day Reservoir.

For the No Action and all other alternatives, the following RFFAs are expected to affect fish species or increase the chances of damage and/or loss of archaeological sites due to exposure, erosion, and/or looting:

- Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development
- Water Withdrawals for Municipal, Agricultural, and Industrial Uses
- New and Alternative Energy Development
- Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization
- Federal and State Wildlife and Lands Management
- Increase in Demand for Water Storage Projects
- Fishery Management
- Bull Trout Passage at Albeni Falls
- Ongoing and Future Habitat Improvement Actions for Bull Trout
- Fish Hatcheries
- Tribal, State, and Local Fish and Wildlife Improvement
- Lower Columbia River Dredged Material Management Plan
- Snake River Sediment Management Plan
- Invasive Species Management
- Climate Change
- Clean Water Act-Related Actions
- Mining in Reaches Upstream of CRS Dams
- Hanford Site

- Columbia Pulp Plant
- Middle Columbia Dam Operations
- SKQ Dam Operations

In essence, any RFFA that may cause water level fluctuations, changes in flows, has effects to fish, causes additional ground disturbance, erosion, or exposure of reservoir or riverbanks in the same space and time as CRSO EIS alternatives could be expected to cause additive adverse effects to cultural resources, including damage and loss.

Under all alternatives, climate change could contribute cumulatively to the exacerbation of direct and indirect effects of the CRSO EIS, by increasing the probability of exposure, erosion, and loss of archaeological sites due fluctuating runoff, scouring sediments, and reservoir level fluctuations. Climate Change could result in longer periods of low summer flows, resulting in increased periods of exposure, which can also lead to potential looting and erosion of archaeological sites. In addition, Climate Change could result in more frequent events of spring flows with higher average runoff volumes, resulting in increased intensity and duration of erosion of archaeological sites.

Two sacred sites were identified in the study area: Bear Paw Rock and Kettle Falls. CRSO EIS alternatives have the potential to affect sacred sites as a result of changes in reservoir elevations or construction activities. Bear Paw Rock showed no change in effects from the No Action Alternative for all of the action alternatives. Kettle Falls showed no change from the No Action Alternative for MO3 and minimal changes for MO1, MO2, and MO4. Overall, the effects from the alternatives in combination with past, present, and reasonably foreseeable future actions would result in minor cumulative effects to sacred sites affected by CRS operations.

The use of BMPs or mitigation measures to exposure, erosion, and looting of archaeological sites could minimize the direct and indirect effects of these activities, thus reducing the potential cumulative effects.

NO ACTION ALTERNATIVE

Under the No Action Alternative, effects to cultural resources from ongoing Columbia River System operations in addition to the cumulative effects discussed above for all alternatives would continue. See Section 3.16.3.1 for more information. In general, past cumulative effects to cultural resources are expected to persist into the future under the No Action Alternative and for many of the action alternatives. The use of BMPs or mitigation measures to exposure, erosion, and looting of archaeological sites could minimize the direct and indirect effects of these activities, thus reducing the potential cumulative effects.

Incorporating mitigation (as identified in Chapter 5) to lessen effects could change the estimated cumulative to cultural resources. In addition, effects to cultural resources would continue to be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

MULTIPLE OBJECTIVE ALTERNATIVE 1

Under this MO, a wide array of measures would affect water levels and flows. Adverse effects related to cultural resources are expected to occur under MO1. The effects of MO1 on cultural resources are described above in Table 6-43 by region.

MO1 is expected to adversely affect archaeological resources, especially during wet years. Increased exposure of archaeological resources under MO1, leading to increased erosion, recreational effects, and possible looting could potentially be exacerbated by climate change, as increased precipitation in the form of rain is expected alongside more extreme weather events. For example, if an archaeological site were exposed for a longer length of time because of measures in MO1 (which is predicted for this MO), there is potential for more rain to fall on that site during the time period of exposure, thus increasing the rate, frequency, or intensity of erosion.

Future higher winter and spring volumes due to climate change could also cumulatively increase the direct and indirect effects of erosion because of the increased scouring caused by higher flows for longer periods. This results in moderate to major cumulative effects to cultural resources under MO1 due to additive exposure. Some mitigation actions are intended to address these effects, as identified in Chapter 5, which could further offset adverse cumulative effects. In addition, effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Under alternative MO2, cumulative effects to cultural resources are expected to be similar to those described under MO1. Mitigation (as identified in Chapter 5) to lessen effects could change the estimated cumulative to cultural resources. In addition, effects to cultural resources would continue to be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

MULTIPLE OBJECTIVE ALTERNATIVE 3

Under alternative MO3, cumulative effects to cultural resources are expected to be largely similar to that as described under MO1. That said, some direct and indirect effects under this alternative related to dam breach would expose archaeological resources and TCPs in the area of the reservoir drawdown. Under MO3, these areas could be inundated with more exposure due to weed infestations, driving, other trampling in sandy areas (where vehicles could go), and increased looting. Similar to MO1, erosion, recreational effects, and possible looting could potentially be exacerbated by climate change, as increased precipitation in the form of rain is expected alongside more extreme weather events. For example, if an archaeological site were exposed for a longer length of time because of measures in MO3 (which is predicted for this alternative), there is potential for more rain to fall on that site during the time period of exposure, thus increasing the rate, frequency, and/or intensity of erosion. That said, the use of BMPs or mitigation measures to exposure, erosion, and looting of archaeological sites could minimize the direct and indirect effects of these activities, thus reducing the potential cumulative effects. In addition, incorporating mitigation (as identified in Chapter 5) to lessen effects could change the estimated cumulative to cultural resources. In addition, effects to cultural resources would continue to be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

MULTIPLE OBJECTIVE ALTERNATIVE 4

For alternative MO4, cumulative effects to cultural resources are expected to be similar to those described under MO1. Mitigation (as identified in Chapter 5) to lessen effects could change the estimated cumulative to cultural resources. In addition, effects to cultural resources would continue to be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

6.3.1.17 Indian Trust Assets, Tribal Perspectives, and Tribal Interests

Section 3.17 discusses the affected environment and environmental consequences for Indian Trust Assets (ITAs), tribal perspectives, and tribal interests. Certain tribes provided their holistic perspectives on how the CRS affects tribal interests, and these perspectives can be found in Appendix P, *Tribal Perspectives*.

The effects from all the alternatives on ITAs, Tribal Perspectives, and Tribal Interests vary. No direct or indirect effects to ITAs were identified for any alternative. Trust lands identified during the geospatial database query and tribal outreach are located outside of any direct or indirect effects identified from the alternatives. These include lands from the Confederated Tribes of Warm Springs Reservation, the Yakama Nation, and the Kootenai Tribe of Idaho, as well as these Indian reservations: The Confederated Tribes of the Colville Indian Reservation; Spokane Tribe of Indians; Kootenai Tribe of Idaho; Nez Perce Tribe; and The Confederated Salish & Kootenai Tribes of the Flathead Reservation. Ongoing activities on Indian Trust lands, for example, would be expected to continue under all of the alternatives. Since the CRSO EIS alternatives are not expected to have direct or indirect effects on Indian Trust Assets, there would likely be no change in effects to these assets, and thus there would be no likely cumulative effects to Indian Trust Assets.

RFFAs with the potential to impact tribal interests in the CIAA are listed in Table 6-44 along with a description of the effects of these actions.

Table 6-44. Reasonably Foreseeable Future Actions Relevant to Tribal Interests

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	Population growth and urban, rural, commercial, industrial, and agricultural development could exacerbate the issues tribes are experiencing related to: loss of anadromous and resident fish important to these communities. increasing costs of power for their communities

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	Water withdrawals could exacerbate the issues tribes are experiencing related to loss of water supply, or loss of habitat for anadromous and resident fish important to their communities due to tributary water withdrawals.
RFFA3	New and Alternative Energy Development	Increasing ground disturbance and/or reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites important to the tribes.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	The planned retirement of coal plants in the region and other decarbonization actions that increase the need for clean power may lead to increases in the price of electricity for tribal communities. However, a beneficial impact would likely be seen from the likelihood of reduced GHG emissions and air pollutant emissions. However, generation could be replaced by gas or renewable sources. If it is replaced by gas, then there could be increased emissions.
RFFA5	Federal and State Wildlife and Lands Management	Land management practices are anticipated to continue to include watershed improvement projects that can benefit fish. Public land management practices can influence ground disturbance, and therefore could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action. Bank stabilization and stormwater runoff management projects, for example, are intended to decrease erosion, which could benefit the preservation of archaeological sites important to tribes.
RFFA6	Increase in Demand for Water Storage Projects	Any new water storage projects could increase ground disturbance or reservoir level fluctuations, and therefore could increase or decrease the chances of exposure, erosion, and looting of archaeological sites important to tribes.
RFFA7	Fishery Management	The goal of Pacific Salmon Management plans is to better manage catch of salmon in ocean waters offshore. This could lead to a trend of beneficial effects to salmon numbers by reducing commercial catch for these species. The U.S. v Oregon Fishery Management Agreement has the overall goal of rebuilding weak runs to full productivity through habitat protection authorities, enhancement efforts, artificial production techniques, and harvest management. Implementation of this agreement could lead to a trend of beneficial effects to species that are important to tribes.
RFFA9	Bull Trout Passage at Albeni Falls	The proposed action is to construct an upstream “trap and haul” fish passage facility at Albeni Falls; downstream passage will occur through the spillway and powerhouse. Ground disturbance from construction of a fish passage facility at Albeni Falls could increase the chances of exposure, erosion, and damage of archaeological sites, thus potentially affecting cultural resources important to tribes.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA10	Ongoing and Future Habitat Improvement Actions for Bull Trout	A common goal among these projects is the improvement of aquatic habitat and water quality to benefit native salmonids, especially bull trout. Any ground disturbance from habitat modifications from restoration efforts could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action. Bank stabilization projects are intended to decrease erosion, which could benefit the preservation of archaeological sites. These actions potentially affect cultural resources important to tribes.
RFFA11	Resident Fisheries Management	There may be adverse effects to tribes from recreational anglers' catching fish over the catch limits thereby reducing fish availability.
RFFA12	Fish Hatcheries	Hatcheries would continue to benefit anadromous populations that are increased through stocking. Any ground disturbance from new hatchery development or maintenance of existing hatchery facilities could increase the chances of exposure, erosion, and damage of archaeological sites important to tribes.
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement	Tribal, State, and local fish and wildlife improvement projects and activities could have a beneficial additive effect to anadromous and resident fish important to tribes.
RFFA14	Lower Columbia River Dredged Material Management Plan	Removal of accumulated sediment in the navigation channel and depositing it in upland locations could increase the chances of exposure, erosion, loss and damage of archaeological sites important to tribes.
RFFA15	Snake River Sediment Management Plan	Removal of accumulated sediment in the navigation channel, depositing it in upland locations, and changing reservoir levels to accommodate dredging could increase the chances of exposure, erosion, loss, looting and damage of archaeological sites important to tribes.
RFFA16	SKQ Dam Operations	Reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites important to tribes.
RFFA17	Invasive Species	Weed management efforts, invasive species prevention and eradication, and vegetation treatments could increase or decrease ground disturbance activities exposing or protecting archaeological sites important to tribes.
RFFA18	Marine Energy and Coastal Development Projects	Coastal development has the potential effects that include non-point source pollution (e.g., stormwater runoff) that would affect tribes that depend on vegetation, wetlands, wildlife and floodplains. There would be adverse effects to anadromous fish, due to collisions with marine mammals (e.g., orcas), and obstruction of migration routes for salmonids and marine mammals would affect tribes that depend on these resources.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA19	Climate Change	Effects from climate change have the potential to result in cumulative effects to multiple resources that are important to tribes. Climate change effects could exacerbate the issues tribes are experiencing related to: loss of anadromous and resident fish important to their communities increasing costs of power for their communities
RFFA20	Clean Water Act-Related Actions	Any ground disturbance from habitat modifications from restoration efforts could increase or decrease the chances of exposure, erosion, and looting of archaeological sites important to tribes. Depending on the nature of the management action, cumulative effects could be beneficial or adverse.
RFFA21	Idaho Power Hells Canyon Complex Mercury Contamination Issues/Remediation	This could result in remediation and cleanup actions as well as lead to a reduction or elimination of fish consumption advisories for mercury in fish tissue, but it is unclear what the timing and extent of remediation would be.
RFFA22	Idaho Power Hells Canyon Complex Temperature Issues	There is potential for temperature effects during summer migration, which may impact fish species important to the tribes.
RFFA23	Mining in Reaches Upstream of CRS Dams	Future or on-going remediation activities, such as those related to mining on the Spokane Arm of Lake Roosevelt, could increase the chances of exposure, erosion, and looting of archaeological sites important to tribes.
RFFA24	Hanford Site	Any ground disturbance from clean-up efforts could increase the chances of exposure, erosion, and looting of archaeological sites important to tribes.
RFFA25	Columbia Pulp Plant	Any ground disturbance from construction of the facility could increase the chances of exposure, erosion, and looting of archaeological sites important to tribes.
RFFA26	Middle Columbia Dam Operations	Reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites important to tribes.

The area potentially affected by the alternatives has served as a homeland since time immemorial for multiple tribes. The rivers and the resources that they have historically supported are critical elements of many tribes' sense of place and identity. As a result, any evaluation of CRS operations should consider how changes to river conditions affect tribal interests. This section accordingly considers those effects, which have also been considered throughout this analysis for resources of particular importance to tribes.

Effects to tribal interests from the alternatives would be negligible for most resources (e.g. Vegetation, Wetlands, Wildlife, and Floodplains, Air Quality and Greenhouse Gases, Power and Transmission, Flood Risk Management, Navigation and Transportation, and Recreation). There is a range of expected effects for all alternatives, including minor beneficial effects such as those from the refined operations in Region A, and potentially minor adverse effects to resident fish in Lake Roosevelt due to deeper drawdowns in high water years. However, mitigation incorporated into the alternatives (as appropriate) includes spawning habitat augmentation to offset these effects. The expected range of effects to fish is described in more detail in the anadromous fish, resident fish, water quality, and fisheries sections. Additionally, ongoing Fish and Wildlife programs would continue under alternatives and extending the boat ramp at the Inchelium-Gifford ferry would mitigate some of the operational effects at Grand Coulee, including accessibility.

RFFAs 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, and 26 would likely affect a variety of tribal interests, including: Anadromous Fish; Resident Fish; Water Quality; Vegetation, Wetlands, Wildlife, and Floodplains; Air Quality and Greenhouse Gases; Power and Transmission, Flood Risk Management; Navigation and Transportation, and Recreation. The descriptions of impacts from these RFFAs for these respective resources are described in depth previously in this Chapter.

6.3.1.18 Environmental Justice

RFFAs with the potential to impact environmental justice communities in the CIAA are listed in Table 6-45 along with a description of the effects of these actions.

Table 6-45. Reasonably Foreseeable Future Actions Relevant to Environmental Justice

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development	Population growth and urban, rural, commercial, industrial, and agricultural development could exacerbate the issues tribes and low-income communities are experiencing related to: loss of anadromous and resident fish important to these communities. increasing costs of power for these communities
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses	Water withdrawals could exacerbate the issues tribes and low-income communities are experiencing related to loss of water supply, or loss of habitat for anadromous and resident fish important to these communities due to tributary water withdrawals.
RFFA3	New and Alternative Energy Development	Increasing ground disturbance and/or reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites important to these communities.
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization	The planned retirement of coal plants in the region and other decarbonization actions that increase the need for clean power may lead to increases in the price of electricity.
RFFA5	Federal and State Wildlife and Lands Management	Public land management practices can influence ground disturbance, and therefore could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action. Bank stabilization and stormwater runoff management projects, for example, are intended to decrease erosion, which could benefit the preservation of archaeological sites important to these communities.
RFFA6	Increase in Demand for Water Storage Projects	Any new water storage projects could increase ground disturbance or reservoir level fluctuations, and therefore could increase or decrease the chances of exposure, erosion, and looting of archaeological sites important to these communities.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA7	Fishery Management	The goal of Pacific Salmon Management plans is to better manage catch of salmon in ocean waters offshore. This could lead to a trend of beneficial effects to salmon numbers by reducing commercial catch for these species. The U.S. v Oregon Fishery Management Agreement has the overall goal of rebuilding weak runs to full productivity through habitat protection authorities, enhancement efforts, artificial production techniques, and harvest management. Implementation of this agreement could lead to a trend of beneficial effects to species that are important to environmental justice communities.
RFFA9	Bull Trout Passage at Albeni Falls	Ground disturbance from construction of a fish passage facility at Albeni Falls could increase the chances of exposure, erosion, and damage of archaeological sites, thus potentially affecting cultural resources important to environmental justice communities.
RFFA10	Ongoing and Future Habitat Improvement Actions for Bull Trout	Any ground disturbance from habitat modifications from restoration efforts could increase or decrease the chances of exposure, erosion, and looting of archaeological sites, depending on the nature of the management action. Bank stabilization projects are intended to decrease erosion, which could benefit the preservation of archaeological sites. These actions potentially affect cultural resources important to environmental justice communities.
RFFA11	Resident Fisheries Management	There may be adverse effects to environmental justice communities from recreational angler's catching fish over the catch limits thereby reducing fish availability for environmental justice communities.
RFFA12	Fish Hatcheries	Hatcheries would continue to benefit anadromous populations that are increased through stocking. Any ground disturbance from new hatchery development or maintenance of existing hatchery facilities could increase the chances of exposure, erosion, and damage of archaeological sites important to environmental justice communities.
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement	Tribal, State, and local fish and wildlife improvement projects and activities could have a beneficial additive effect to anadromous and resident fish important to tribes and low-income communities.
RFFA14	Lower Columbia River Dredged Material Management Plan	Removal of accumulated sediment in the navigation channel and depositing it in upland locations could increase the chances of exposure, erosion, loss and damage of archaeological sites important to environmental justice communities.
RFFA15	Snake River Sediment Management Plan	Removal of accumulated sediment in the navigation channel, depositing it in upland locations, and changing reservoir levels to accommodate dredging could increase the chances of exposure, erosion, loss, looting and damage of archaeological sites important to environmental justice communities.
RFFA16	SKQ Dam Operations	Reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites important to environmental justice communities.
RFFA17	Invasive Species	Weed management efforts, invasive species prevention and eradication, and vegetation treatments could increase or decrease ground disturbance activities exposing or protecting archaeological sites important to environmental justice communities.

RFFA ID	RFFA Description	Cumulative Impact Description
RFFA18	Marine Energy and Coastal Development Projects	Coastal development has the potential effects that include non-point source pollution (e.g., stormwater runoff) that would affect environmental justice communities that depend on vegetation, wetlands, wildlife and floodplains. There would be adverse effects to anadromous fish, due to collisions with marine mammals (e.g., orcas), and obstruction of migration routes for salmonids and marine mammals would affect environmental justice communities that depend on these resources.
RFFA19	Climate Change	Effects from climate change have the potential to result in cumulative effects multiple resources that are important to environmental justice populations. Refer to section 4.2.16 for more information. Climate change effects could exacerbate the issues tribes and low-income communities are experiencing related to: loss of anadromous and resident fish important to these communities increasing costs of power for these communities
RFFA20	Clean Water Act-Related Actions	Any ground disturbance from habitat modifications from restoration efforts could increase or decrease the chances of exposure, erosion, and looting of archaeological sites important to environmental justice communities. Depending on the nature of the management action, cumulative effects could be beneficial or adverse.
RFFA21	Idaho Power Hells Canyon Complex Mercury Contamination Issues/Remediation	This could result in remediation and cleanup actions as well as lead to a reduction or elimination of fish consumption advisories for mercury in fish tissue, but it is unclear what the timing and extent of remediation would be.
RFFA23	Mining in Reaches Upstream of CRS Dams	Future or on-going remediation activities, such as those related to mining on the Spokane Arm of Lake Roosevelt, could increase the chances of exposure, erosion, and looting of archaeological sites important to environmental justice communities.
RFFA24	Hanford Site	Any ground disturbance from clean-up efforts could increase the chances of exposure, erosion, and looting of archaeological sites important to environmental justice communities.
RFFA25	Columbia Pulp Plant	Any ground disturbance from construction of the facility could increase the chances of exposure, erosion, and looting of archaeological sites important to environmental justice communities.
RFFA26	Middle Columbia Dam Operations	Reservoir level fluctuations and flow modifications could increase the chances of exposure, erosion, and looting of archaeological sites important to environmental justice communities.

Anticipated future environmental justice concerns under the No Action Alternative are anticipated to be consistent with current conditions. Direct and indirect effects of the Action Alternatives are listed below in Table 6-46.

Table 6-46. Summary of Direct and Indirect Effects to Environmental Justice

Region	MO1	MO2	MO3	MO4
A (Libby, Hungry Horse, Albeni Falls)	Adverse effects on resident fish (bull trout and Kootenai River white sturgeon) could adversely impact ceremonial and subsistence fishing opportunities. An increase in electricity rates could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	Resident fish species may be adversely impacted downstream of Libby and in Hungry Horse Reservoirs. There could be reduced sturgeon habitat in the Kootenai River. These effects have the potential to adversely affect ceremonial and subsistence fishing opportunities.	Similar to MO1, MO3 would have adverse effects to bull trout and Kootenai River white sturgeon, adversely impacting ceremonial and subsistence fishing opportunities. An increase in electricity rates of up to $53 per year could impact low-income households at a regional level, but these effects would be felt across the region and therefore would not result in an EJ effect (disproportionate effect).	Bull trout, westslope cutthroat trout, and Kootenai River white sturgeon would have increased entrainment risk and some reduced habitat and food availability. An increase in electricity rates of up to $113 per year could impact low-income households, but these effects would occur across the region and therefore would not result in an EJ effect (disproportionate effect).
B (Grand Coulee, Chief Joseph)	Adverse effects on fish could adversely impact ceremonial and subsistence fishing opportunities. An increase in electricity rates could impact low-income households, but these effects would occur across the region. The Inchelium-Gifford ferry is expected to have 9 fewer operational days during wet years.	Increased entrainment risk for some resident species (bull trout, kokanee, rainbow trout, and burbot) could adversely affect the recreational fishery at Lake Roosevelt. Adverse effects on fish (Upper Columbia River salmon and steelhead) could adversely impact ceremonial and subsistence fishing opportunities. An increase or decrease in electricity rates could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	Small increases in the abundance of key anadromous recreational fishing species are anticipated, particularly Columbia River runs of Chinook and steelhead, increasing fishing opportunities for these species over the long term below Chief Joseph Dam. Reduced entrainment risk for some resident species (bull trout, kokanee, rainbow trout, and burbot) could benefit the fishery at Lake Roosevelt. An increase in electricity rates of up to $54 per year could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	MO4 has the potential to adversely affect ceremonial and subsistence fishing opportunities for low-income populations, minority populations, and Indian tribes. The effects to the Inchelium-Gifford ferry are similar to MO1. An increase in electricity rates of up to $85 per year could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).

Region	MO1	MO2	MO3	MO4
C (Dworshak, Four Lower Snake River Projects)	Adverse effects on fish could adversely impact ceremonial and subsistence fishing opportunities. An increase in electricity rates could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	Decreased abundance of Snake River Spring Chinook and Snake River steelhead could contribute to adverse effects on ceremonial and subsistence, and tribal commercial fishing opportunities. Adverse effects to kokanee at Dworshak Reservoir are also anticipated. These losses could represent an adverse impact to Indian tribes in the region for whom salmon and steelhead are a predominant element of cultural traditions, traditional diet, as well as sources of revenue.	People would be able to access landscapes and locations that have been inaccessible since the dams were completed, allowing practitioners of traditional lifeways and religions to physically access the landforms and Traditional Cultural Properties (TCPs) to practice their traditional lifeways. Archaeological resources could also be damaged through increasing exposure and erosion associated with increased reservoir level fluctuations associated with dam breach. An increase in electricity rates of up to $47 per year could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	Adverse effects to bull trout and other resident fish have the potential to impact ceremonial and subsistence fishing opportunities in Region C. An increase in electricity rates of up to $98 per year could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).

Region	**MO1**	**MO2**	**MO3**	**MO4**
D (Four Lower Columbia River Projects)	Adverse effects on fish could adversely impact ceremonial and subsistence fishing opportunities. An increase in electricity rates could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	Decreased abundance of Snake River Spring Chinook and Snake River steelhead, Upper Columbia River Spring Chinook, and decreased in-river survival rates of Upper Columbia River steelhead could contribute to adverse effects on ceremonial and subsistence, and tribal commercial fishing opportunities. These losses could represent an adverse impact to Indian tribes in the region for whom salmon and steelhead are a predominant element of cultural traditions, traditional diet, as well as sources of revenue.	Short-term increased sedimentation above McNary Dam would adversely affect fishing conditions. Long-term increases in the abundance of key anadromous recreational fishing species, including Chinook salmon and other salmonids as well as white sturgeon, are anticipated to occur. An increase in electricity rates of up to $80 per year could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).	Adverse effects on resident fish have the potential to adversely impact ceremonial and subsistence fishing opportunities in Region D. An increase in electricity rates of up to $109 per year could impact low-income households, but these effects would occur across the region, and therefore would not result in an EJ effect (disproportionate effect).

NO ACTION ALTERNATIVE

Under the No Action Alternative, effects from ongoing Columbia River System operations on minority populations, low-income populations, and Indian tribes would continue. As described in the Environmental Justice section (Section 3.18), "the construction of the dams and the current system operations have ongoing effects on tribal culture, lifeways (e.g., customs and practices), and traditions. The loss of foundational aspects of tribal culture resulting from the inundation of important fishing sites and the reduction in wild salmon populations has adversely affected tribal communities." These ongoing effects include adverse outcomes related to ceremonial, subsistence and other tribal fishing practices; energy affordability; water supply needs; and cultural resources important to Environmental Justice communities. This past cumulative effect is expected to persist into the future under the No Action Alternative and many of the action alternatives.

Natural and cultural resources associated with the Columbia River System are of critical importance to tribes in the region for subsistence, commerce, preservation of cultural traditions and history, religious practice, and self-determination as sovereign nations. As discussed in the Cultural Resources section, ongoing effects of ground disturbance, inundation, variable flows, and reservoir fluctuation would continue to have substantial adverse effects on traditional cultural properties and archaeological resources under the No Action and all MOs. The discussion under the cumulative effects section for cultural resources 6.3.1.15 below describes how RFFAs would cumulatively impact cultural resources through increasing exposure and erosion, resulting in effects associated with public access, including looting, vandalism, creation of trails, and unauthorized activities. In addition, Table 6-42 details numerous RFFAs that could have additive effects to cultural resources that could be important to environmental justice communities, and what those effects could be. Any RFFA that has an additive effect to ground disturbance, water levels and flows, access to certain areas, and/or abundance and distribution of fish in the CIAA would be considered a cumulative effect under the No Action and Action Alternatives

In addition, commercial, ceremonial, and subsistence fishing activity occurs in various locations on the mainstem Columbia and Snake Rivers and in tributaries throughout the study area. The MOs have the potential to affect the availability of fish for harvest for low-income populations, minority populations, and Indian tribes participating in these activities. Insofar as indirect and direct effects combine with RFFAs to cumulatively impact fish, as described in Section 6.3.1.4 for Anadromous fish and Section 6.3.1.5 for Resident fish, environmental justice communities would also be affected if they relied on those fish for subsistence, ceremonial, or commercial fishing. Please refer to these sections for discussions on the cumulative effects for fish species throughout the Columbia River Basin. That said, tribal, State, and local fish and wildlife improvement projects and activities could have a beneficial additive effect when it comes to effects to loss of anadromous and resident fish important to environmental justice communities.

Low-income communities, minority communities, and Indian Tribes, and particularly low-income households in these communities, already experience potentially unaffordable electricity costs under the No Action Alternative. Any increase in electricity rates in this region would be acutely felt by low-income households, for whom electricity costs are a larger percent of their income than for other households. In some cases, these low-income households are also minority, tribal, or both. However, these effects would be felt across the region and therefore would not result in an EJ effect (disproportionate effect).

MULTIPLE OBJECTIVE ALTERNATIVE 1

Under this alternative, a wide array of measures would affect water levels and flows, as well as the abundance and distribution of fish. Adverse effects related to the following resources and therefore cumulative effects to the same resources may occur under MO1: power generation and transmission, rates for power customers, navigation and transportation, and cultural resources. The effects of MO1 on environmental justice populations resulting from changes in these resources are described above in Table 6-46 by region. See Section 6.3.1.16 for discussion of cumulative effects to cultural resources under MO1.

Low-income households typically spend a larger portion of their income on home electricity costs than other households spend and would likely have a more difficult time adapting to a higher cost of living if annual electricity bills increase. Annual potential power rate increases for residential customers could be as high as $29 in Region A, $24 in Region B, $25 in Region C, and $44 in Region D as compared to the No Action Alternative. Any increase in electricity cost could be acutely felt by low-income or minority households (or both), for whom electricity costs are a larger percent of their income. In some cases, these low-income households are also minority, tribal, or both. RFFAs such as population growth could exacerbate this issue by creating a larger demand for energy, or by driving up other costs to low income or minority households (or both) that tend to increase alongside population growth, such as housing costs. However, these effects would be felt across the region and therefore would not result in an EJ effect (disproportionate effect).

In terms of navigation, Inchelium-Gifford ferry is operated by the Confederated Tribes of the Colville Reservation and primarily serves the tribal population as the primary and most practical means of transportation across Lake Roosevelt. However, the ferry becomes inoperable when the lake falls below a certain elevation. There are other longer or more costly modes of transportation that could be used in case of emergency if the ferry was out of service. MO1 is expected to adversely affect the Inchelium-Gifford Ferry on Lake Roosevelt because it is expected to have nine fewer operational days during wet years. Effects would primarily fall on the Confederated Tribes of the Colville Reservation. Future spring volumes due to climate change could cumulatively increase the direct and indirect effects of the alternatives on the Inchelium-Gifford Ferry operations because of higher winter and spring volumes, but mitigation actions are intended to address this impact, as identified in Chapter 5, which could further offset adverse cumulative effects. In addition, effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

Effects related to effects on water supply on low-income, minority, and Indian tribes are anticipated to be negligible under MO1.

Incorporating mitigation to lessen effects could change the estimated cumulative effects to environmental justice, and effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program. Therefore, through analysis considering effects detailed in Chapter 3 Affected Environment and Environmental Consequences; Chapter 4 Climate; Chapter 5 Mitigation; and this chapter (Cumulative Effects), there would not likely be a disproportionately high and adverse effect on environmental justice populations for MO1.

MULTIPLE OBJECTIVE ALTERNATIVE 2

Adverse effects related to the following resources may occur under MO2: fish; navigation and transportation; and cultural resources. The effects of MO2 on environmental justice populations resulting from changes in these resources are described in Table 6-46 above by region.

Ferry operations on Lake Roosevelt are expected to be affected under MO2 similar to the effects described under MO1, so cumulative effects are expected to be similar as well. Similarly, mitigation actions identified in Chapter 5 to address these effects could minimize cumulative effects. In addition, effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

Under MO2, decreased abundance of Snake River spring Chinook and Snake River steelhead would contribute to adverse effects on ceremonial and subsistence, and tribal commercial fishing opportunities in Region C under MO2. Adverse effects to kokanee at Dworshak Reservoir are also anticipated. These losses could represent an adverse impact to Indian tribes in the region for whom salmon and steelhead are a predominant element of cultural traditions and traditional diet, as well as sources of revenue. Cumulative effects to these species are described in detail in Sections 6.3.1.4 and 6.3.1.5. RFFAs such as population growth could exacerbate the loss of revenue by driving up other economic costs to low income or minority households (or both) that tend to increase alongside population growth, such as housing costs. There is potential for Tribal, State, and local fish and wildlife improvement projects and activities to offset some of the loss of anadromous and resident fish important to environmental justice communities.

In addition to the resources identified under section 3.15.3.1, effects related to effects of water supply on low-income, minority, and Indian tribes are anticipated to be negligible under MO2. Therefore, through analysis considering effects detailed in Chapter 3 Affected Environment and Environmental Consequences; Chapter 4 Climate; Chapter 5 Mitigation; and this chapter (Cumulative Effects) there would not likely be a disproportionately high and adverse effect on environmental justice populations for MO2.

Incorporating mitigation (as identified in Chapter 5) to lessen effects could change the estimated cumulative effects to environmental justice, and effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 involves the breaching of the four Lower Snake projects, which would reduce hydropower generation, increase regional emissions and air pollutants, affect navigation along the Snake River, adversely affect resident non-native fish populations, and could potentially benefit anadromous fish populations, as well as white sturgeon and bull trout.

Any increase in electricity cost could impact low-income and/or minority households, for whom electricity costs are a larger percent of their income than for other households. In some cases, these low-income households are also minority, tribal, or both. RFFAs such as population growth could exacerbate this issue by creating a larger demand for energy, or by driving up other costs to low income or minority households (or both) that tend to increase alongside population growth, such as housing costs. However, these effects would be felt across the region and therefore would not result in an EJ effect (disproportionate effect).

Incorporating mitigation to lessen effects could change the estimated cumulative effects to environmental justice, and effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program. Therefore, through analysis considering effects detailed in Chapter 3 Affected Environment and Environmental Consequences; Chapter 4 Climate; Chapter 5 Mitigation; and this chapter (Cumulative Effects) there would not likely be a disproportionately high and adverse effect on environmental justice populations for MO3.

MULTIPLE OBJECTIVE ALTERNATIVE 4

The MO4 alternative includes substantial operational changes to Libby, Hungry Horse, and Grand Coulee Dams, and operational changes at the Lower Columbia and Snake River projects. The effects of MO4 on environmental justice populations resulting from changes in these resources are described in Table 6-46 above by region. Adverse effects related to the following resources are expected under MO4: fish; power generation and transmission; navigation and transportation; water supply; and cultural resources.

In addition, commercial, ceremonial, and subsistence fishing activity occurs in various locations Please refer to Section 6.3.1.4 for Anadromous Fish and Section 6.3.1.5 for Resident fish for discussions of the cumulative effects for fish species throughout the Columbia River Basin. That said, tribal, State, and local fish and wildlife improvement projects and activities could have a beneficial additive effect when it comes to effects to loss of anadromous and resident fish important to environmental justice communities.

Annual potential power rate increases for residential customers could be as high as $113 in Region A, $85 in Region B, $98 in Region C, and $109 in Region D as compared to the No Action Alternative. Any increase in electricity costs could be acutely felt by low-income or minority households (or both), for whom electricity costs are a larger percent of their income than for other households. In some cases, these low-income households are also minority, tribal, or both. RFFAs such as population growth could exacerbate this issue by creating a larger demand for energy, or by driving up other costs to low income or minority households (or both) that tend to increase alongside population growth, such as housing costs. However, these effects would be felt across the region and therefore would not result in an EJ effect (disproportionate effect).

In terms of navigation, cumulative effects to the Inchelium-Gifford ferry are the same as those described under MO1.

Please see the discussion under the cumulative effects section for cultural resources in Section 6.3.1.16, which describes how RFFAs would cumulatively impact cultural resources through increasing exposure and erosion.

Incorporating mitigation to lessen effects could change the estimated cumulative effects to environmental justice, and effects to cultural resources would be mitigated through the ongoing Federal Columbia River Power System Cultural Resource Program.

Under MO4, certain pumps may need to be extended to allow for continued provision of water supply. If these pumps provide drinking water or agricultural water sources for minority populations, low-income populations, or Indian tribes, this could affect the costs of living in an area as well as the availability of employment opportunities.

Through analysis considering effects detailed in Chapter 3 Affected Environment and Environmental Consequences; Chapter 4 Climate; Chapter 5 Mitigation; and this chapter (Cumulative Effects) there would not likely be a disproportionately high and adverse effect on environmental justice populations for MO2.

CHAPTER 7 - PREFERRED ALTERNATIVE

7.1 INTRODUCTION

This chapter describes the alternatives introduced in Chapter 2 and analyzed in Chapters 3, 4, 5, and 6. Alternatives were evaluated based on their ability to meet the Purpose and Need, degree to which they met the objectives, as well as consideration of environmental, economic, and social effects. Major and moderate environmental, economic, and social effects to affected resources from the No Action Alternative, Multiple Objective Alternatives (MOs) and the Preferred Alternative are summarized in Table 7-1. This chapter focuses on how the Preferred Alternative was developed, including the operational, structural, and mitigation actions as well as preliminary measures to be included in the Endangered Species Act (ESA) consultations associated with this environmental impact statement (EIS). It includes the effects analysis related to the direct, indirect, climate, and cumulative effects analyses.

The Preferred Alternative includes a combination of measures that meet the Purpose and Need and objectives of the Columbia River System Operations (CRSO) EIS, while balancing the authorized purposes of the 14 Federal dam and reservoir projects that make up the Columbia River System (CRS). The Preferred Alternative is a combination of measures included in the five alternatives described in Chapter 2 and information that was evaluated in Chapter 3. In some instances, measures were modified to improve their ability to meet the Purpose and Need or objectives, as well as to avoid, reduce, or minimize environmental, economic, and social impacts. It is expected that the Preferred Alternative would allow the co-lead agencies to meet the congressionally authorized purposes of the system and the Purpose and Need and objectives of the EIS, including those to benefit ESA-listed species. The Preferred Alternative balances the multiple purposes of the Federal projects while complying with relevant laws and regulations.

While developing the Preferred Alternative, the co-lead agencies also considered the benefits, environmental consequences, tradeoffs, and costs of alternatives within and outside of current authorities as reflected in Chapters 3 to 6. This included evaluating the effects of each alternative as described in Chapter 3; projected changes to future regional climatic and hydrologic conditions as described in Chapter 4; possible mitigation measures to avoid, minimize, and reduce impacts to the human environment as described in Chapter 5; and cumulative effects as described in Chapter 6. Collectively, this information was used to help identify suites of measures from the alternatives described in Chapter 2 for inclusion in the Preferred Alternative.

As part of the development process for the Preferred Alternative, the co-lead agencies met with and considered input from cooperating agencies, members of the congressional delegation, state governors and other officials, tribes, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and other groups with a vested interest in system operations that included utility customers, irrigators, environmental organizations, and representatives from the navigation sector.

Many tribal representatives were vocal about past impacts to tribal resources and ways of life that resulted from the construction of the CRS. For thousands of years, salmon have been an important food source to tribes within the Pacific Northwest and are an important part their cultural identity, spiritualty, and ways of life. Impacts from the CRS, such as the loss of important fishing sites at Celilo and Kettle Falls, among an uncountable number of other locations, have adversely impacted tribal resources and ways of life. In addition, the lack of fish passage at some dams, including Chief Joseph and Grand Coulee Dams, within the region has restricted the range of salmonids from some locations where they were historically present. Impacts such as these have adversely affected how tribal communities define themselves, interact with each other, and live full spiritual lives. Many of the tribes have not only lost access to traditional places on the river due to construction of dams, but they have also lost access to shared resources that bound them together: salmon and steelhead. For many of the tribes, any discussion pertaining to the CRS must include actions to return salmon and steelhead to historical numbers and to improve access to historical fish habitat. In addition to evaluating significant analytical input from regional tribes throughout this process, agency decision-makers also considered the “Tribal Perspectives” narratives from those tribes who elected to submit one (see Chapter 3.17 and Appendix P) in the process of identifying measures to be included as part of the Preferred Alternative.

The co-lead agencies met with the irrigation stakeholders, who expressed concerns that any measures that allowed reservoir levels to be lowered behind Ice Harbor Dam or McNary Dam will result in operation concerns and increased costs to irrigators. They were concerned about elevation changes, increased lift to stranding of some pump stations, and major sediment loads moving through the system resulting from potential dam breach.

Navigation interests and local stakeholders expressed concerns that include the potential for rail and truck rates to increase substantially if shallow draft barges no longer operate, reduce grain growers’ cost competitiveness, having adequate capacity for transportation by rail and road, and the high cost of adding capacity to these other transportation modes. Cruise line industries expressed concern about no longer being able to come to port and the loss of tourism.

The scope of this EIS focuses on the operation, maintenance, and configuration of the 14 Federal projects. The Preferred Alternative also includes measures to benefit ESA-listed juvenile adult salmon and steelhead and resident fish, as well as to improve conditions for Pacific lamprey within the CRS. As with salmon and steelhead, Pacific lamprey is a species that is important to many tribes.

The Preferred Alternative includes structural modifications to infrastructure at certain projects to benefit passage of adult salmon, steelhead, and Pacific lamprey (e.g., *Modify the Bonneville Ladder Serpentine Weir, Lamprey Passage Ladder Modifications*). Additionally, proposed operational changes in the upper basin would avoid adverse impacts to resident fish, including ESA-listed bull trout and Kootenai River white sturgeon. As discussed in Chapter 2 under the No Action Alternative, ongoing actions to benefit resident and anadromous fish would be continued into the future. The *Juvenile Fish Passage Spill Operations* measure in the Preferred Alternative builds off the range of spill analyzed in the alternatives, as well as the core principles, objectives, and model of successful regional collaboration underlying the *2019-2021 Spill Operation Agreement* and includes an updated approach to adaptively implement spill. Over time, the proposed spill operation would allow for more scientific certainty regarding latent mortality (as discussed in Chapter 3.5), and it would address uncertainty in outputs from fish models related to potential benefits of increased spill to ESA-listed salmon and steelhead in the lower Columbia and Snake Rivers.

Unless otherwise noted, all other actions that were planned or part of ongoing CRS operations and maintenance in 2016 when the EIS was initiated are included as part of the Preferred Alternative. For example, the co-lead agencies are proposing to include measures to benefit ESA-listed fish, and are planning to continue certain ongoing fish and wildlife mitigation actions for non-listed species in the Preferred Alternative (see Chapter 7.5). A more detailed discussion of the Preferred Alternative is presented later in this chapter.

7.2 ABILITY TO MEET THE PURPOSE AND NEED

As part of evaluating the effectiveness of the alternatives, the co-lead agencies used the Purpose and Need Statement to determine if the alternatives met the co-lead agencies' purposes. The co-lead agencies’ assessment of this included an evaluation of the ability of the U.S. Army Corps of Engineers (Corps) and U.S. Bureau of Reclamation (Reclamation) to operate and maintain the 14 CRS projects to meet all congressionally authorized purposes, and Bonneville’s congressionally mandated ability to market power from the projects. This assessment also evaluated the co-lead agencies’ ability to mitigate for the ongoing operations of the CRS, and to incorporate new information and adjust system operations to respond to changing environmental conditions.

The co-lead agencies’ assessment also addressed the need to respond to the Opinion and Order issued by the U.S. District Court for the District of Oregon[1] to evaluate how the system can be operated in compliance with Section 7(a)(2) of the ESA. The co-lead agencies are also responding to observations the Court made regarding the reasonable range of alternatives that could be considered, and comments received during public scoping, to consider breaching the four lower Snake River dams as part of a reasonable range of alternatives. The co-lead agencies considered the ability of each alternative to comply with all applicable Federal laws and regulations, as well as to uphold the unique trust relationship between federally recognized tribes and the United States, including upholding tribal rights that legally accrue to a tribe or tribes by virtue of inherent sovereign authority, unextinguished aboriginal title, treaty, statute, judicial decision, Executive Order, or agreement. Under this section of the ESA, the co-lead agencies are responsible for ensuring that their actions are not likely to jeopardize the continued existence of endangered or threatened species or result in the destruction or

[1] *National Wildlife Federation, et al. v. National Marine Fisheries Service (NMFS), et al.*, 184 F. Supp. 3d 861 (D Or. 2016).

adverse modification of designated critical habitat. While federal agencies must ensure their actions do not "…reduce appreciably the likelihood of both the survival and recovery of a listed species…"[2], the co-lead agencies are not, however, obliged under Section 7(a)(2) to contribute affirmatively toward recovery achievement. Recovery is an important, but distinct, public policy objective that is furthered through a separate planning process governed by ESA Section 4(f) to guide societal actions by both federal and non-federal actors.

The co-lead agencies determined that the No Action Alternative, MO1, MO2, and MO4 (described in Chapter 2), allow for the operation of the projects in furtherance of all of the congressionally authorized purposes to varying degrees (the rationale for these differences is described in Section 7.2 and 7.3). This includes flood risk management, navigation, irrigation, hydropower generation, fish and wildlife conservation, and recreation. See Part 1 in Table 7-1 for additional detail. Alternative MO3 would not meet the congressionally authorized purposes of operating and maintaining the four lower Snake River dams for navigation, hydropower, envisioned recreational benefits, and providing irrigation. New congressional authority through the passage of new laws and associated funding would be required to implement the dam breaching measures in MO3. However, the dam breaching measures in MO3 were carried forward in the analysis to align with the District Court's Opinion and Order, and in response to comments received during public scoping that requested this alternative be evaluated. Breaching of the four lower Snake River dams also received substantial interest by several tribes who believe that this alternative is the best option to offset some of the substantial adverse impacts of the CRS.

7.3 EVALUATION OF THE NO ACTION ALTERNATIVE AND MULTIPLE OBJECTIVE ALTERNATIVES

The co-lead agencies evaluated the alternatives to determine how effectively they meet the objectives as described in Chapter 2, including objectives related to several key tribal resources and treaty reserved rights—an important consideration for decision-makers. The specific objectives are as follows:

1) Improve ESA-listed anadromous salmonid juvenile fish rearing, passage, and survival within the CRS project area through actions including but not limited to project configuration, flow management, spill operations, and water quality management.
2) Improve ESA-listed anadromous salmonid adult fish migration within the CRS project area through actions including but not limited to project configuration, flow management, spill operations, and water quality management.
3) Improve ESA-listed resident fish survival and spawning success at CRS projects through actions including but not limited to project configuration, flow management, improving connectivity, project operations, and water quality management.

[2] 50 C.F.R. § 402.02.

4) Provide an adequate, efficient, economical, and reliable power supply that supports the integrated Columbia River Power System.
5) Minimize greenhouse gas emissions from power production in the Northwest by generating carbon-free power through a combination of hydropower and integration of other renewable energy sources.
6) Maximize operating flexibility by implementing updated, adaptable water management strategies to be responsive to changing conditions, including hydrology, climate, and the environment.
7) Meet existing contractual water supply obligations and provide for authorized additional regional water supply.
8) Improve conditions for lamprey within the CRS projects through actions potentially including but not limited to project configurations, flow management, spill operations, and water quality management.

The alternatives met the authorized purposes and objectives to varying degrees, as detailed in Part 2 of Table 7-1. The co-lead agencies developed a reasonable range of alternatives to be able to select a long-term operating strategy for the CRS. The effects analysis showed the impacts, benefits and tradeoffs to affected resources, which informed which measures would be identified in the Preferred Alternative. Some measures that provide the ability to meet one objective sometimes conflict with the ability to meet other objectives. For example, drafting reservoirs deeper in the upper Columbia River Basin storage projects to benefit downstream ESA-listed fish species results in adverse effects on upper basin resident fish species.

7.3.1 No Action Alternative

The No Action Alternative includes all operations, maintenance, fish and wildlife programs, and mitigation in effect when the EIS was initiated in September 2016. Juvenile fish passage spill operations at the four lower Columbia River and four lower Snake River dams would follow the 2016 Fish Operations Plan developed by the Corps. This plan used performance standard spill developed under previous ESA biological opinions. The co-lead agencies would also implement structural measures that were already budgeted and scheduled as of September 2016 that affected CRS operations. The majority of these structural measures are dam modifications to improve conditions for fish listed as threatened and endangered under the ESA. For example, installation of improved fish passage turbines planned for Ice Harbor and McNary Dams would occur. Other ongoing habitat and mitigation programs would continue, as was planned for at the time the EIS process started. A detailed description of measures included in the No Action Alternative is included in Section 2.4.2.

The No Action Alternative met the Purpose and Need of the EIS, but it did not meet all of the objectives developed for the EIS. The No Action Alternative generally satisfied the objective for hydropower generation as it resulted in no additional upward power rate pressure or potential regional reliability issues. However, it only partially met the objectives for water supply and adaptable water management because it does not provide the additional authorized regional water supply. Further, it does not include effects of the changes to CRS operations from important maintenance activities at Grand Coulee needed in the near term.

The No Action Alternative did not provide adequate improvements to meet the juvenile salmon, adult salmon, resident fish, and lamprey objectives. As outlined in this alternative, improvements to fish survival and abundance would be achieved through construction of additional fish passage structural measures at the lower Columbia River and lower Snake River projects. Additional measures could be adopted to improve fish survival to meet these objectives.

It is not expected that there would be any new moderate or major impacts to environmental, economic, or social effects as a result of continuing the No Action Alternative. The co-lead agencies used the analysis to develop a Preferred Alternative that balances managing the system for all authorized purposes while providing additional benefits to fish.

7.3.2 Multiple Objective Alternative 1

MO1 was developed with the goal to benefit or avoid adverse effects to congressionally authorized purposes while also benefiting ESA-listed fish species relative to the No Action Alternative. MO1 differs from the other alternatives by carrying out a juvenile fish passage spill operation referred to as a block spill design. The block spill design alternates between two operations: a base operation that releases surface flow, where juvenile fish are most present, over the spillways using different flows at each project based on historical survival tests; and a fixed higher spill target at all projects. For the block that uses the same target at all projects, the operators would release flow through the spillways up to a target of no more than 120 percent total dissolved gas (TDG) in the tailrace of projects and 115 percent TDG in the forebay of those projects. The intent of these two spill operations is to demonstrate the benefit of different spill levels to fish passage. In addition, MO1 sets the duration of juvenile fish passage spill to end based on a fish count trigger, rather than a predetermined date. MO1 proposes to initiate transport operations for juvenile fish approximately 2 weeks earlier than under the No Action Alternative.

MO1 also incorporated measures to increase hydropower generation flexibility in the lower basin projects and alters the use of stored water at Dworshak for downstream water temperature control in the summer. MO1 includes measures similar to the other action alternatives, which include increased water management flexibility and water supply, and using local forecasts in whole-basin planning. MO1 includes measures to disrupt predators of ESA-listed fish. A detailed description of the measures that are included in MO1 are described in Chapter 2.4.3 of the EIS.

Following the detailed evaluation in Chapter 3, 4, 5, and 6, MO1 would provide minor benefits to most ESA-listed anadromous salmonid fish species, both juvenile and adult. The expected degree of these benefits varied depending on specific species, location, and the outputs from two separate models (Fish Passage Center's Comparative Survival Study [CSS] and NMFS's Life Cycle Model [LCM]). The CSS model generally predicted minor improvements for the species modeled while the LCM generally predicted negligible decreases to minor improvements to anadromous species that were modeled. This alternative would also result in localized moderate adverse effects to ESA-listed resident fish species in the upper Columbia River basin. With regard to cultural resources, there would be additional major effects at Hungry Horse, Lake Roosevelt, and Dworshak reservoirs. There would also be the potential to impact the Kettle Falls sacred site if changes in reservoir elevations were to result in increased potential for looting. MO1 marginally meets the objective to provide an adequate, efficient, economical, and reliable power supply. In particular, the *Implement modified timing of Lower Snake Basin reservoir draft for additional cooler water* measure did not provide the intended water temperature benefits and largely contributed to lower power generation in the summer. In addition, this alternative would not meet the objective to minimize greenhouse gas emissions if reductions in hydropower generation were replaced by carbon-producing sources for power generation. MO1 met the objectives for implementing adaptable water management strategies, water supply, ESA-listed anadromous fish and resident fish. MO1 also includes structural modifications to infrastructure at the dams (e.g., *Modify the Bonneville Ladder Serpentine Weir, Lamprey Passage Ladder Modifications*) to benefit passage of adult salmon, steelhead, and Pacific lamprey that are expected to meet the objectives to benefit ESA-listed salmon and steelhead and Pacific lamprey. Overall, the expected degree of improvements to ESA-listed salmonids was less than was desired by the co-lead agencies.

Under MO1, there would likely be moderate adverse effects to water quality in the lower Snake River from the *Implement modified timing of Lower Snake Basin reservoir draft for additional cooler water* measure. There would also likely be moderate adverse effects to resident fish in the upper Columbia River basin due to changes in reservoir operations and elevations that would require mitigation. There would likely be no major or moderate economic effects, but there are major social effects, including adverse impacts to cultural resources at Hungry Horse, Lake Roosevelt and Dworshak reservoirs. The co-lead agencies used this analysis to inform the development of the Preferred Alternative that balances managing the system for all authorized purposes while providing additional benefits to fish.

7.3.3 Multiple Objective Alternative 2

MO2 was developed with the goal to increase hydropower production and reduce regional greenhouse gas emissions while avoiding or minimizing adverse impacts to other authorized project purposes. MO2 would slightly relax the No Action Alternative's restrictions on operating ranges and ramping rates to evaluate the potential to increase hydropower production efficiency, and increase operators' flexibility to respond to changes in power demand and changes in generation of other renewable resources. The measures within MO2 would increase the ability to meet power demand with hydropower production during the most valuable periods (e.g., winter, summer, and daily peak demands). The upper basin storage projects would be allowed to draft slightly deeper, allowing more hydropower generation in the winter and less during the spring. MO2 also differs from the other alternatives by excluding the water supply measures and evaluating an expanded juvenile fish transportation operation season. This alternative proposes to transport all collected ESA-listed juvenile fish for release downstream of the Bonneville project, by barge or truck, and reduce juvenile fish passage spill operations to a target of up to 110 percent TDG. Inclusion of the target up to 110 percent TDG spill operation provides the lowest end of the range of juvenile fish passage spill operations evaluated in this EIS.

Structural measures of MO2 are aimed at benefits for ESA-listed fish and lamprey. These measures are similar to other alternatives and include making improvements to adult fish ladders, upgrading spillway weirs, adding powerhouse surface passage, and turbine upgrades at John Day. A detailed description of measures that are included in MO2 are described in Chapter 2.4.4 of the EIS.

Following the detailed evaluation in Chapter 3, 4, 5, and 6, MO2 resulted in the greatest benefits to providing an adequate, efficient, economical and reliable power supply and to minimizing greenhouse gas emissions from power production. It was not as effective at meeting objectives for ESA-listed salmonids in certain instances. This varied depending on the specific species, location, and by the outputs from the two distinct models (CSS and LCM) used in this analysis. The CSS model generally predicted moderate to major adverse effects for the species modeled while the LCM generally predicted negligible to moderately adverse effects to anadromous species that were modeled. There were also major adverse effects predicted to upper Columbia River basin resident fish due to changes in reservoir operations and elevations that would require mitigation. There would also be additional major effects to cultural resources at Dworshak and Lake Roosevelt reservoirs. There would also be the potential for major effects to the sacred site, Kettle Falls, if changes in reservoir elevations result in increased looting.

MO2 also includes structural modifications to infrastructure at the dams (e.g., *Improved Fish Passage Turbines at John Day, Lamprey Passage Ladder Modifications*) to benefit passage of adult salmon, steelhead, and Pacific lamprey. MO2 did meet the existing contractual water supply obligations, but did not provide for authorized additional regional water supply.

There is the potential for minor beneficial to major adverse effects for anadromous fish that vary by species, location, and models. There would be major beneficial economic effects to hydropower if the *McNary Powerhouse Surface Passage* structural measure is excluded; no other major economic effects are expected. Additionally, there would be ongoing major social effects, including impacts to cultural resources and tribal interests at Lake Roosevelt and Dworshak. There would also be the potential for major effects to the sacred site, Kettle Falls, if changes in reservoir elevations result in increased looting. The co-lead agencies used this analysis to inform the development of the Preferred Alternative that balances managing the system for all authorized purposes while providing additional benefits to fish.

7.3.4 Multiple Objective Alternative 3

MO3 was developed to integrate actions for water management flexibility, hydropower generation at the remaining CRS projects, and water supply with measures that would breach the four lower Snake River dams (Lower Granite, Little Goose, Lower Monumental, and Ice

Harbor). In addition to breaching these four projects, MO3 differs from the other alternatives by carrying out a juvenile fish passage spill operation that sets flow through the spillways up to a target of no more than 120 percent TDG in the tailrace of the four lower Columbia River projects (McNary, John Day, The Dalles, and Bonneville). This alternative also proposes an earlier end to summer juvenile fish passage spill operations than the No Action Alternative. Instead, flows would transition to increased hydropower generation when low numbers of juvenile fish are anticipated.

Structural measures in this alternative include breaching the four lower Snake River dams by removing the earthen embankment at each dam location, resulting in a controlled drawdown.

A detailed description of measures that are included in MO3 is described in Chapter 2 of the EIS.

MO3 was developed with the goal to meet objectives to benefit ESA-listed fish while integrating actions for water management flexibility for flood risk management, provide hydropower generation flexibility at the remaining CRS projects, and additional water supply. This alternative would eliminate hydropower generation and navigation on the lower Snake River which affects the ability of this alternative to meet the Purpose and Need.

The measure to breach the four lower Snake River dams in MO3 (a main component of this alternative) has been the topic of a large amount of public discourse for decades. Many environmental organizations and some tribes have been strong proponents of breaching the dams. They assert breaching the dams will result in large improvements to certain salmonid populations, and this in turn would have beneficial impacts to the overall function of the Northwest ecosystem and for tribal ways of life. At the same time, many stakeholders within the navigation industry, and agricultural producers within the region that depend on the navigation industry to export grains to overseas markets, have expressed high concern with the potential regional socioeconomic impacts from breaching the dams. There would also be an adverse effect to irrigation and power from this MO.

As described in Chapter 3, model estimates for MO3 showed the highest predicted potential smolt-to-adult returns (SARs)for Snake River salmon and steelhead amongst the alternatives. The two models used to evaluate effects to certain salmon and steelhead (see section 3.5 for specific species) predict a wide range of improved SARs for this alternative, indicating higher uncertainty pertaining to the level of benefits compared to the other alternatives. For example, MO3 is predicted to result in improvements to SARs for Snake River Spring/Summer Chinook that range from 14 percent (LCM) to 140 percent (CSS) relative to the No Action Alternative. Additionally, under MO3 there is a slight increase predicted in upper Columbia spring Chinook salmon in-river survival due to increased spill levels in the lower Columbia River. The quantitative model results vary in the magnitude of their predictions due to how they factor in latent mortality and density dependence. Model predictions also vary by Evolutionarily Significant Unit (ESU). MO3 is also expected to provide a long-term benefit to species that spawn or rear in the mainstem Snake River habitats, such as fall Chinook. By breaching the four lower Snake River dams, there would be short-term adverse impacts to fish in the Snake River associated with initially breaching the dams and drawing down the reservoirs, but these effects are expected to diminish over time.

In the upper basin, there were also major and moderate adverse effects to resident fish due to changes in operations at Libby and Hungry Horse dams respectively that would require mitigation. MO3 also includes structural modifications to infrastructure at the lower Columbia River dams (e.g., *Improved Fish Passage Turbines at John Day, Lamprey Passage Ladder Modifications*) to benefit passage of adult salmon, steelhead, and Pacific lamprey that are expected to meet the objectives to benefit ESA-listed salmon and steelhead and Pacific lamprey.

MO3 would only partially meet the objective for an adequate, efficient, economical, and reliable power supply due to the loss of hydropower generation, system flexibility and peaking capabilities at the four lower Snake River projects. As discussed in more detail below, without adequate and timely resource replacement, including battery storage (at utility level scales), MO3 would not meet the objective for hydropower due to the loss of 1,100 average megawatts (aMW) of hydropower generation, more than 2,000 megawatts (MW) of sustained peaking capabilities during the winter, and a quarter of Bonneville's current reserves holding capability provided by the four lower Snake River projects. The detailed evaluation in Section 3.7.3.5 describes different portfolios that were designed to replace these capabilities.

The analysis of power impacts started with the question of what resources would be needed to maintain the current No Action Alternative Loss of Load Probability (LOLP) of 6.6 percent (also see Section 3.7.2.2).[3] Two potential resource replacement portfolios were developed for this approach. The first was the conventional-least cost portfolio, where the region would need to purchase or build 1,120 MW of combined cycle natural gas generation. The second was a zero-carbon portfolio.

Several states in the western United States have passed, or are likely to pass, legislation directed at decarbonizing the electric grid. California began implementing an economy-wide cap-and-trade program in 2013. In 2018, the California legislature passed a law seeking to achieve 100 percent carbon-free electricity by 2045 (Senate Bill 100). Washington enacted the Clean Energy Transformation Act (CETA) in 2019, requiring that Washington utilities eliminate coal costs from their retail rates by 2025. CETA also directs Washington retail utilities to serve loads with 100 percent carbon-neutral power by 2030, and 100 percent carbon-free power by 2045 (RCW 19.405). Oregon has been considering a cap-and-trade program similar to California's program. Additionally, Nevada (Senate Bill 358, 2019) and New Mexico (Senate Bill 489, 2019) both adopted 100 percent carbon-free goals for the electricity sector. The province of British Columbia has had a carbon tax in place since 2008.

[3] As discussed in Section 3.7.2.2, the LOLP is a measure of system reliability. The Northwest Power and Conservation Council targets an LOLP of 5.0 percent, and higher numbers represent less reliability and higher risk of power shortages and blackouts.

In light of this legislative and policy trend, the co-lead agencies assume that no new gas-fired generation would be built to replace the lost generation from the lower Snake River dams, only zero-carbon resources may be selected. At the utility-scale, the current best options are solar and wind resources, some batteries, and demand response programs. For MO3, the EIS analysis identified a potential zero-carbon replacement portfolio consisting of 2,550 MW of solar resources, , and 600 MW of demand response to restore LOLP. Tis portfolio relies on using the existing regional system to help make up for some of the lost capabilities of the lower Snake River projects - primarily by operating thermal plants more frequently to meet regional load. However, in light of regional policy initiatives to curtail or cease the operation of thermal plants, a zero-carbon resource replacement portfolio with insufficient dispatchable sustained capacity may not be feasible. If the replacement does not include firm generating capacity with only 600 MW of dispatchable capability, it is likely not a realistic assumption for MO3 where a substantial amount of generation capacity is lost.

In order to partially reflect the permanent loss of sustained dispatchable hydropower peaking capacity, reserve capability and flexibility at the lower Snake River projects an additional 1,275 MW of battery storage was added to the zero-carbon portfolio for the base case analysis. While this portfolio with batteries continues to rely on regional thermal resources to make up for lost energy, capacity and reserves, it lessens that reliance. This portfolio is captured in the Base Case section of the rate analysis described in in Section 3.7.3.5.

The zero-carbon replacement portfolio for MO3 discussed above does not replace the full capability of the hydropower that would be lost in MO3. To estimate what would be needed to replace the lower Snake River projects' full operational capabilities, including integrating replacement resources, another zero-carbon replacement portfolio was developed, called the Lower Snake River Replacement portfolio. In this portfolio, 3,306 MW of wind, 1,144 MW of solar and 2,515 MW of batteries were considered. This portfolio assumes that the larger quantity of batteries would come closer to replacing the reserve capability of the lower Snake River projects than the portfolios described above. More analysis would need to be done to test if the Lower Snake River Replacement portfolio is capable of a full replacement of the lost generation (i.e., heavy load hour and light load hour energy, ramping capacity and ability to provide operating reserves at similar levels currently provided by the lower Snake River projects). To provide a sense of scale for this portfolio, currently, the largest lithium ion battery system in the world is 100 MW in South Australia, so battery storage of the proposed scale in the replacement portfolio has not been developed and tested. While grid scale battery storage technology is undoubtedly improving, existing studies focus on storage in the hundreds of MW, not the thousands that would be required under the full replacement portfolio. Siting wind and solar projects along with the routing of new transmission power lines required to bring the renewable energy to load would also need to undergo environmental review and permitting. This would need to be completed prior to absorbing the loss of hydropower generation identified in MO3, if the LOLP is to remain within a reasonable range. This portfolio is captured in the Rate Sensitivity section of the rate analysis.

Other resource possibilities that were contemplated included pumped storage and small modular nuclear reactors. More details on these resources can be found in Section 3.7.3.5. As also discussed in Chapter 3, if Bonneville were to pursue a major resource acquisition under current law, then Bonneville would need to conduct a formal Section 6(c) process under the Northwest Power Act in which further analysis and public involvement would need to occur. These processes would consider a full range of resource options and prioritization in accordance with the Northwest Power Act.

MO3 would meet the objective for water supply, but there are adverse impacts to irrigation in the lower Snake River.

MO3 does not meet the objective to minimize greenhouse gas emissions because of the loss of hydropower and the loss of navigation on the Snake River. The power analysis considered a range of scenarios for replacing the hydropower to maintain system reliability. Greenhouse gas emissions increase the most if the hydropower is replaced with natural gas (an 8.9 percent or 3.3 MMT of CO2 increase in power-related emissions across the Pacific Northwest). However, even assuming that new replacement resources are renewable (i.e., solar and additional storage), some increase in fossil fuel based generation would occur in order to maintain system reliability. This zero-carbon replacement scenario therefore increases power-related emissions by 2.7 percent or 1.0 MMT of CO2 across the region. In addition, MO3 results in a shift of shipping activities from barge to road and rail transport. As barge transportation is a relatively low source of emissions per ton-mile of freight, MO3 would also increase transportation-related emissions for wheat that is currently transported along the lower Snake River by up to 53 percent (0.056 MMT of CO2).

Additionally, Snake River barge navigation would be eliminated. The lower Snake River shallow draft navigation channel would no longer be available and commercial navigation would be eliminated. As a result, the cost to transport goods to market would increase (the cost to transport wheat to market is estimated to increase by $0.07-$0.24/bushel. Farmers would experience increased production costs associated with higher transportation costs (i.e., fertilizer, crops). There would be additional demands on existing road and rail infrastructure as well as at barging facilities near the Tri-Cities area in Washington. Additional capacity and infrastructure improvements would likely be required. Some port facilities within Lake Wallula would require additional dredging to maintain access to the navigation channel. Commercial cruise lines that operate on the lower Columbia and lower Snake River would be adversely affected from reduced numbers and distance of trips, with adverse effects to tourism revenues and associated jobs and income. These communities, such as Clarkston, Lewiston and Asotin, would lose their 'river port' community identity. There would be potential for increased accident rates with increased truck traffic. Section 3.10 discusses navigation in more detail.

Based on the analyses in Chapters 3, 4, 5, and 6, there would likely be major adverse short-term effects to environmental resources along the lower Snake River due to the impacts associated with the initial breaching of the dams and drawing down the existing reservoirs, but there would be major long-term beneficial effects to vegetation, wildlife, wetlands, floodplains, fish, in the lower Snake River. Overall, long-term water quality would improve in the lower Snake River under MO3, with improved water temperatures during the fall and increased nighttime cooling in the summer. In addition, riverine processes would be restored, eliminating some of the pH, and harmful algal bloom problems that currently exist. Elevated TDG would also be eliminated. Additionally, there would be major increases in Snake River fall Chinook spawning habitat and associated potential beneficial effects for recreational, tribal, and commercial fishing.

There are expected to be major adverse impacts at Libby reservoir and moderate adverse impacts at Hungry Horse reservoir for resident fish from reservoir operation changes, which would be mitigated.

In terms of economic effects, there would also be major long-term adverse effects to lower Snake River barge navigation and reservoir-based recreation in the lower Snake River, including impacts to recreation facilities. There could also be a major adverse social effect to the port communities along the lower Snake River (e.g., economics, potential shift in employment, etc.). Transitional effects from the loss of Snake River barging would decrease over time as the transportation industry expanded to one that would be entirely dependent on trucks and rail to move goods. There would be major adverse effects to reservoir-based recreation because these reservoirs, and boat ramp access, would cease to exist, but there would likely be major long-term beneficial effects to river-based recreation. Other major long-term impacts to community identity from loss of lower Snake River ports (e.g., Clarkston, Lewiston, Asotin) could also occur. Long-term beneficial effects to recreational, tribal and commercial fishing may be realized.

In the lower Snake River, MO3 would result in the potential for additional major adverse effects to cultural resources due to potential exposure of 14,000 acres that are currently inundated. The exposure of Traditional Cultural Properties, however, could allow for some traditional uses that have not been possible since the dams were built. There is also the potential for additional major adverse effects to cultural resources at Hungry Horse Reservoir from changes to reservoir elevations and operations.

The co-lead agencies used the MO3 analysis to inform the development of the Preferred Alternative that balances managing the system while meeting the purpose and need and project objectives, and minimizes adverse effects. Based on the overall major and moderate long term adverse effects to environmental, social, and economic resources in the region, and the inability to mitigate the scale of these effects, this alternative was not identified as the Preferred Alternative.

7.3.5 Multiple Objective Alternative 4

MO4 was developed to examine an additional combination of measures to benefit ESA-listed fish, integrated with measures for water management flexibility, hydropower production in certain areas of the basin, and additional water supply. This alternative includes the highest fish passage spill level considered in this EIS, dry-year augmentation of spring flow with water stored in upper basin reservoirs, and annually drawing down the lower Snake River and Columbia River reservoirs to their minimum operating pools. This alternative also includes spillway weir notch inserts, changes to the juvenile fish transportation operations, and increased powerhouse surface passage for kelt and overshoots. In MO4, the juvenile fish transport program would operate only in the spring and fall, while juvenile fish passage spill is set to no more than 125 percent TDG during the spring and summer spill season. The alternative also contains a measure for restricting winter flows from the Libby project to protect newly established downstream riparian vegetation to improve conditions for ESA-listed resident fish, bull trout, and Kootenai River White Sturgeon in the upper Columbia River Basin.

The structural measures in this alternative are primarily focused on improving passage conditions for ESA-listed salmonids and Pacific lamprey. The inclusion of spillway weir notch inserts is the only structural measure unique from the other action alternatives. A detailed description of measures that are included in MO4 is described in Chapter 2.4.6 of the EIS.

Following a detailed evaluation of this alternative in Chapter 3, 4, 5 and 6, it was determined that MO4 does not meet the objective for hydropower generation because the impacts to cost and reliability would not allow Bonneville to provide an adequate, efficient, economical, and reliable power supply. It is expected that there would be an approximate one in three probability of blackouts in a given year. It would not meet the objective to minimize greenhouse gas emissions if reductions in hydropower generation were replaced by carbon-producing sources for power generation or if zero-carbon resources were built to restore reliability because the existing thermal resources (gas and potentially coal) would be operated more often to meet demand for power.

This alternative would meet the objectives for implementing adaptable water management strategies and water supply; however, it would have moderate effects to irrigation in the John Day reservoir from impacts due to the *McNary Flow Target*.

This alternative could meet the objectives related to ESA-listed anadromous salmonids providing major beneficial impacts, but could also have potential adverse effects to some stocks depending largely on the degree to which higher spill reduces latent mortality. This high range of potential results from MO4 is evident in the differing estimates of SARs produced by the two models. The CSS model predicts major increases in Snake River Spring Chinook salmon and steelhead returns, to both the Columbia and Snake Rivers. For example, the CSS model estimates an increase of 75 percent in the SARs for Snake River Spring/Summer Chinook. These predictions are primarily driven by increased spill levels that would increase the number of fish passing via the spillways and avoiding powerhouses, which the CSS model predict would reduce latent mortality associated with CRS passage. In contrast, the NMFS LCM predicts minor increases in benefits to Upper Columbia spring Chinook and steelhead, but potential detrimental effects for Snake River stocks. For example, the LCM estimates a 12 percent reduction in SARs for Snake River Spring/Summer Chinook relative to the No Action Alternative. This potential decrease in overall adult returns is driven by reductions in transportation rates due to high spill, a relationship that could be similar for Snake River steelhead. However, the NMFS LCM estimates that if changes in passage through the CRS can increase ocean survival by at least 10 percent (i.e., latent mortality effects are decreased by 10 percent), the net impact to

Snake River Chinook salmon could switch from adverse to beneficial. The objective for resident fish would not be met in the upper basin due to the deep drafts to the upper basin storage projects. MO4 also includes structural modifications to infrastructure at the dams (e.g., *Improved Fish Passage Turbines at John Day, Lamprey Passage Ladder Modifications*) to benefit passage of adult salmon, steelhead, and Pacific lamprey.

This alternative would potentially have moderate to major adverse environmental effects, depending on the affected resources. For ESA-listed salmonids, there are potential benefits ranging from major beneficial to moderate adverse effects. Results varied depending on the specific species, location, and by the outputs from the two separate models (CSS and LCM). It would result in major adverse effects to vegetation, wildlife, wetlands, floodplains, and resident fish in the upper basin that would require mitigation.

Overall, there would also be major adverse economic effects under MO4. For irrigation on the lower Columbia, the reservoirs levels may be lowered to the point where pumping could no longer be possible. Additionally, in low water years, major adverse effects to water-based recreational access at Lake Pend Oreille could occur.

Finally, there could be major social effects, including impacts to cultural resources at Lake Roosevelt, John Day, and Hungry Horse reservoirs due to impacts from the *McNary Flow Target* measure. There would be additional moderate effects to cultural resources at the remaining lower Columbia River projects due to additional drawdown. There is the potential for major effects to Kettle Falls (sacred site) if changes in reservoir elevations lead to increased looting. Changes in reservoir elevation at Albeni Falls may result in reduced access to Bear Paw Rock (sacred site), which may result in less tribal visitation. As with the other alternatives, the co-lead agencies used this analysis to inform and improve the Preferred Alternative that balances managing the system for all authorized purposes while providing additional benefits to fish.

7.4 SUMMARY

The alternatives met the authorized purposes and objectives to varying degrees and with varying levels of beneficial and adverse effects. Because of this, the co-lead agencies used the information from the evaluation of the alternatives in Chapters 3, 4, 5, and 6 to develop the Preferred Alternative that better met the Purpose and Need and objectives while avoiding, reducing, or minimizing adverse effects to environmental, economic, and social resources. To do this, measures included in the Preferred Alternative were combined and modified from the existing alternatives described in Chapter 2. In addition, the co-lead agencies modified the juvenile fish passage spill operation for the Preferred Alternative using the analysis from the range of spill levels evaluated in the No Action Alternative and MOs. The Preferred Alternative was also informed by actual operations in 2019 and considers the adaptive implementation framework that uses the planned 2020 spill operation, as described in the December 2018 "2019-2021 Spill Operation Agreement," as a starting point for implementation. Details of the development and evaluation of the Preferred Alternative are included in the remaining sections of this chapter.

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Table 7-1. Evaluation of alternatives. Part 1 indicates whether each alternative met the Purpose and Need of the EIS. Part 2 indicates whether each alternative met the objectives of the EIS. Part 3 summarizes major and moderate effects for each of the alternatives.

Evaluation Criteria	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Part 1: Purpose and Need						
Can the System Be Operated for the Following Authorized Purposes of the Projects?	–	–	–	–	–	–
Flood Risk Management	Yes	Yes	Yes	Yes	Yes	Yes
Navigation	Yes	Yes	Yes	Partially. This alternative eliminates navigation in the lower Snake River.	Yes	Yes
Hydropower	Yes	Yes	Yes	Partially. This eliminates hydropower generation on the lower Snake River.	Partially, due to increased costs and reliability impacts.	Yes
Irrigation	Yes	Yes	Yes	Partially. Dam breaching has major adverse effects on irrigation in the lower Snake River region.	Partially. Has major effects to irrigation in the John Day Resevoir.	Yes
Fish and Wildlife Conservation	Yes	Yes	Yes	Yes	Yes	Yes
Recreation	Yes	Yes	Yes	Yes	Yes	Yes
Does the Alternative Comply with Legal and Institutional Purposes?	Yes	Yes	Yes	No. Due to the impacts to the integrated Columbia River Power System.	Yes[1/]	Yes
Part 2: Study Objectives						
Improve ESA-Listed Anadromous Salmonid Juvenile Fish Rearing, Passage, And Survival	No change from 2016 actions	Yes. Minor benefits to in-river survival and PITPH that vary by species, location, and model. PITPH is decreased with potential benefits ranging from minor to moderate compared to No Action Alternative. Minor to moderate increased TDG exposure	Mixed negligible to major adverse effects vary by species, location, and model. Decreased in-river survival, increased PITPH, increased proportion of transport and associated effects compared to the No Action Alternative. Decreased exposure to TDG.	Yes. In the long term, beneficial effects for all stocks, short term adverse impacts to Snake River stocks, Effects vary by species, location, and model. In-river survival generally moderately higher than No Action Alternative. PITPH shows a major decrease compared to No Action Alternative. Similar TDG exposure with minor effects for upper Columbia species and Snake River species. Major increase in Snake River fall Chinook spawning habitat.	Mixed major beneficial to moderate adverse effects vary by species, location, and model. Increased in-river survival, major decrease in PITPH, decreased proportion of transport and associated effects compared to the No Action Alternative. Increased exposure to TDG	Yes. Minor benefit to in-river survival. PITPH is decreased with potential benefits ranging from minor to moderate compared to No Action Alternative. Moderate increase in TDG exposure.
Improve ESA-Listed Anadromous Salmonid Adult Fish Migration	No change	Yes. SARs vary depending on model used, but generally show minor increases compared to the No Action Alternative.	Mixed beneficial and adverse effects based on model. SARs vary depending on model used, showing minor increases to moderate decreases compared to the No Action Alternative.	Yes. Long-term benefits in lower Snake and Columbia Rivers, but short-term adverse effects for Snake River stocks. SARs vary depending on model used, showing minor to major increases compared to the No Action Alternative.	Yes. SARs vary widely depending on model used, showing moderate decreases to major increases compared to the No Action Alternative. Increased exposure to TDG and increased fallback and passage delay.	Yes. Estimated SARs expected to vary depending on model used, likely showing minor increases to major increases compared to the No Action Alternative. TDG exposure is expected to increase.

Evaluation Criteria	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Improve ESA-Listed Resident Fish Survival and Spawning Success	No change	Yes. Similar to No Action Alternative in most regions. Localized moderate adverse effects in upper Columbia River basin compared to No Action Alternative.	No. Major adverse effects to upper Columbia River basin ESA-listed resident fish compared to No Action Alternative.	Mixed effects. Upper basin and lower Columbia River similar to No Action Alternative with the exception of adverse impacts at Libby (major) and Hungry Horse (moderate). In the lower Snake River, long-term benefits, but short-term adverse effects compared to No Action Alternative.	No. In upper Columbia basin there are major adverse effects to ESA-listed resident fish and critical habitat compared to No Action Alternative. In lower basin, minor adverse effects from higher TDG spill and exposure duration compared to the No Action Alternative.	Yes. It is expected to be similar to No Action Alternative in most regions. Localized minor beneficial effects in upper Columbia basin, minor adverse effects in Lake Roosevelt, as well as minor mixed effects in the Lower basins compared to No Action Alternative.
Improve Conditions for Lamprey Within the Project Area	No change	Yes	Yes	Yes	Yes	Yes
Maximize Operating Flexibility by Implementing Updated Adaptable Water Management Strategies	No change	Yes	Yes	Yes. There is no adaptable water management on the lower Snake River.	Yes	Yes
Meet Existing Contractual Water Supply Obligations and Provide for Authorized Additional Water Supply	Partially. Does not provide authorized additional water supply.	Yes	Partially. Does not provide authorized additional water supply.	Yes[2/]	Yes[2/]	Yes
Provide an Adequate, Efficient, Economical, And Reliable Power Supply That Supports the Integrated Columbia River Power System	No change	No. Due to upward rate pressure and nearly twice the risk to regional reliability relative to the No Action Alternative.	Yes. Increases hydropower production and allows for flexibility for wind and solar integration relative to the No Action Alternative.	No. Due to loss of hydropower generation on Lower Snake Projects, which adversely affects the adequacy, economics and reliability of the system, and leads to significant upward pressure on power rates relative to the No Action Alternative.	No. Due to loss of hydropower generation in spring and summer on the Lower Columbia and Lower Snake River Projects. There would be a one in three probability of blackouts in a given year. Adversely affects the adequacy, economics and reliability of the system, and leads to high upward pressure on power rates relative to the No Action Alternative.	Yes. Power reliability is met and upward rate pressure is expected to be minor relative to the No Action Alternative.
Minimize Greenhouse Gas Emissions from Power Production in The Northwest By Generating Carbon Free Power Through A Combination Of Hydropower And Integration Of Other Renewables	No change	No. Hydropower generation would decrease resulting in increased generation from existing gas and coal plants resulting in increased GHG.	Yes. Increases hydropower production thereby decreasing natural gas and coal power production and allows flexibility for integration of wind and solar.	No. Breaching the lower Snake River dams would require replacement of lost power generation and flexible capacity. Lost power generation could be replaced by gas or renewable sources. Loss of navigation would result in an increase in truck and/or train transport.	No. The forgone hydropower generation could be replaced by gas or large amounts of renewable sources combined with large amounts of storage capacity. Even if only renewable sources were used as replacements, greenhouse gas emissions would still increase because existing coal and gas fired generation could increase leading to elevated emissions.	No. Hydropower generation would decrease resulting in increased generation from existing gas and coal plants resulting in increased greenhouse gas emissions.

Evaluation Criteria	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Part 3: Summary of Major Effects						
Environmental	No change	No major adverse effects to wetlands, floodplains, water quality, vegetation, wildlife, air quality and fish. There are localized moderate adverse effects to water quality in the lower Snake River and fish in the upper Columbia River basin, which would be mitigated to reduce the effects.	No major adverse effects to wetlands, floodplains, water quality, vegetation, wildlife, and air quality. Minor beneficial effects to major adverse effects for anadromous fish that vary by species, location, and models. Major adverse effects to upper Columbia River basin resident fish compared to No Action Alternative. Effects to fish would be mitigated to reduce effects.	Major short-term adverse effects to wetlands, floodplains, water quality, fish, wildlife and vegetation due to breaching of lower Snake River dams. Major long-term beneficial effects to wetlands, floodplains, fish, wildlife, and vegetation in the lower Snake River. For water quality, there would be warmer water temperatures in the summer (during the day) that may exceed water quality standards, but spring and fall water temperature improvements are anticipated. Major increase in Snake River fall Chinook spawning habitat. Mixed effects to upper basin and lower Columbia River fish similar to No Action Alternative with the exception of adverse impacts at Libby (major) and Hungry Horse (moderate), which will be mitigated. Long-term adverse effects from increased regional greenhouse gas emissions if lost power generation is replaced by gas or renewable sources.	Major adverse effects in the upper basin to wetlands, floodplains, vegetation, wildlife, and resident fish, which would be mitigated to reduce effects. Mixed major beneficial to moderate adverse effects vary by species, location, and models for anadromous fish, which would be mitigated to reduce effects. Long-term adverse effects from increased regional greenhouse gas emissions if lost power generation is replaced by gas or renewable sources.	No major adverse effects to wetlands, floodplains, water quality, vegetation, wildlife, and air quality. For waterfowl in the Columbia River estuary, there would be a moderate beneficial effect to reproductive success associated with improved abundance and condition of juvenile salmon and steelhead. For water quality, there would be moderate increases in TDG associated with juvenile fish passage spill up to 125% TDG. For anadromous salmon and steelhead in Regions C and D, effects may range from moderate adverse (if adult returns are reduced) to major beneficial (if adult returns increase). For resident fish, there would be moderate beneficial effects to the food web in Lake Koocanusa (increased macroinvertebrates) and minor to moderate adverse effects in Lake Roosevelt from potential dewatering of kokanee, burbot, and redband trout eggs.
Economic	No change	No major effects to economics.	Major beneficial impact to hydropower when McNary powerhouse surface passage structural measure is excluded. No other major effects to economics are expected.	Major long-term adverse effects to hydropower, irrigation, lower Snake River barge navigation and reservoir-based recreation in the lower Snake River. Impact to recreation facilities would be partially mitigated. Major long-term effect to community identify from loss of lower Snake River ports (e.g., Clarkston, Lewiston, Asotin). Potential for major beneficial effects to river-based recreation, and beneficial effects to recreational, tribal and commercial fishing.	Major adverse effects to hydropower generation and localized moderate adverse effects to irrigation operations in the lower Columbia River. Potential beneficial effects to recreational, tribal and commercial fishing. Under low water years major adverse effects to water based recreational access at Lake Pend Oreille. These impacts would be partially mitigated.	Major beneficial to moderate adverse effects to recreational, tribal and commercial fishing in Regions C and D dependent upon increase or decrease in adult returns of salmon and steelhead. No other major economic effects are expected.

Evaluation Criteria	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Social	No change	Ongoing major effects to cultural resources and tribal interests. Additional major effects to cultural resources at Hungry Horse, Lake Roosevelt and Dworshak reservoirs. There is the potential for major effects to the sacred site, Kettle Falls, if changes in reservoir elevations result in increased looting. Major effects to Inchelium-Gifford Ferry at Lake Roosevelt which would be mitigated. No major effects to Environmental Justice populations are anticipated.	Ongoing major effects to cultural resources and tribal interests. Additional major effects to cultural resources at Dworshak and Lake Roosevelt. There is the potential for major effects to the sacred site, Kettle Falls, if changes in reservoir elevations result in increased looting. Major adverse effects to important tribal resources, specifically resident and anadromous fish. Major effects to Inchelium-Gifford Ferry at Lake Roosevelt which would be mitigated. No major effects to Environmental Justice populations are anticipated.	Ongoing major effects to cultural resources and tribal interests. Potential for additional major adverse effects to cultural resources compared to No Action Alternative in the lower Snake River due to potential exposure of 14,000 acres currently inundated. The exposure of the TCPs would allow for some traditional uses that have not been possible since the dams were built. There is also the potential for additional major adverse effects to cultural resources at Hungry Horse Reservoir. Major effects to Inchelium-Gifford Ferry at Lake Roosevelt which would be mitigated. No major effects to Environmental Justice populations are anticipated.	Ongoing major effects to cultural resources and tribal interests. Additional major effects to cultural resources at Lake Roosevelt, John Day, and Hungry Horse. Additional moderate effects at the remaining Lower Columbia River projects due to additional drawdown. There is the potential for major effects to Kettle Falls (sacred sites) if changes in reservoir elevations cause increased looting. Changes in reservoir elevation at Albeni Falls may result in a decrease of access to Bear Paw Rock, which may result in less tribal visitation or access to the site. Major adverse effects to numerous tribal interests and resources in upper basin. Major effects to Inchelium-Gifford Ferry at Lake Roosevelt which would be mitigated. No major effects to Environmental Justice populations are anticipated.	Ongoing major effects to cultural resources and tribal interests. Additional minor to moderate effects to the built environment at Grand Coulee from potential increased erosion. Major beneficial effects to archaeological resources at Libby due to reduced frequency of high draft rate events. No major effects to Environmental Justice populations are anticipated.

1/ The Washington Water Quality Standard for TDG is pending approval by EPA.
2/ The objective does not include irrigation and municipal and industrial that was impacted under MO3 and MO4 in Regions C and D as opposed to new or existing contractual water supply.

7.5 DEVELOPMENT OF THE PREFERRED ALTERNATIVE

Based on the information above, insights that resulted from the evaluation of the alternatives in Chapters 3, 4, 5, and 6, and information presented in Sections 7.1 through 7.2, the co-lead agencies developed the Preferred Alternative. The co-lead agencies worked together, with input from cooperating agencies, to identify a suite of measures to form an alternative that allowed for the agencies to continue to operate the system in accordance with congressionally authorized purposes, while best meeting the objectives of the EIS in a balanced manner. Following the evaluation of the No Action and MO alternatives, the co-lead agencies selected a combination of measures for the Preferred Alternative based on how well the measures met the Purpose and Need and study objectives, with consideration of environmental, economic, and social effects. Development of the Preferred Alternative allowed the co-lead agencies to refine several measures based on information learned during the modeling and evaluation process of the alternatives detailed in Chapter 3. In addition, new information on juvenile fish passage from the 2018 and 2019 operations for spring juvenile fish spill that benefit downstream migration of juvenile anadromous fish became available after the alternatives were developed. Using this information, the co-lead agencies modified the juvenile fish spill operation for the Preferred Alternative using the analysis from the range of spill levels evaluated in the MOs to attempt to provide a high potential benefit to salmon and steelhead through increased spill while avoiding many of the adverse impacts to power generation and reliability associated with MO4. The primary method to accomplish this was a flexible spill operation that spills more for fish passage when power is less valuable and spills less when power is more valuable. The Preferred Alternative also acknowledges the range of potential outcomes predicted by the models used to estimate impacts to anadromous fish, including a study to evaluate the potential benefits and unintended consequences of a flexible spill operation.

All actions included in the Preferred Alternative are either: 1) carried forward from the No Action Alternative; 2) original measures or refined measures that were evaluated in MO1 to MO4; 3) added measures for lamprey passage (e.g., Closeable Floating Orifice Gates); or 4) measures identified as part of the associated CRS ESA consultation processes. This led to a Preferred Alternative that is a balanced approach that enables the co-lead agencies to meet the multiple congressionally authorized purposes of the system and requirements for fish and wildlife, including ESA-listed species. Following the initial development of the Preferred Alternative, it was shared with NMFS, USFWS, tribes, and cooperating agencies to solicit feedback.

7.6 DESCRIPTION OF THE PREFERRED ALTERNATIVE

The Preferred Alternative includes a description of measures that would be implemented, in addition to components of the No Action Alternative, to operate the CRS to better meet the Purpose and Need and objectives developed for the EIS. Operations, maintenance and programs that were ongoing or planned as of 2016 are carried forward into the Preferred

Alternative unless described otherwise. Ongoing operations and maintenance measures are described in more detail in Chapter 2.4.2.1.

As discussed in Chapter 2, the CRS is operated for a number of purposes: to reduce flood risk, generate hydropower, provide water for irrigation and water supply, to provide navigation, provide recreation, and to conserve fish and wildlife. These operations would continue unless modified by the Preferred Alternative below or under emergency operations described in Chapter 2. An operational emergency may be related to hydropower generation, transmission loss or interruption, fish emergencies related to equipment failure or other interruption of fish protection measures, and other unexpected circumstances such as fires, human health and safety concerns, or threats to dam infrastructure.

Consistent with Chapter 2, there are also research studies that may require special operations that differ from the routine operations otherwise described in the current Fish Passage Plan. Variations in normal operations for research actions are coordinated with the Technical Management Team (TMT). Additionally, the co-lead agencies conduct monitoring activities. For example, under the Preferred Alternative, Bonneville is funding USFWS to conduct monitoring and surveys of plant and waterbird communities, including aquatic invasive species, and public outreach efforts during the implementation of the *Predator Disruption Operations* measure. This effort would evaluate whether there are impacts to critical plant and waterbird communities and habitat along the reservoir and Umatilla National Wildlife Refuge.

Moreover, the Corps, Reclamation and Bonneville will continue to implement a maintenance program at each CRS project, consisting of routine inspection and maintenance of both power and non-power assets. The co-lead agencies conduct annual routine maintenance at all projects. Preventive and corrective maintenance coordinated and planned to occur at regular intervals is referred to as scheduled, or routine, maintenance. This type of routine maintenance would continue to be performed on all fish facilities, spillway components, navigation locks, generating units, and supporting systems to ensure project safety and reliability and to comply with North American Electric Reliability Corporation (NERC)/Western Electricity Coordinating Council (WECC) regulatory requirements (16 U.S.C. 824o[c]). Unplanned maintenance would also continue under the Preferred Alternative. It is unscheduled and may occur any time a problem, unforeseen maintenance issue, or emergency requires a project feature (e.g., a generating unit), be taken offline in order to resolve the problem.

Additionally, ongoing actions are being carried forward from the No Action Alternative in

Chapter 2, which includes measures committed to in the past to benefit ESA-listed fish species. These include actions under Bonneville's Fish and Wildlife (F&W) Program, Corps' Columbia River Fish Mitigation Program and Reclamation's Tributary Habitat Program.

The Preferred Alternative includes actions to benefit ESA-listed fish, and these actions also benefit tribal interests and treaty resources. These actions include measures such as management of invasive species, improvements to fish and wildlife habitat, fish hatchery production, and management of avian and pinniped predators of ESA-listed salmonids. Most of the structural measures and some of the operational measures are intended to improve survival of anadromous salmon and steelhead, lamprey and resident fish. These fish are important to tribes and the exercise of treaty-reserved rights, and traditional cultural practices including fishing, hunting, and gathering. In some locations, the Corps and Reclamation also operate the dams to support tribal interests, primarily to benefit fish and wildlife and tribal fishing. Operations that support specific tribal interests are described in Chapter 2.4.2.1.

The rest of this section provides additional detail on the structural, operational, and mitigation measures included in the Preferred Alternative. They have been grouped into the following categories:

1) Structural and operational measures carried forward, modified, or added to the Preferred Alternative from those described in the MOs in Chapter 2;
2) Mitigation measures to avoid, minimize, or offset adverse effects from the current suite of measures being proposed; and
3) Other measures to comply with Section 7(a)(2) of the ESA.

7.6.1 Measures Carried Forward, Modified, or Added from Alternatives in Chapter 2

This section describes a complete list of structural and operational measures that are being carried forward, modified, or added to the Preferred Alternative from those described as part of the MO alternatives in Chapter 2. These measures are listed in Table 7-2.

Table 7-2. List of Measures that were Carried Forward, Modified, or Added to the Preferred Alternative from Alternatives in Chapter 2

Description
Structural Measures
Hungry Horse Project Power Plant Modernization[1/]
Third Powerplant Overhaul Project
John W. Keys III Pump-Generating Plant Modernization Project
Grand Coulee G1 through G18 Plant Modernization Project
Lower Granite Trap Modifications
Lower Granite Juvenile Facility Bypass Improvements[1/]
Lower Granite Spillway Passive Integrated Transponder (PIT) Monitoring System[1/]
Little Goose Adjustable Spillway Weir Closure[1/]
Little Goose Adult Ladder Temperature Improvements[1/]
Little Goose Boat Barrier[1/]
Little Goose Trash Shear Boom Repair[1/]
Ice Harbor Turbines 1–3 Replacement and Generator Rewind[1/]
McNary Turbine Replacement[1/]
John Day Adult Passive Integrated Transponder Tag (PIT) Monitoring System[1/]
John Day Improved Fish Passage Turbines

Description
Bonneville Gatewell Orifice Modifications[1/]
Bonneville Ladder Serpentine Weir Modifications
Closeable Floating Orifice Gates for Lamprey
Bypass Screen Modifications for Lamprey
Lamprey Passage Ladder Modifications
Turbine Strainer Lamprey Exclusion
Fewer Fish Screens
Operational Measures
Sliding Scale at Libby and Hungry Horse
Modified Draft at Libby
Planned Draft Rate at Grand Coulee
Grand Coulee Maintenance Operations
Update System FRM Calculation at Grand Coulee
Lake Roosevelt Incremental Storage Release Project
Lake Roosevelt Additional Water Supply
Fall Operational Flexibility for Hydropower (Grand Coulee)
Slightly Deeper Draft for Hydropower (Dworshak)
Juvenile Fish Passage Spill Operations
Contingency Reserves within Juvenile Fish Passage Spill
Above 1% Turbine Operations
Increased Forebay Range Flexibility
Early Start Transport
Zero Generation Operations
Predator Disruption Operations
John Day Full Pool

1/ Carried forward from No Action Alternative.

7.6.2 Preferred Alternative Structural Measures

The following structural measures are included in the Preferred Alternative.

7.6.2.1 Hungry Horse Project Power Plant Modernization

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. The power plant at Hungry Horse Project began an extensive modernization effort in Fiscal Year (FY) 2018 to bring the facilities to current industry standards. It will include the full overhaul or replacement of governors, exciters, fixed-wheel gates, and turbines; a generator rewind; overhaul of the selective withdrawal system; and recoating the penstocks. This power plant overhaul will occur over 1 year and will limit the powerplant availability to two units during the overhaul period. In addition, cranes that service the power plant will be refurbished or replaced, and the power plant will be brought up to modern fire protection standards. The full effort is expected to take 10 years to complete.

7.6.2.2 Third Powerplant Overhaul Project

Third Powerplant Overhaul Project includes work on the six generating units, turbines, shafts, and auxiliary equipment at the Grand Coulee Third Powerplant. The main portion of the overhaul work is being completed within the confines of the third powerplant.

7.6.2.3 John W. Keys III Pump-Generating Plant Modernization Project

John W. Keys III Pump-Generating Plant Modernization Project includes pump-generating and auxiliary equipment. Work will be within the confines of the plant and completed in 2034.

7.6.2.4 Grand Coulee G1 through G18 Modernization and Overhaul Project

Reclamation is implementing this project to modernize and overhaul the power-generating units G1 through G18 in the left and right powerhouses at Grand Coulee Dam, by refurbishing or replacing key components. Reclamation would maintain current operations for FRM to protect communities and generate hydropower while the project is being implemented. Under the G1 through G18 Modernization and Overhaul Project, current hydrologic operations would be maintained and, therefore, the project is not expected to have any impacts on water or fisheries resources in the Columbia River or Lake Roosevelt.

7.6.2.5 Lower Granite Trap Modifications

This measure was included in MO1 and MO4, but was refined to reduce the scope to improvements to the trap gate. The existing trap gate would be replaced with a gate operated by a dedicated hoist and would reduce cost while retaining anticipated benefits to fish. The trap would be designed and implemented to reduce delay and stress for adult salmonids and other species such as Pacific lamprey. The new gate would be designed to more efficiently shed debris and would include a gap in the bottom to allow upstream passage of lamprey. This measure is intended to increase adult salmon and steelhead survival by reducing upstream travel times.

7.6.2.6 Lower Granite Project Juvenile Facility Bypass Improvements

This structural measure was carried forward from the No Action Alternative in Chapter 2 with no changes. This action modified the existing bypass system to construct an open channel with increased orifice size, intended to move fish from the collection channel to the existing juvenile fish collection facility. The work was intended to reduce the time fish spend in the system, moving them more quickly and reducing stress and delays. The project included an enlarged collection channel, flow reduction through the transport channel, improved water supply to the location downstream of the collection channel, and a relocation of the primary outfall to reduce predation. Construction was complete and the system became fully operational in FY 2019.

7.6.2.7 Lower Granite Project Spillway Passive Integrated Transponder Monitoring System

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. A passive integrated transponder (PIT)-tag monitoring system was installed over spillbay 1, the location of the removable spillway weir. The system includes a set of antennas mounted in the surface of the spillway and connected to an electrical transceiver located on the tailrace deck. These antennas support collection of data so numbers of juvenile fish migrating over the spillway can be compared with using the bypass system or other routes. This system is scheduled to become functional in FY 2020.

7.6.2.8 Little Goose Project Adjustable Spillway Weir Closure

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. An adjustable spillway weir (ASW) was fabricated and installed in spillbay 1 at Little Goose Dam. The project included a mechanical system to adjust the crest elevation of the spillway to allow juvenile salmon and steelhead to pass the dam near the water surface. This allows operators to adjust quickly to changing conditions, thus increasing the likelihood of juvenile salmon and steelhead survival.

7.6.2.9 Little Goose Project Adult Ladder Temperature Improvements

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. This structural measure includes a 90-foot-deep chimney attached to the face of the dam to pull cool water from lower reservoir elevations and release it into the fish ladder. In the ladder, the cold water mixes with warmer surface water from the forebay to lower water temperatures. The cold water is also sprayed onto the surface water in the forebay to cool water at the ladder exit. This project is intended to keep ladder water temperatures within an acceptable range, and prevent delays in fish passage during periods of high water and air temperatures. Construction was completed in FY 2018.

7.6.2.10 Little Goose Project Boat Barrier

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. This structure is comprised of a set of anchors and lines holding a string of booms and cables in the forebay of the Little Goose Project. It is a safety measure intended to keep boats from approaching the spillway. The cables have bird spikes to keep piscivorous birds off the structure in an attempt to reduce predation in the forebay. Construction was completed in FY 2018.

7.6.2.11 Little Goose Project Trash Shear Boom Repair

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. This is a repair of an existing boom. The action included replacement of longitudinal cable to reconnect 20 concrete floats. The floats are 40 feet long and 8 inches wide. This boom is intended to direct debris away from the powerhouse to protect powerhouse infrastructure.

7.6.2.12 Ice Harbor Project Turbines 1 to 3 Replacement and Generator Rewind

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. The Ice Harbor turbine replacement and rewind will replace existing turbine runner blades on units 1, 2, and 3, with state-of-the-art improved fish passage runners. The project will also rewind the electrical components and replace the distributors. Collectively, these changes will improve hydraulic conditions for fish and increase hydropower generating efficiency. Units 1 and 3 will be replaced with adjustable blades for increased operating flexibility to adjust to changing river conditions. Unit 2 will remain a fixed-blade unit. The turbine replacement is scheduled to be completed in FY 2021, with some turbines being installed sooner than FY 2021.

7.6.2.13 McNary Project Turbine Replacement

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. This action includes full replacement of all 14 turbines at McNary with new turbines. This includes replacement of runners, discharge rings, windings, wicket gates, and potential draft tube modifications, pending final design. The replacement will increase reliability, increase generating efficiency, increase hydraulic capacity, and improve hydraulic conditions for fish. Construction began in 2018 and is expected to continue through FY 2033.

7.6.2.14 Adult Passive Integrated Transponder Tag (PIT) Monitoring System at John Day Project

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. PIT antennas were installed in both the north and south adult fish ladders during the 2016/2017 winter maintenance period. A PIT detection system at John Day Project will allow biologists to track and monitor adult upstream migration and assist in development of more accurate estimates of adult salmon survival through the CRS.

7.6.2.15 Improved Fish Passage Turbines at John Day Dam

The co-lead agencies would install Improved Fish Passage (IFP) turbines at John Day Dam starting in FY 2025 to improve hydraulic conditions for fish passing through the turbines. The IFP turbines would be designed to improve hydropower turbine efficiency and hydraulic conditions for fish, similar to the IFP turbines installed at Ice Harbor. Under current plans, the existing turbines (up to 16) would be replaced two at a time over a period of approximately 8 to 12 years, beginning around the time turbine improvements at McNary and Ice Harbor have been completed. Installation of the IFP turbines has the potential to improve fish passage conditions, improve hydropower efficiency and capacity, minimize greenhouse gas emissions, and indirectly improve water quality by reducing total dissolved gas (TDG).

7.6.2.16 Bonneville Project Gatewell Orifice Modifications

This structural measure was carried forward from the No Action Alternative description in Chapter 2 with no changes. Biological testing in 2008, 2009, and 2013 showed elevated mortality for juvenile salmon in the gatewells when the units are operating at the upper end of the peak efficiency range (greater than 15 thousand cubic feet per second [kcfs]). This project is designed to improve juvenile salmon survival in the gatewells at the Bonneville Project's second powerhouse.

7.6.2.17 Bonneville Ladder Serpentine Weir Modifications

This measure was included in MO1 and MO3, but was refined to reduce the scope to limit modifications to improvements to the trap gate. The Corps would modify the serpentine-style flow control sections of Bonneville Dam's Washington Shore and Bradford Island fish ladders, converting them to an Ice Harbor-style vertical slot with submerged orifice configurations. This would improve passage conditions for adult lamprey and likely reduce stress and delay for adult salmon, steelhead and bull trout. This action has the potential to increase adult salmon and steelhead survival by reducing upstream passage time at the dam.

7.6.2.18 Closeable Floating Orifice Gates for Lamprey

This measure was developed for inclusion in the Preferred Alternative to meet the lamprey objective to provide a benefit to Pacific lamprey passage at Bonneville Dam. It installs closeable gates on Bonneville Powerhouse 2 floating orifice gates to reduce incidences of lamprey falling out of the Washington Shore Fish Ladder. Closeable gates would allow seasonal closure during the lamprey passage season. This measure is intended to increase adult lamprey upstream passage success. This action was identified after the development of measures and has been added to the Preferred Alternative to provide a benefit to lamprey passage at Bonneville Dam.

7.6.2.19 Bypass Screen Modifications for Lamprey

This measure was included in all MOs to provide a benefit to lamprey passage at Little Goose, Lower Granite and McNary projects. It has been modified to only be implemented at Lower Granite and Little Goose. Turbine intake bypass screens used to divert fish into the collection channel of the juvenile bypass system would be replaced at Little Goose and Lower Granite projects. The Corps would replace the existing extended length bar screens with screens designed to reduce juvenile lamprey entanglement. The reason that it would not be implemented at McNary is because it would conflict with another measure, *Fewer Fish Screens* planned for this location. These upgrades would occur when the existing screens need replacement. This measure has the potential to reduce lamprey mortality from impingement on the fish screens.

7.6.2.20 Lamprey Passage Ladder Modifications

This measure is included in all MOs to provide a benefit to Pacific lamprey passage. Existing fish ladders at the lower Snake River and lower Columbia River projects would be modified as described:

- **Install ramps to salmon orifices at Bonneville Dam.** Install concrete or aluminum ramps in the Bradford Island Fish Ladder to make salmon orifices elevated above fish ladder floors more accessible to lamprey. Ramps would enable adult lamprey to more easily and directly access the salmon passage openings by removing right angles at the approach.
- **Install diffuser grating plating at Bonneville (south and Cascade Island ladders), The Dalles (north ladder), and Lower Monumental (north and south ladders).** Where feasible, install steel plating over floor diffuser grating immediately adjacent to submerged weir orifices within the existing fish ladders. Floor diffusers add water to the fish ladder to provide attraction flows for fish, but the grating makes it difficult for lamprey to attach as they attempt to pass through submerged weir orifices. Steel plating would provide an attachment surface for lamprey to attach and rest as they swim upstream through the fish ladder.
- **Install additional refuge boxes at Bonneville Dam.** At Washington Shore and Bradford Island fish ladders, install metal refuge boxes or similar structures on the floors or walls of fish ladders to provide a protected resting environment for lamprey migrating upstream.
- **Install a wetted wall in the fish ladder at Bonneville Dam.** At the Bonneville Dam Washington Shore Fish Ladder, install a metal wall in the control section of the fishway (similar to the structure already installed in the Bradford Island Fish Ladder). This would provide an alternate upstream passage route for migrating adult lamprey and allow the lamprey to escape the higher water velocities and turbulence in the adjacent control section of the fish ladder.
- **Install entrance weir caps at McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite.** Install rounded entrance caps at fish ladder entrance weirs to eliminate 90-degree corners which hinder lamprey from entering fish ladders on the lower Snake and McNary projects. Rounding the edges would provide lamprey a constant attachment surface to overcome the high-water velocities encountered at fish ladder entrances. This measure is intended to improve adult lamprey passage through the fish ladders.
- **Lamprey Passage Structures (LPS).** Ramp-like flume structures would be installed or modified in fish ladders at Bonneville, The Dalles, and John Day dams to guide adult lamprey out of fish ladders and into parallel systems for volitional passage or collection for upstream transport or passage studies. The LPSs would use independent water sources (pumps or gravity-flow systems) and may be placed in various locations within fish ladders, such as collection channels, junction pools, or auxiliary water supply channels. New structures would be installed at Bonneville Dam's Bradford Island and Washington Shore fish ladders, The Dalles Dam's east fish ladder, or John Day Dam's south fish ladder. At John Day Dam,

the existing LPS on the north fish ladder may be extended from the tailrace deck to the forebay. This measure is intended to increase adult lamprey passage at the dams.

7.6.2.21 Turbine Strainer Lamprey Exclusion

This measure was included in all MOs to provide a benefit to lamprey passage. Structures would be installed to prevent juvenile lamprey, juvenile salmonids, and other fish from being entrained into the intakes of turbine unit cooling water systems. Hood-like structures would be installed over existing intake gratings and would allow sweeping flows to move fish past the opening, reducing entrainment and related risk of fish injury or mortality. This measure may be implemented at all lower Snake River and all lower Columbia River Projects. This measure has the potential to reduce lamprey mortality.

7.6.2.22 Fewer Fish Screens

This measure was included in MO2 and MO3. This measure would potentially cease installation of fish screens to increase the efficiency of new hydropower turbines at Ice Harbor, McNary, and John Day dams once Improved Fish Passage turbines are installed. This measure is intended to consider running the new IFP turbines unscreened if acceptable biologically. The co-lead agencies would collaborate with NMFS and USFWS to develop a Turbine Intake Bypass Screen Management and Future Strategy process to monitor success of the IFP turbines and determine if and when it would best to remove fish screens at these projects.

7.6.3 Preferred Alternative Operational Measures

The following operational measures are included in the Preferred Alternative:

7.6.3.1 Sliding Scale at Libby and Hungry Horse

This operational measure was included in all MOs. To implement this measure, the Corps and Reclamation would determine the summer draft from the Libby and Hungry Horse projects for delivery of flow augmentation for downstream fish based on a local water supply forecast. Additionally, this elevation objective would be incrementally adjusted over a range of water supply conditions. These changes would allow water managers to balance local resident fish priorities in the upper basin with downstream flow augmentation for the Columbia River downstream of Chief Joseph Dam. This operation continues with the No Action Alternative ramping rates and minimum downstream flow requirements.

7.6.3.2 Modified Draft at Libby

This operational measure was included in all four MOs, but was modified to remove the December draft target elevation at Libby to those targets in the No Action Alternative in years when the water supply forecast is expected to be greater than 6.9 million acre-feet (Maf). This measure would modify operations at Libby to provide water managers more flexibility to incorporate local conditions in the upper basin. The measure would change flow management so that local flood durations and start of refill operations are tied to Kootenai Basin runoff. In order to provide flexibility to respond to local conditions, years with an April-August water supply of less than 6.9 Maf at Libby would be drafted lower than No Action after December. Draft targets remain the same as No Action in December and for all months with an April-August water supply forecast greater than 6.9 Maf at Libby. During refill (generally Apr/May–July), this measure would modify the VarQ refill flow calculation so that it: (1) modifies the past release calculation to occur in real time; (2) takes into account planned releases, such as the sturgeon volume release, before it occurs, thereby eliminating "double-accounting;" (3) changes the duration over which VarQ flows are determined so that local flood duration, along with the start of refill, is tied to the Kootenai River Basin for forecasts less than 6.9 Maf; and (4) adjusts the initial VarQ flows to be appropriate to the modified draft levels. This measure would modify refill based on local conditions by setting the start of refill to May 1 for forecasts less than 6.9 Maf and the earlier of May 1 or No Action Alternative methodology in all other years. Implementing this action would improve water management flexibility to respond to local flood risk management conditions in the upper basin. It would also provide greater flexibility to provide suitable temperature and flow conditions to benefit resident fish. As this operation is implemented adjustments to provide more space in the reservoir may be made with input from interested parties if new information emerges about nutrient flushing and temperature impacts that could not be captured with the current modeling tools.

7.6.3.3 Planned Draft Rate at Grand Coulee

This operational measure was included in all four MOs. The Storage Reservation Diagram for Grand Coulee would be modified to include a planned draft rate of 0.8 feet per day; this would not change the draft rate limit of 1.5 feet per day or the deepest flood risk management elevation, typically on April 30. This measure changes the planned timing and rate of the draft to satisfy the flood risk management requirements. Flood risk management space requirements are determined by water supply forecasts and upstream storage reservoir capacity. The reduced draft rate would reduce the risk of erosion along the shoreline and may reduce spill in some years. This action will maintain the same level of flood risk and allow water managers to better manage drafts for Grand Coulee under a wide range of hydrologic conditions.

7.6.3.4 Grand Coulee Maintenance Operations

This operational measure was included in all four MOs. This measure could expedite the maintenance schedule for the power plants and spillways of the Grand Coulee project relative to the No Action Alternative schedule. The maintenance on the power plants could reduce the number of generating units available, requiring additional spill in some situations. The project could keep 27 of the 40 regulating gates and/or 8 drum gates in service and take the others out of service to perform spillway maintenance activities. This action could improve safety, reliability, and the capacity of power plants and spillways at Grand Coulee Dam.

7.6.3.5 Update System FRM Calculation at Grand Coulee

This operational measure was included in all four MOs with slight variation. The Preferred Alternative includes the MO3 version of this measure, which, under a range of water supply, attempts to maintain the elevation of Grand Coulee above 1,222.7 feet for irrigation pump efficiency (NGVD29). This measure modifies the procedure used to determine Grand Coulee flood risk management drafts by changing the current upstream correction method calculation to reflect the relationship between the geographic and hydrologic location of flood risk storage and the project's ability to manage flooding within the basin. This measure is not intended to increase or decrease the current level of CRS flood risk. This measure allows the Grand Coulee project to reciprocally respond to unanticipated trapped storage in an upstream CRS reservoir. Under certain conditions it could result in more draft for flood risk management at Grand Coulee compared to the No Action Alternative.

7.6.3.6 Lake Roosevelt Incremental Storage Release Project

The Lake Roosevelt Incremental Storage Release Project is a component of the Columbia River Water Management Program (CRWMP). It is intended to improve municipal and industrial water supply, provide water to replace some groundwater use in the Odessa Subarea, enhance stream flows in the Columbia River to benefit fish, and provide water to interruptible water right holders in drought years. The Lake Roosevelt Incremental Storage Release Project does not reduce flows during the salmon flow objective period (April through August). This project provides for Lake Roosevelt to be drafted an additional 1.0 foot in non-drought years and up to 1.8 feet in drought years by the end of August. One-third of this water will go to instream flows.

7.6.3.7 Lake Roosevelt Additional Water Supply

This operational measure was included in MO1, MO3, and MO4 where an additional 1.15 million acre-feet could be pumped from Lake Roosevelt at Grand Coulee above what was provided in the No Action. This measure was updated for the Preferred Alternative to pump up to 45,000 acre-feet of water above the No Action due to the uncertainty over the timing and extent of the development of new water supply projects for the full volume. Additionally, this measure would change the timing of delivery of recently developed water supplies for the Odessa Subarea of the Columbia Basin Project (164,000 acre-feet for irrigation and 15,000 acre-feet for M&I of the current supplies) from September and October to when the water is needed, on demand. The 45,000 acre-feet water supports near-term additional development of authorized project acres. Water pumped from Lake Roosevelt would be delivered as the demand arises during the irrigation season (March to October).

7.6.3.8 Fall Operational Flexibility for Hydropower (Grand Coulee)

This measure modifies the Lake Roosevelt minimum refill elevation of 1,283 feet from the end-of-September to the end-of-October to allow more operational flexibility for power generation while also meeting downstream flow objectives including Priest Rapids minimum flows and lower Columbia River minimum flows for navigation. This measure may result in lower end of September Lake Roosevelt elevations when compared to the No Action Alternative, particularly in low water years. Short-term operations would continue to be coordinated with the tribes.

7.6.3.9 Slightly Deeper Draft for Hydropower (Dworshak)

This measure has been modified from the original measure in MO2. The Corps would define a rule curve through further coordination and study with Bonneville to operate Dworshak. The project would be operated to increase hydropower generation in winter and reduce spill in the spring. The reservoir drafts would be calculated in-season to improve flood risk management operations, reduce spring spill at Dworshak, and increase hydropower generation in the January to March timeframe when market demand is higher. These modifications would result in a reduction of non-fish passage spill in the spring, resulting in reduced TDG exposure to fish in the Clearwater River below Dworshak Dam, and in particular, fish in hatcheries downstream of the dam. This measure would be implemented in a manner to limit the risk of the reservoir not refilling later in the year.

7.6.3.10 Juvenile Fish Passage Spill Operations

This measure was modified using the analysis from the range of spill levels evaluated in the MOs to attempt to provide a high potential benefit to salmon and steelhead through increased spill while avoiding many of the adverse impacts to power generation and reliability associated with MO4. Juvenile fish passage spill would be implemented to aid juvenile salmonid migration at the lower Snake River projects and the lower Columbia River projects. The initial spring component of juvenile fish passage spill is a flexible spill operation over a 24-hour period to take advantage of peak and off-peak load hours for hydropower, while also providing high levels of spill intended to test the CRSO EIS modeled estimates of the benefits to downstream juvenile passage[4], while also ensuring operational feasibility for the Corps. The implementation of the juvenile fish passage spill operations is intended to decrease the number of juvenile fish that bypass the dams through non-spillway routes, improve fish travel through the forebays, gain scientific information on latent (delayed) mortality, and provide flexibility for hydropower generation.

The juvenile spill operation would be adaptively implemented over time, but the initial operation is expected to include the following elements. Over the course of a 24-hour period, 16 hours would be operated to spill up to the 125 percent TDG cap[5] at most projects with the intention of benefiting juvenile outmigration. Some projects are limited below 125 percent for dam safety, countervailing impacts on juveniles or to balance adverse hydropower impacts (or a combination). For the remaining 8 hours, the projects would spill at a lower level (referred to as performance standard spill[6] in the table below). Because performance standard spill levels have been implemented in the past, the 8 hours of reduced spill each day provide a degree of protection against unexpected or unintended consequences that may occur due to spilling up to the 125 percent TDG cap during juvenile fish passage spring operations such as adult

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[4] This measure also will allow the co-lead agencies to gather important scientific information on the relationship between the CRS and latent (delayed) mortality.
[5] Spill up to 125% TDG is dependent upon ongoing state water quality processes.
[6] "Performance standard" spill is a NMFS term and refers to spill levels intended to meet NMFS's performance standard testing, as described in the 2008 Biological Opinion and accompanying administrative record.

migration delay, gas bubble trauma, or damage to infrastructure. These spill levels are slightly variable, depending on the project, and may be higher or lower, depending on river conditions and the opportunity to spill. Expected operations are described in Table 7-3, below. This operation would allow increased hydropower generation during times of peak demand, while still providing high spill for fish when it is expected to be most important. The co-lead agencies would implement these operations in the spring, April 3 to June 20, at the lower Snake River projects, and April 10 to June 15 at the lower Columbia River projects. Summer spill would be implemented as described in Table 7-4. Spill operations would be managed adaptively, through the established Regional Forum processes,[4] to address unexpected challenges, such as potential delays to adult migration, effects to navigation, and other challenges or opportunities that may require either a temporary or permanent change.

Table 7-3. Estimated Juvenile Spring Fish Passage Spill and Performance Standard Spill Operations by Columbia River System Project

Location	Juvenile Fish Spill Cap (16 hours)	Performance Standard Spill (8 hours)
Lower Granite (125 flex)	125% TDG	20 kcfs
Little Goose (125 flex)	125% TDG	30%
Lower Monumental (125 flex)	125% TDG	30 kcfs
Ice Harbor (125 flex)	125% TDG	30%
McNary (125 flex)	125% TDG	48%
John Day (120 flex)	120% TDG	32%
The Dalles (Performance Standard)	40%	40%
Bonneville (125 flex with 150 kcfs spill constraint)	125% TDG	100 kcfs

The details of the *Juvenile Fish Passage Spill* operation have been refined and coordinated with regional fish managers. Several site-specific conditions apply to the juvenile fish passage spill operations. These conditions were developed to address site conditions at specific locations, as described:

- Spill may be temporarily reduced at any project if necessary to ensure navigation safety or transmission reliability.
- Spring spill operations would be initiated April 3 at lower Snake River projects and April 10 at lower Columbia River projects and transition to summer spill operations on June 20 at lower Snake River projects and on June 15 at lower Columbia River projects.
- The 8 hours of performance standard spill may occur with some flexibility (with the exception of Little Goose and Lower Granite operations as specifically described below). Other than at The Dalles Dam, performance standard spill would occur in either a single 8 hour block or in up to two separate blocks per calendar day. No more than 5 hours of performance standard spill may occur between sunset and sunrise, as defined in the annual Fish Passage Plan (FPP). Performance standard spill shall not be implemented between 10 pm and 3 am.

- Little Goose Exception One: As soon as practicable (and, in any event, no more than 24 hours) after a cumulative total of 25 adult spring Chinook salmon (not including jacks) pass Lower Monumental Dam, operate Little Goose spill at 30 percent spill for 8 consecutive morning hours (April 3 to 15 start at 5 am; April 16 to June 20 start at 4 am).
- Little Goose Exception Two: During periods of involuntary spill above specified fish passage spill levels (due to lack of market availability or hydraulic capacity at the dam), the Corps would spill at 30 percent for 8 hours/day (daylight hours as defined in the Fish Passage Plan) and store additional inflows that exceed hydraulic capacity in the forebay above minimum operating pool (MOP) if necessary. When it is necessary to pond water to achieve the lower spill levels due to high inflows, water stored above MOP should be drafted out over the remaining hours by increasing spill to pass inflow from 1200 to 1600 hours, then increasing spill as necessary from 1600 to 0400 to draft the pool back to MOP. If it is forecasted that the drafting spill would generate TDG levels in the tailrace in excess of 130 percent, use all 16 hours to return the pool to MOP.

Lower Granite Exception One: If adult passage delays are observed at Lower Granite during operations to increase spill up to 125 percent TDG, the Corps would follow the Adaptive Implementation Framework (Appendix R) and may implement performance standard spill at Lower Granite Dam for at least 4 hours in the morning (beginning near dawn).

- Voluntary Spill at Bonneville Dam is capped at 150 kcfs due to structural integrity risks from erosion.
- Voluntary Spill at The Dalles Dam would be contained between the walls (Bays 1-8) unless river flows are over 350 kcfs, in which case spill outside the walls is permitted. TDG levels in The Dalles tailrace may fluctuate up to 125 percent TDG prior to reducing spill at upstream projects, subject to the 40 percent spill cap.
- Attempts should be made to minimize in-season changes to the proposed operations. However, if serious deleterious effects to fish or infrastructure as a result of these spill operations are observed, existing adaptive management processes may be employed to help address such issues.

Summer spill operations are described in Table 7-4, below. Cessation of juvenile transportation would occur June 21 through July 15 with allowance for adaptive management adjustments through the TMT.

Table 7-4. Typical Summer Juvenile Fish Passage Spill Operations by Columbia River System Project

Location	Initial Summer Spill Operation: Volume/Percent of Total Flow routed to Spillway (June 21/16 to August 14)	Late Summer Transition Spill Operation: Volume/Percent of Total Flow Routed to Spillway (August 15 to August 31)
Lower Granite	18 kcfs	RSW or 7 kcfs
Little Goose	30%	ASW or 7 kcfs
Lower Monumental	17 kcfs	RSW or 7 kcfs
Ice Harbor	30%	RSW or 8.5 kcfs
McNary	57%	20 kcfs
John Day	35%	20 kcfs
The Dalles	40%	30%
Bonneville	95 kcfs	55 kcfs – includes 5 kcfs corner collector

Note: RSW = removable spillway weir.

7.6.3.11 Contingency Reserves Within Juvenile Fish Passage Spill

This measure was included in all four MOs. This measure would allow operations to change fish spill for short durations during fish passage spill season at all lower Columbia and Snake River projects. This measure would provide operating flexibility to allow Bonneville to carry required reserves on the turbines to ensure grid reliability. The measure would be implemented to meet energy demands that are caused by unexpected events such as transmission interruption or the failure of a generator. These events are rare and, when they occur, the co-lead agencies may be able to cover the contingencies without temporarily reducing spill. The expected impact on spill reductions is typically once per month for less than an hour. This measure would increase the available capacity of hydropower generation and reduce the overall cost to consumers of implementing the Preferred Alternative.

7.6.3.12 Above 1% Turbine Operations

This measure was included in MO3 and MO4. Turbines may be operated above 1 percent peak efficiency for hydropower generation flexibility, with an increased likelihood of this operation during high flow periods. The operation is expected to occur primarily when there is insufficient turbine capacity to generate with the available water after providing fish passage spill. This occurs most frequently in high flow periods, a time when operating above 1 percent would also help manage for high TDG by reducing spill. This operation may also occur to maintain power system reliability if contingency reserves are deployed or for limited durations during periods of high power demand. This operation is expected to occur infrequently as the co-lead agencies strive to operate turbine units in the most efficient manner possible (i.e., within the 1 percent efficiency band) because it is typically the best operation for power. However, having this operation available for power use allows Bonneville to carry contingency reserves in the upper generation band with a benefit during all hours. Bonneville estimates that it would actually operate the turbines above 1 percent roughly once per month for deployment of contingency reserves, averaging about 35 minutes. Operating above 1 percent when there is insufficient turbine capacity would primarily occur in high-flow periods, which are 20 percent of years at McNary and 5 to 10 percent of the years at the other projects. There may be other instances (e.g., unexpected outages) where operating above 1 percent occurs. Recent studies showed that turbine operations above 1 percent can provide similar turbine survival for juveniles, for example, at Bonneville Powerhouse 1 (Weiland et al. 2015).

7.6.3.13 Increased Forebay Range Flexibility

This measure was included in MO1. As part of this operation, the Corps would implement operating elevation range restrictions consistent with actual 2019 operations. This operation was described in the *2019-2021 Spill Operation Agreement* at the lower Snake River projects and John Day to provide operating flexibility during the fish passage season (April 3 to August 31). The lower Snake River projects would operate within a 1.5-foot MOP range, and John Day would operate within a 2-foot minimum irrigation pool (MIP) range (262.5 to 264.5 feet), except from April 10 to June 1 (or as late as June 15) when the John Day forebay operating range would remain between elevations 264.5 and 266.5 feet for *Predator Disruption Operations*. The operating range restrictions would end when spill is reduced (as described for summer spill in the *Juvenile Fish Passage Spill* measure) or ends. Safety related restrictions would continue, including but not limited to maintaining ramp rates to minimize shoreline erosion and maintain power grid reliability. This measure is intended to increase flexibility for water management, shape hydropower production to meet energy demand, and maintain power grid reliability. At John Day, the reservoir would be operated at or above MIP (262.5 feet) throughout the irrigation season (March 15 through November 15), except as needed for flood risk management.

7.6.3.14 Early Start Transport

This measure was modified from the version of the measure in MO1. The transport of juvenile salmon collected at Lower Granite, Little Goose, and Lower Monumental projects could begin as early as April 15, approximately 2 weeks earlier than current fish transport operations described in the No Action Alternative, if warranted based on transportation benefits or to facilitate transport research. Transport operations would end September 30 at Lower Monumental and October 31 at Lower Granite and Little Goose. Collected juvenile fish would be transported to a location below Bonneville Dam via barge or truck on a daily or every-other-day schedule, depending on the numbers of fish collected at the collector projects. This measure does not preclude the co-lead agencies from ceasing juvenile transportation June 21 through August 14 with allowances for adaptive management adjustments through the TMT as was contemplated in the *2019-2021 Spill Operation Agreement*. This action could increase the number of juvenile fish transported to the estuary.

7.6.3.15 Zero Generation Operations

This measure was modified from MO2. This action would expand the ability of the Corps to temporarily stop flows through the turbines on the lower Snake River projects. These operations would be undertaken when there is little demand for hydropower, unless limited by grid stability requirements. This measure would allow operators to save water in low demand periods to use for hydropower generation during high demand periods. Currently, these projects are allowed to operate at Zero Generation from early or mid-December through February 28 (based on an implementation trigger). The updated operation would begin as early as October 15 and could continue through February 28, when power markets warrant and when river conditions make it feasible. These operations would be implemented at night only from October 15 to November 30 and would cease 2 hours before dawn to reestablished flows for adult salmon migration upstream during the day. Between December 1 and February 28 this operation could also be implemented for up to 3 hours daily during the daylight hours. These dates were selected to minimize impacts to anadromous salmon and steelhead.

7.6.3.16 Predator Disruption Operations

This measure would allow the Corps to manipulate the John Day reservoir elevation to decrease avian predation on ESA-listed juvenile salmon and steelhead in the lower Columbia River. The John Day reservoir normal operating range is up to 266.5 feet (although it is authorized to operate up to 268 feet). The Corps would operate John Day within a 2-foot MIP range of 262.5 to 264.5 feet, except from April 10 to as late as June 15, when the John Day forebay would operate from 264.5 to 266.5 feet, except as needed for flood risk management. These operations would be initiated prior to the start of nesting by Caspian terns, to avoid take. Unless adaptively managed due to changing run timing, the co-lead agencies intend to return to reservoir elevations of 262.5 to 264.5 on June 1, which generally captures 95 percent of the annual juvenile steelhead migration. The results of this action would be monitored and coordinated with USFWS and NMFS.

7.6.3.17 John Day Full Pool

This measure would remove current restrictions on seasonal pool elevations at John Day project in the winter, allowing more operating flexibility for hourly and daily shaping of hydropower generation. The measure would allow for operation of the reservoir across the full range possible, between 262.0 to 266.5 feet elevation outside of fish passage season, except as needed for flood risk management. Also, there would be a minimum elevation of 262.5 feet during the irrigation season.

7.6.4 Mitigation Measures

In some instances, the measures carried forward, modified, or added from alternatives in Chapter 2 resulted in undesirable effects. Mitigation measures were incorporated into the Preferred Alternative to avoid, reduce, or minimize these effects. These include operational, land management and mitigation actions from ongoing programs, measures developed as part of the EIS process, and measures developed as part of the CRS ESA consultations.

7.6.4.1 Ongoing Programs

MANAGEMENT OF LANDS FOR FISH AND WILDLIFE

The Corps is authorized by Congress to manage Corps-owned lands across the Columbia Basin for fish and wildlife purposes. These lands vary by vegetative cover type and the species supported, from wetlands that support ducks and aquatic invertebrates to uplands that support deer and game birds such as quail. Corps management actions include invasive species management, installation of facilities such as gallinaceous guzzlers as water sources for upland birds, or planting of native species to provide food and cover for birds, reptiles, and mammals on Corps-owned lands, as examples.

FISH AND WILDLIFE ACTIONS

In addition to routine operations and maintenance of the CRS, the co-lead agencies implement a number of actions and programs, intended to benefit ESA-listed species in the Columbia River Basin. These actions range from items like dry year operations to chum salmon spawning flows, which are adaptively managed by the TMT. These actions are listed in Table 7-5. These actions are included in greater detail in the Biological Assessment and are expected to be contained in the Biological Opinions. To make the most of available funds, investments in fish and wildlife protection, mitigation and enhancements will be prioritized based on biological and cost-effectiveness and their connection to mitigating for impacts of the CRS.

BONNEVILLE'S FISH AND WILDLIFE PROGRAM AND LOWER SNAKE RIVER COMPENSATION PLAN

Bonneville's Fish and Wildlife (F&W) Program funds hundreds of projects each year to mitigate the impacts of the development and operation of the Federal hydropower system on fish and wildlife. Bonneville began this program to fulfill mandates established by Congress in the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act), 16 USC § 839b(h)(10)(A), to protect, mitigate, and enhance fish and wildlife affected by the development and operation of the FCRPS. Each year Bonneville funds projects with many local, state, tribal, and Federal entities to fulfill its Northwest Power Act fish and wildlife responsibilities and to implement offsite mitigation actions listed in various Biological Opinions for ESA-listed species. Offsite protection and mitigation actions typically address impacts to fish and wildlife not caused directly by the CRS, but they are actions that can improve overall conditions for fish to help address uncertainty related to any residual adverse effects of the CRS. For example, F&W Program funding improves habitat in the mainstem as well as tributaries and the estuary, builds hatcheries and boosts hatchery fish production, evaluates the success of these efforts, and improves scientific knowledge through research. This work is implemented through annual contracts, many of which are associated with multi-year agreements like the Columbia River Basin Fish Accords, the Accord extensions, or wildlife settlements.

In addition to the hatchery operations that are funded through the F&W Program, Bonneville directly funds the USFWS' annual operations and maintenance of the Lower Snake River Compensation Plan (LSRCP). Congress authorized the LSRCP as part of the Water Resources Development Act of 1976 (90 Stat. 2917) to offset fish and wildlife losses caused by construction and operation of the four lower Snake River dams. A major component of the authorized plan was the design and construction of fish hatcheries and satellite facilities. The LSRCP is administered through the USFWS. The LSRCP hatcheries and satellite facilities produce and release more than 19 million salmon, steelhead and rainbow trout each year as part of the program's mitigation responsibility.

COLUMBIA RIVER FISH MITIGATION PROGRAM

The Columbia River Fish Mitigation Program is the Corps' construction account for studying, designing, and constructing new anadromous fish, including lamprey, passage improvements at CRS dams. Nearly all fish passage improvements required under past Biological Opinions have been constructed, and few new anadromous fish improvements requiring construction have been identified. Therefore, it is assumed that for CRS dams, requirements for new construction will be completed within the next 10 years.

COLUMBIA RIVER TRIBUTARY HABITAT PROGRAM

Reclamation has a Columbia-Snake salmon program to help meet its ESA obligations for its two projects, Grand Coulee and Hungry Horse. The program funds, designs, and implements tributary habitat improvements for anadromous fish, including lamprey, in specified Columbia River sub-basins. This program also provides funds avian predation management.

Table 7-5. Measures Included in the Preferred Alternative to Benefit Endangered Species Act–listed Fish that are Being Carried Forward from Previous Commitments by the Co-Lead Agencies

	Measure	Description
Habitat Measures	Tributary Habitat Improvements for both Chinook salmon and steelhead	Implementation of specified construction projects, research, monitoring and evaluation (RM&E) actions, and species status and trend data collection on habitat and survival improvement.
	Kootenai White Sturgeon Habitat Restoration	Implementation of habitat projects as included in the CRS Biological Assessment (BA).
	Estuary Habitat Implementation	Implementation of specified construction projects, RM&E actions, and species status and trend data collection on habitat and survival improvement.
	Kootenai River White Sturgeon Nutrient Enhancement	Continued Bonneville support of nutrient enhancement in the Kootenai River through FY 2025.
	Dworshak Reservoir Long-Term Nutrient Supplementation Program	Continued nutrient enhancement in the Dworshak Reservoir to enhance biological productivity of the reservoir for kokanee and reduction of algal blooms.
Operational Measures	Storage Project Operations (Upper Columbia Basin)	Operate storage projects to deliver additional flow in spring and summer to augment flows for anadromous fish migration. These operations would continue to be communicated through an Annual Water Management Plan and Fish Operations Plan.
	Lower Columbia and Snake River Operations	Develop Annual Water Management Plan and Fish Operations Plan for flow to aid juvenile fish passage.
	Sturgeon Operations at the Libby Project	Ongoing, seasonal flow augmentation from Libby Dam for Kootenai River White Sturgeon, as described in the 2006 USFWS Biological Opinion and 2008 update, consistent with the Flow Plan Implementation Protocol; Real-Time Management.
	Kootenai River Operations for Bull Trout	Libby Dam minimum flow to aid bull trout as included in the CRS BA.
	Hungry Horse Bull Trout Operations	Hungry Horse operations for minimum flows, ramping rate restrictions, temperature and TDG management, reservoir elevation management, and avoiding double peak flows in the Flathead River to aid bull trout as included in the CRS BA.
	In-Season Water Management	Communication and potential adjustments to in-season water management will be documented in seasonal Updates to the Annual Water Management Plan.
	Operational Emergencies	Real-Time Management for unforeseen events.
	Fish Emergencies	Real-Time Management for unforeseen events coordinated with Regional Forum.
	Dry Year Operations	Real-Time Management when a dry water year is declared per CRS BA definition.
	Water Quality Plan for TDG and Water Temperature	Maintain Water Quality Plan for Total Dissolved Gas and Water Temperature in the mainstem Columbia and Snake Rivers to continue to operate in a way to reduce system TDG and temperature.
	Chum Spawning Flow	Coordination of operations via the Technical Management Team (TMT); Real-Time Management.

	Measure	Description
	Develop Annual Fish Passage Plan	The Fish Passage Plan (FPP) is developed annually by the Corps in coordination with Bonneville and regional Federal, state, and tribal fish agencies. The FPP describes year-round operation and maintenance activities at Corps dams on the Columbia and Snake rivers. Detailed criteria and guidelines for Lower Snake River Project operations are included in annual Water Management Plans (WMP) and the FPPs.
Hatcheries	FCRPS Mitigation Hatcheries – Programmatic	Continued support of hatcheries and adopt programmatic criteria for funding decisions on mitigation programs for the FCRPS that incorporate best management practices.
Hatcheries	Kootenai River White Sturgeon Conservation Aquaculture	Continued Bonneville support of hatchery-raised Kootenai River White Sturgeon for supplementation due to lack of wild, natural recruitment.
Hatcheries	Implement Safety Net Programs	Continue to identify and plan for ongoing "safety net" programs to provide benefits to ESA-listed stocks at high risk of extinction.
Hatcheries	Conservation Programs to Build Genetic Resources	Continue to fund conservation programs that assist in recovery.
Predation	Northern Pikeminnow Management Program (NPMP)	Ongoing base program and general increase in northern pikeminnow sport-reward fishery reward structure.
Predation	Reduce Caspian Terns on East Sand Island in the Columbia River Estuary	Annual site preparations and hazing/dissuasion to maintain 1.0 acre of suitable habitat at ESI and prevent birds from establishing satellite colonies outside of 1.0 acre colony site.
Predation	Double-Crested Cormorant Management	Plan implementation completed March 2019. Annual hazing ongoing with limited egg-take to maintain colony size objectives, as necessary.
Predation	Inland Avian Predation	Plan implementation concluded in 2018. Ongoing monitoring of tern colony during nesting season through 2021 breeding season.
Predation	Other Avian Deterrent Actions	Monitor avian predator activity, continue avian deterrent programs at all lower Snake and Columbia River dams. Part of annual Fish Passage Plan.
Predation	Marine Mammal Control Measures	Install and improve, as needed, sea lion excluder gates at all main adult fish ladder entrances at Bonneville Dam annually.

	Measure	Description
Hatchery and Habitat Program	Lower Snake River Fish & Wildlife Compensation Plan	Congress authorized the Lower Snake River Compensation Plan (LSRCP) as part of the Water Resources Development Act of 1976 (90 Stat. 2917) to offset fish and wildlife losses caused by construction and operation of the four lower Snake River dams. A major component of the authorized plan was the design and construction of fish hatcheries and satellite facilities. Administered through the USFWS, the 25 LSRCP hatcheries and satellite facilities are operated by Idaho Fish and Game (IDFG), Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), USFWS, the Nez Perce Tribe (NPT), Confederated Tribes of the Umatilla River (CTUIR), and Shoshone-Bannock Tribes (SBT). The LSRCP hatcheries and satellite facilities produce and release more than 19 million salmon, steelhead and rainbow trout as part of the program's mitigation responsibility. Bonneville directly funds USFWS for the annual operation and maintenance of these LSRCP facilities. Corps also provides annual funding to implement other components of the LSRCP such as the management units for upland and riparian habitat (woody riparian initiative), a game bird farm, and other ongoing habitat management at locations across the lower Snake River basin.

7.6.4.2 Additional Mitigation Developed As Part of the Columbia River System Operations Environmental Impact Statement

PLANT COTTONWOOD TREES (UP TO 100 ACRES) NEAR BONNERS FERRY

The flow regime at Libby makes natural establishment of riparian vegetation downstream of the dam challenging. Higher winter flows make it difficult to sustain young stands of cottonwoods to maturity. The co-lead agencies would plant up to 100 acres of riparian forest along the Braided and Meander reaches of the Kootenai River near Bonners Ferry, using 1-2 gallon cottonwood trees, with the expectation that the larger size trees would be better suited to withstand the higher winter flows. This would improve habitat and floodplain connectivity to benefit ESA-listed Kootenai River White Sturgeon, and complement other actions already being taken in the region to benefit their habitat. To the extent possible, this work will be completed through ongoing projects under Bonneville's F&W Program, such as the Kootenai Tribe of Idaho's Kootenai River White Sturgeon Habitat Restoration Program.

PLANT NATIVE WETLAND AND RIPARIAN VEGETATION (UP TO 100 ACRES) ON THE KOOTENAI RIVER DOWNSTREAM OF LIBBY

The co-lead agencies would plant up to 100 acres of native forested and scrub-shrub wetland vegetation at a lower river elevation in Region A. This would offset effects to existing wetlands and riparian forests downstream of Libby, which would be caused by the *Modified Draft at Libby*, and result in lower water levels on the Kootenai River.

TEMPORARY EXTENSION OF PERFORMANCE STANDARD SPILL OPERATIONS

It is expected that higher spill levels and the resultant TDG associated with the *Juvenile Fish Passage Spill* measure could result in delays to adult passage. Eddies created by a high spill operation may confound upstream passage by salmonids. If a delay in adult salmon and steelhead upstream passage is observed, operations would revert to performance standard spill until the adult fish pass the dam.

UPDATE AND IMPLEMENT INVASIVE SPECIES MANAGEMENT PLANS

Deeper drafts at Libby would result in lower lake elevations in spring, exposing previously submerged lands during the growing season and potentially allowing establishment of invasive weeds. The Corps would update and implement an invasive species management plan to combat the establishment and proliferation of invasive species, as required by Executive Order 13751.

SPAWNING HABITAT AUGMENTATION AT LAKE ROOSEVELT

Increased flexibility of refilling Lake Roosevelt that may occur through the month of October, depending on the annual water conditions, may impact the spawning success of kokanee, burbot and redband rainbow trout. In 2019, Bonneville funded year one of a 3-year study to determine if modifications in Lake Roosevelt refill would impact resident fish access to spawning habitat. If the results indicate that resident fish spawning habitat is impacted by the operation, the co-lead agencies would supplement spawning habitat at locations along reservoir and tributaries (up to 100 acres).

EXTENSION OF THE BOAT RAMP FOR THE INCHELIUM-GIFFORD FERRY IN LAKE ROOSEVELT

Earlier and longer drafts at Grand Coulee would affect water levels, making the Inchelium-Gifford Ferry on Lake Roosevelt unavailable approximately 4 days per year more than under the No Action Alternative. To mitigate this impact, the co-lead agencies would extend the ramp at the Gifford-Inchelium Ferry on Lake Roosevelt so that it would be available at lower water elevations.

MONITORING AT LOWER GRANITE, LOWER MONUMENTAL, AND MCNARY TO EVALUATE EFFECTS OF SHOALING FROM INCREASED SPILL, AND IF WARRANTED, INSTALL COFFER CELLS TO DISSIPATE ENERGY

It is expected that higher spill and variable timing of the spill over the course of a day could result in changes to the tailraces at Lower Granite, Lower Monumental and McNary projects. The Corps would monitor the tailrace at each project to track changes that could affect safe navigation or conditions for ESA-listed fish. If changes to the tailrace warrant action, coffer cells to dissipate energy would be constructed.

INCREASED DREDGING AT MCNARY, ICE HARBOR, LOWER MONUMENTAL, AND LOWER GRANITE PROJECTS

In Regions C and D, the increased spill operations and lower tail water would increase shoaling in the navigation channel due to increased spill operations in the lower Snake and Columbia rivers, adversely effecting navigation. In order to maintain the navigation channel and reduce impacts to negligible, effects would be mitigated by increasing the frequency and total volume of dredging at McNary, Ice Harbor, Lower Monumental, and Lower Granite at a 4- to 7-year interval. As discussed above, shoaling would also be monitored to determine if additional installation of coffer cells at Lower Monumental, Little Goose, and McNary could reduce dredging needs and further maintain the channel. Coffer cells would dissipate energy during high spill operations, which would support movement of sediment in the navigation channel, thereby maintaining navigational capacity and river transportation. This would increase overall maintenance costs for the projects, but would reduce the adverse effects to negligible.

FCRPS CULTURAL RESOURCE PROGRAM AND SYSTEM-WIDE PROGRAMMATIC AGREEMENT

For new effects to archaeological resources, traditional cultural properties, and the built environment at storage projects caused by implementation of the Preferred Alternative relative to the No Action Alternative, the co-lead agencies would use the existing FCRPS Cultural Resources Program and the System-Wide Programmatic Agreement to implement mitigation actions, as warranted and appropriate.

7.6.4.3 Preliminary Measures Agreed to During Endangered Species Act Consultation

This section describes preliminary measures agreed to by the co-lead agencies during informal ESA consultation with NMFS and USFWS on the Preferred Alternative. Due to the fact that the consultation is ongoing, the measures in this list may be modified or expanded prior to the Final EIS. A list of the preliminary measures is included in Table 7-6 and more detailed descriptions follow.

Table 7-6. Preliminary List of Measures Agreed to by the Co-Lead Agencies during Endangered Species Act Consultation on the Preferred Alternative

Measure
Bull Trout Access to Perched Tributaries in the Kootenai River
Study Off-season Surface Spill for Downstream Passage of Adult Steelhead & Bull Trout
Maintenance Improvements to Little Goose Dam Jetty & Retaining Wall
Enhanced Debris Management at Lower Snake River dams & McNary
Investigate Shad Deterrence at Lower Granite Dam
Reduce Mortality Associated with Dworshak Dam Turbine Maintenance & Testing
Adult Fish Ladder Temperature Differentials
Adjust Refill at Grand Coulee to Offset Reclamation Water Withdrawal Request
Adult Separator at the Lower Granite Dam Juvenile Bypass System (JBS)

BULL TROUT ACCESS TO PERCHED TRIBUTARIES IN KOOTENAI RIVER

Based on recent conversations with USFWS, the co-lead agencies are evaluating whether delta formations at tributaries of the Kootenai River may be causing upstream fish passage barriers to bull trout seeking spawning grounds during late spring and summer months. In 2021, the co-lead agencies would contribute funding for an initial assessment of blocked passage to bull trout key spawning tributaries identified by USFWS. Upon completion of the initial assessment, tributaries identified as having blocked passage would be prioritized based on biological effectiveness provided by passage of adult bull trout and feasibility of restoration actions that are unlikely to result in long-term operations and maintenance needs. The co-lead agencies would work with USFWS and cooperating agencies to complete the assessment and initiate two restoration or improvement projects benefitting upstream passage opportunities over the period of 2021–2026. Any additional improvement opportunities to benefit bull trout passage in Kootenai River tributaries would be evaluated based on biological priorities and available funding.

STUDY OFFSEASON SURFACE SPILL FOR DOWNSTREAM PASSAGE OF ADULT STEELHEAD (AND BULL TROUT)

Based on recent conversations with the NMFS, the Corps would continue to refine and implement a multi-year research study to determine the frequency, timing, and duration of off-season surface spill needed to effectively pass adult steelhead downstream of McNary Dam.

The co-lead agencies would assume that modifications to operations or structures designed to safely and effectively pass adult steelhead via surface spill would also benefit bull trout that are attempting to migrate downstream past McNary Dam.

- Pending results of the evaluation, the co-lead agencies would, in coordination with NMFS, USFWS, and the Fish Passage Operations and Maintenance (FPOM) workgroup, develop and implement an off-season surface spill operation at McNary Dam.
- The Corps would use existing information and, if warranted, targeted studies to determine whether other lower Columbia or lower Snake River dams should be considered for similar off- season surface spill operations. The co-lead agencies may also investigate potential structural modifications to spillway weirs that would allow reduced off-season spill volumes, while providing effective and safe passage of adult steelhead (and bull trout).
- For all actions and studies, steelhead, or in the case of hydroacoustic evaluations, steelhead-sized targets, would be used as surrogates for adult bull trout. The co-lead agencies would assume that modifications to operations or structures designed to safely and effectively pass adult steelhead via surface spill would also benefit adult bull trout.

MAINTENANCE IMPROVEMENTS TO LITTLE GOOSE DAM JETTY AND RETAINING WALL

The Corps would repair the existing jetty and retaining wall located near the north shore adult ladder entrance where erosion has occurred.

ENHANCED DEBRIS MANAGEMENT AT LOWER SNAKE RIVER DAMS AND MCNARY PROJECTS

Based on recent conversations with the NMFS, the Corps would continue to investigate potential operational or structural solutions for effective forebay debris management at McNary Dam and the lower Snake River dams. Seasonally, pulses of woody debris and vegetation (both aquatic and terrestrial) enter the Snake River and drift downstream. This debris can accumulate on turbine unit trash racks and enter bypass systems, and can injure ESA-listed salmonids. Woody debris causes considerable operations and maintenance challenges for dam operators. Corps personnel use trash rakes and other tools to remove debris from trash racks and gatewells. Air burst systems are used to flush debris from orifices that guide fish from gatewells into bypass systems. In recent years, Lower Granite Dam's removable spillway weirs (RSWs) have effectively passed large amounts of debris, increasing debris loads at downstream lower Snake River dams and McNary Dam. In response, the Corps, in coordination with NMFS and the FPOM workgroup, has begun to identify potential new operational or structural solutions for managing debris. Where necessary and feasible, the Corps would design and implement cost-effective solutions designed to minimize and reduce ESA-listed salmonid injury and mortality associated with debris accumulation.

INVESTIGATE SHAD DETERRENCE AT LOWER GRANITE DAM

The Corps would investigate the feasibility of deterring adult shad from approaching and entering the Lower Granite Dam adult fish trap, alleviating the need to remove shad from the trap while processing adult salmon and steelhead, and thereby reducing stress and delay for ESA-listed target species. Measures for consideration may include acoustic deterrents and operational changes, such as instituting plunging flows or blocking overflow weirs. If feasible, the Corps would implement operational or small-scale structural measures to address this issue. Any associated evaluations or changes in fishway operations or configurations would be coordinated with the appropriate regional coordination forums (e.g., FPOM).

REDUCE MORTALITY ASSOCIATED WITH DWORSHAK DAM TURBINE MAINTENANCE AND TESTING

To further minimize and avoid Snake River B-run steelhead injury and mortality, the Corps would continue to implement and improve protocols regarding Dworshak Dam turbine unit operation and maintenance and associated FPOM coordination, consistent with the 2019 FPP.

Adult Fish Ladder Temperature Differentials

The Corps would continue the following actions:

- Continue monitoring and reporting of all mainstem fish ladder temperatures and identify ladders that have substantial temperature differentials (>1.0°C).
- Where beneficial and feasible, develop and implement operational or structural solutions to address high temperatures and temperature differentials in adult fish ladders at mainstem lower Snake and Columbia River dams identified as having these problems.
- After development of a contingency plan by NMFS and state and tribal fish managers, complete a study that evaluates alternatives to assess the potential to trap-and-haul adult sockeye salmon at lower Snake River dams. The study would recommend the least-cost method to meet the goal and objectives of a contingency plan.
- The Corps would maintain or improve the adult trap at Ice Harbor Dam to allow for emergency trapping of adult salmonids as necessary. The Corps may refurbish the trap in the future to prepare for the implementation of emergency trap-and-haul activities (e.g., sockeye during high temperature water years similar to 2015).

ADJUST REFILL AT GRAND COULEE TO OFFSET RECLAMATION WATER WITHDRAWAL REQUEST

To reduce impacts from the *Lake Roosevelt Additional Water Supply* measure, when the water is withdrawn, Reclamation would adjust the refill target of the reservoir by up to 0.25 feet of stored water released downstream in the spring period. Without a decrease in the refill target elevation, downstream flows would decrease by the volume of the additional water supply delivery. This measure is not modeled as the changes to flows and elevations are very small; additionally, this would be implemented along with the water supply deliveries of this additional 45 thousand acre-feet (kaf).

ADULT SEPARATOR AT THE LOWER GRANITE DAM JUVENILE BYPASS SYSTEM (JBS)

The Corps would complete follow-on modifications to a new adult separator integrated into the Lower Granite Dam JBS to reduce delay, injury, and stress to salmon and steelhead, bull trout, and non-target species.

7.7 EFFECTS OF THE PREFERRED ALTERNATIVE

The environmental, economic, and social effects of the Preferred Alternative were evaluated following its initial development. The effects of the Preferred Alternative have been evaluated both quantitatively and qualitatively, depending on the resource. The effects analyses of the existing MOs detailed in Chapter 3 reflect the range of possible effects associated with the Preferred Alternative. The Final EIS may include updated information in response to public comment when it is published.

The Affected Environment described in Chapter 3 is still applicable for the Preferred Alternative. The alternatives were evaluated using the same scale of effects that was applied in Chapter 3. The changes are measured in relation to the No Action Alternative (No Action Alternative). The following same descriptors are used in this chapter to describe the level of effects:

- **No Effect**: The action would result in no effect as compared to the No Action Alternative.
- **Negligible Effect**: The effect would not change the resource character in a perceptible way. Negligible is defined as of such little consequence as to not require additional consideration or mitigation.
- **Minor Effect**: The effect to the resource would be perceptible; however, it may result in a small overall change in resource character.
- **Moderate Effect**: The effect to the resource would be perceptible and may result in an overall change in resource character.
- **Major Effect**: The effect to the resource would likely result in a large overall change in resource character.

The results of this evaluation are described below, and may reference comparatively similar effects as those modeled and described in Chapter 3.

7.7.1 Hydrology and Hydraulics

As the effects of the Preferred Alternative are presented, they will be displayed along with the No Action Alternative to illuminate the timing and magnitude of differences in water conditions between it and the No Action Alternative. The operational measure (or measures) from the Preferred Alternative which would result in changes from the No Action Alternative are identified to the extent that this is possible based on experience with system operation and hydroregulation modeling. However, because the measures were combined into an alternative that was then modeled, isolating the effect of a single measure would have is not possible in many cases.

7.7.1.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

LAKE KOOCANUSA (LIBBY DAM RESERVOIR) ELEVATION

Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures would have a direct effect on Libby Dam operations and reservoir elevations. Reservoir water levels in Lake Koocanusa would differ from the No Action Alternative, as shown in Figure 7-1.

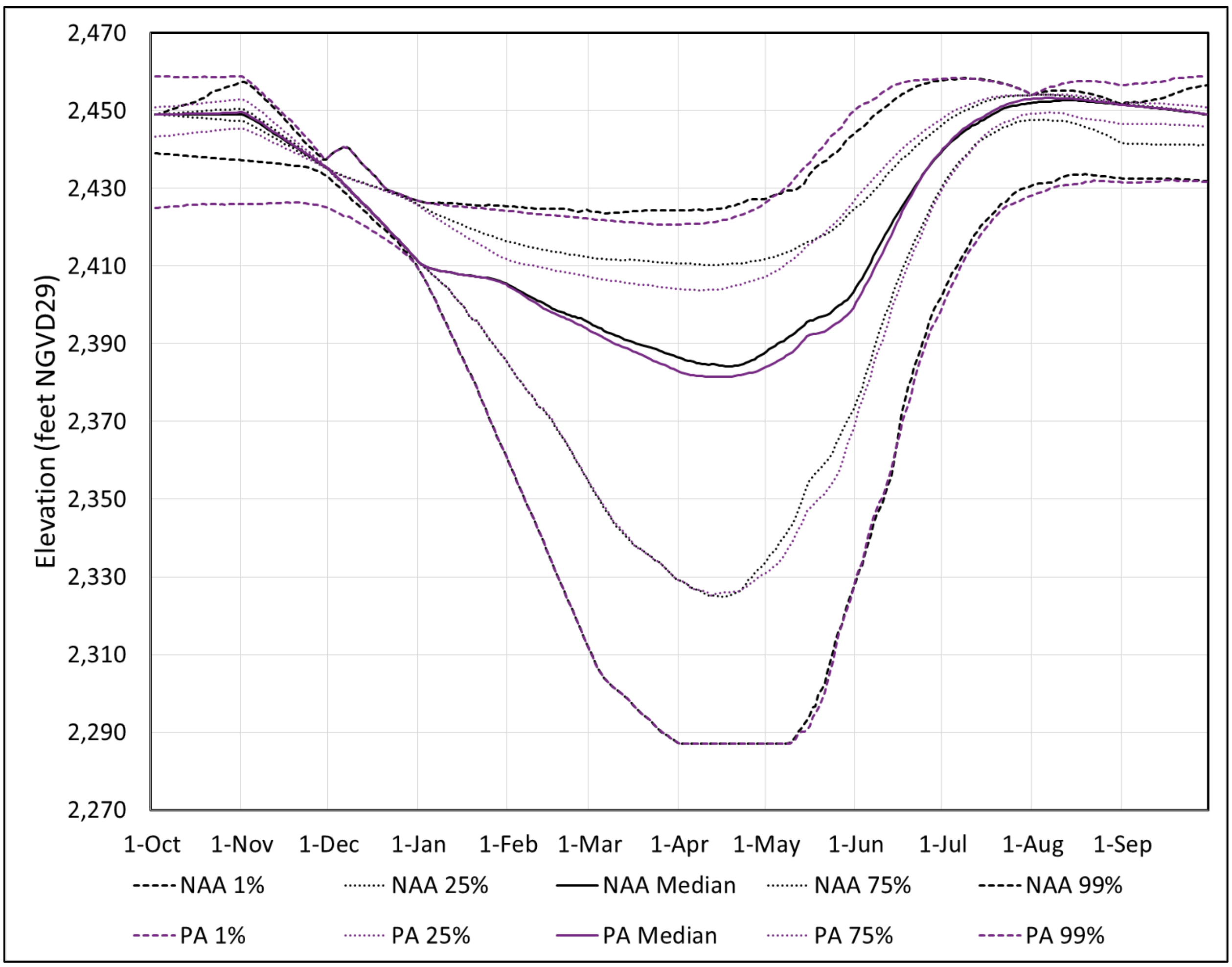

Figure 7-1. Lake Koocanusa Summary Hydrograph for the Preferred Alternative

The *Modified Draft at Libby* measure would begin influencing reservoir elevations after December 31, and its effects are best understood by looking at the spring, when the lowest reservoir elevation typically occurs. The *Modified Draft at Libby* measure causes the spring reservoir elevation to be lower than the No Action Alternative when the seasonal water supply forecast is less than 6.9 Maf at Libby Dam. The intent of the deeper draft is to help the reservoir warm faster in the spring so that warmer water will be available for flows to benefit Kootenai River White Sturgeon (the Sturgeon Pulse) that starts in mid-May.

The *Modified Draft at Libby* measure then adjusts the refill equations for all years, which results in increased likelihood of reservoir refill in all but the lowest 5 percent of years. The change in refill shaping is most notable prior to the Sturgeon Pulse, and then again after it. The Sturgeon Pulse shape and volume remain unchanged from the No Action Alternative, which starts in mid-May and continues through sometime in June depending on the required volume to be released.

For the Preferred Alternative, there would be a 4 percent increased chance of the reservoir reaching elevation 2,454 feet NGVD29 or higher (within 5 feet of the full pool elevation of 2,459 feet NGVD29) by July 31, as compared to the No Action Alternative. The peak reservoir elevation would usually be achieved in July or early August.

In August and September, the reservoir elevation for the Preferred Alternative would generally be about 1 to 4 feet higher than for the No Action Alternative. The reason for this is the *Modified Draft at Libby* measure, which tends to increase the peak refill elevation, and the *Sliding Scale at Libby and Hungry Horse* measure which calls for a sliding scale end-of-September target elevation that would be dependent on the Libby Dam water supply forecast, rather than the system-wide water supply forecast at The Dalles. The *Sliding Scale at Libby and Hungry Horse* measure targets a higher elevation than the No Action Alternative in the wettest 25 percent of years. These changes can carry over into October and November in some years.

Reservoir water levels in Lake Koocanusa under the Preferred Alternative would differ from the No Action Alternative to varying extents, depending on the water year type. Median hydrographs of the reservoir level for dry, average, and wet years are shown in Figure 7-2.

Finally, the three panels in Figure 7-3 show monthly elevation duration curves for July, August, and September, respectively. The curve for the Preferred Alternative is plotted along with the curve for the No Action Alternative in each month, showing that the reservoir level would be higher in each of the 3 months for the Preferred Alternative. In July, this is attributable to the *Modified Draft at Libby* measure, which tends to increase the peak refill elevation. In August the higher reservoir levels are attributable to a combination of the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures. In September, the higher reservoir levels are attributable to the *Sliding Scale at Libby and Hungry Horse* measure, which has fewer years drafting to 2,449 feet NGVD29 than the No Action Alternative (due to the change in forecast location), and many more years with elevations above 2,452 feet NGVD29 (described in Chapter 3) than the No Action Alternative.

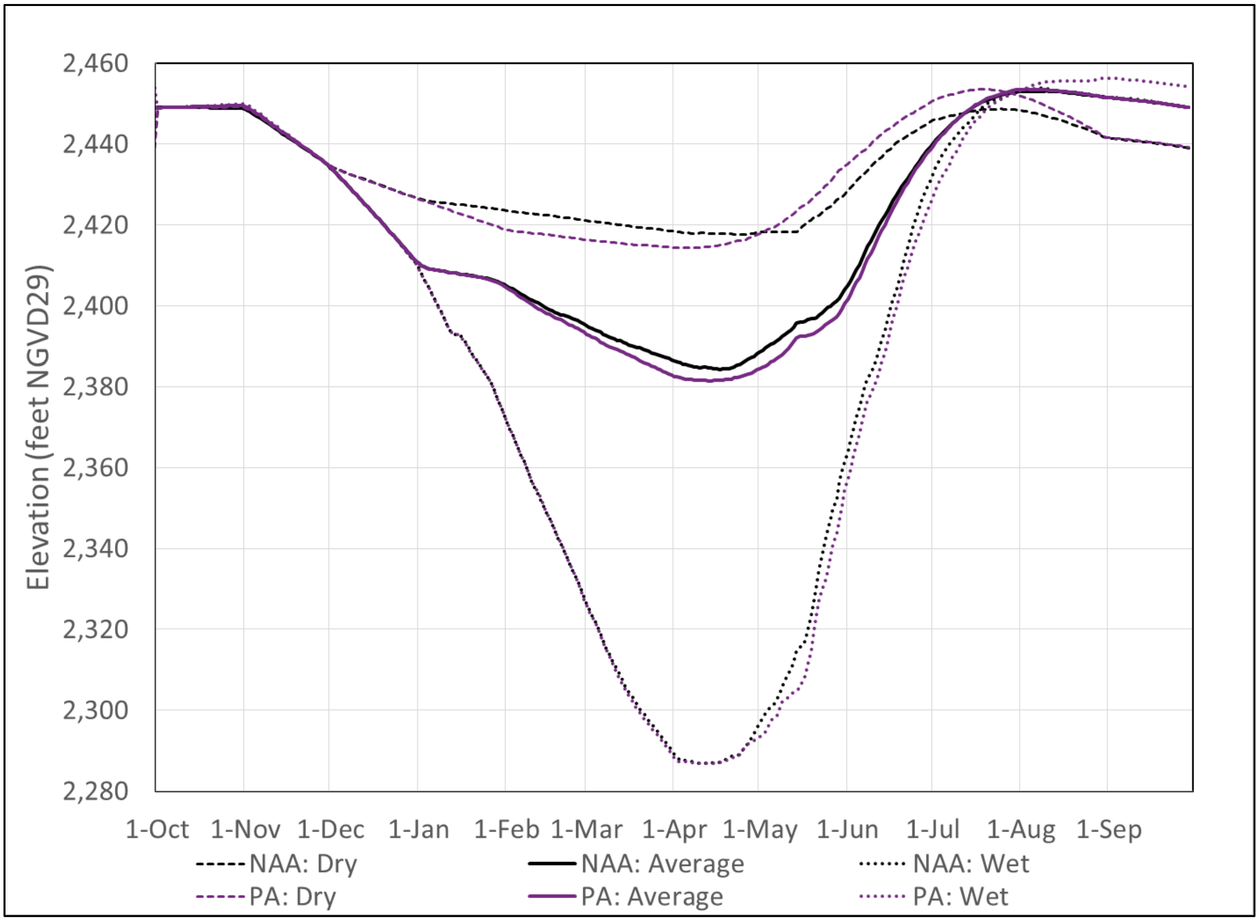

Figure 7-2. Lake Koocanusa Water Year Type Hydrographs for the Preferred Alternative

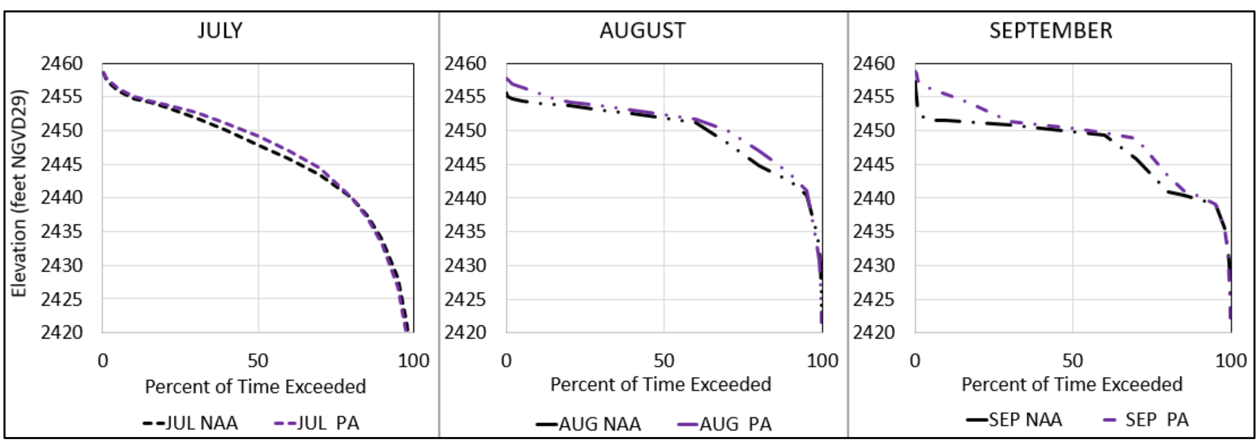

Figure 7-3. Lake Koocanusa Summer Elevations for the Preferred Alternative

Libby Dam Outflow

Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby* measures would have a direct effect on Libby Dam outflows. The outflows would differ from the No Action Alternative in a variety of ways throughout the year. Figure 7-4 shows median hydrographs for Libby Dam outflow in dry, average, and wet years. Notably, in dry years Libby releases lower flows in late April and May and higher flows in June, July and August and in wet years Libby releases higher flows in late April and lower flows in late June, July and August.

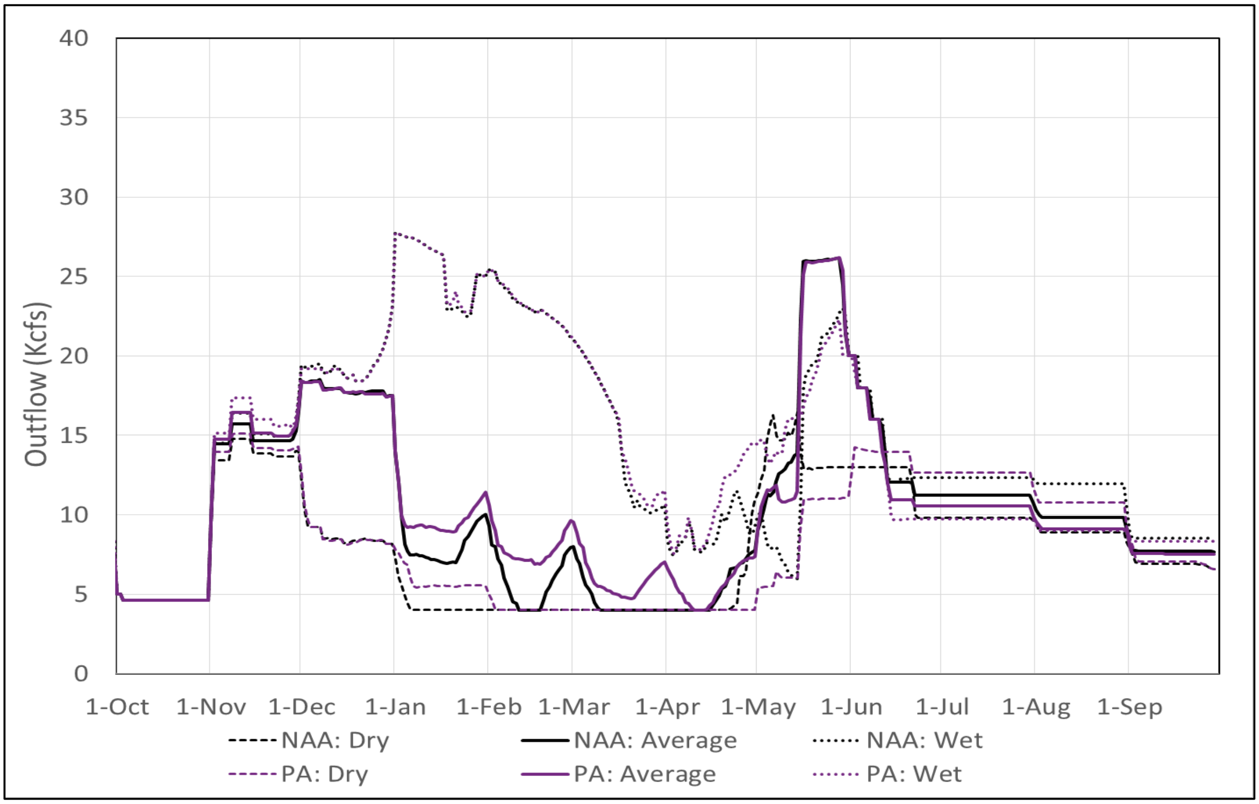

Figure 7-4. Libby Dam Outflow Water Year Type Hydrographs for the Preferred Alternative

The change in average monthly outflow throughout the water year is presented in Table 7-7. A range of exceedance percentiles is presented because in some months, the direction and magnitude of change varies depending on whether one looks at flows more likely to be exceeded (99 percent exceedance, 75 percent exceedance) or flows less likely to be exceeded (25 percent exceedance, 1 percent exceedance).

Table 7-7. Libby Dam Monthly Average Outflow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	4.9	23.5	22.0	27.1	25.8	23.0	20.8	22.7	22.6	22.9	17.8	12.0
		25%	4.7	16.2	18.9	18.3	20.0	12.2	9.9	19.2	17.1	14.3	12.1	8.8
		50%	4.7	14.3	17.7	8.8	6.3	5.5	7.0	16.4	14.2	11.5	10.3	7.9
		75%	4.7	12.0	9.9	5.6	4.0	4.0	4.4	14.0	12.9	9.0	9.0	6.8
		99%	4.7	7.0	8.2	4.3	4.0	4.0	4.0	11.6	8.8	7.1	7.1	6.0
Preferred Alternative	Change (kcfs)	1%	2.0	0.4	0.2	0.0	0.0	-0.4	-0.6	-0.6	0.7	0.2	-2.2	0.0
		25%	0.0	1.8	0.0	0.0	-0.2	0.2	0.6	0.0	-1.0	-0.2	-0.9	-0.1
		50%	0.0	0.4	0.1	1.6	1.6	1.0	-1.0	0.0	-0.7	-0.6	-0.9	-0.3
		75%	0.0	-0.4	0.1	0.7	0.5	0.0	-0.4	-2.1	-0.4	0.0	0.0	-0.4
		99%	0.0	-1.3	0.0	0.5	0.0	0.0	0.0	-5.0	1.3	0.9	0.7	0.1
	Percent change	1%	40%	2%	1%	0%	0%	-2%	-3%	-2%	3%	1%	-12%	0%
		25%	0%	11%	0%	0%	-1%	2%	6%	0%	-6%	-2%	-8%	-1%
		50%	0%	3%	0%	19%	26%	18%	-14%	0%	-5%	-5%	-8%	-4%
		75%	0%	-3%	1%	13%	13%	0%	-9%	-15%	-3%	0%	0%	-5%
		99%	0%	-19%	-1%	11%	0%	0%	0%	-43%	14%	12%	9%	1%

Note: Ave. = average; mo. = monthly. Values for the No Action Alternative are shaded gray. Orange shading denotes Preferred Alternative flows that are lower than the No Action Alternative flows; green shading denotes Preferred Alternative flows that are higher than the No Action Alternative flows.

Monthly average outflow from Libby Dam increased in January, February, and March in typical to dry years, followed by a reduction in outflow in April and May as refill begins. These changes are all caused by the *Modified Draft at Libby* measure. The Sturgeon Pulse volume and shape remain unchanged from the No Action Alternative, which happens in all but the 20 percent driest years. The reduction in outflows in those years happens prior to the mid-May start of the Sturgeon Pulse. The Sturgeon Pulse continues through sometime in June depending on the water supply forecast. In dry years, the summer outflows can be 2 to 3 kcfs higher compared to the No Action Alternative due to the higher refill elevations resulting from the *Modified Draft at Libby* measure. After the annual Sturgeon Pulse is completed, changes in outflow occur as a result of the *Sliding Scale at Libby and Hungry Horse* and *Modified Draft at Libby* measures. The *Sliding Scale at Libby and Hungry Horse* measure calls for a higher end-of-September target elevation in the wettest 25 percent of years based on the Libby Dam water supply forecast.

Bonners Ferry Flow

Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures would affect flows at Bonners Ferry. In general, the flows would differ from the No Action Alternative in much the same way as at Libby Dam, albeit to a smaller degree due to dilution effects of major tributaries downstream of the dam. The reason for the changes seen at Bonners Ferry are the same as those described for Libby Dam outflow. The change in average monthly flow at Bonners Ferry throughout the water year is presented in Table 7-8.

Table 7-8. Bonners Ferry Monthly Average Flow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	9.0	26.6	29.2	31.3	29.7	27.5	30.4	40.8	40.7	27.2	19.0	13.3
		25%	6.1	18.1	20.7	21.0	23.2	15.3	19.4	34.3	27.8	17.3	13.3	9.7
		50%	5.6	15.4	18.9	10.4	8.5	8.4	14.6	31.1	23.8	14.6	11.4	8.6
		75%	5.4	13.0	11.4	6.5	5.1	5.9	10.2	27.6	20.3	11.8	9.9	7.4
		99%	5.1	7.7	9.0	5.1	4.5	4.9	7.0	18.3	12.6	9.0	8.1	6.7
Preferred Alternative	Change (kcfs)	1%	0.7	0.6	0.0	0.0	0.0	0.1	2.8	1.3	1.0	-0.4	-2.6	0.3
		25%	0.0	1.7	0.0	-0.1	-0.3	0.3	0.4	0.3	-1.0	-0.8	-0.9	-0.1
		50%	0.0	0.6	-0.1	1.5	1.3	1.0	-0.7	0.0	-0.5	-0.4	-0.8	-0.4
		75%	0.0	-0.2	0.0	1.1	0.6	0.3	-0.3	-3.7	-0.4	0.1	0.0	-0.2
		99%	0.0	-0.9	-0.1	0.5	0.1	0.0	0.0	-3.8	1.1	0.4	0.3	-0.1
	Percent change	1%	8%	2%	0%	0%	0%	0%	9%	3%	2%	-2%	-13%	2%
		25%	0%	9%	0%	-1%	-1%	2%	2%	1%	-4%	-5%	-7%	-1%
		50%	0%	4%	-1%	14%	16%	12%	-5%	0%	-2%	-3%	-7%	-4%
		75%	0%	-1%	0%	16%	11%	5%	-3%	-13%	-2%	1%	0%	-3%
		99%	0%	-11%	-1%	10%	2%	0%	0%	-21%	9%	5%	4%	-1%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

Hungry Horse Reservoir Elevation

Under the Preferred Alternative, the *Sliding Scale at Libby and Hungry Horse* measure would have a direct effect on Hungry Horse Dam operations and reservoir elevations. Reservoir water levels would differ from the No Action Alternative, as shown in Figure 7-5.

The *Sliding Scale at Libby and Hungry Horse* measure reduces the draft requirements in some years by setting a higher elevation target for summer flow augmentation than the No Action Alternative. As a result, reservoir levels could be several feet higher than those under the No Action Alternative in the summer and into the fall months in low water level years. In most years, reservoir levels would be drafted slightly less deep (less than a foot) compared to the No Action Alternative for most of the year.

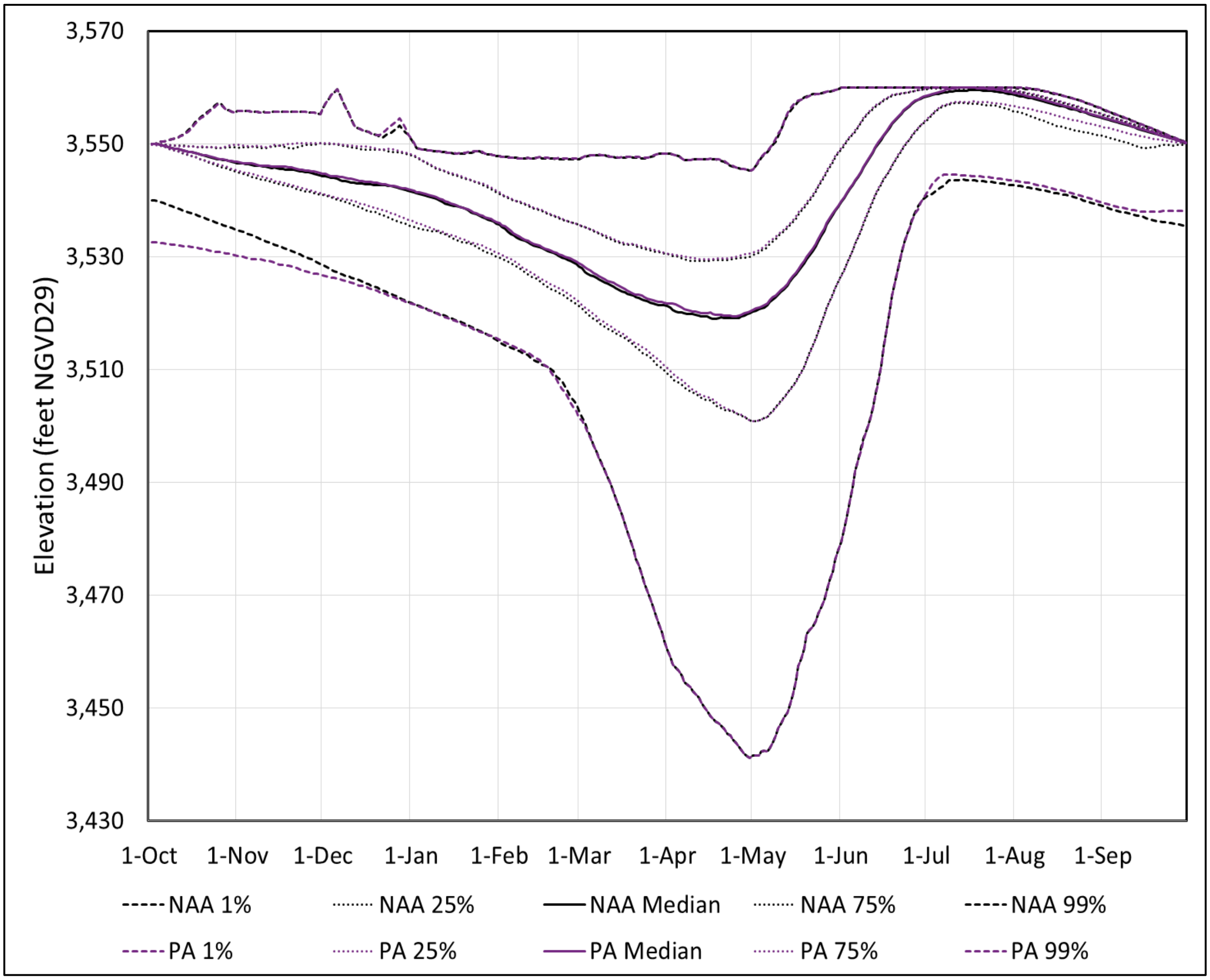

Figure 7-5. Hungry Horse Reservoir Summary Hydrograph for the Preferred Alternative

Hungry Horse Dam Outflow

Under the Preferred Alternative, the *Sliding Scale at Libby and Hungry Horse* measure would have a direct effect on Hungry Horse Dam outflows. The outflows would differ from the No Action Alternative depending on the time of year. Figure 7-6 shows median hydrographs for Hungry Horse Dam outflow in dry, average, and wet years. The change in average monthly outflow from Hungry Horse Dam throughout the water year is presented in Table 7-9.

Average outflow from Hungry Horse Dam would differ from the No Action Alternative:

- In July, August, and September, the monthly average outflow would decrease as compared to the No Action Alternative by less than 100cfs in most years.
- After September and through the spring, the median monthly average outflow would generally be slightly higher (up to 1 percent) compared to the No Action Alternative. The higher outflows would occur because the reservoir would be higher at the end of September than under the No Action Alternative.

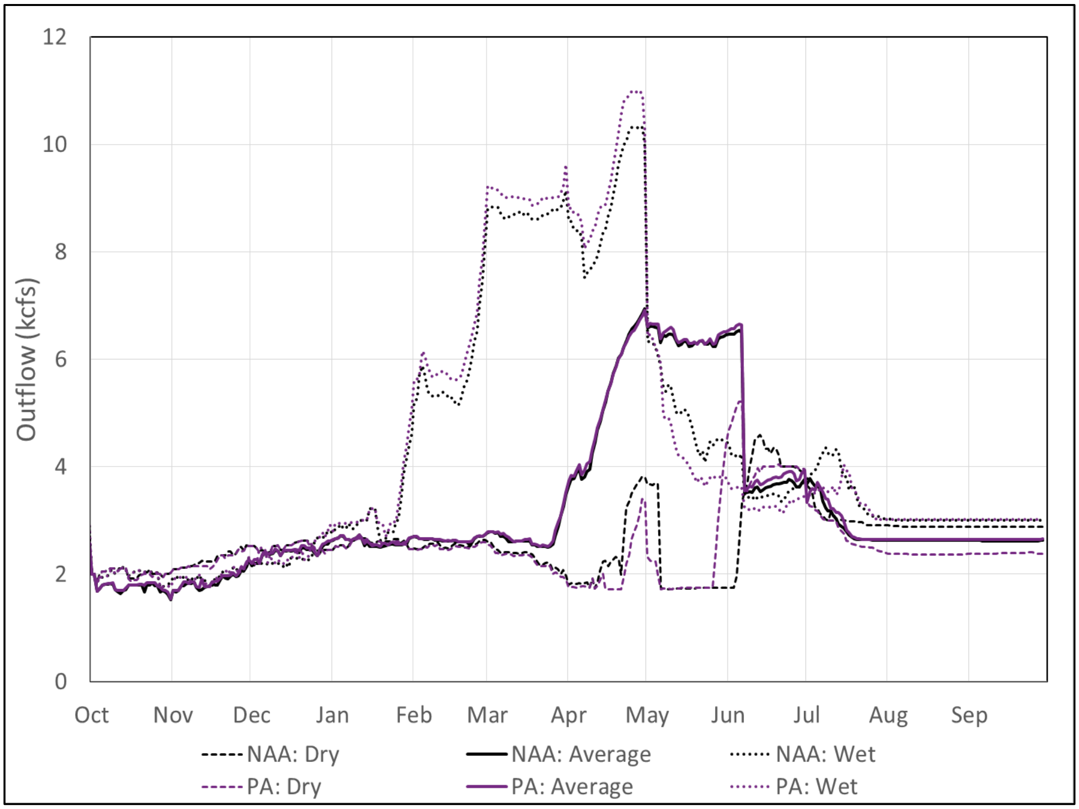

Figure 7-6. Hungry Horse Dam Outflow Water Year Type Hydrographs for the Preferred Alternative

Table 7-9. Hungry Horse Dam Monthly Average Outflow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	2.5	4.7	6.9	7.1	11.5	14.5	15.6	9.6	10.7	6.9	4.4	4.4
		25%	2.2	2.4	2.7	3.1	4.0	5.7	8.1	7.0	6.1	4.2	3.1	3.1
		50%	1.9	2.0	2.4	2.6	2.7	2.7	5.4	5.7	4.3	3.4	2.7	2.7
		75%	1.4	1.4	2.1	2.3	2.4	2.2	3.1	4.1	3.2	2.6	2.4	2.4
		99%	0.8	0.8	1.6	2.0	1.7	1.5	1.7	1.7	1.7	1.8	1.9	2.0
Preferred Alternative	Change (kcfs)	1%	0.0	-0.3	0.0	-0.1	0.1	0.0	0.0	0.0	0.0	-0.1	-0.7	-0.7
		25%	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
		50%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
		75%	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.1	0.0	0.0
		99%	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
	Percent change	1%	0%	-7%	0%	-1%	1%	0%	0%	0%	0%	-1%	-15%	-15%
		25%	0%	0%	1%	2%	2%	1%	0%	1%	1%	-3%	-3%	-3%
		50%	0%	1%	0%	1%	0%	0%	1%	1%	1%	-5%	-1%	-1%
		75%	0%	0%	0%	1%	0%	0%	2%	1%	0%	-3%	-2%	-1%
		99%	0%	1%	3%	1%	1%	0%	0%	0%	0%	-3%	-5%	-7%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

Columbia Falls Flow

Under the Preferred Alternative, the *Sliding Scale at Libby and Hungry Horse* measure would affect flows at Columbia Falls. Compared to the No Action Alternative, there would be decreased flow in July, August, and September in some years, while the other months of the year would have flows similar to or slightly higher than those under the No Action Alternative, while still meeting minimum flow requirements. The change in average monthly flow at Columbia Falls throughout the water year, as compared to the No Action Alternative, is presented in Table 7-10.

Table 7-10. Columbia Falls Monthly Average Flow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	8.9	14.4	14.8	11.0	14.2	17.4	30.5	38.0	43.2	23.9	8.8	8.7
		25%	4.0	4.2	4.5	5.0	5.8	7.9	15.9	29.7	31.5	15.1	6.9	5.4
		50%	3.8	3.7	3.7	3.8	3.8	4.5	12.3	25.5	24.8	11.5	5.8	4.7
		75%	3.6	3.6	3.6	3.6	3.6	3.7	8.5	21.4	20.0	8.4	4.9	4.2
		99%	3.5	3.5	3.5	3.5	3.5	3.5	5.4	15.7	12.4	5.5	3.9	3.6
Preferred Alternative	Change (kcfs)	1%	0.0	-0.3	0.0	-0.2	0.2	0.0	0.0	0.0	-0.2	-0.1	0.0	-0.7
		25%	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
		50%	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.1	-0.1	-0.1
		75%	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.2	-0.2	-0.1
		99%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1
	Percent change	1%	0%	-2%	0%	-2%	1%	0%	0%	0%	0%	0%	0%	-8%
		25%	0%	0%	3%	1%	1%	1%	0%	0%	0%	0%	-1%	0%
		50%	0%	0%	0%	1%	1%	1%	1%	0%	0%	-1%	-2%	-1%
		75%	0%	0%	0%	0%	0%	0%	1%	0%	0%	-2%	-5%	-3%
		99%	0%	0%	0%	0%	0%	0%	1%	0%	0%	-1%	-5%	-3%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

Lake Pend Oreille Elevation

While the *Sliding Scale at Libby and Hungry Horse* measure in the Preferred Alternative would affect Hungry Horse Dam operations, the changes would not impact annual peak reservoir levels in Lake Pend Oreille, nor would they impact the timing of refill or drawdown. Thus, there would not be any noticeable difference in the level of Lake Pend Oreille as compared to the No Action Alternative.

Albeni Falls Outflow

Under the Preferred Alternative, the *Sliding Scale at Libby and Hungry Horse* measure would affect the monthly average outflow from Albeni Falls Dam, but to a lesser degree than at

Hungry Horse Dam or Columbia Falls. In the summer months, the monthly average outflow from Albeni Falls Dam under the Preferred Alternative would be similar to the No Action Alternative in higher flow years and up to several hundred cfs lower in lower water years. The changes in median monthly average flows are shown in Table 7-11.

Table 7-11. Pend Oreille Basin Median Monthly Average Flows for the Preferred Alternative (as change from No Action Alternative)

	Location	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative (kcfs)	Hungry Horse	1.9	2.0	2.4	2.6	2.7	2.7	5.4	5.7	4.3	3.4	2.7	2.7
	Columbia Falls, MT	3.8	3.7	3.7	3.8	3.8	4.5	12.3	25.5	24.8	11.5	5.8	4.7
	Albeni Falls	23.7	16.7	15.3	14.5	16.6	19.8	25.2	50.7	55.6	27.4	12.0	13.7
Change (kcfs)	Hungry Horse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
	Columbia Falls, MT	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.1	-0.1	-0.1
	Albeni Falls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2
Percent Change	Hungry Horse	0%	1%	0%	1%	0%	0%	1%	1%	1%	-5%	-1%	-1%
	Columbia Falls, MT	0%	0%	0%	1%	1%	1%	1%	0%	0%	-1%	-2%	-1%
	Albeni Falls	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	-2%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

REGION B – GRAND COULEE AND CHIEF JOSEPH DAMS

Columbia River flow upstream of Grand Coulee Dam

Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures from Region A would affect Columbia River flow upstream of Grand Coulee Dam. The flows are depicted in Figure 7-7, which shows flows near RM 748 (just downstream of the U.S.-Canada border, about 151 river miles upstream of Grand Coulee Dam).

Figure 7-7 characterizes the timing and magnitude of flow changes between the No Action Alternative and the Preferred Alternative due to the combined effect of measures at Libby Dam and Hungry Horse Dam. A majority of these changes in winter and spring months is due to the *Modified Draft at Libby* measure. Changes in Lake Roosevelt inflow between Preferred Alternative and the No Action Alternative are small, typically within 1 percent, with increases being more prevalent in the winter months and decreases occurring in the spring and summer months. However, as discussed in the Grand Coulee Dam Outflow section, the change in upstream flow accounts for much of the change seen in the Grand Coulee outflow.

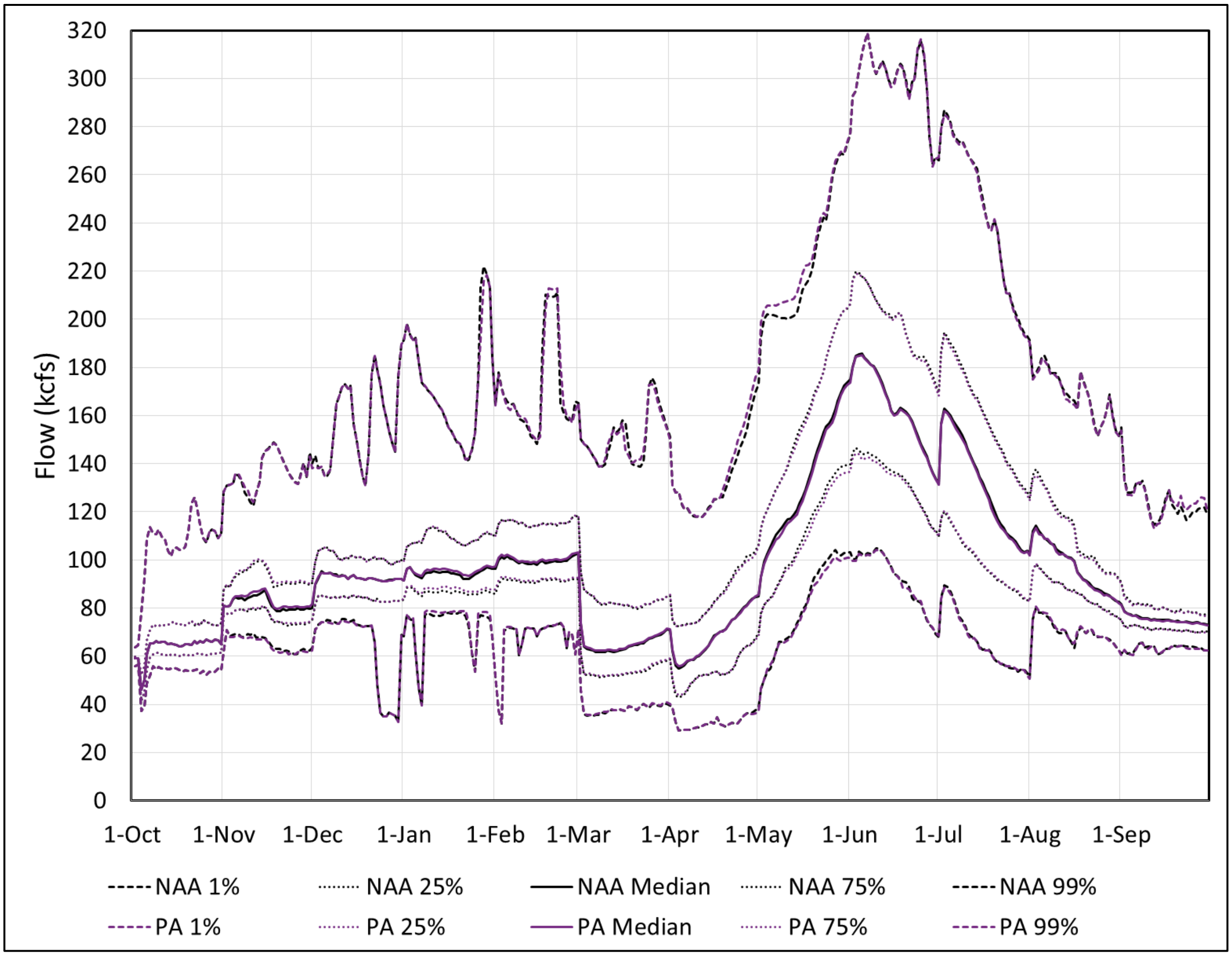

Figure 7-7. Lake Roosevelt Inflow Summary Hydrograph for the Preferred Alternative

Lake Roosevelt (Grand Coulee Dam Reservoir) Elevation

Under the Preferred Alternative, the *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, F*all Operational Flexibility for Hydropower (Grand Coulee)*, and *Lake Roosevelt Additional Water Supply* measures relate directly to Grand Coulee Dam, and all of these (with the exception of *Lake Roosevelt Additional Water Supply*) would influence reservoir elevations at Lake Roosevelt. Although not modeled, the A*djust Refill at Grand Coulee to Offset Reclamation Water Withdrawal Request* mitigation measure to adjust the refill elevation would have minor effects to reservoir elevations (maximum impact would be 0.25 feet). Operational changes in Region A upstream may also have a slight effect on Lake Roosevelt water levels. The *Grand Coulee Maintenance Operations* measure would not impact reservoir elevations or total outflows, but would affect power generation, frequency of spill, and water quality. Reservoir water levels in Lake Roosevelt under the Preferred Alternative would differ from the No Action Alternative, as shown in Figure 7-8.

The *Planned Draft Rate at Grand Coulee* measure under the Preferred Alternative calls for earlier deeper drafts for years with larger water supply forecast. It does this by decreasing the daily draft rate in planning drawdown to the deepest draft point so that the reservoir has to start drafting sooner in the winter, but can draft less each day than it would under the No Action Alternative. This causes the lower reservoir levels in January and February in wet years. The median Preferred Alternative elevation is about 5 feet lower at the end of February than the No Action Alternative in the wettest 20 percent of years. The *Planned Draft Rate at Grand Coulee* does not change the deepest draft of the season values. The deepest draft point of the season may change either due to change in the start of refill timing or the *Update System FRM Calculation* measure, which adjusts the Grand Coulee elevation to account for storage space within the system. The *Update System FRM Calculation* can cause the Preferred Alternative elevation to be slightly different than the No Action Alternative in April and May.

Median reservoir levels under the Preferred Alternative are about a half foot lower compared to No Action Alternative in September and October due to the *Fall Operational Flexibility for Hydropower (Grand Coulee)* measure. The end of September elevation is below 1,283 feet in approximately 40 percent of years; and in October the elevation is projected to be below 1,283 feet in approximately 10 percent of the days.

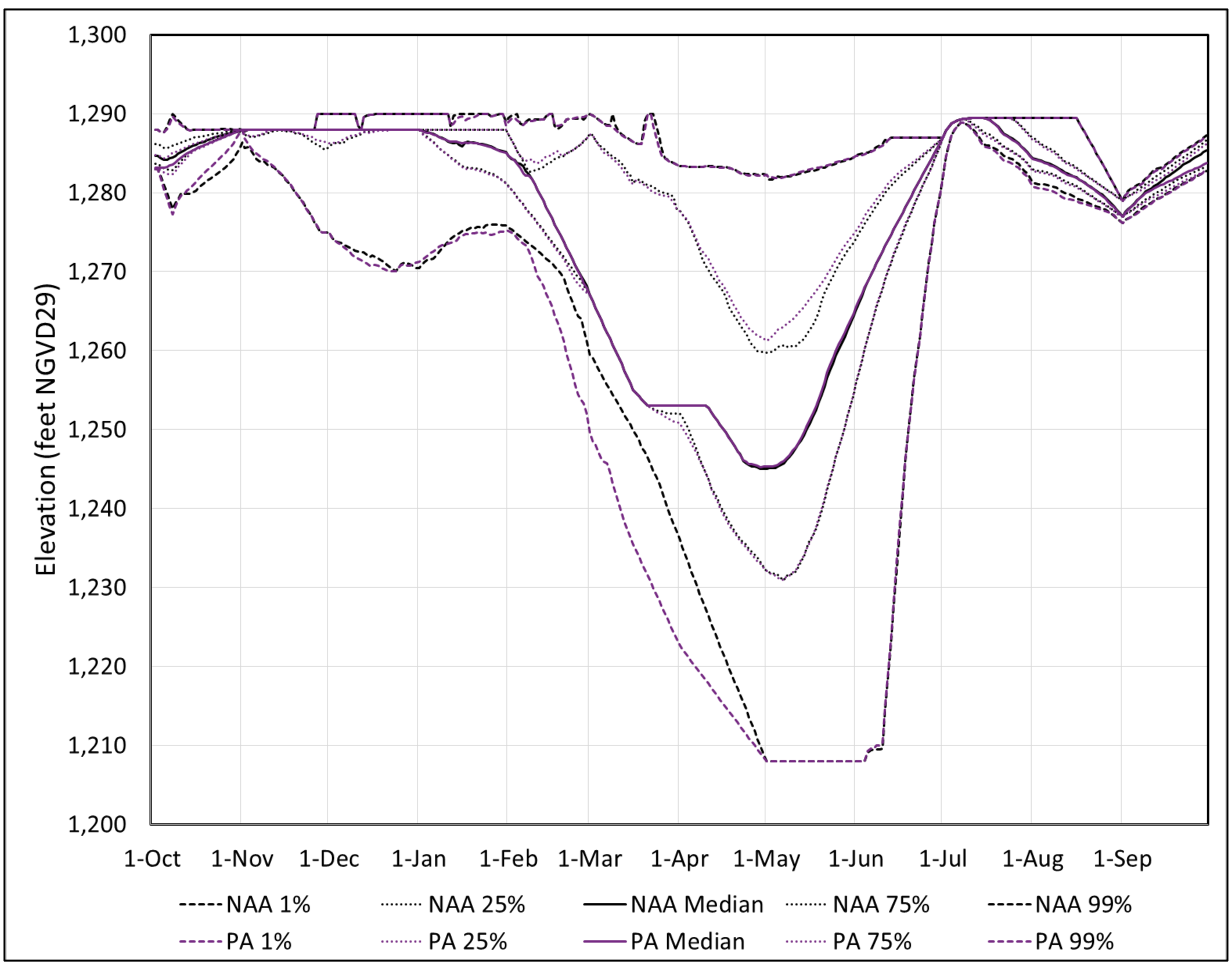

Figure 7-8. Lake Roosevelt Summary Hydrograph for the Preferred Alternative

For the No Action Alternative, the reservoir was modeled to be at or above 1,283 feet by the end of September each year; however, during dry years this may not be possible to meet all operational objectives. Finally, Figure 7-9 shows median hydrographs for Lake Roosevelt in dry, average, and wet years. The figure provides another way to picture the effects described above, this time categorized by water year type.

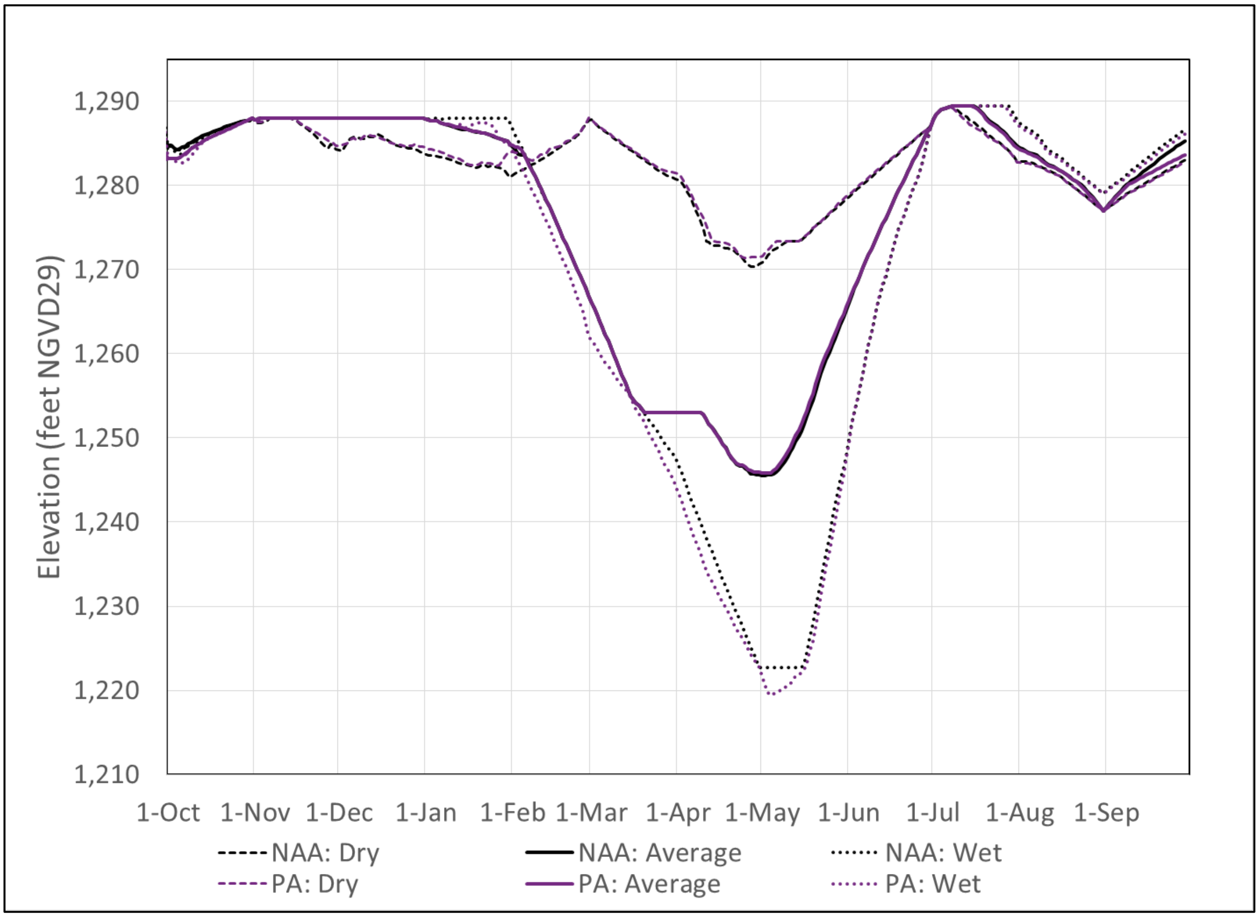

Figure 7-9. Lake Roosevelt Water Year Type Hydrographs for the Preferred Alternative

Grand Coulee Dam Drum Gate Maintenance

Under the Preferred Alternative, the *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, and *Fall Operational Flexibility for Hydropower (Grand Coulee)* measures would influence reservoir elevations during spring months. The *Grand Coulee Maintenance Operations* measure would not impact reservoir elevations or total outflows, but would affect power generation, frequency of spill, and water quality. The ability to perform some inspection and maintenance has a direct link to Lake Roosevelt water levels, requiring water levels to be at or below critical elevations for a certain period of time. Drum gate maintenance at Grand Coulee Dam is planned to occur annually during March, April, and May, but is not conducted in all years. The reservoir must be at or below elevation 1,255 feet NGVD29 for 8 weeks to complete drum gate maintenance. In addition to the annual drum gate maintenance, an annual inspection and maintenance activity is planned for the 57-inch butterfly drum gate intake valves in late April or early May. The external inspection and maintenance requires water levels at or below 1,219 feet NGVD29. This inspection and maintenance must occur once every 10 years.

The changes in elevations for the Preferred Alternative that influence the decision to conduct drum gate maintenance would not change substantially relative to the No Action Alternative(April 30 FRM elevation targets and drum gate initiation methodology is discussed in more detail in Part 1 of Appendix B). The decision to conduct drum gate maintenance is based on the February water supply forecast and the resulting April 30 FRM elevation projection (April 30 flood risk management elevation target at or below 1,255 or 1,265 feet NGVD29 depending on how recently the maintenance has been conducted.) In both the Preferred Alternative and the No Action Alternative, drum gate maintenance would be achievable in 65 percent of the years; maintenance for the 57-inch butterfly drum gate intake valves would be achievable in 8 to 13 percent of years (corresponding to elevation 1,219 and 1,222.7 feet NGVD29).

Grand Coulee Dam Outflow

Under the Preferred Alternative, the *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, *Fall Operational Flexibility for Hydropower (Grand Coulee)*, and *Lake Roosevelt Additional Water Supply*[7] measures would directly affect outflows from Grand Coulee Dam. In addition, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures from Region A upstream would affect inflows and outflows at Grand Coulee Dam.

The outflows from Grand Coulee Dam would differ from the No Action Alternative depending on the time of year, as seen in Figure 7-10. The change in average monthly outflow throughout the water year is presented in Table 7-12.

In almost every month of the year, the outflow from Grand Coulee Dam under the Preferred Alternative would differ from the No Action Alternative due to various measures at Grand Coulee Dam and in Region A upstream. However, these changes are relatively small, with median monthly average flows typically within 1 percent of those under the No Action Alternative. A more detailed description is provided below for completeness, and attempts are made to identify individual measures responsible for specific changes wherever possible:

- Increases in January and February outflow (typically less than 1 percent) are largely attributed to the increase in outflow released from Libby Dam as a result of the *Modified Draft at Libby* measure. The *Update System FRM Calculation* and *Planned Draft Rate at Grand Coulee* measures also contribute to this increase in larger forecast years.
- In the early spring, a reduction in Grand Coulee outflow is expected, especially in April where the median decrease in outflow is 1.6 kcfs (-2 percent). This is partially attributed to the earlier drafts linked to the *Planned Draft Rate at Grand Coulee* and *Update System FRM*

[7] The *Lake Roosevelt Additional Water Supply* measure in this Preferred Alternative calls for an increased volume of 45 kaf to be pumped from Lake Roosevelt into Banks Lake. This is a notably smaller volume than that described in Chapter 2 and modeled under the various MOs.

Calculation measures. Some of these flow decreases would be reduced due to the measure to *Adjust Refill at Grand Coulee to Offset Reclamation Water Withdrawal Request*, which is not modeled.

- May through August, outflow continues to be lower in most years. This is due to the combined effect of the *Modified Draft at Libby, Sliding Scale at Libby and Hungry Horse,* and *Lake Roosevelt Additional Water Supply* measures. The change in median monthly average flow ranges from -0.3 kcfs to -1.8 kcfs. Although some of these flow decreases would be reduced due to the *Adjust Refill at Grand Coulee to Offset Reclamation Water Withdrawal Request*.

Figure 7-11 shows median hydrographs for Grand Coulee Dam outflow in dry, average, and wet years. The figure provides another way to picture the effects described above, this time categorized by water year type.

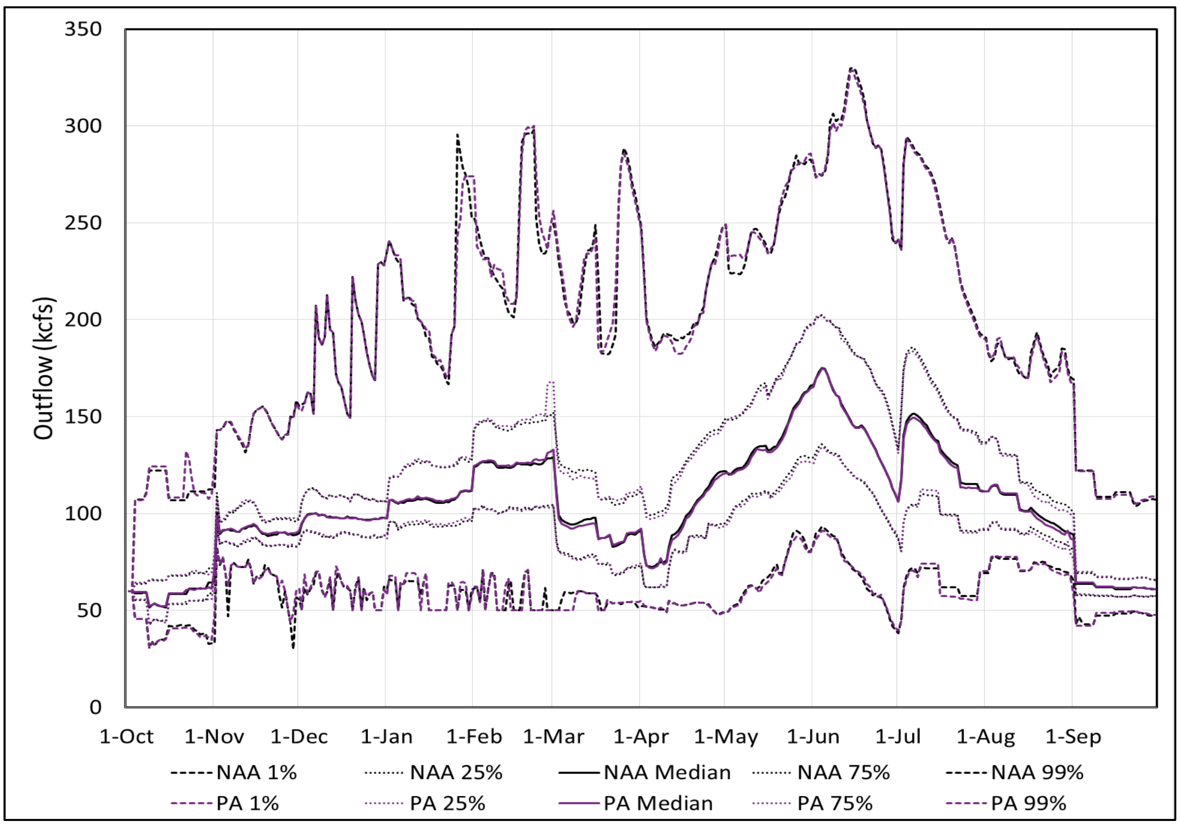

Figure 7-10. Grand Coulee Dam Outflow Summary Hydrograph for the Preferred Alternative

Table 7-12. Grand Coulee Dam Monthly Average Outflow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	94	130	174	190	213	186	191	231	275	247	175	111
		25%	67	99	109	124	147	117	120	165	181	158	118	68
		50%	59	91	97	108	126	93	97	138	150	134	102	63
		75%	54	84	88	96	105	78	79	118	121	98	92	59
		99%	49	78	79	76	81	66	60	97	91	81	81	53
Preferred Alternative	Change (kcfs)	1%	0.8	0.7	0.0	1.3	8.8	0.8	-6.9	-0.8	2.0	-1.5	-1.8	-0.5
		25%	0.1	0.6	0.0	0.5	1.8	-0.4	-1.8	-1.5	-0.3	-1.5	-2.4	0.4
		50%	0.4	0.3	-0.1	0.5	1.6	-0.4	-1.6	-1.0	-0.3	-1.8	-0.9	0.0
		75%	0.2	0.6	0.1	1.1	-0.6	-0.1	0.0	-1.3	-0.3	-0.3	-0.6	0.2
		99%	0.4	0.6	0.5	1.6	0.0	0.1	0.3	-3.0	0.8	0.3	-0.5	0.3
	Percent change	1%	1%	1%	0%	1%	4%	0%	-4%	0%	1%	-1%	-1%	0%
		25%	0%	1%	0%	0%	1%	0%	-1%	-1%	0%	-1%	-2%	1%
		50%	1%	0%	0%	0%	1%	0%	-2%	-1%	0%	-1%	-1%	0%
		75%	0%	1%	0%	1%	-1%	0%	0%	-1%	0%	0%	-1%	0%
		99%	1%	1%	1%	2%	0%	0%	1%	-3%	1%	0%	-1%	1%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes Preferred Alternative flows higher than the No Action Alternative flows.

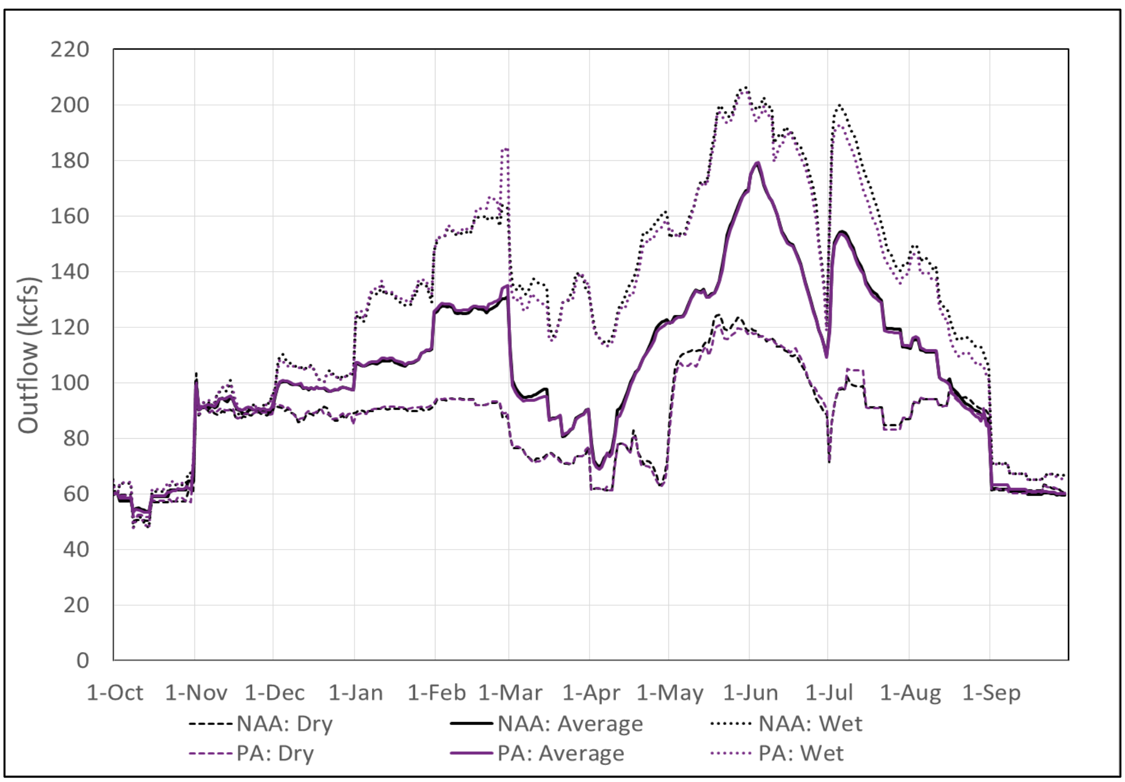

Figure 7-11. Grand Coulee Dam Outflow Water Year Type Hydrographs for the Preferred Alternative

Under the Preferred Alternative, the pattern of flow changes from Grand Coulee Dam outflow would continue through the middle Columbia River. Table 7-13 shows changes in the median values of monthly average flows for Lake Roosevelt Inflow, Grand Coulee Dam outflow, and other dam outflow locations downstream in Region B.

Table 7-13. Middle Columbia River Monthly Average Flows for the Preferred Alternative (as change from No Action Alternative)

	Location	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative (kcfs)	Lake Roosevelt Inflow	64	82	92	95	100	65	69	131	166	133	98	75
	Grand Coulee	59	91	97	108	126	93	97	138	150	134	102	63
	Chief Joseph	58	91	96	108	127	94	98	139	150	135	103	63
	Wells	59	93	98	110	129	95	101	150	163	141	105	65
	Priest Rapids	60	96	102	115	133	100	108	162	178	147	108	68
Change (kcfs)	Lake Roosevelt Inflow	0.0	1.3	0.0	0.6	0.9	0.4	-0.7	-1.2	-0.2	-1.0	-0.6	-0.2
	Grand Coulee	0.4	0.3	-0.1	0.5	1.6	-0.4	-1.6	-1.0	-0.3	-1.8	-0.9	0.0
	Chief Joseph	0.3	0.4	0.1	0.6	1.4	-0.6	-1.4	-1.4	-0.4	-1.9	-0.5	0.1
	Wells	0.1	0.3	0.0	0.6	1.5	-0.4	-1.3	-1.9	-0.3	-2.2	-0.5	0.0
	Priest Rapids	0.3	0.3	0.1	0.5	1.3	-0.2	-1.3	-1.7	0.0	-1.9	-0.6	0.0
Percent Change	Lake Roosevelt Inflow	0%	2%	0%	1%	1%	1%	-1%	-1%	0%	-1%	-1%	0%
	Grand Coulee	1%	0%	0%	0%	1%	0%	-2%	-1%	0%	-1%	-1%	0%
	Chief Joseph	0%	0%	0%	1%	1%	-1%	-1%	-1%	0%	-1%	-1%	0%
	Wells	0%	0%	0%	1%	1%	0%	-1%	-1%	0%	-2%	-1%	0%
	Priest Rapids	0%	0%	0%	0%	1%	0%	-1%	-1%	0%	-1%	-1%	0%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

REGION C – DWORSHAK, LOWER GRANITE, LITTLE GOOSE, LOWER MONUMENTAL, AND ICE HARBOR DAMS

Dworshak Reservoir Elevation

Under the Preferred Alternative, the *Slightly Deeper Draft for Hydropower at Dworshak* measure would have a direct effect on Dworshak Dam operations and reservoir elevations. Water levels would differ from the No Action Alternative, as shown in Figure 7-12.

In the Preferred Alternative, the *Slightly Deeper Draft for Hydropower at Dworshak* measure would allow for additional hydropower generation and hydropower flexibility by drafting the reservoir to elevations lower than what is required for FRM purposes. This measure would result in lower water levels than the No Action Alternative in larger forecast years in the months January, February, and March, and then similar water levels for the rest of the year.

After no changes through December, the reservoir would start to be drafted deeper in January in about 60 percent of years. Generally, the larger the forecasted runoff volume, the deeper the draft, and the greater the change from the No Action Alternative. January 31 water levels would be lower than No Action Alternative by 10 feet or more in the wettest 10 percent of years, and 20 feet or more in the wettest 5 percent of years. By the end of February, only the wettest 10 percent of years would have deeper drafts than the No Action Alternative, but the difference could exceed 30 feet. By the end of March, reservoir levels are effectively the same as the No Action Alternative, typically less than a foot lower. There is no change in refill probability under the Preferred Alternative. Similar to the No Action Alternative, the drawdown of Dworshak Reservoir over the summer months to provide cool water to the lower Snake River, provide flows for salmon migration, and meet the flows per the Agreement between the U.S. and the Nez Perce Tribe would continue unchanged from current operations.

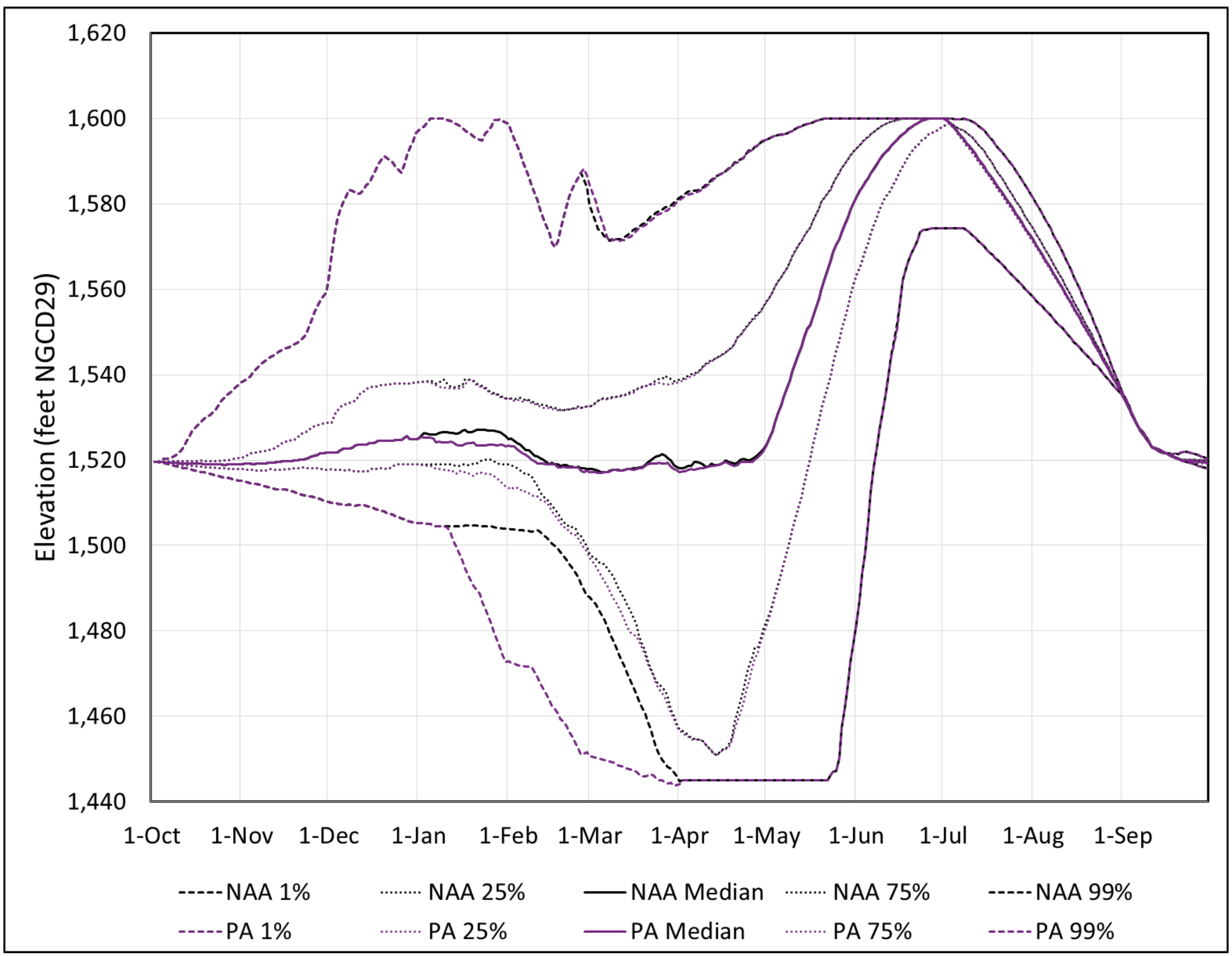

Figure 7-12. Dworshak Reservoir Summary Hydrograph for the Preferred Alternative

Water levels at Dworshak Reservoir under the Preferred Alternative would differ from the No Action Alternative to varying extents, depending on the water year type. Median hydrographs of the reservoir level for dry, average, and wet years are shown in Figure 7-13.

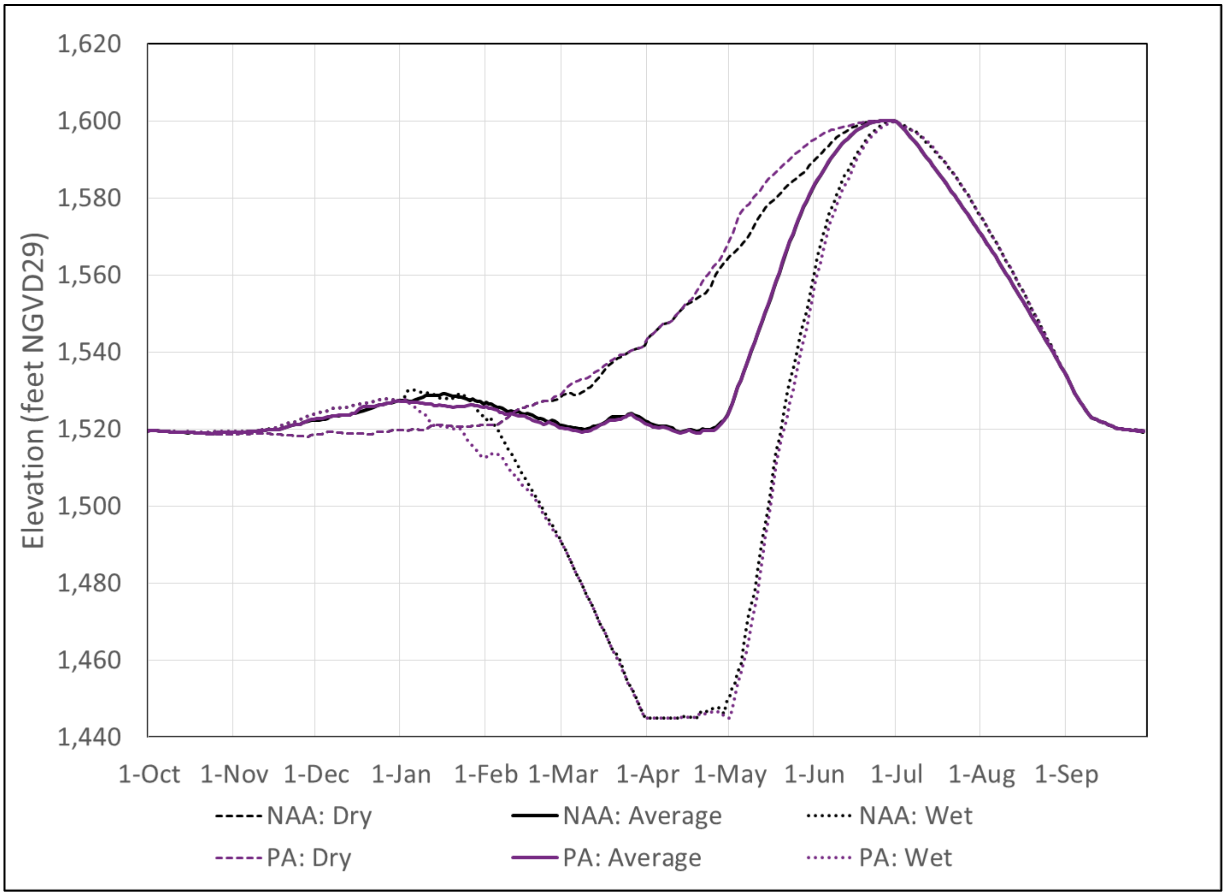

Figure 7-13. Dworshak Reservoir Water Year Type Hydrographs for the Preferred Alternative

DWORSHAK DAM OUTFLOW

Under the Preferred Alternative, the *Slightly Deeper Draft for Hydropower at Dworshak* measure would have a direct effect on Dworshak Dam outflows. The outflows would differ from the No Action Alternative primarily in January, February, and March, as seen in Figure 7-14. The change in average monthly outflow is characterized in Table 7-14.

The month of January would have a notable increase in project outflow as compared to the No Action Alternative. The median (50^{th} percentile) increase in monthly average flow is 0.3 kcfs (12 percent), and there is a 3.3 kcfs (77 percent) increase in the 25^{th} percentile. In February and March, decreases in monthly average flow are 1 kcfs or less (up to 15 percent).

Finally, Figure 7-15 shows median hydrographs for Dworshak Dam outflow in dry, average, and wet years. The figure provides another way to picture the effects described above, this time categorized by water year type.

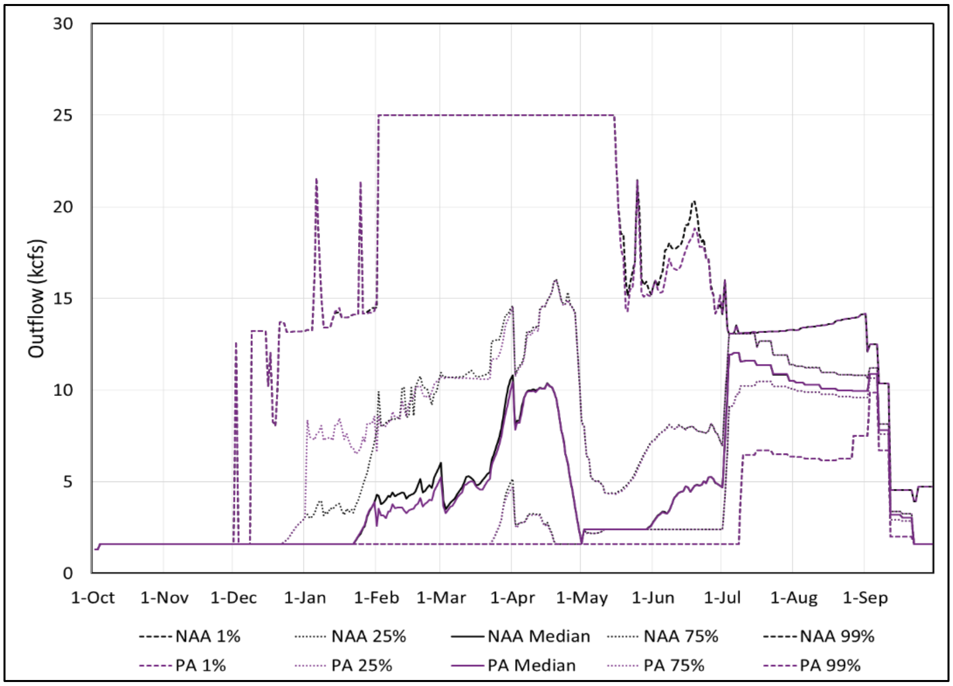

Figure 7-14. Dworshak Dam Outflow Summary Hydrograph for the Preferred Alternative

Table 7-14. Dworshak Dam Monthly Average Outflow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	1.7	1.6	8.7	13.5	23.3	25.0	25.0	17.3	15.6	13.2	13.6	6.4
		25%	1.6	1.6	1.9	4.2	9.3	11.8	13.2	6.2	7.5	11.9	11.0	5.2
		50%	1.6	1.6	1.6	2.1	5.1	6.2	9.6	3.5	4.8	10.7	10.2	5.0
		75%	1.6	1.6	1.6	1.6	1.6	2.3	4.6	2.4	2.4	9.6	9.8	4.8
		99%	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	7.4	9.3	4.5
Preferred Alternative	Change (kcfs)	1%	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	0.0	-0.2	0.0	0.0	0.0
		25%	0.0	0.0	0.0	3.3	-0.7	-0.8	0.0	0.0	0.0	0.0	0.0	0.0
		50%	0.0	0.0	0.0	0.3	-0.8	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
		75%	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
		99%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent change	1%	0%	0%	0%	0%	-4%	0%	-4%	0%	-1%	0%	0%	0%
		25%	0%	0%	0%	77%	-7%	-6%	0%	0%	0%	0%	0%	0%
		50%	0%	0%	0%	12%	-15%	-5%	0%	-1%	0%	0%	0%	0%
		75%	0%	0%	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%
		99%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

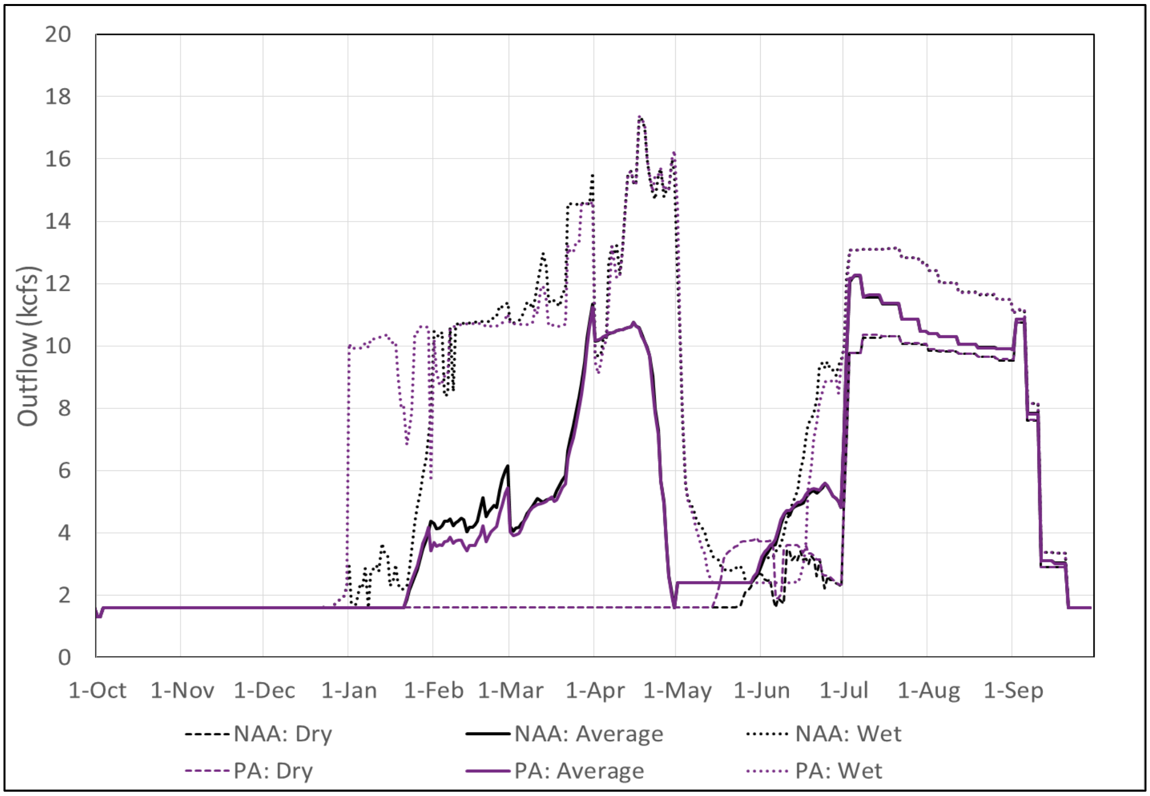

Figure 7-15. Dworshak Dam Outflow Water Year Type Hydrographs for the Preferred Alternative

Lower Snake River Reservoir Elevations

Under the Preferred Alternative, the operating reservoir elevation restrictions at the four lower Snake River projects would be changed to provide operating flexibility during the fish passage season April 3 through August 31 due to the *Increased Forebay Range Flexibility* measure. At all four projects, the seasonal MOP range is increased from a 1.0-foot range to a 1.5-foot range, each with a 0.5-foot increase in the upper end of the range. The proposed elevation ranges for April 3 to August 31 at each of the four projects are described below:

- Lower Granite Dam: the Preferred Alternative would have a MOP range of 733.0 to 734.5 feet NGVD29, compared to 733.0 to 734.0 feet NGVD29 under the No Action Alternative.
- Little Goose Dam: the Preferred Alternative would have MOP range of 633.0 to 634.5 feet NGVD29, compared to 633.0 to 634.0 feet NGVD29 under the No Action Alternative.
- Lower Monumental Dam: the Preferred Alternative would have a MOP range of 537.0 to 538.5 feet NGVD29, compared to 537.0 to 538.0 feet NGVD29 under the No Action Alternative).
- Ice Harbor Dam: the Preferred Alternative would have MOP range of 437.0 to 438.5 feet NGVD29, compared to 437.0 to 438.0 feet NGVD29 under the No Action Alternative).

Clearwater River below Dworshak Dam and the Lower Snake River

Under the Preferred Alternative, the pattern of outflow changes from Dworshak Dam in January through March would continue downstream. While the percent changes in flow from the No Action Alternative would be pronounced in the Clearwater River system, they would become diluted at the confluence of the Clearwater River and the Snake River near Lewiston, Idaho. The *Increased Forebay Range Flexibility* measure at the lower Snake River dams has a negligible effect on flow through the reach, so all changes are attributable to the *Slightly Deeper Draft for Hydropower at Dworshak* measure in the Preferred Alternative. This is seen in Table 7-15, which shows changes in median values of monthly average flows.

Table 7-15. Lower Snake Basin Monthly Average Flows for the Preferred Alternative (as change from No Action Alternative)

	Location	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative (kcfs)	Dworshak	1.6	1.6	1.6	2.1	5.1	6.2	9.6	3.5	4.8	10.7	10.2	5.0
	Spalding, ID	3.4	4.5	4.7	5.9	10.6	15.5	26.8	33.4	28.7	17.0	12.2	6.5
	Snake+Clearwater	19.7	20.9	23.9	28.3	39.0	47.2	69.7	94.4	96.4	47.9	29.2	22.6
	Lower Granite	19.8	21.0	23.7	28.4	39.3	48.0	71.8	95.6	97.4	48.6	29.1	22.5
	Ice Harbor	20.2	21.4	24.5	29.4	42.0	50.7	73.0	95.4	97.2	48.4	28.1	21.2
Change (kcfs)	Dworshak	0.0	0.0	0.0	0.3	-0.8	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Spalding, ID	0.0	0.0	0.0	0.8	-0.3	-0.7	0.0	0.0	0.0	0.0	0.0	0.0
	Snake+Clearwater	0.0	0.0	0.0	1.6	-0.5	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0
	Lower Granite	0.0	0.0	0.0	1.2	-0.8	-0.2	-0.2	0.0	0.0	0.0	0.0	0.0
	Ice Harbor	0.0	0.0	0.0	1.0	-0.8	-0.3	-0.2	0.0	0.0	0.0	0.0	0.1
Percent Change	Dworshak	0%	0%	0%	12%	-15%	-5%	0%	-1%	0%	0%	0%	0%
	Spalding, ID	0%	0%	0%	13%	-3%	-4%	0%	0%	0%	0%	0%	0%
	Snake+Clearwater	0%	0%	0%	6%	-1%	0%	0%	0%	0%	0%	0%	0%
	Lower Granite	0%	0%	0%	4%	-2%	-1%	0%	0%	0%	0%	0%	0%
	Ice Harbor	0%	0%	0%	3%	-2%	-1%	0%	0%	0%	0%	0%	0%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows greater than the No Action Alternative flows; green shading denotes the Preferred Alternative flows less than the No Action Alternative flows.

REGION D – MCNARY, JOHN DAY, THE DALLES, AND BONNEVILLE DAMS

Lower Columbia River Reservoir Elevations

Under the Preferred Alternative, there would be no change to the reservoir elevations at McNary Dam, The Dalles Dam, or Bonneville Dam. At John Day Dam, the *John Day Full Pool*, *Predator Disruption Operations,* and *Increased Forebay Range Flexibility* measures relate to the reservoir operating range. The *John Day Full Pool* allows for operation across the full range possible outside of fish passage season (September 1 to April 9); the *Predator Disruption Operations* measure increases the operating range compared to the No Action Alternative from April 10 to June 15 to disrupt Caspian tern nesting in the Columbia River Plateau; and the *Increased Forebay Range Flexibility* measure provides slightly more forebay operating flexibility between June 15 and August 31 by eliminating MOP restrictions when spill is reduced in late summer. The John Day Dam operating ranges associated with these measures are listed in Table 7-16 and shown graphically in Figure 7-16.

Table 7-16. Normal Operating Ranges at John Day Reservoir for the Preferred Alternative

Period	Elevation (feet NGVD29)		Measure
	Minimum	Maximum	
September 1 to November 15	262.5	266.5	John Day Full Pool
November 16 to March 14	262	266.5	
March 15 to April 9	262.5	266.5	
April 10 to June 15	264.5	266.5	Predator Disruption Operations
June 15 to August 31	262.5	264.5	Increased Forebay Range Flexibility

The full operating range (257–268 feet NGVD29) may be used throughout the year if needed for flood risk management.

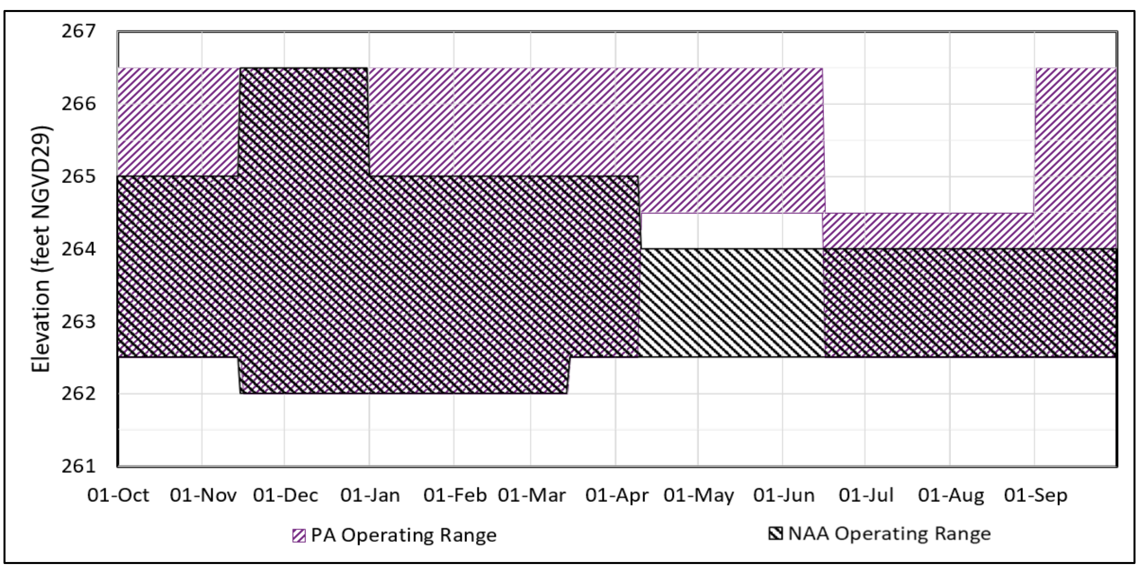

Figure 7-16. Normal Operating Range at John Day Dam for the Preferred Alternative and the No Action Alternative

Note: John Day may be operated between 257 feet and 268 feet NGVD29 for FRM purposes. These limits are not shown on this figure in order to show greater detail in the vertical scale.

Lower Columbia River Flows

Under the Preferred Alternative, the *Modified Draft at Libby*, *Sliding Scale at Libby and Hungry Horse*, *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, *Lake Roosevelt Additional Water Supply*, *Fall Operational Flexibility for Hydropower (Grand Coulee)*, and *Slightly Deeper Draft for Hydropower at Dworshak* measures would cause changes in flow patterns in the lower Columbia River at McNary Dam. Changes in operations at John Day Dam, including the *John Day Full Pool*, *Predator Disruption Operations*, and *Increased Forebay Range Flexibility* measures, would affect John Day outflow and flow through the Columbia River to the Pacific Ocean.

At McNary Dam, the outflows under the Preferred Alternative would differ from the No Action Alternative to various extents through the water year. The magnitude and timing of differences in flow are displayed in Figure 7-17. The change in average monthly outflow is characterized in Table 7-17.

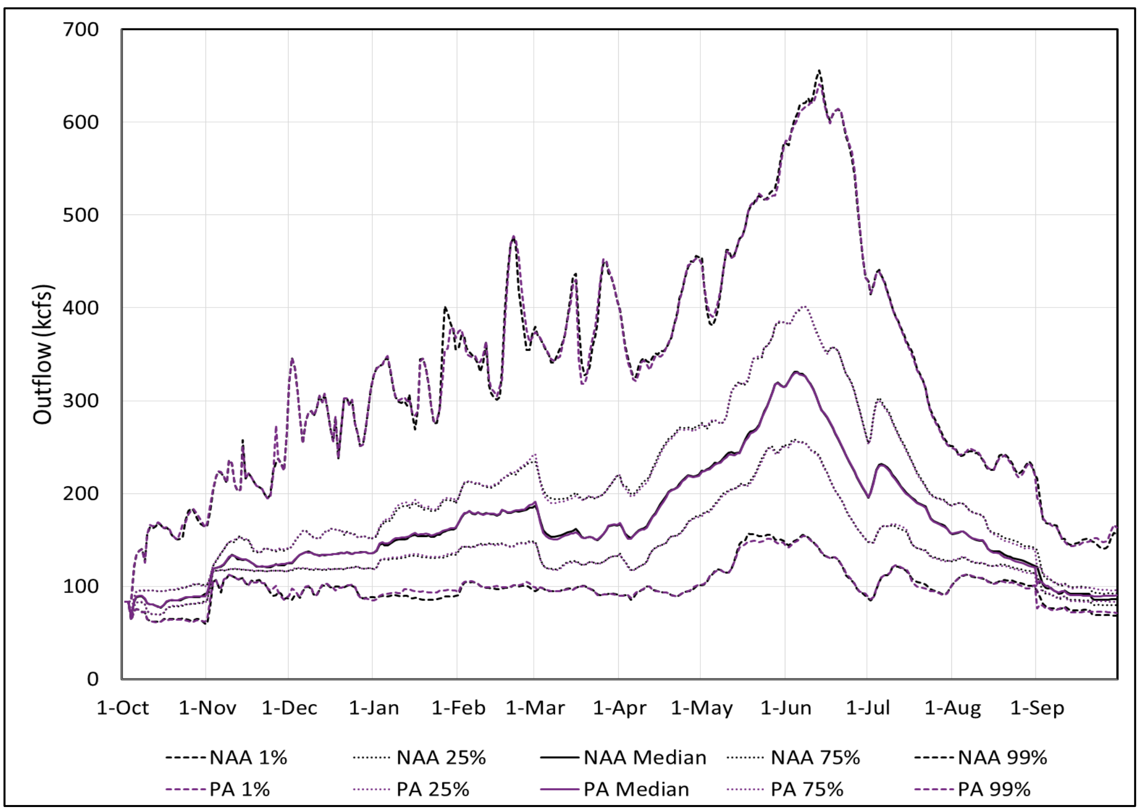

Figure 7-17. McNary Dam Outflow Summary Hydrograph for the Preferred Alternative

Table 7-17. McNary Dam Monthly Average Outflow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	141	187	279	280	327	329	346	451	562	342	231	152
		25%	95	143	155	181	216	200	236	313	352	243	163	100
		50%	85	124	136	154	182	159	192	260	285	198	141	93
		75%	79	116	118	133	147	130	147	231	217	147	124	87
		99%	73	112	109	108	115	107	106	178	160	122	114	81
Preferred Alternative	Change (kcfs)	1%	0.5	0.3	0.0	3.9	2.2	1.3	-3.5	-0.2	-1.5	-1.7	-0.7	-0.8
		25%	0.4	0.2	0.1	2.7	1.2	-0.9	-2.3	0.3	-1.6	-1.7	-2.3	0.4
		50%	0.4	0.3	0.0	1.9	1.7	-1.0	-1.2	-1.3	-0.2	-1.4	-0.9	0.1
		75%	0.4	0.7	0.8	1.4	-0.8	-0.1	0.1	-1.3	-0.8	0.6	-0.2	0.7
		99%	0.5	0.1	0.3	-1.1	0.6	0.4	0.5	-4.4	-0.9	0.4	-0.7	-0.5
	Percent change	1%	0%	0%	0%	1%	1%	0%	-1%	0%	0%	-1%	0%	-1%
		25%	0%	0%	0%	1%	1%	0%	-1%	0%	0%	-1%	-1%	0%
		50%	0%	0%	0%	1%	1%	-1%	-1%	0%	0%	-1%	-1%	0%
		75%	0%	1%	1%	1%	-1%	0%	0%	-1%	0%	0%	0%	1%
		99%	1%	0%	0%	-1%	1%	0%	0%	-2%	-1%	0%	-1%	-1%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows greater than the No Action Alternative flows; green shading denotes the Preferred Alternative flows less than the No Action Alternative flows.

In general, flows in January and February under the Preferred Alternative tend to be higher than the No Action Alternative, especially in wetter years, and spring and summer flows tend to be lower than the No Action Alternative. The winter increases are related to the operational changes at Libby, Grand Coulee, and Dworshak dams, as are the decreases seen in early spring months. The summer decreases are related mostly to operational changes at Libby, Hungry Horse, and Grand Coulee dams. The largest increase and decrease in median monthly average flow, as compared to the No Action Alternative, occurs in January (1.9 kcfs, 1.3 percent) and July (-1.4 kcfs, -0.7 percent), respectively. All changes are within 2 percent of the No Action Alternative.

Finally, Figure 7-18 shows median hydrographs for McNary Dam outflow in dry, average, and wet years. The figure provides another way to picture the effects described above, this time categorized by water year type.

Changes in flow below John Day Dam are caused by both flow changes coming from upstream in the Columbia River, evident in McNary Dam outflow, and the flow changes resulting from operational changes at John Day Dam. Modification to the normal operating range throughout the years (see the Lower Columbia River Reservoir Elevations section) result in notable changes in monthly average flows in all seasons. The change in average monthly outflow from John Day Dam is characterized in Table 7-18. The flow changes seen in John Day Dam outflow generally continue downstream through The Dalles and Bonneville dams to the Pacific Ocean. Table 7-19 shows the change in median monthly average flows in the Columbia River from the Snake River confluence to the Cowlitz River confluence 40 miles downstream of Portland.

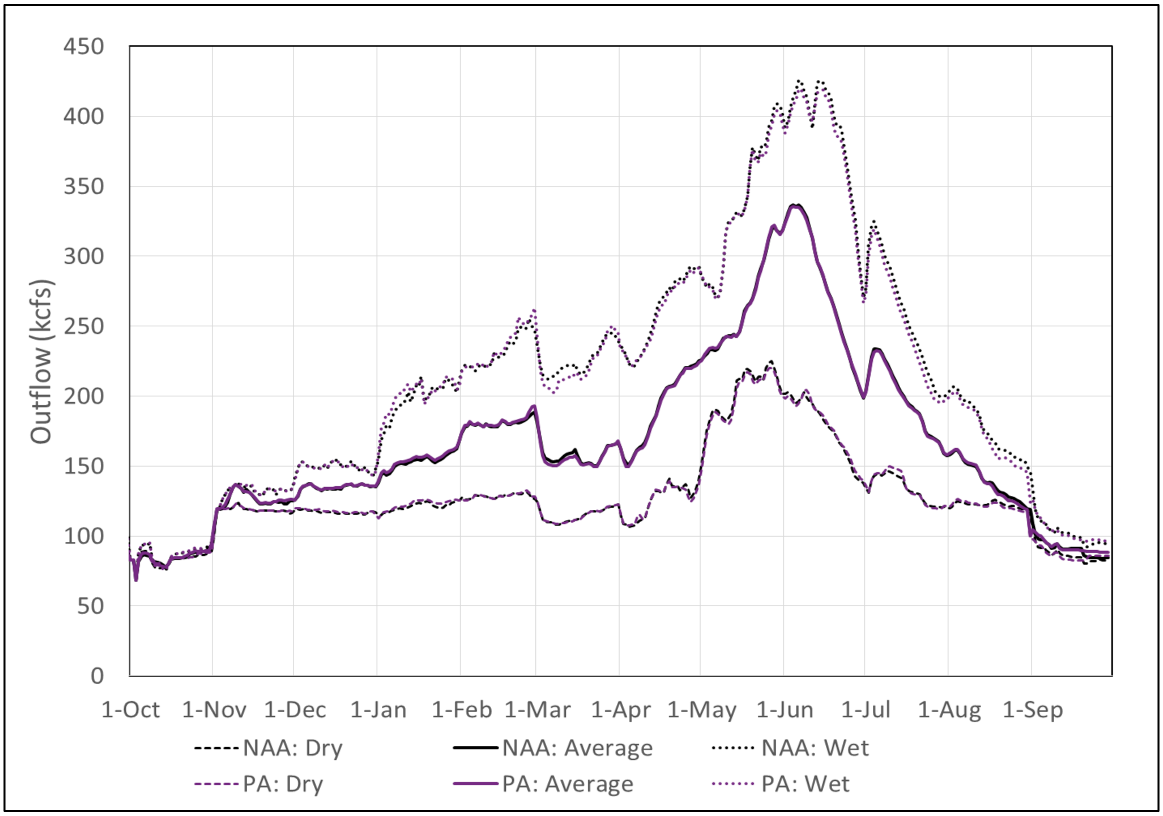

Figure 7-18. McNary Dam Outflow Water Year Type Hydrographs for the Preferred Alternative

Table 7-18. John Day Dam Monthly Average Outflow for the Preferred Alternative (as change from No Action Alternative)

		Exceedance Probability	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative	Ave. mo. outflow (kcfs)	1%	140	192	283	283	335	342	355	452	573	340	225	147
		25%	95	143	158	186	221	205	243	320	355	241	162	100
		50%	85	125	140	156	185	165	198	267	288	197	141	93
		75%	78	116	121	136	150	136	152	235	218	146	123	88
		99%	72	112	111	110	116	110	110	180	162	122	113	80
Preferred Alternative	Change (kcfs)	1%	2.0	0.2	-0.8	4.1	1.2	-0.9	-6.4	0.8	-0.8	-0.6	-0.8	-2.1
		25%	1.5	0.3	-0.8	2.8	1.3	-0.7	-3.7	0.0	0.5	-1.8	-2.7	-0.8
		50%	1.8	0.2	-0.6	1.6	1.6	-0.9	-1.8	-1.5	1.5	-1.2	-0.9	-0.9
		75%	1.7	0.5	-0.9	1.4	-1.3	-0.3	-1.0	-1.8	0.7	-0.1	-0.5	-1.0
		99%	1.8	0.2	-0.4	0.0	1.0	-0.1	0.4	-3.7	0.8	0.1	-1.0	-1.7
	Percent change	1%	1%	0%	0%	1%	0%	0%	-2%	0%	0%	0%	0%	-1%
		25%	2%	0%	-1%	1%	1%	0%	-2%	0%	0%	-1%	-2%	-1%
		50%	2%	0%	0%	1%	1%	-1%	-1%	-1%	1%	-1%	-1%	-1%
		75%	2%	0%	-1%	1%	-1%	0%	-1%	-1%	0%	0%	0%	-1%
		99%	2%	0%	0%	0%	1%	0%	0%	-2%	1%	0%	-1%	-2%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

Table 7-19. Lower Columbia River Median Monthly Average Flows for the Preferred Alternative (as change from No Action Alternative)

	Location	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
No Action Alternative (kcfs)	Columbia + Snake	83	122	134	151	181	157	188	260	288	199	140	91
	McNary	85	124	136	154	182	159	192	260	285	198	141	93
	John Day	85	125	140	156	185	165	198	267	288	197	141	93
	The Dalles	90	130	146	163	192	172	206	273	293	202	146	97
	Bonneville	91	135	152	170	199	179	213	275	296	204	149	99
	Columbia + Willamette	108	178	225	252	267	233	260	314	319	216	159	111
	Columbia + Cowlitz	115	196	257	282	295	255	283	334	336	226	165	117
Change (kcfs)	Columbia + Snake	0.2	0.1	0.0	1.6	1.3	-0.9	-1.7	-1.3	-0.2	-1.6	-1.1	0.2
	McNary	0.4	0.3	0.0	1.9	1.7	-1.0	-1.2	-1.3	-0.2	-1.4	-0.9	0.1
	John Day	1.8	0.2	-0.6	1.6	1.6	-0.9	-1.8	-1.5	1.5	-1.2	-0.9	-0.9
	The Dalles	1.5	0.2	-0.5	1.6	1.3	-1.3	-1.8	-1.5	1.5	-1.2	-1.2	-0.9
	Bonneville	1.8	0.6	-0.9	1.1	1.6	-1.4	-1.9	-1.8	1.6	-1.4	-1.1	-1.2
	Columbia + Willamette	2.0	1.5	-0.8	1.5	1.5	-1.1	-2.1	-0.8	1.6	-1.2	-1.1	-1.2
	Columbia + Cowlitz	1.8	1.4	-0.7	1.0	0.5	-1.2	-1.9	-0.4	0.9	-0.9	-0.9	-1.2
Percent Change	Columbia + Snake	0%	0%	0%	1%	1%	-1%	-1%	-1%	0%	-1%	-1%	0%
	McNary	0%	0%	0%	1%	1%	-1%	-1%	0%	0%	-1%	-1%	0%
	John Day	2%	0%	0%	1%	1%	-1%	-1%	-1%	1%	-1%	-1%	-1%
	The Dalles	2%	0%	0%	1%	1%	-1%	-1%	-1%	1%	-1%	-1%	-1%
	Bonneville	2%	0%	-1%	1%	1%	-1%	-1%	-1%	1%	-1%	-1%	-1%
	Columbia + Willamette	2%	1%	0%	1%	1%	0%	-1%	0%	1%	-1%	-1%	-1%
	Columbia + Cowlitz	2%	1%	0%	0%	0%	0%	-1%	0%	0%	0%	-1%	-1%

Note: Values for the No Action Alternative are shaded gray. Orange shading denotes the Preferred Alternative flows lower than the No Action Alternative flows; green shading denotes the Preferred Alternative flows higher than the No Action Alternative flows.

The largest changes in median monthly flow in the Lower Columbia River below John Day Dam occur in October and April, though both typically have less than 2 kcfs change. The percent change in median monthly average flow below John Day Dam is within 1 percent of the No Action Alternative for all months except October, which is 2 percent. The flow changes for various months are linked to the measures most responsible below:

- The flow change in October, which can mostly be attributed to the *John Day Full Pool* measure, translates to a 2 percent increase in average monthly flow downstream of the project. This measure is also responsible for the smaller changes in average monthly flow in December and September. This is because John Day is modeled to hold a single elevation from September to early April instead of filling and drafting as it does in the No Action Alternative during that time.
- The increase in January and February flows are caused by operational changes further upstream at Grand Coulee and Libby dams, as are the decreases in March, May, July, and August.

- The decrease in April flow is attributed to combined effect of the *Modified Draft at Libby* measure*,* the *Update System FRM Calculation* and *Lake Roosevelt Additional Water Supply* measures at Grand Coulee Dam, and the *Predator Disruption Operations* measure at John Day Dam.
- The increase in June flow is mostly attributed to the *Predator Disruption Operations* measure.

SUMMARY OF EFFECTS

Water level changes under the Preferred Alternative are generally much smaller than those under the other MOs, with moderate changes common only at Libby, and major changes occurring only at Dworshak in the winter in some years. At Libby Dam, Lake Koocanusa has minor to moderate decreases in water levels in lower and average forecast years in the winter and spring, followed by a minor increase in water levels in the summer with increased refill probability. Hungry Horse has negligible increases in reservoir levels throughout the year with minor to moderate increases occurring in the late summer and early fall in the lower 20 percent of years. At Grand Coulee Dam, Lake Roosevelt water levels can be slightly lower from February through April in very high forecast years, otherwise changes are negligible. Dworshak water levels can also be moderately lower January through February in larger forecast years, with major decreases occurring in 5 percent of years. Change in operating ranges at John Day Dam result in minor but consistent increases in the elevation range over which water levels can fluctuate under normal operations. Elevations at the lower Snake and other lower Columbia River projects are not projected to change substantially.

The largest changes to river flow occur immediately below Libby and Dworshak dams, and the largest total flow changes occur below Grand Coulee and through the lower Columbia River projects. At Libby Dam, there are minor to moderate flow increases in January, February, and March, followed by negligible to minor flow decreases in April and May. Most years have a negligible to minor decrease in the summer flows, but dry years in the summer have a minor flow increases at Libby Dam. Negligible to minor flow decreases occur immediately downstream of Hungry Horse Dam in the summer, resulting in negligible changes downstream through the Flathead, Clark Fork, and Pend Oreille River systems. Flow changes downstream of Grand Coulee are negligible, within 2 percent of the No Action Alternative. Dworshak Dam has a moderate increase in January outflow in wetter years, followed by minor decreases in February and March. Flow changes below John Day Dam are negligible, typically within 1 percent of the No Action Alternative. Flows at the lower Snake and other lower Columbia River projects are not projected to change substantially.

The amount of water spilled at each project was modeled using a spill allocation methodology described in the H&H Appendix (Appendix B, Part 2, *Spill Analysis*). Table 7-20 summarizes the spill operations for the Preferred Alternative and the No Action Alternative. Further details and modeling results from the extended year dataset (water years 2008 through 2016) are presented and discussed in the H&H Appendix (Appendix B, Part 2, *Spill Analysis*).

Table 7-20. Summary of Spill Operations for the Preferred Alternative and No Action Alternative

Project	Alternative	Start Date	End Date	Spill Operation
Bonneville (Region D)	No Action Alternative	April 10	June 15	100 kcfs
		June 16	August 31	Alternating between 85/121 kcfs day/night and 95 kcfs in 2-day treatments
	Preferred Alternative	April 10	June 15	125% Daily Flex: 150 kcfs (spillway limitation) 16 hrs/100 kcfs 8 hrs
		June 16	August 14	95 kcfs
		August 15	August 31	55 kcfs
The Dalles (Region D)	No Action Alternative	April 10	August 31	40% Total Outflow
	Preferred Alternative	April 10	August 14	40% Total Outflow
		August 15	August 31	30% Total Outflow
John Day (Region D)	No Action Alternative	April 10	April 26	30% Total Outflow
		April 27	July 20	Alternating between 30% and 40% in 2-day treatments
		July 21	August 31	30% Total Outflow
	Preferred Alternative	April 10	June 15	120% Daily Flex: 146 kcfs 16 hrs/32% Total Outflow 8 hrs
		June 16	August 14	35% Total Outflow
		August 15	August 31	20 kcfs
McNary (Region D)	No Action Alternative	April 10	June 15	40% Total Outflow
		June 16	August 31	50% Total Outflow
	Preferred Alternative	04-10	06-15	125% Daily Flex: 265 kcfs 16 hrs/48% Total Outflow 8 hrs
		06-16	08-14	57% Total Outflow
		08-15	08-31	20 kcfs
Ice Harbor (Region C)	No Action Alternative	April 03	April 27	45 kcfs day/gas cap night
		April 28	July 13	Alternating between 45 kcfs/gas cap day/night and 30% in two/day treatments
		July 14	August 31	45 kcfs day/gas cap night
	Preferred Alternative	April 03	June 20	125% Daily Flex: 119 kcfs 16 hrs/30% Total Outflow 8 hrs
		June 21	August 14	30% Total Outflow
		August 15	August 31	8.5 kcfs
Lower Monumental (Region C)	No Action Alternative	April 03	June 20	33 kcfs (Waiver Gas Cap)
		June 21	August 31	17 kcfs
	Preferred Alternative	April 03	June 20	125% Daily Flex: 98 kcfs 16 hrs/30 kcfs 8 hrs
		June 21	August 14	17 kcfs
		August 15	August 31	7 kcfs

Project	Alternative	Start Date	End Date	Spill Operation
Little Goose (Region C)	No Action Alternative	April 03	August 31	30% Total Outflow
	Preferred Alternative	April 03	June 20	125% Daily Flex: 79 kcfs 16 hrs/30% Total Outflow 8 hrs
		June 21	August 14	30% Total Outflow
		August 15	August 31	overridden by ASW req: 7.2 kcfs
Lower Granite (Region C)	No Action Alternative	April 03	June 20	20 kcfs
		June 21	August 31	18 kcfs
	Preferred Alternative	April 03	June 20	125% Daily Flex: 72 kcfs 16 hrs/20 kcfs 8 hrs
		June 21	August 14	18 kcfs
		August 15	August 31	7 kcfs

Note: ASW = adjustable spillway weir; TDG = total dissolved gas. The Region B run-of-river projects (Wells, Rocky Reach Rock Island, Wanapum, and Priest Rapids dams) are unchanged from No Action Alternative. The major storage projects do not include modeled fish spill.

7.7.2 River Mechanics

Consistent with Chapter 3.3, the effects to river mechanics were evaluated against seven metrics for the four physiographic regions of the CRS study area. Detailed information is presented in Appendix C. The storage reservoirs were evaluated for three of the seven metrics: trap efficiency (the rate at which the reservoir holds sediment); shoreline exposure, which describes the change in the number of days that a reservoir spends at any elevation to identify change in shoreline exposure and indicate the potential for change in shoreline erosion; and head of reservoir mobilization, which describes the potential change in sediment scour and deposition patterns at the head (most upstream portion) of a reservoir. Under the Preferred Alternative, the effects to the storage projects in Region A is estimated to be negligible with the exception of the Kootenai River entering Lake Kookanusa upstream of Libby Dam where there is potential for a minor change in depositional patterns with temporary head-of-reservoir deposits shifting downstream. The ultimate long-term fate of head-of-reservoir sediments within the reservoir is unchanged given no changes in the Libby Dam operational range. The storage project effects in Regions B and C are estimated to be negligible due to the combined operational changes upstream and within this region would not translate into movement of sediments as compared to the No Action Alternative. In Region D, the effects to the storage projects were estimated to be negligible with the exception of the Columbia River entering John Day Reservoir where there is potential for a minor decrease in head-of-reservoir sediment mobilization due to deposits becoming finer.

The run-of-river reservoirs and free-flowing reaches were evaluated using three metrics to determine the potential for changes in the size of bed material (e.g., transition from medium grained to fine grained sediment), the potential for sediment passing through a reservoir or reach, and the potential for change to the width-to-depth ratio as a surrogate for geomorphic change. With the exception of a minor change in the John Day reservoir, the Preferred Alternative effects to CRS run-of-river projects for these three metrics relative to the No Action

Alternative are estimated to be negligible indicating that related processes will continue at the magnitudes and rates to those historically experienced. In the John Day reservoir, there is potential for a minor amount of bed sediment to become finer due to changes in reservoir elevations relative to the No Action Alternative. The final run-of-river metric evaluated potential changes to navigation channel dredging volumes in the Snake River and Lower Columbia River. Estimated results for the Preferred Alternative indicate negligible impacts due to the operational changes resulting in less than 1 percent dredging volume change relative to the No Action Alternative for both rivers.

7.7.3 Water Quality

7.7.3.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

WATER QUALITY

Water Temperature

In general, the water temperature response at the Libby and Hungry Horse Dams are expected to be similar to the No Action Alternative. However, slight changes in water temperature downstream of Libby Dam could occur from Preferred Alternative operations that cause an increase in median monthly outflows, from January through March, to draft the reservoir deeper (Appendix D, *Water Quality*). During the cold winter months, Kootenai River water can cool by several degrees between Libby Dam and Bonners Ferry if flows are held low. By increasing winter flows to draft the reservoir deeper, the Preferred Alternative may prevent the natural cooling of the river as it moves downstream. These higher winter temperatures in the Kootenai River may affect certain fish species, such as burbot, which require near freezing river temperatures (<35°F or <2°C) to spawn. Overall, the Preferred Alternative is expected to result in negligible to minor changes in water temperature as compared to the No Action Alternative downstream of Libby Dam, and negligible to no effects downstream of Hungry Horse Dam.

There are no changes to operations expected at Albeni Falls Dam under the Preferred Alternative, so the temperature conditions in Lake Pend Oreille and the Pend Oreille River are expected to remain unchanged and reflect conditions as described in the No Action Alternative.

Total Dissolved Gas

In general, the Preferred Alternative would have little to no impact on TDG conditions below Libby, Hungry Horse, and Albeni Falls Dams as compared to the No Action Alternative.

Libby Dam is operated to minimize spill. Under the Preferred Alternative, Libby Dam's draft and refill operations would be modified, resulting in a minor increase in spill compared to the No Action Alternative. For the 80-year period from 1928 to 2008, model results predict 11 years with spill under the Preferred Alternative compared to 2 years when spill would occur for the No Action Alternative. In those years identified as having spill at Libby Dam, the model predicts 35 days with TDG exceeding 110 percent for the Preferred Alternative versus 8 days with TDG exceedances under the No Action Alternative. Regardless, Libby Dam is not expected to spill frequently under the Preferred Alternative, so downstream TDG saturations should remain less than 110 percent the majority of time (Appendix D, *Water Quality*).

TDG below Hungry Horse Dam under the Preferred Alternative is expected to be relatively similar to the No Action Alternative in most years. Spill at Hungry Horse Dam would increase slightly in a few years due to the increase in carryover in some dry years from the *Sliding Scale at Libby and Hungry Horse* measure; the duration of spill would decrease in most years compared to the No Action Alternative. Overall, the Preferred Alternative and No Action alternatives are similar in the number of exceedance days; the effects are considered negligible.

Albeni Falls Dam spill is highly dependent on runoff volumes. Historically, Albeni Falls Dam spills most years. Because there is no change in Albeni Falls Dam operations between the Preferred Alternative and the No Action Alternative, spillway operations and TDG conditions under the Preferred Alternative are expected to remain unchanged.

Other Physical, Chemical, and Biological Processes

The Preferred Alternative modifies operations at Libby Dam resulting in changes in the drafting depth and refill elevations of Lake Koocanusa that may impact physical, chemical, and biological water quality parameters when compared to the No Action Alternative. The Preferred Alternative reservoir elevations and outflows during median and high water supply years would be relatively similar to the No Action Alternative, and water quality changes are not anticipated. However, for low water supply years, the reservoir would be drafted deeper with mid-April water elevations up to 8 feet lower in the driest 40 percent of years. Reservoir refill and summer reservoir elevations for all water supply years are improved over the No Action Alternative with the reservoir reaching full by the end of July and maintaining higher elevations (about 1 to 4 feet higher) in August and September. For water quality concerns, of particular interest are the 8 foot lower mid-April water elevations for low water supply years because they equate to less volume of water in Lake Koocanusa during the spring runoff and a shorter water retention time. Retention time, which is the inverse of the flushing rate, refers to the length of time water remains in a waterbody. It is possible that shorter retention times may allow certain chemical constituents (nutrients such as phosphorus and nitrogen or metals such as selenium) to move farther down-reservoir toward the forebay and outflow before settling out or transforming. Overall, these impacts are anticipated to be negligible.

Negligible impacts to the physical, chemical, or biological processes at Hungry Horse Reservoir and the South Fork Flathead River downstream of the dam, are expected under the Preferred Alternative as compared to the No Action Alternative. This is because the *Sliding Scale at Libby and Hungry Horse* only result in slight changes in elevations and flows compared to the No Action Alternative.

There are no proposed changes to operations in the Preferred Alternative at Albeni Falls. Water quality conditions of Lake Pend Oreille and the Pend Oreille River are not expected to change under the Preferred Alternative as compared to the No Action Alternative. Conditions would remain as described in Chapter 3, Section 3.4.2, and Appendix D, Section 3.1.3.

SEDIMENT QUALITY

Operational changes at Libby and Hungry Horse Dams under the Preferred Alternative are not expected to affect sediment movement downstream in the Kootenai and Flathead Rivers, respectively. The Preferred Alternative would not impact Albeni Falls Dam operations and would not affect sediment sources or movement.

7.7.3.2 Region B – Grand Coulee and Chief Joseph Dams

WATER QUALITY

Water Temperature

Under the Preferred Alternative, the *Update System FRM Calculation, Planned Draft Rate at Grand Coulee, Fall Operational Flexibility for Hydropower (Grand Coulee), Lake Roosevelt Additional Water Supply,* and *Grand Coulee Maintenance Operations* measures would be implemented at Grand Coulee Dam. All of these measures (with the exception of *Lake Roosevelt Additional Water Supply and Grand Coulee Maintenance Operations*) would influence reservoir elevations at Lake Roosevelt; negligible effects to water temperature are anticipated (Appendix D, *Water Quality)*.

Model results predict little change in Rufus Woods Lake forebay elevations for the Preferred Alternative when compared to the No Action Alternative (Appendix D, *Water Quality*). Monthly outflows from Chief Joseph Dam are predicted to be similar to or about 1 percent less than the No Action Alternative for all types of water years. Consequently, modeled temperatures under the Preferred Alternative downstream of Chief Joseph Dam are similar to the No Action (Appendix D, *Water Quality*). Tailrace temperatures under both the Preferred Alternative and No Action Alternative are predicted to exceed the Washington State water quality standard of 63.5F (17.5°C) as measured by the 7-day average of the daily maximum temperature in August and September. Existing water quality monitoring would continue under the Preferred Alternative. Similar to the No Action Alternative, there is little difference in temperature between Grand Coulee Dam and Chief Joseph Dam under the Preferred Alternative, showing that water temperatures below Lake Roosevelt are unchanged through Rufus Woods Lake.

Total Dissolved Gas

Under the Preferred Alternative, TDG downstream of Grand Coulee Dam ranges from 95 percent to 125 percent; historically TDG in excess of 125 percent has been recorded and is still possible under the Preferred Alternative depending on inflowing TDG and flow conditions. The *Grand Coulee Maintenance Operations* measure reduces power plant hydraulic capacity and the *Planned Draft Rate at Grand Coulee* measure allows for earlier draft in wetter years. The combination of these two measures could affect TDG below the dam, but these measures tend to partially offset each other in this analysis resulting in negligible changes from the No Action Alternative Preferred Alternative (Appendix D, *Water Quality*).

In general, predicted Preferred Alternative TDG saturations in Lake Roosevelt are similar to the No Action Alternative for the different flow and air temperature conditions modeled (Appendix D, *Water Quality*). Operations of the spill deflectors at Chief Joseph Dam would continue to decrease TDG saturations between the forebay and tailrace during high flow and high spill years, consistent with the Preferred Alternative. Overall TDG impacts at Chief Joseph Dam under the Preferred Alternative as compared to the No Action Alternative are expected to be negligible.

Other Physical, Chemical, and Biological Processes

Turbidity from bank erosion within Lake Roosevelt, is correlated to the rate of drawdown and refill at Grand Coulee Dam. The operational measure to decrease the *Planned Draft Rate at Grand Coulee* changes the target maximum drawdown from 1.0 ft/day to a target of 0.8 ft/day. A slower drawdown rate may result in lower turbidity throughout the reservoir. Under the Preferred Alternative, the *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, and *Fall Operational Flexibility for Hydropower* measures are all predicted to influence Lake Roosevelt reservoir elevations. However, changes in reservoir elevation are small and are not predicted to impact mercury cycling (Appendix D, *Water Quality*). Overall, impacts to water quality within Lake Roosevelt are anticipated to be negligible as compared to the No Action Alternative.

Under the Preferred Alternative, only minor changes to operations, reservoir elevations, and flows at Chief Joseph Dam are expected. Given this, the physical, chemical, and biological water quality of Rufus Woods Lake and the Columbia River downstream of Chief Joseph Dam under the Preferred Alternative are expected to remain relatively unchanged from the No Action Alternative.

SEDIMENT QUALITY

Under the Preferred Alternative, the *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, and *Fall Operational Flexibility for Hydropower* measures are all predicted to influence Lake Roosevelt reservoir elevations. However, changes in reservoir elevation are small (Appendix D, *Water Quality*). No operational changes are proposed for Chief Joseph project in the Preferred Alternative. Negligible changes are expected to sediment quality in Region B under the Preferred Alternative.

7.7.3.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

WATER QUALITY

Water Temperature

Outflow water temperatures from Dworshak Dam under the Preferred Alternative would be very similar to No Action Alternative conditions (Appendix D, Water Quality). Daily average and maximum temperatures would be less than 52°F throughout the year. Water temperatures in the lower Snake River under the Preferred Alternative would be very similar to the No Action Alternative as well; any differences predicted between the two alternatives are due to the way reservoir elevations were modeled under the Preferred Alternative (these differences are discussed in more detail in Appendix D, see Table 8-2). Differences between the Preferred Alternative and No Action Alternative are not anticipated during implementation. Water temperatures, as predicted by the ResSim and water quality models, show maximum daily temperatures of less than 68°F most of the time between April and September downstream of Lower Granite Dam; the water quality standard would be exceeded for about 5 days during a LF/AT (low flow, average air temperature) year, and 17 days during a LF/HT (low flow, high air temperature) year. At the Little Goose and Lower Monumental projects, the frequency of exceeding the water quality standard downstream from the dam during an average-flow year would be 38 and 45 days, respectively. The frequency of exceedances downstream of Little Goose Dam would increase during low flow years to 47 and 60 days under average and high air temperature conditions, respectively. Exceedances downstream of Lower Monumental Dam would increase to 69 days regardless of the air temperatures. Water temperatures downstream of Ice Harbor Dam would be warmer than the other three projects, with the frequency of exceeding 68°F (20°C) ranging from 28 days during a high flow year to 73 days during a low flow, high air temperature year. Tailrace temperatures could surpass 72°F (22°C) at Ice Harbor Dam during AF/AT and LF /HT years. Overall, however, water temperature impacts are expected to be negligible under the Preferred Alternative and similar to that of the No Action Alternative.

Total Dissolved Gas

TDG downstream from Dworshak Dam under the Preferred Alternative would be very similar to the No Action Alternative model results. TDG would remain below the 110 percent water quality standard the majority of the time for each of the five flow and air temperature conditions modeled. TDG impacts downstream of Dworshak Dam are negligible.

The Preferred Alternative contains the *Juvenile Fish Passage Spill* measure, which is based on the results of the spring 2019 Flexible Spill Test Operation and analyses of the four MO Alternatives. The *Juvenile Fish Passage Spill* measure would be implemented during the spring juvenile salmonid migration season at the lower Snake River and involve 16 hours of spill operations up to the 125 percent TDG gas cap at most projects for juvenile outmigration. For the remaining 8 hours, the projects would spill at a lower level (this level is referred to as performance standard spill). These performance standard spill levels are slightly variable depending on the project, and may be slightly higher or lower depending on river conditions and the opportunity to spill. This operation would allow hydropower generation during times of peak demand, while still providing for higher spill for fish when it is expected to be most important (generally in the evenings and very early morning hours). These operations would be implemented during the downstream juvenile migration season, which at the lower Snake River projects occurs from April 3 through June 20. When *Juvenile Fish Passage Spill* ceases, the projects would transition to summer spill operations.

Tailrace TDG would increase at the four lower Snake River projects under the Preferred Alternative due to the *Juvenile Fish Passage Spill* measure that would allow for spill up to 125 percent TDG 16 hours per day, from the beginning of April through the third week of June. Under the No Action Alternative, spill was limited to 120 percent TDG (Appendix D, *Water Quality*). During the April through August fish passage season, there would be increases in the percent of time that TDG would be between 120 percent and 125 percent during each of the five flow and air temperature conditions modeled.

Other Physical, Chemical, and Biological Processes

Slightly Deeper Draft for Hydropower (Dworshak) has small impacts to flow and elevations in the spring. These changes are not anticipated to impact physical, chemical and biological conditions in Dworshak Reservoir and the four lower Snake River reservoirs under the Preferred Alternative as compared to the No Action Alternative.

SEDIMENT QUALITY

Consistent with *Slightly Deeper Draft for Hydropower (Dworshak)* as described, negligible changes are expected to sediment quality in Region C under the Preferred Alternative.

7.7.3.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

WATER QUALITY

Water Temperature

Water temperatures in the lower Columbia River under the Preferred Alternative would be very similar to the No Action Alternative. Just as with the No Action Alternative model results, the Preferred Alternative model results show that tailwater temperatures can exceed 68°F at all four dams during any of the years and conditions presented; and maximum water temperatures, and the frequency of water temperature violations of state water quality standards would be higher during a year when river flows are lower than normal and summer ambient air temperatures are higher (as in LF/HT). The average frequency of water temperature violations of the state water quality standards would be nearly identical for the No Action

Alternative and the PA for all four lower Columbia River dams (Figure 7-19). Under the No Action, the State water quality standard for temperature is violated on average (for the five years simulated) 57, 71, 71 and 58 days downstream of McNary, John Day, The Dalles and Bonneville dams, respectively. As comparison, under the Preferred Alternative, the State water quality standard is violated (on average for the five years simulated) 63, 71, 72, and 59 days downstream of McNary, John Day, The Dalles and Bonneville dams, respectively. The differences in tailwater temperatures under the No Action Alternative and the Preferred Alternative are considered negligible.

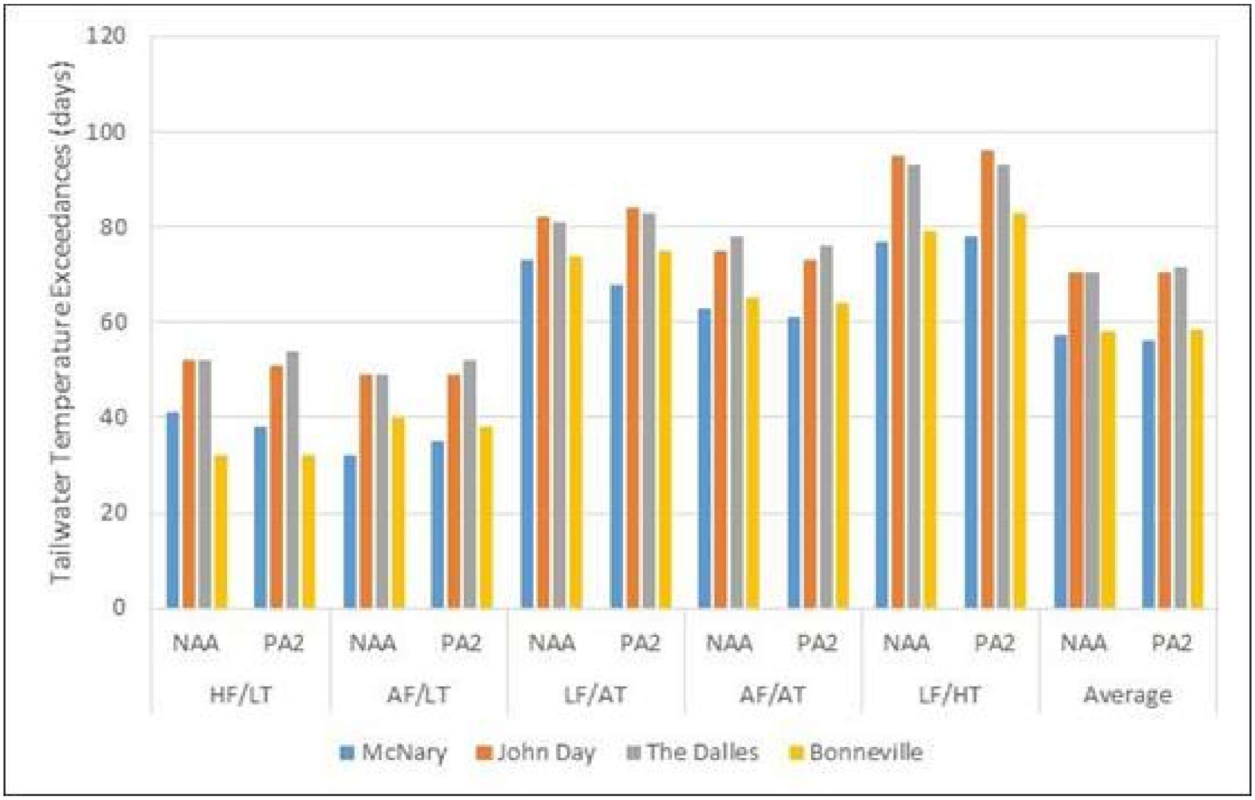

Figure 7-19. Frequency of Modeled Tailwater Temperature Violations of State Water Quality Standards the Preferred Alternative and No Action Alternative at McNary, John Day, The Dalles, and Bonneville Dams Under a 5-year Range of River and Meteorological Conditions

Dissolved Gas

Similar to that described for the lower Snake River projects in Region C, the *Juvenile Fish Passage Spill* measure would be implemented at the lower Columbia River projects during the downstream juvenile outmigration season from April 10 through June 16. When *Juvenile Fish Passage Spill* ceases, the projects would transition to summer spill operations.

Maximum forebay TDG saturations would be higher during a year when river flows were higher than normal (Appendix D, *Water Quality*]). Forebay TDG saturations would be similar under the Preferred Alternative and the No Action Alternative for McNary Dam during spill season. At John Day, The Dalles, and Bonneville, forebay TDG saturations would be similar under the

Preferred Alternative as compared to the No Action Alternative, except for some periods in the early parts of juvenile fish passage spill season when TDG saturations under the Preferred Alternative would be higher than those for the No Action Alternative. Tailrace TDG saturations in the Preferred Alternative would be generally similar to those for the No Action Alternative for all four dams during juvenile fish passage spill season, though there are periods during juvenile fish passage spill season where Preferred Alternative TDG saturations would be higher or lower than for the No Action Alternative. This is likely due to the assumed higher amount of lack of market spill used in the analysis of the No Action Alternative; model results do not show a notable difference in tailrace TDG in the Preferred Alternative as compared to the No Action Alternative. TDG effects are negligible in Region D.

Other Physical, Chemical, and Biological Processes

For Region D, the combination of all operational changes upstream result in similar flows and elevations in this region. An exception is the small change in elevation at the John Day Reservoir due to *Predator Disruption Operation* and *John Day Full Pool* measures. Therefore, the Preferred Alternative would result in no change to the physical, chemical, or biological water quality impairments.

SEDIMENT QUALITY

Negligible changes are expected to sediment quality in Region D under the Preferred Alternative.

7.7.3.5 Summary of Effects

Although the effects of the Preferred Alternative differ across the various projects in terms of water and sediment quality, they can generally be categorized as follows:

In Region A, the Preferred Alternative is expected to have negligible to minor effects to water temperatures and TDG conditions at the projects when compared to what would occur under the No Action Alternative. Minimal changes to the physical, chemical, or biological processes in most locations in Region A would occur. Elevated concentrations of selenium and nitrate-nitrogen in Lake Koocanusa and the Kootenai River downstream may occur due to the reduced reservoir elevations and residence time of water within the reservoir. Lastly, the Preferred Alternative would not impact turbidity or sediment concentrations in the region. Overall, these effects are expected to be negligible to minor.

In Region B, the Preferred Alternative is expected to have negligible effects on water temperatures and TDG when compared to the No Action Alternative. In addition, changes in reservoir elevation within Lake Roosevelt and Rufus Woods Lake are small and are not predicted to impact the physical, chemical, or biological processes in the reservoirs as compared to the No Action Alternative. Overall, impacts are anticipated to be negligible.

In Region C, the Preferred Alternative is expected to have negligible effects to water temperature at Dworshak and all four lower Snake River projects. For TDG, moderate increases are anticipated due to the *Juvenile Fish Passage Spill* measure that would allow for spill up to 125 percent TDG 16 hours per day, from the beginning of April through the third week of June. Impacts to other water quality parameters would be negligible.

In Region D, the Preferred Alternative is expected to result in little to no change to water temperatures, TDG, sediment quality, or other water quality parameters when compared to the No Action Alternative. These effects are expected to be negligible.

For further details, please refer to the Water Quality Technical Appendix D.

7.7.4 Anadromous Fish

7.7.4.1 Salmon and Steelhead

There are no anadromous fish in Region A (Bull Trout are evaluated in the resident fish section) and upstream of Chief Joseph Dam in Region B. The effects of the Preferred Alternative on anadromous fish are expected to be negligible in Region B downstream of Chief Joseph Dam due to minor changes in operations, and depending on the model and Evolutionarily Significant Unit (ESU)/Distinct Population Segment (DPS), the effects to anadromous fish in Regions C and D have the potential to range from a moderate adverse impact to a major beneficial effect. The ranges in potential effects are due to uncertainty and spread between modeled estimates for the *Juvenile Fish Passage Spill* measure because of the unknown magnitude of latent mortality and an unknown level of reduction in transportation for some species.

The increased levels of spill included in the Preferred Alternative are intended to provide a more effective passage method to avoid direct injury from turbine or bypass passage. Results for upper Columbia River stocks are beneficial based on LCM estimates. In-river survival and SARs are anticipated to increase. The CSS model predicts higher Smolt to Adult Return (SARs) rates from increased spill largely due to reductions in latent mortality (delayed death of salmon following passage through the CRS). The predicted level of benefit from increased spill differs between the two suites of models used to evaluate impacts to anadromous fish. For example, the CSS model predicts the Preferred Alternative would result in a relative increase of 35 percent for Snake River Spring/Summer Chinook compared to the No Action Alternative. In contrast, NMFS' Life Cycle Model (LCM) shows a reduction in SARs of -7.5 percent for Snake River Spring/Summer Chinook relative to the No Action Alternative. This predicted reduction in SARs by the NMFS LCM is primarily a function of reduced transportation rates (see below for more discussion). The LCM also assessed SARs under several levels of assumed latent mortality reductions (10, 25, and 50 percent). If latent mortality is decreased by more than 10 percent, the LCM predicts increased SARs compared to the No Action Alternative. As noted in Chapter 3, the science continues to evolve on the causal factors and the magnitude of latent effects caused by passage through the CRS. This Preferred Alternative is anticipated to, and is specifically designed to improve the region's understanding of this issue.

Increased levels of spill are generally associated with lower transport rates as fish are diverted from turbine and bypass routes to spill routes. Past data has shown that transported fish can have higher adult return rates than in-river fish depending on species and time of year, but the relationship is especially relevant for Snake River steelhead. However, as in-river conditions improve, the difference in adult return rates between fish that were transported and those that remained in-river becomes smaller. The co-lead agencies are proposing to continue to monitor this relationship, and manage transportation adaptively to continue to improve effectiveness.

Increase in gas bubble trauma can result in injury or even death of juvenile and adult salmonids if TDG exposure is of sufficient magnitude and duration. In addition, spill levels being proposed in the Preferred Alternative have been shown to delay adult migrants as they search for fishway entrances. Increased incidence of adult fish falling back over spillways would also be expected with the higher spill levels. Monitoring would be in place to help the co-lead agencies identify and remedy any of the potential adverse effects noted above. Other measures in the alternative intended to reduce adult delay at dams and increase juvenile survival were determined to provide negligible to minor positive effects for anadromous fish.

Several different ESU/DPS units of salmon and steelhead share a similar life cycle and experience similar effects from the Preferred Alternative, but also have ESU-DPS specific traits that drive effects differently from one another. Common effects analyses across all salmon and steelhead are discussed first, and then those ESU/DPS specific effects are displayed.

EFFECTS COMMON ACROSS SALMON AND STEELHEAD[8]

Summary of Key Effects

The Preferred Alternative includes several structural measures intended to improve juvenile migration. Juvenile fish spill generally increases the amount of spill at each of the lower Columbia River and lower Snake River projects for improved juvenile survival, and predator disruption operations at John Day would reduce predation by birds on juvenile salmon and steelhead. Latent effects may be reduced that could increase ocean survival. Structural measures in the Preferred Alternative would make small, incremental improvements in adult migration.

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[8] On February 4, 2020, the co-lead agencies viewed a presentation prepared by NMFS regarding returns for the 2019 fish passage season and the Adaptive Management Implementation Plan (see Section 3.5 for more information). Although not all adult returns occurred prior to the presentation, NMFS utilized current return numbers to estimate final return numbers if current return rates continued in 2020 and 2021. These projects signaled that returns are low, especially for Snake River steelhead. The co-lead agencies are currently evaluating the draft information provided by NMFS and will have a more detailed discussion of this information in the Final EIS, including any updates that NMFS may provide once all returns have occurred, if appropriate.

Juvenile Fish Migration/Survival

There are structural measures in the Preferred Alternative that may affect juvenile salmon and steelhead.

- Improved Fish Passage (IFP) turbines at John Day Dam (up to 16) are scheduled for replacement after similar replacements have been completed at Ice Harbor (up to 3 turbines) and at McNary Dam. Ice Harbor and McNary Dam turbine replacements are part of the No Action Alternative. As John Day turbine replacement would follow Ice Harbor and McNary improvements, these improvements are currently scheduled to occur between 2025 and 2039. The new IFP turbines would have similar improvements in fish passage performance as the replacement turbines designed for install at Ice Harbor Dam. The Ice Harbor Dam turbines were specifically designed for fish passage using a process similar to what may be used for future turbine runners at John Day Dam. Turbine mortality was split into direct and indirect mortality. Direct turbine mortality includes injuries that occur during turbine passage while indirect turbine mortality can include effects like predation that occur as a result of disorientation or poor egress following turbine passage. The primary sources of direct turbine mortality come from mechanical-, shear-, or pressure-related injuries.

  Physical hydraulic models were used to evaluate the potential for mechanical and sheer related injuries, while potential for pressure related injuries were evaluated using sensor fish or computation fluid dynamic models. These analyses suggested that IFP turbines could reduce injury and mortality by as much as 68 percent for fixed-blade turbines and as much as 49 percent for adjustable blade turbines.

  For modeling and analysis purposes, a value of 50 percent was used to evaluate reductions in injuries to juvenile salmon and steelhead that pass through turbine routes. COMPASS modeling incorporates these values directly into the model, and the results reflect the change in survival. For non-modeled species, qualitative analyses and surrogate species were used to evaluate effects of new IFP turbines. See Appendix E for more information regarding these assumptions.

Several operational measures warrant discussion here individually, regarding effects to juvenile fish. Measures that would result in changes to spill, flows, passage routes, or temperatures were incorporated into the fish models. Others are not readily incorporated into modeling for effects analysis, or are modeled but may be difficult to separate from other factors, and so effects of these measures are discussed qualitatively.

- Cease installation of fish screens to increase the efficiency of new hydropower turbines at Ice Harbor, McNary, and John Day Dams once IFP turbines are installed. This measure is intended to consider running the new IFP turbines unscreened if acceptable biologically. The co-lead agencies would collaborate with NMFS and USFWS to develop a Turbine Intake Bypass Screen Management and Future Strategy process to monitor success of the IFP turbines and determine if and when best to remove fish screens at these projects. For this analysis, it is assumed that fish screens would not be removed if appropriate testing demonstrated a reduction in juvenile fish survival.

- Manipulation of John Day reservoir elevations to deter nesting of bird predators at Blalock Islands: Caspian terns have been shown to consume large numbers of juvenile salmon and steelhead during their downstream migration to the ocean. Blalock Islands are situated in the John Day Dam reservoir and provide nesting habitat for Caspian terns. Under the No Action Alternative, approximately 500 breeding pairs of Caspian terns consume nearly 150,000 steelhead at these small islands annually. This measure calls for a change in operations to raise water levels in the John Day Dam reservoir in April and May to elevations between 263.5 and 265 feet. Effects of this operation would greatly reduce potential nesting habitat for Caspian terns at the Blalock Islands. In fact, an increase in elevation of 1 foot, from 263.5 to 264.5 feet, would reduce habitat by approximately 90 percent. Recent studies show that regional efforts to dissuade Caspian tern nesting have led to a 44 percent decline in the number of Caspian terns nesting in the Columbia Plateau region (Collis et al. 2019). Continued reductions in nesting habitat would likely be associated with continued reductions in nesting predators and increases in juvenile salmon and steelhead survival.

- *Juvenile Fish Passage Spill* would be implemented to aid juvenile salmonid migration at the lower Snake River projects and the lower Columbia River projects (see Table 7-21 and Table 7-22 for more details). The implementation of the *Juvenile Fish Passage Spill* operations is intended to decrease the number of juvenile fish that pass the dams through non-spillway routes, decrease fish travel time through the forebays, gain scientific information on latent (delayed) mortality, and provide flexibility for hydropower generation. The effects vary by model and ESU/DPS.

- The transport of juvenile salmon collected at Lower Granite, Little Goose, and Lower Monumental projects could begin as early as April 15, approximately 2 weeks earlier than current fish transport operations described in the No Action Alternative. Transport operations would end September 30 at Lower Monumental and October 31 at Lower Granite and Little Goose. Collected juvenile fish would be transported to a location below Bonneville Dam via barge or truck on a daily or every-other-day schedule, depending on the numbers of fish collected at the collector projects. This measure does not preclude the co-lead agencies from implementing a cessation of juvenile transportation June 21 through August 14 with allowance for adaptive management adjustments through TMT as was contemplated in the *2019-2021 Spill Operation Agreement* (Agreement). This action could increase the number of juvenile fish transported to the estuary.

Adult Fish Migration/Survival

There are several structural measures in the Preferred Alternative that may affect adult salmon and steelhead. Many of these structures are in one or more other MOs as well. The effects of these measures are described here.

- Design and implement structural modifications to the Lower Granite Dam adult fish trap gate to reduce delay and stress for adult salmonids and non-target species such as Pacific Lamprey. The Corps would replace the existing trap gate with a gate operated by a dedicated hoist to improve efficiency. The new gate would be designed to more efficiently shed debris and would include a gap in the bottom to allow upstream passage of lamprey. This measure is intended to increase adult salmon and steelhead survival by reducing upstream travel times.
- The Corps would modify the serpentine-style flow control sections of Bonneville Dam's Washington Shore and Bradford Island fish ladders, converting them to an Ice Harbor-style vertical slot fishway with in-line submerged orifices. This modification would increase passage success for adult lamprey and reduce stress and delay for adult salmon, steelhead and bull trout. This action has potential to increase adult salmon and steelhead survival by reducing upstream passage time at the dam. A similar modification at John Day Dam, the only other CRS dam to use this type of ladder, resulted in significant passage time reductions for salmon and steelhead. Similar improvements are expected for Bonneville Dam.
- Install closeable gates on Bonneville Powerhouse 2 floating orifice gates to reduce the occurrence of lamprey falling out of the powerhouse adult fish collection channel. Closeable gates would allow seasonal closure during the lamprey passage season. This measure is intended to increase adult lamprey upstream passage success. While this measure is intended to improve adult lamprey passage success at Bonneville Dam, it may affect adult salmon and steelhead passage as well. Studies of similar powerhouse adult fish collection systems at Bonneville Powerhouse 1, The Dalles Dam, and Priest Rapids Dam (Keefer et al. 2008; Bjornn et al. 1997) suggest that this action could improve overall adult salmon and steelhead passage. The floating orifice gates at those projects were permanently closed as a result of this research. However the co-lead agencies are proposing to install gates that can be closed during the adult lamprey migration (June to September), and opened during the rest of the year, due to concerns over springtime sea lion predation on adult salmon and steelhead that are attempting to pass Bonneville Dam.

While the Preferred Alternative contains structural measures at lower Columbia River and lower Snake River projects that may reduce delay for adult fish passing those projects, juvenile fish passage spill may increase adult fallback rates under the Preferred Alternative due to higher spill levels. Higher fallback rates would increase adult fish mortality and delay their migration through the system (Boggs et al. 2004; Keefer et al. 2005). Higher spill may also delay adult passage at some dams by causing unfavorable tailrace hydraulic patterns such as eddies, that mask adult fish ladder attraction flow. It is important to note that regional managers use in-season adaptive management to identify and remedy any excessive fallback and delay.

UPPER COLUMBIA RIVER SALMON AND STEELHEAD

Upstream of McNary Dam, upper Columbia salmon and steelhead migrate past as many as five non-federal dams and reservoirs which also impact the survival and passage of this species. The federal parties do not dictate generation or spill levels at these projects so metrics such as powerhouse encounter rate are not directly affected, but are influenced by river flow levels coming through the Upper Basin. The timing and volume of flow levels affected by CRS operational decisions are reflected in model analysis. COMPASS and LCM estimates of powerhouse encounter rate and SARs include passage effects from a combination of federal and non-federal dam passage (Rock Island Dam to Bonneville Dam).

Unless otherwise noted, quantitative results from COMPASS and the LCM are based on a combination of hatchery and natural origin fish. This applies for both juvenile and adult results. CSS cohort analysis for upper Columbia River salmon and steelhead are not included because no model exists.

Upper Columbia Spring-Run Chinook Salmon

Summary of Key Effects

For juvenile fish passage under the Preferred Alternative, the COMPASS modeling results show slightly increased survival rates (+0.9 percent) from McNary Dam to Bonneville Dam, and reduced travel times (-0.5 days) relative to the No Action Alternative. *Juvenile Fish Passage Spill* under the Preferred Alternative would increase compared to the No Action Alternative. Predator disruption operations would further increase juvenile survival. Structural improvements would increase adult migration success, but higher spill may cause additional fallback and delay compared to the No Action Alternative. Exposure to supersaturated TDG would increase slightly for both adult and juvenile fish as they migrate through the CRS. Abundance would increase by 7 percent assuming no reduction in latent mortality to about 155 percent if latent mortality were reduced by 50 percent.

Juvenile Fish Migration/Survival

This population migrates through the Columbia River downstream past the four lower CRS projects and up to five non-federal dams. Structural and operational measures in the *Effects Common Across Salmon and Steelhead* (*Common Effects*) section that describe changes from the No Action Alternative at McNary, John Day, The Dalles, and Bonneville projects would apply to these fish. COMPASS modeling estimates that the Preferred Alternative could result in a 0.9 percent increase in average juvenile survival, an 8 percent decrease in average juvenile travel time from McNary Dam to Bonneville Dam, and a 10 percent decrease in the number of powerhouse passage events. Predator disruption operations, also described in *Common Effects*, would further increase juvenile survival by reducing predation on out-migrating smolts. TDG exposure would increase 1.3 percent compared to the No Action Alternative for these fish.

Table 7-21 summarizes COMPASS and University of Washington's TDG model results for upper Columbia River spring-run Chinook salmon under the Preferred Alternative.

Table 7-21. Preferred Alternative Juvenile Model Metrics for Upper Columbia River Spring-Run Chinook Salmon

Metric (Model)	NAA	Preferred Alternative	Change from NAA	% Change
Juvenile Survival (COMPASS) McNary to Bonneville	69.5%	70.4%	+0.9%	+1%
Juvenile Travel Time (COMPASS) McNary to Bonneville	6.1 days	5.6 days	-0.5 days	-8%
% Transported (COMPASS)	0%	0%	0	0%
Powerhouse Passages (COMPASS) Rock Island to Bonneville	3.29	2.96	-0.33	-10%
TDG Average Exposure (TDG Tool)	116.0% TDG	117.3% TDG	+1.3% TDG	+1%

Adult Fish Migration/Survival

The *Modify Bonneville Ladder Serpentine Weir* measure, described in the Common Effects section, would decrease delay of upstream migration, although higher spill could increase fallback rates. Adult exposure to TDG would be higher than the No Action Alternative.

The LCM estimated SARs and abundance of the Wenatchee population which are used here as an index population for Upper Columbia River spring Chinook salmon (Table 7-22). SARs are estimated to increase from 0.94 percent under the No Action Alternative to 0.97 percent under the Preferred Alternative. The LCM results predict that abundance of the Wenatchee population, would increase relative to the No Action Alternative, ranging from about 7 percent assuming no reduction in latent mortality to 155 percent assuming a 50 percent reduction in latent mortality. CSS modeling was not available for this population, but the theory in CSS modeling indicating fewer powerhouse encounters would reduce latent mortality can be considered here.

Table 7-22. Preferred Alternative Model Metrics for Adult Upper Columbia River Spring Chinook Salmon

Metric (Model)	No Action Alternative	Preferred Alternative	Change from No Action Alternative	% Change
Rock Island to Bonneville SARs (NMFS LCM)	0.94%	0.97%	0.03%	3.2%
NMFS LCM abundance range for Wenatchee spring Chinook, with decreased latent mortality[1/] (number of adults)	498	536 (0%) 642 (10%) 855 (25%) 1,268 (50%)	+38 (0%) +144(10%) +357 (25%) +770 (50%)	+7% (0%) +30% (10%) +72% (25%) +155% (50%)

Note: Percentages in parentheses indicate assumed potential decreases in latent mortality.
1/ NMFS LCM does not factor latent mortality due to the Columbia River System into the SARs or abundance output. For discussion purposes, potential decreases in latent mortality of 10 percent, 25 percent, and 50 percent are shown for abundance estimates. The value for 0 percent is the actual model output, the 10 percent, 25 percent, and 50 percent values represent scenarios of what abundance hypothetically could be under the increased ocean survival if changes in the alternative were to decrease latent mortality by that much.

Upper Columbia River Steelhead

Summary of Key Effects

There are no life cycle models for upper Columbia steelhead to estimate adult returns, only COMPASS model estimates of juvenile downstream survival. Upper Columbia River steelhead juvenile migration would be similar the No Action Alternative. Predator disruption operations in the John Day reservoir would further increase juvenile survival. Structural improvements could increase adult migration success.

Juvenile Fish Migration/Survival

Juveniles from this population migrate through the Columbia River downstream past the four lower CRS projects and up to five non-federal dams. COMPASS modeling estimates that the Preferred Alternative results in a 0.1 percent decrease in average juvenile survival for upper Columbia steelhead, travel time would be the same as the No Action Alternative, and powerhouse passage events would decrease by 5 percent. Predator disruption operations, also described in Common Effects, would increase juvenile survival by reducing predation on out-migrating smolts. TDG exposure would be 1.5 percent higher than in the No Action Alternative. Table 7-23 summarizes COMPASS and TDG model results for upper Columbia River steelhead under the Preferred Alternative.

Table 7-23. Preferred Alternative Model Metrics for Juvenile Upper Columbia Steelhead

Metric (Model)	NAA	Preferred Alternative	Change from NAA	% Change
Juvenile Survival (COMPASS) McNary to Bonneville	65.8%	65.7%	-0.1%	-0.2%
Juvenile Travel Time (COMPASS) McNary to Bonneville	6.6 days	6.6 days	0 days	0%
% Transported (COMPASS)	No transport of upper Columbia steelhead			
Powerhouse Passages (COMPASS) Rock Island to Bonneville	2.72	2.58	-0.14	-5%
TDG Average Exposure (TDG Tool)	116.0% TDG	117.5% TDG	+1.5% TDG	+1%

Adult Fish Migration/Survival

The *Modify Bonneville Ladder Serpentine Weir* measure, described in the Common Effects section, could decrease delay of upstream migration. Higher spill could increase survival of kelts by increasing their passage through non-turbine routes. Adult steelhead exposure to supersaturated TDG would be higher than in the No Action Alternative. River temperatures would be similar to No Action Alternative.

Upper Columbia River Coho Salmon (Non ESA-listed)

See Upper Columbia spring-run Chinook salmon analysis as a surrogate for juvenile Upper Columbia coho salmon and Upper Columbia fall Chinook salmon analysis as a surrogate for adult Upper Columbia coho salmon.

Summary of Key Effects

Effects on Upper Columbia coho salmon include the conditions they encounter during upstream and downstream migrations. Downstream survival and migration for juveniles is dependent on water flow and routing at the dams. Higher flows and higher spills generally lead to higher survival. Juvenile coho survival would be similar to Upper Columbia spring-run Chinook salmon, with structural measures and spill increases potentially increasing juvenile survival and additional increases in survival due to lower predation by birds in the John Day reservoir. Adult coho salmon migration timing is similar to Upper Columbia fall Chinook salmon so that species is used as a surrogate for upstream migration effects.

Juvenile Fish Migration/Survival

See Upper Columbia spring-run Chinook salmon results as a surrogate for juvenile Upper Columbia coho salmon.

Adult Fish Migration/Survival

Upper Columbia fall Chinook, are used as a surrogate for adult Upper Columbia coho in this analysis. Adult migration conditions would be similar to the No Action Alternative. The Preferred Alternative water quality modeling showed no change in the frequency of water temperatures exceeding 20°C (68°F) relative to the No Action Alternative. Structural improvements could increase adult migration success compared to the No Action Alternative. Based on Upper Columbia spring Chinook juvenile migration, powerhouse encounter rates would be reduced, and this could result in increased adult return rates.

Upper Columbia River Sockeye Salmon (Non ESA-listed)

Summary of Key Effects

Changes to Upper Columbia sockeye salmon would be similar to estimated changes for Upper Columbia Spring Chinook: survival rates from McNary Dam to Bonneville Dam would increase, travel times would be reduced, and predator disruption operations could further increase juvenile survival. Structural improvements would increase adult migration success, but higher spill may cause additional fallback and delay compared to the No Action Alternative. Exposure to high levels of TDG would increase for both adult and juvenile fish as they migrate through the CRS.

Juvenile Fish Migration/Survival

Juvenile survival of Upper Columbia sockeye salmon are estimated using COMPASS juvenile modeling results for Upper Columbia spring Chinook salmon as a surrogate. Operational and structural measures described in *Common Effects* would increase survival by increasing the proportion of spillway passage, increasing survival of sockeye juveniles that pass through John Day Dam turbines and reducing the risk of predation by birds. Exposure to elevated TDG would increase relative to the No Action Alternative.

Adult Fish Migration/Survival

The *Modify Bonneville Ladder Serpentine Weir* measure, described in the *Common Effects* section, would decrease delay of upstream migration, although higher spill could increase fallback rates and delay. Adult exposure to TDG would be higher than the No Action Alternative. The summer water temperatures in the river during the upstream migration would be similar to the No Action Alternative, with thermal issues continuing to reduce adult survival in the warmest years. Based on Upper Columbia River spring Chinook juvenile migration, powerhouse encounter rates would be reduced, and this could result in increased adult returns.

Upper Columbia River Summer/Fall-Run Chinook Salmon (Non ESA-listed)

Summary of Key Effects

Juvenile Upper Columbia summer/fall-run Chinook salmon would be similar to the No Action Alternative, with potential increases in juvenile survival due to lower predation in the John Day Reservoir.

Larval Development/Juvenile Rearing in Mainstem Habitats

None of the measures of the Preferred Alternative would change the substrate sizes or distribution in the spawning areas or expand suitable spawning areas; therefore, this alternative is expected to have the same larval development and juvenile rearing habitat conditions as the No Action Alternative. The same is true for river depths in the spawning areas; no change is anticipated for eggs incubating in the gravel. No change is anticipated in McNary and John Day Dam reservoir plankton communities or shoreline habitats under the Preferred Alternative, relative to the No Action Alternative. Likewise, juvenile rearing habitat below Bonneville Dam is not expected to change relative to the No Action Alternative.

Juvenile Fish Migration/Survival

Juvenile summer/fall Chinook salmon are susceptible to predation in the Columbia River. Water temperatures would be the same as the No Action Alternative, and therefore, there would be no change in temperature-related predation rates in this reach. Downstream migration of juveniles would be similar to the No Action Alternative.

Adult Fish Migration/Survival

The number of days water temperatures in the McNary Dam tailrace exceed 20°C would not change relative to the No Action Alternative, so no change in migration delay, fallback, or susceptibility to disease are anticipated due to overall warmer mainstem water temperatures at the lower Columbia River Dams.

Specific to Okanogan upper Columbia summer/fall Chinook salmon, there would be no change in the number of days the mainstem would be 20°C or higher at the confluence of the Okanogan River, relative to the No Action Alternative. This means that there would be no change anticipated in the ability of the Okanogan fish to wait (hold) in the mainstem until water temperatures in the Okanogan River are cool enough for adults to move up from the mainstem. This allows these salmon to migrate without having to experience water temperatures typically considered lethal for salmon and steelhead (Ashbrook et al. 2009).

The frequency of meeting the Vernita Bar Agreement to protect the prolific fall Chinook salmon spawning in and around the Hanford Reach of the Columbia River in Washington is not expected to change under the Preferred Alternative relative to the No Action Alternative. Other operational changes under the Preferred Alternative are likewise not anticipated to affect upper Columbia summer/fall Chinook salmon spawning from the tailrace of Chief Joseph Dam to Bonneville Dam in terms of changes in flows or water temperatures. There could be increased TDG exposure from McNary to below Bonneville Dam.

Middle Columbia River Spring-Run Chinook Salmon

See Upper Columbia spring Chinook analysis as a surrogate for Middle Columbia Spring Chinook Salmon.

Summary of Key Effects

Changes to Middle Columbia spring Chinook salmon would be similar to estimated changes for upper Columbia spring Chinook: survival rates from McNary Dam to Bonneville Dam would increase, travel times would be reduced, and predator disruption operations would further increase juvenile survival. Structural improvements would increase adult migration success, but higher spill may cause additional fallback and delay compared to the No Action Alternative. Exposure to higher levels of TDG would increase for both adult and juvenile fish as they migrate through the CRS.

Juvenile Fish Migration/Survival

Using the surrogate species of upper Columbia spring Chinook salmon, and based on COMPASS model results, the Preferred Alternative may result in nearly a 1 percent increase in Middle Columbia spring Chinook salmon average juvenile survival from the McNary Dam to the Bonneville Dam tailrace. This would be an 8 percent decrease in average travel time, and a 10 percent decrease in the average number of powerhouse passage events. Middle Columbia juvenile salmon would typically experience higher absolute survival than Upper Columbia spring Chinook salmon because they do not experience the additional mortality associated with the Columbia River from Chief Joseph Dam downstream through up to five non-federal dams. However, the surrogate metric used for Upper Columbia spring- Chinook salmon is survival from McNary to Bonneville Dam and would be similar for Middle Columbia spring Chinook salmon that pass the same CRS projects.

Adult Fish Migration/Survival

The *Modify Bonneville Ladder Serpentine Weir* measure, described in the *Common Effects* section, would decrease delay of upstream migration, although higher spill could increase fallback rates. Adult exposure to TDG would be higher than the No Action Alternative. Based on Upper Columbia spring Chinook juvenile migration, powerhouse encounter rates would be reduced, and this could result in increased adult returns.

Middle Columbia River Steelhead

Summary of Key Effects

Changes in effects to Middle Columbia steelhead juvenile and adult migration and returns under the Preferred Alternative would be similar to the No Action Alternative. Certain structural measures and higher spill levels should result in higher survival rates for adult steelhead falling back through the dams and kelts migrating downstream.

Juvenile Fish Migration/Survival

Populations of Middle Columbia steelhead are distributed in the lower Columbia River between the confluences of the Deschutes and Walla Walla rivers. These steelhead pass between two to four CRS dams on their downstream outmigration to the ocean. No quantitative model exists for Middle Columbia steelhead, so COMPASS estimates from juvenile survival of Upper Columbia steelhead were used as a surrogate. CSS models do not exist for this population. COMPASS modeling predicts that the Preferred Alternative would decrease in average juvenile survival for Upper Columbia steelhead by 0.1 percent, cause no change in travel time, and decrease powerhouse passage events by 5 percent for fish passing all four lower Columbia River dams. Predator disruption operations, also described in *Common Effects*, would further increase juvenile survival by reducing predation on out-migrating smolts. Higher levels of TDG exposure would be higher than in the No Action Alternative. Outflows and temperatures would be similar to the No Action Alternative. Predator disruption operations, as described in the *Common Effects* section, would reduce predation on out-migrating Middle Columbia steelhead smolts. In general, the survival and outmigration of Middle Columbia steelhead would be very similar to the No Action Alternative.

Adult Fish Migration/Survival

Structural measures such as modifying the upper ladder serpentine sections at Bonneville Dam are expected to reduce delay associated with upstream passage. Higher spill levels during April periods should result in higher survival rates or for adult steelhead falling back through dams and kelts migrating downstream, as fewer adults use powerhouse passage routes when a spill or surface passage route is available (Normandeau et al. 2014; Richins and Skalski 2018). Based on Upper Columbia steelhead juvenile migration, powerhouse encounter rates would be reduced, and this could result in increased adult returns.

Snake River Salmon and Steelhead

Snake River Spring/Summer-Run Chinook Salmon

Summary of Key Effects

Depending on the model used and assumptions regarding latent mortality, CSS and LCM modeling indicate that the Preferred Alternative would result in lower (7 percent) to substantially higher (35 percent) SARs for Snake River spring/summer Chinook salmon. Juvenile survival would be very similar to the No Action Alternative (about 0.6 percent higher). Adults could see benefits to upriver migration with some structural measures. The Compass and CSS models both predicted substantial reductions in the proportion of fish transported. Unless otherwise noted, quantitative results from COMPASS, CSS, and the LCM are based on a combination of hatchery and natural origin fish. This applies for both juvenile and adult results.

Juvenile Fish Migration/Survival

This population migrates through the Snake and Columbia rivers downstream past the eight lower CRS projects. Structural and operational measures in the *Common Effects* section describe changes at all of these dams and would apply to these fish. The combination of several measures would decrease travel time and powerhouse encounters and overall, increase juvenile outmigration survival. For Snake River spring/summer Chinook salmon, the COMPASS and CSS cohort models estimate that the Preferred Alternative would increase juvenile survival from Lower Granite Dam to Bonneville Dam by up to 3 percent, and travel time would decrease by about 7 percent relative to the No Action Alternative. The increase in *Juvenile Fish Passage Spill* is expected to decrease powerhouse encounters substantially, with the models predicting a decrease of about 48 to 54 percent. Predator disruption operations, also described in *Common Effects*, would further increase juvenile survival by reducing predation on out-migrating smolts. TDG exposure would be 2.9 percent higher than the No Action Alternative, with a reach average exposure of 118.0 percent TDG. See Table 7-24 for a list of model outputs related to juvenile migration and survival.

Table 7-24. Preferred Alternative Juvenile Model Metrics for Snake River Spring/Summer Chinook Salmon

Metric (Model)	No Action Alternative	Preferred Alternative	Change from No Action Alternative	% Change
Juvenile Survival (COMPASS)	50.4%	51.0%	+0.6%	1%
Juvenile Survival (CSS)	57.6%	60.5%	+2.9%	5%
Juvenile Travel Time (COMPASS)	17.7 days	16.5 days	-1.2 days	-7%
Juvenile Travel Time (CSS)	15.8 days	14.7 days	-1.1 days	-7%
% Transported (COMPASS)	38.5%	19.0%	-19.5%	-51%
% Transported (CSS)	19.2%	10.2%	-9.0%	47%
Transport: In-River Benefit Ratio (CSS)	0.86	0.62	-0.24	-27%

Metric (Model)	No Action Alternative	Preferred Alternative	Change from No Action Alternative	% Change
Powerhouse Passages (COMPASS)	2.3	1.2	-1.1	-48%
Powerhouse Passages (CSS)	2.15	0.98	-1.17	-54%
TDG Average Exposure (TDG Tool)	115.1% TDG	118.0% TDG	+2.9% TDG	2.5%

Several measures in the Preferred Alternative would affect juvenile Snake River spring/summer Chinook salmon transportation rates. Both the LCM and CSS models predicted that the proportion of fish transported would be about half that of the No Action Alternative. CSS also predicts a decrease in the benefit to survival for transported smolts, likely due to improved in-river conditions that are driven by shorter juvenile fish travel times and decreased powerhouse passage.

Smolts may be collected for transportation at the three Snake River projects starting as early as April 15, which is earlier than the No Action Alternative start date of April 25. The intent of this measure is to increase the region's understanding of early season transport effects and benefits to early migrating Snake River steelhead. However, for Snake River Chinook, the earlier start to juvenile fish transport would have a neutral effect on the Transport In-River Benefit Ratio (TIR), though hatchery-origin Chinook salmon smolts have a greater benefit of transportation during this timeframe than natural-origin smolts (Transport COP, Gosselin et al. 2018). Without a clear benefit for the early period, earlier transport may slightly decrease Snake River spring/summer Chinook salmon adult returns.

Increased spill would also increase the number of juveniles passing via spillways. This means they would not be collected in the juvenile fish bypasses for transportation. LCM results reflect that reducing transport rates, especially in May and June, would be expected to reduce SARs because transported fish typically return at higher rates than those of in-river migrants during this period. Overall across the entire spring migration season in both the No Action Alternative and the Preferred Alternative, the CSS cohort model predicted that natural-origin fish transported as juveniles returned at a lower rate than fish that migrated in-river as juveniles, partially due to modeled improvements to in-river survival rates. Both models reflect the relative benefits of juvenile transport in the Preferred Alternative could be less than the No Action Alternative because transportation rates would be reduced.

Adult Fish Migration/Survival

Several structural measures in the Preferred Alternative are anticipated to benefit adult Snake River spring/summer Chinook salmon upstream passage, including modifying the adult trap and bypass loop at Lower Granite Dam and modifying the upper ladder serpentine sections at Bonneville Dam (reducing delay). However, the Preferred Alternative has higher spring spill, and fallback rates of Snake River spring/summer Chinook salmon may increase since fallback for this population has been associated with higher flow and higher spill levels at many dams (Boggs et al. 2004; Keefer et al. 2005). Higher spill levels can also result in hydraulic patterns that mask adult fish ladder attraction flow at some dams, and this can cause delay the migration of adult salmon. In recent years, adult passage delays have been observed at Little Goose Dam with spill over 30 to 35 percent. It is important to note that regional managers use in-season adaptive management to identify and remedy any excessive fallback and delay, which would likely mitigate for this increase in spill. Spill reduction starting August 15 may reduce fallback for the few summer migrating adults that may still be passing CRS dams in August.

Increasing the operating range by 6 inches at the lower Snake River Dams (MOP 1.5-foot range) and at John Day Dam (MIP 2-foot range) would have little effect on flow, and thus is not expected to affect adult migration timing or survival rates (NMFS 2019). Similarly, holding contingency reserves within juvenile fish passage spill is likely to have little effect, if any, on adult migration.

Table 7-25 displays the median model outputs for adult metrics from both NMFS LCM and CSS. NMFS LCM results include different scenarios of latent mortality in the ocean survival phase, including decreased mortality of 0 percent, 10 percent, 25 percent, and 50 percent (scenario indicated in parentheses).

Table 7-25. Preferred Alternative Adult Model Metrics for Snake River Spring/Summer Chinook Salmon

Metric (Model)	No Action Alternative	Preferred Alternative	Change from No Action Alternative	% Change
Lower Granite to Bonneville (LGR-BON) SARs1/ (NMFS LCM) (Percent)	0.88%	0.81% (0%) 0.88% (10%) 0.97% (25%) 1.12% (50%)	-0.07% (0%) 0% (10%) +0.0.09% (25%) +0.24% (50%)	-7.5% (0%) 0% (10%) +10% (25%) +28% (50%)
SARs LGR-BON (CSS)	2.0%	2.7%	+0.7%	+35%
Abundance of Middle Fork, South Fork and upper Salmon River representative populations (Number of adults; NMFS LCM)2/	2,351	1,790 (0%) 2,149 (10%) 2,645 (25%) 3,600 (50%)	-561 (0%) -202 (10%) +294 (25%) +1,249 (50%)	-24% (0%) -9% (10%) +13% (25%) +53% (50%)
Abundance of Grande Ronde/Imnaha representative populations (CSS)3/	6,114	9,632	+3,518	+58%

1/ NMFS LCM does not factor latent mortality due to the System into the SARs or abundance outputs. For discussion purposes, potential decreases in latent mortality of 10 percent, 25 percent, and 50 percent are shown. The value for 0 percent is the actual model output, the 10 percent, 25 percent, and 50 percent values represent scenarios of what SARs or abundance hypothetically could be under the increased ocean survival scenario if changes in the alternative were to decrease latent mortality by that much.

2/ NMFS LCM provided results for 16 populations in the upper Salmon River, South Fork Salmon River, and Middle Fork Salmon River major population groups. The absolute values include these populations only, the percent change is considered indicative of the Snake River population for the purpose of comparing between MOs.

3/ CSS provided results for six populations in the Grande Ronde/Imnaha major population group. The absolute values represent those populations only; the percent change is considered indicative of the Snake River population for the purpose of comparing between MOs.

The LCM estimates SARs and abundance of the Upper Salmon River, South Fork Salmon River, and Middle Fork Salmon River Major Population Groups (MPGs). CSS estimates the abundance of Grande Ronde/Imnaha MPG. Both models use a combination of hatchery and natural-origin fish. For comparison purposes, the percent change from the No Action Alternative is considered indicative of the effects of Preferred Alternative on the Snake River spring Chinook salmon population.

The LCM predicts the Preferred Alternative would result in reducing SARs (Lower Granite to Bonneville) by 7.5 percent with no latent mortality reduction to increasing adult returns by 28.0 percent with a 50 percent latent mortality reduction. The CSS model predicts a 35 percent increase in the SARs (Lower Granite Dam to Bonneville Dam) for Snake River spring/summer Chinook salmon.

With increases in juvenile survival both in the freshwater migration and in the ocean to adulthood, increases in abundance of fish to the spawning grounds would be expected. The NMFS model, looking at the Middle Fork Salmon, South Fork Salmon, and Upper Salmon populations, showed an average decrease in abundance of about 24 percent without factoring in any change to latent mortality and an increase of 53 percent assuming a 50 percent reduction in latent mortality. The CSS models, using the Grande Ronde/Imnaha MPG, indicated a 58 percent increase in abundance.

Snake River Steelhead

Summary of Key Effects

Depending on the model, juvenile survival is similar or increases. COMPASS and CSS both predict that juvenile travel time is similar to the No Action Alternative. TDG exposure would increase and powerhouse encounters would decrease substantially. The proportion of Snake River steelhead transported as juveniles would decrease under the Preferred Alternative. Predation is expected to decrease with the predator disruption measure in the John Day reservoir. Structural measures and higher spill may increase kelt survival. Based on the CSS model, SARs may increase by 28 percent.

Juvenile Fish Migration/Survival

This Distinct Population Segment (DPS) migrates through the Snake and Columbia rivers downstream past the eight lower CRS projects. Structural and operational measures described in the *Common Effects* section that describe changes at these dams would apply to these fish. The combination of several measures would decrease travel time and powerhouse encounters and increase survival. For Snake River steelhead, the COMPASS model predicts an increase in juvenile survival of 0.1 percent, and CSS cohort models estimate that Preferred Alternative would increase juvenile survival from Lower Granite Dam to Bonneville Dam by 7.4 percent. Both models agree that travel time would be similar and that powerhouse encounters would decrease 46 to 55 percent. Predator disruption operations, also described in *Common Effects*, would further increase juvenile survival by reducing predation on out-migrating smolts. TDG exposure would be higher than the No Action Alternative, with a reach average exposure of 118.1 percent TDG compared to 115.1 percent under the No Action Alternative. See Table 7-26 for a list of model outputs related to juvenile migration and survival.

Table 7-26. Juvenile Model Metrics for Snake River Steelhead under the Preferred Alternative

Metric (Model)	No Action Alternative	Preferred Alternative	Change from No Action Alternative	% Change
Juvenile Survival (COMPASS)	42.7%	42.8%	+0.1%	NA
Juvenile Survival (CSS)	57.1%	64.5%	+7.4%	NA
Juvenile Travel Time (COMPASS)	16.4 days	16.5days	+0.1 days	+0.1%
Juvenile Travel Time (CSS)	16.2 days	15.8 days	-0.4 days	-2%
% Transported (COMPASS)	39.7%	20.9%	-18.8%	NA
% Transported (CSS)	Unknown			
Transport: In-River Benefit Ratio (CSS)	1.41	1.09	-0.32	-23%
Powerhouse Passages (COMPASS)	1.73	0.93	-0.80	-46%
Powerhouse Passages (CSS)	1.96	0.88	-1.08	-55%
TDG Average Exposure (TDG Tool)	115.1% TDG	118.1% TDG	+3.0% TDG	N/A

Specific measures that would affect the change in transportation include potential earlier start of transport (April 15) relative to the No Action Alternative (April 25). The earlier juvenile fish transport start date would likely increase adult returns for hatchery-origin steelhead and would have a neutral effect on natural-origin steelhead. Thus, the earlier transport date is likely not a driver of the TIR response relative to the No Action Alternative because the effect should be positive or neutral, not negative.

Higher spill increases the number of juveniles passing via spillways and thus reduces collection of juvenile fish for transportation. Reducing transport rates, especially in May and June, would be expected to decrease total adult returns of steelhead. Higher in-river survival under the Preferred Alternative compared to the No Action Alternative may also be a factor in the lower season-wide TIR and is the most likely driver of the change in the Preferred Alternative relative to the No Action Alternative.

Additionally, the CSS cohort model estimates a 23 percent reduction in TIR (i.e., reduction in transport benefit), relative to migration in-river compared the No Action Alternative. While a Preferred Alternative TIR of 1.1 represents a reduction in TIR relative to the No Action Alternative (TIR 1.4), the TIR still represents a season-wide benefit to transport relative to in-river migration, measured in terms of relative SARs (DeHart CRSO-24/2019).

Adult Fish Migration/Survival

Several structural measures in the Preferred Alternative are anticipated to benefit adult steelhead passage upstream, including modifying the adult trap at Lower Granite Dam and modifying the upper ladder serpentine sections at Bonneville Dam (reducing delay). Adult exposure to higher levels of TDG would increase relative to the No Action Alternative.

Higher spill levels during April periods should result in higher survival rates for adult steelhead falling back through dams and kelts migrating downstream. This is because fewer adults would use powerhouse passage routes when a spill route is available, and downstream passage rates increase when surface passage is available (Normandeau et al. 2014; Keefer et al. 2016).

For Snake River steelhead, the CSS cohort model estimates that SARs would increase from 1.8 percent under the No Action Alternative to 2.3 percent under the Preferred Alternative which is a 28 percent increase from the No Action Alternative. Table 7-27 displays the CSS cohort model results for Snake River steelhead. There is no NMFS LCM model for Snake River steelhead.

Table 7-27. Preferred Alternative Adult Model Metrics for Snake River Steelhead

Metric (Model)	No Action Alternative	Preferred Alternative	Change from No Action Alternative	% Change
SARs LGR-BON (CSS)	1.8%	2.3%	+0.5%	+28%

Snake River Coho Salmon

See Snake River spring/summer Chinook as a surrogate for Snake River coho salmon.

<u>Summary of Key Effects</u>

Juvenile survival would be very similar to the No Action Alternative (about 0.6 percent higher). Adults could see benefits to upriver migration with some structural measures.

<u>Juvenile Fish Migration/Survival</u>

Juvenile survival of Snake River coho salmon is estimated using COMPASS and CSS juvenile modeling results for Snake River spring Chinook salmon as a surrogate. Structural and operational measures described in the *Common Effects* section that describe changes at these dams would apply to these fish. The combination of several measures would decrease travel time and powerhouse encounters and overall increase juvenile outmigration survival. The COMPASS and CSS cohort models estimate that the Preferred Alternative would increase juvenile survival from Lower Granite Dam to Bonneville Dam by less than 1 percent, and travel time would decrease by about 7 percent. The increase in juvenile fish spill would be expected to decrease powerhouse encounters substantially, with the models predicting a decrease of about 48 to 54 percent. TDG exposure would be 2.9 percent higher than the No Action Alternative, with a reach average exposure of 118.0 percent TDG.

<u>Adult Fish Migration/Survival</u>

Spill levels during the Snake River adult coho salmon migration would be similar to the No Action alternative; however, the duration may change with early spill reduction in the Preferred Alternative. Zero nighttime generation on the Snake River may delay later migrating Snake River coho salmon, but shaping this operation to occur only at night is expected to minimize this effect (Liscom et al. 1985). There would be no change to water temperatures, sediment concentrations or Dissolved Oxygen levels from any measures in the Preferred Alternative during the Snake River adult coho salmon migration period.

Snake River Sockeye Salmon

<u>Summary of Key Effects</u>

Juvenile survival would be very similar to the No Action Alternative (about 0.6 percent higher). Travel time would be faster and powerhouse encounters substantially fewer. Fewer juvenile Snake River sockeye would be transported. Adults could see benefits to upriver migration with some structural measures, but may experience potentially higher fallback. Both adults and juveniles would be exposed to higher levels of TDG.

<u>Juvenile Fish Migration/Survival</u>

Juvenile survival of Snake River sockeye salmon is estimated using COMPASS and CSS juvenile modeling results for Snake River spring Chinook salmon as a surrogate, which indicates an increase in juvenile survival from Lower Granite Dam to Bonneville Dam by less than 1 percent, and a travel time decrease by about 7 percent. The increase in juvenile fish spill would be expected to decrease powerhouse encounters substantially, with the models predicting a decrease of about 48 to 54 percent. Predator disruption operations, also described in *Common Effects*, would further increase juvenile survival by reducing predation on out-migrating smolts. TDG exposure would be 2.9 percent higher than the No Action Alternative, with a reach average exposure of 118.0 percent TDG. See Table 7-27 for a list of model outputs related to juvenile migration and survival.

Transportation of juvenile Snake River sockeye salmon could change due to spill and transportation measures in the Preferred Alternative. The outmigration window is more compressed, with the bulk of the smolts passing April through the end of May. However, starting transport in early April could increase transportation of juvenile Snake River sockeye salmon.

<u>Adult Fish Migration/Survival</u>

Several structural measures in the Preferred Alternative are anticipated to increase adult Snake River sockeye salmon passage success, including modifying the adult trap at Lower Granite Dam and modifying the upper ladder serpentine sections at Bonneville Dam.

Transport of juvenile Snake River sockeye salmon is expected to decrease under the Preferred Alternative. Juvenile sockeye transported in the Snake River are more likely to fall back as adults than in-river migrating adult sockeye (Crozier et al. 2015). Transportation of juveniles appears to impair adult homing ability (i.e., ability to return back to their natal streams), which results in migration delay, increased fallback, and straying. This impaired homing ability may contribute to higher incidental harvest rates in the lower Columbia River than Middle Columbia sockeye salmon, which are the targets of the fishery. This impaired homing ability can be lethal during warm water years such as 2015.

Snake River Fall-Run Chinook Salmon

<u>Summary of Key Effects</u>

Overall, no change or minimal change is anticipated for Snake River fall Chinook salmon, relative to the No Action Alternative. Juvenile survival and travel time would be similar to the No Action Alternative. Adult migration and survival would be similar to the No Action Alternative. Predator disruption operations, also described in *Common Effects*, would increase juvenile survival by reducing predation on out-migrating smolts. Improvements to the Lower Granite Dam adult fish trap, and Bonneville Adult fish ladders could reduce adult migration delay.

<u>Larval Development/Juvenile Rearing</u>

None of the measures of the Preferred Alternative would change the substrate sizes or distribution in the spawning areas or expand suitable spawning areas; therefore, this alternative is expected to have the same larval development and juvenile rearing habitat conditions as the No Action Alternative. The same is true for river depths in the spawning areas; no change is anticipated for eggs incubating in the gravel.

<u>Juvenile Fish Migration/Survival</u>

In-river survival would be expected to be similar to the No Action Alternative because summer spill levels would be the same. When spill levels are reduced in August under the Preferred Alternative, lower numbers of fish are actively migrating through the Snake River. Because transportation typically benefits Snake River juvenile fall Chinook in August, any decreases in dam passage survival due to reduced spill would likely be offset by increased returns from smolts that were transported downstream. Bird predation risk would decrease slightly due to changing operations at John Day Dam to reduce availability of Caspian tern nesting habitat prior to nesting season. Effects would be more noticeable for species like spring Chinook salmon and steelhead that migrate earlier, but would still be effective for Snake River fall Chinook salmon. None of the measures in the Preferred Alternative would affect turbidity during the juvenile outmigration months of May through July; therefore, their visual cover from predation would not change.

<u>Adult Fish Migration/Survival</u>

Several structural measures in the Preferred Alternative are anticipated to benefit adult Snake River fall Chinook salmon passage upstream, including modifying the adult trap at Lower Granite Dam and modifying the upper ladder serpentine sections at Bonneville Dam. Spill reduction starting August 15 may reduce fallback over the spillway, while still maintaining a non-powerhouse fallback route for adult fish that fallback. Zero generation operation could delay Snake River fall Chinook migrating in the Lower Snake River after October 15 (Liscom et al. 1985) but shaping this operation to occur only at night during the adult migration period is expected to minimize this effect. There would be no change to water temperatures, sediment concentrations or Dissolved Oxygen levels from any measures in Preferred Alternative during the Snake River fall Chinook adult migration period.

Lower Columbia River Salmon and Steelhead

Lower Columbia River Chinook Salmon

<u>Summary of Key Effects</u>

Lower Columbia River Juvenile Chinook salmon survival and travel time would be similar to the No Action Alternative. Adult migration and survival would be similar to the No Action Alternative, with potentially higher fallback during the higher spill periods for the spring fish.

<u>Juvenile Fish Migration/Survival</u>

Five of the 32 sub-populations of Lower Columbia River Chinook salmon pass Bonneville Dam on their downstream outmigration to the ocean. There is no quantitative model for Lower Columbia River Chinook salmon; therefore, juvenile survival of Snake River spring/summer Chinook salmon at Bonneville Dam were used as a surrogate of juvenile survival. COMPASS modeling predicts a juvenile survival of 88.9 percent through the Bonneville Project, including the reservoir and the dam, which is similar to the No Action Alternative.

Outflows can influence juvenile outmigration if changes in flows are enough to noticeably affect travel time and therefore survival. Hydrology modeling predicts Lower Columbia River Chinook spring and late-fall fish would experience outflows within 1 percent of the No Action Alternative with the exception of October, which is estimated to have 2 percent higher flows. The slight changes to river flow in the lower river would result in negligible changes to travel time and survival of Lower Columbia River Chinook. Likewise, water quality modeling indicated there would not be a perceptible change in temperature in the lower river due to the Preferred Alternative operations. Juvenile fish exposure to higher levels of TDG is expected to increase in the Preferred Alternative.

<u>Adult Fish Migration/Survival</u>

Structural measures such as modifying the upper ladder serpentine sections at Bonneville Dam could reduce delay associated with upstream passage for the five populations in the Lower Columbia River Chinook Salmon ESU that spawn upstream of Bonneville Dam. Fallback rates for spring-run Chinook may increase slightly with higher spill in April under the Preferred Alternative as fallback is associated with higher spill levels (Boggs et al. 2004; Keefer et al. 2005). Hydrology and water quality modeling predicts increased exposure to higher levels of TDG that could affect Lower Columbia River Chinook salmon adult migration and survival.

Lower Columbia River Steelhead

Summary of Key Effects

Lower Columbia River Juvenile steelhead survival and travel time would be similar to the No Action Alternative, with similar modeled dam survival, and hydrology. Exposure to higher levels of TDG would increase under the Preferred Alternative for both juvenile and adult steelhead. Adult migration and survival would be similar to the No Action Alternative, with potentially higher fallback during the higher spill for the spring-run steelhead populations that spawn upstream of Bonneville Dam.

Juvenile Fish Migration/Survival

Four of the 23 populations of Lower Columbia River steelhead pass Bonneville Dam on their downstream outmigration to the ocean. There is no quantitative model available for Lower Columbia River steelhead. Hydrology modeling predicts spring-run and late-fall-run steelhead would experience outflows within 1 percent of the No Action Alternative with the exception of October, which is estimated to have 2 percent higher flows. The slight changes to river flow in the lower river would result in negligible changes to travel time and survival of Lower Columbia River steelhead. Likewise, water quality modeling indicated there would not be a perceptible change in temperature in the lower river under the Preferred Alternative operations. Juvenile fish exposure to higher levels of TDG is expected to increase in the Preferred Alternative.

Adult Fish Migration/Survival

Modifying the upper ladder serpentine sections at Bonneville Dam could reduce adult steelhead delay associated with upstream passage for the populations that spawn upstream of Bonneville Dam. Spill for juvenile spring migrants at Bonneville Dam would be higher than the No Action Alternative and could result in slightly higher survival rates for adult steelhead falling back through dams and kelts migrating downstream. This is because fewer adults use powerhouse passage routes when a spill route is available and downstream passage rates increase when surface passage is available (Normandeau et al. 2014). Kelts that pass via surface passage at Bonneville Dam experience 100 percent survival (Rayamajhi et al. 2012). Hydrology and water quality models predict flows, and temperatures would be similar to the No Action Alternative. Higher TDG exposure could affect adult survival.

Lower Columbia River Coho Salmon

Summary of Key Effects

Overall, no change or minimal change is anticipated for Lower Columbia River coho salmon relative to the No Action Alternative. Lower Columbia River coho juvenile salmon survival and travel time would be similar to the No Action Alternative. Adult Lower Columbia River coho salmon migration and survival would be similar to the No Action Alternative. Improvements to the Bonneville Dam adult fish ladders could reduce delay of adult coho for populations that spawn above Bonneville Dam.

Juvenile Fish Migration/Survival

Hydrology modeling predicts spring-run fish would experience outflows within 1 percent of the No Action Alternative with the exception of October, which is estimated to have 2 percent higher flows. The slight changes to river flow in the lower river would result in negligible changes to travel time and survival of Lower Columbia River coho salmon. Likewise, water quality modeling indicated there would be a negligible change in temperature in the lower river under the Preferred Alternative. Lower Columbia River coho juvenile salmon exposure to higher TDG is expected to increase under the Preferred Alternative.

Adult Fish Migration/Survival

Modifying the upper ladder serpentine sections at Bonneville Dam could reduce delay associated with upstream passage of Lower Columbia River coho salmon and this would benefit the populations in this ESU that spawn upstream of Bonneville Dam. Hydrology and water quality models predict flows and temperatures would be similar to the No Action Alternative during the adult coho salmon migration period.

Columbia River Chum Salmon

Summary of Key Effects

Effects under the Preferred Alternative would be similar to the No Action Alternative for chum salmon. The ability to meet flow targets and TDG exposure threshold (105 percent) during spawning and incubation would be similar to the No Action alternative. Adult and juvenile chum salmon migration and survival would be similar to the No Action Alternative.

Larval Development/Juvenile Rearing

Under the Preferred Alternative, chum flows would be similar to No Action Alternative and expected to be met in more than 90 percent of all years. TDG is also expected to be similar, exceeding 105 percent TDG in 5 out of 80 years.

Juvenile Fish Migration/Survival

Chum salmon encounter only one CRS project, Bonneville Dam, so none of the structural measures described in *Common Effects* for juvenile salmon and steelhead would apply to these fish, and only a small proportion of spawning occurs above Bonneville.

Adult Fish Migration/Survival

The structural measure to modify the Bonneville Dam serpentine weir ladder would improve passage for the small portion of Columbia River chum salmon that pass this project, but most chum spawn downstream of Bonneville Dam. Migration of adult chum into the Columbia River is in October and November. Bonneville Dam average monthly outflows would be about 2 percent higher in October and the same as the No Action Alternative in November.

OTHER ANADROMOUS FISH

Pacific Eulachon

Summary of Key Effects

Effects in the Preferred Alternative would be similar to the No Action Alternative for juvenile Pacific eulachon migration and survival.

Compared to the No Action Alternative, the Preferred Alternative would have no change in the time between the peak spawning runs, egg development, and larval emergence for Pacific eulachon. The spring freshet that disperses larvae to adequate food sources would continue to be highly variable, with an average of 168 days between spawning temperature triggers and peak flows (158 days in high-flow years, and 156 days in low-flow years).

Spring flow rates would be expected to be within 1 percent of the No Action Alternative during outmigration, so any changes affecting Pacific eulachon feeding would be negligible.

Pacific eulachon would continue to migrate into the Columbia River from November through March, with specific dates of migration and spawning based on a variety of environmental factors, including temperature, high tides, and ocean conditions (NMFS 2017). Modeled data for the Preferred Alternative (based on the period of record for Bonneville Dam tailwater temperatures) indicate that temperatures would not be substantially different than the No Action Alternative. Spawning locations and substrate conditions would not be expected to differ from the No Action Alternative.

Bird predation risk can be influenced by flow rates. Higher flows are linked to higher predation rates on Pacific eulachon, whereas at lower flows, birds tend to switch to marine prey. Under the Preferred Alternative, there would be negligible change in flows (0 to 2 percent) in all months and water year types.

Green Sturgeon

Summary of Key Effects

Green sturgeon use the Columbia River primarily for foraging habitat for adults and subadults. Key effects of the Preferred Alternative are focused on how flows and temperatures influence the cues for entering the Columbia River from the Pacific Ocean as well as the availability and distribution of food sources. Overall, the lower Columbia River would continue to provide good foraging and rearing habitat for green sturgeon. There would be negligible changes to foraging habitat from flows (within 1 percent) compared to the No Action Alternative in all months but October, which would have 2 percent higher flow in the Lower Columbia River on average.

Pacific Lamprey

Summary of Key Effects

The Preferred Alternative has measures intended to increase upstream passage success and reduce injury and mortality for Pacific lamprey. These measures are proposed structural improvements that include converting extended-length submersible bar screen material to screen material that would not impinge or entangle juvenile lamprey, expanding the network of lamprey passage structures to bypass impediments in fish ladders, changing the design for turbine cooling water strainers, and replacing turbines for safer fish passage.

As described for the No Action Alternative, upstream and downstream passage at the lower Columbia River and Snake River Dams has influenced population decline and reduced distribution of Pacific lamprey. The most substantial benefit of the Preferred Alternative would be the improvements to get lamprey to enter and pass the fish ladders; this would occur through expanding the network of lamprey passage structures and modifying fish ladders to incorporate lamprey passage criteria into the structural modifications.

Larval Development/Juvenile Rearing

The Preferred Alternative includes manipulation of the John Day Reservoir for predator disruption. Water levels would be increased prior to Caspian tern nesting season and then dropped back down to the normal operating pool in June. Depending on dewatering rates, larval lamprey could become stranded if they are rearing in the shallows when the pool level would be dropped. Otherwise, ramping rates and dewatering issues would be the same in the Preferred Alternative as for the No Action Alternative.

Juvenile Fish Migration/Survival

Several measures would improve conditions and reduce injuries and losses of juvenile lamprey that migrate past lower Snake and Columbia River dams.

Proposed actions include the following:

- Replace the extended-length submersible bar screen material with screen material that would not impinge and entangle juvenile lamprey. Because turbine routes are generally associated with lower survival of migrating juvenile salmon and steelhead, turbine intakes are equipped with screens that help bypass these fish to higher survival routes. Some of these screens are made of closely spaced bars. These screens are effective at safely diverting juvenile salmon and steelhead, but juvenile lamprey are often so small they become impinged between these bars. The modification or replacement of these screens with woven mesh or more tightly spaced bar material would reduce lamprey mortality.
- Turbine cooling water intakes within the turbine scroll case are equipped with a strainer that prevents debris from entering the cooling water system. However, these strainers do not prevent the entrainment of juvenile lamprey and some juvenile salmon and steelhead.

The retrofitting of these intakes with hoods that allow water flow but prevent debris and juvenile fish entry would reduce lamprey losses in the cooling water intake system.

- Replacing turbines at the John Day Project (also defined in the *Common Effects to Salmon and Steelhead* section) with a newer design of turbine could improve conditions for fish passage and reduce the injury rate for lamprey.

Because of the high degree of uncertainty surrounding how many juvenile lamprey are injured on their downstream migration, and the relative effects to juvenile lamprey due to passage via surface routes or turbine routes, it is difficult to quantify the improvement represented by all of the measures. For fish that encounter multiple dams on their migration downstream, reducing the total number of hazards would increase their probability for survival to the adult life stage.

Adult Migration/Survival

Key structural measures in the Preferred Alternative that are intended to provide improvements to adult lamprey passage and survival include:

- Expand network of lamprey passage structures at Bonneville, The Dalles, and John Day Dams: Fish ladders at most of the projects were designed primarily for salmon and steelhead passage. More recent work has shown some parts of the structures create migration delays and even barriers for lamprey.
- Modify the upper ladder serpentine flow control ladder sections at Bonneville Dam. At Bonneville Dam's Bradford Island and Washington Shore ladder flow control sections, the baffles that help slow velocities and control flows do not allow for direct line movement of fish passing the dam, but requires fish to weave through the baffles. This construction reduces fish passage efficiency and increases migration delays. The modification of these baffles would include replacing baffles allow for direct faster movement through the ladder baffles from this section of the ladders and replace them with baffles that have in-line vertical slots and orifices. This measure has the potential to increase adult salmon and steelhead survival by reducing upstream travel times and higher conversion rates. A similar modification at John Day Dam, the only other CRS dam to use this type of ladder, resulted in substantial reduced passage time for salmon and steelhead. Similar improvements are expected for Bonneville Dam. In addition, these improvements would reduce migration delays and barriers for Pacific lamprey.
- Installing closeable gates on Bonneville Powerhouse 2 floating orifice gates would reduce incidences of lamprey falling out of the Washington Shore Fish Ladder. Closeable gates would allow seasonal closure during the lamprey passage season (June to September). Lamprey passage studies have shown that a large portion of the adult lamprey run enters the main south shore fishway entrance at Powerhouse 2. However, the passage success rate for these fish is low because many fall back out of the fishway through the floating orifice gates as they traverse the collection channel that crosses the powerhouse and connects the south entrance to the fish ladder. Closing the floating orifice gates would eliminate this problem, and increase the success rate of adult lamprey passing Bonneville

Dam. The floating orifice gates would be re-opened outside the adult lamprey passage season to allow additional entrances to the ladder system for salmon and steelhead, in particular, when sea lions are present in the spring. This measure is expected to increase adult lamprey upstream passage success by keeping adult lamprey from failing out of the ladder once they enter it.

The overall expected improvements in lamprey passage efficiency should decrease susceptibility to physical stress and mortality, and shorter holding time, which is beneficial to the fish. Increasing passage success at each dam, starting lower in the system, puts more adults further upstream. Therefore, these structural measures for lamprey are expected to provide a benefit to the spatial distribution of Pacific lamprey in the Columbia Basin. All of the structural measures to reduce losses would also have benefits to the population and recruitment in the next generation. Pacific Lamprey do not exhibit strong homing tendencies to their river of natal origin, hence, improved survival rates from adult return to juvenile outmigration would benefit the north Pacific population rather than only the Columbia Basin.

American Shad

Summary of Key Effects

No change is anticipated to juvenile American shad because plankton communities and shoreline habitat are not changing in the Preferred Alternative. The proportion of adult shad counted at Bonneville Dam that migrate upstream past McNary Dam is expected to remain similar relative to the No Action Alternative.

7.7.5 Resident Fish

7.7.5.1 Region A

KOOTENAI RIVER BASIN

Summary of Key Effects

Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures would have a direct effect on Libby Dam operations and reservoir elevations. The key effects of the Preferred Alternative would be the continued effects described under the No Action Alternative, many of which limit important biological processes, with a mix of effects from the measures in the Preferred Alternative. The Preferred Alternative includes operational measures that would have minor to moderate adverse and beneficial effects to resident fish compared to the No Action Alternative. The relationships that affect food webs in Lake Koocanusa would have moderate beneficial effects. Below Libby Dam, there would be minor adverse effects to riparian function in median years, but minor beneficial effects to riparian habitat function, fish growth, and food production in wet years. Riparian processes for cottonwood generation would be similar or slightly better than under the No Action Alternative, with minor adverse effects to riparian habitat functionality and minor beneficial effects to rates of flow recession during the riparian recruitment period. Riparian function and cottonwood recruitment would benefit from mitigation measures to increase riparian vegetation. Additional mitigation measures included in the Preferred Alternative are *Plant Cottonwood Trees (up to 100 acres) on the Kootenai River below Libby Dam* and *Plant native wetland and riparian vegetation (up to 100 acres) on the Kootenai River downstream of Libby.* Conditions for Kootenai River white sturgeon and burbot would be variable, but overall minor beneficial effects to ecosystem productivity would be realized compared to the No Action Alternative, especially in wet years. Effects to other native fish below Libby Dam would be either negligible or minor beneficial effects.

Habitat Effects Common to All Fish

The Preferred Alternative would have slightly lower flows during the early spring freshet than the No Action Alternative, which would translate to a greater delay in growth and development of resident fish and their food sources compared to the No Action Alternative. Conversely, in wet years, there would be a beneficial effect because the flows in early spring would be higher than the No Action Alternative; the higher flows would increase productivity in the river because more river margins and floodplain areas would be inundated, allowing these habitats to become warmer and more productive sooner than in the No Action Alternative. For further description and graphic representation of the hydrograph in wet, dry, and average year types see Section 7.7.1 for Region A.

The Preferred Alternative measures would result in similar potential timeframes for cottonwood and willow seeding and recruitment compared to the No Action Alternative; on average, about half of the time winter flows would exceed a stage of 1,753 feet at Bonners Ferry (considered representative of the previous summer's seeding elevation), leading to mortality of seedlings recruited the previous spring. The potential riparian habitat area provided for seeding and recruitment would decrease by about 30 percent under the Preferred Alternative, which provides about 0.7-foot band of potential vegetation, compared to a 1.0-foot band in the No Action Alternative. However, mitigation measures would provide up to 100 acres of riparian (cottonwood) plantings large enough to withstand inundation by winter flows. Additionally, the rate of recession would be slower after flows have reached their highest point in the spring. This would allow for greater riparian recruitment because the slower rate of recession is closer to the optimum rate for the roots of seedlings to maintain contact with the water table as it recedes. However, the slower rate is more prevalent in dry years, leading to riparian recruitment in lower elevations that are more susceptible to inundation the following winter. In wet and average years, the rate of hydrograph recession would be similar to the No Action Alternative. Considering all of these factors, the Preferred Alternative, coupled with the additional mitigation for cottonwoods discussed previously, would provide a minor beneficial effect to riparian recruitment.

Bull Trout

The metrics for food productivity under the Preferred Alternative varies for different food sources, but overall the Preferred Alternative would provide moderate beneficial effects for bull trout in the reservoir. Lake Koocanusa would be above elevation 2,450 feet for 60 days, compared to only 44 in the No Action Alternative on average during the summer when productivity is critical. The increased volume of productive water would be a moderate beneficial effect to food source productivity.

The average minimum annual pool elevation of Lake Koocanusa under the Preferred Alternative would be approximately 3 feet lower in dry and average years than under the No Action Alternative. The expected result would be more area during these year types subject to annual dewatering and decreased benthic insect production. In wet years, the minimum pool elevation would be the same as the No Action Alternative. There would be a minor decrease in bull trout growth or survival (or both), particularly for juveniles as they out-migrate from tributaries, but before they switch to fish for prey, during dry and average years. However, the annual maximum elevation of Lake Koocanusa under the Preferred Alternative would be about 2 feet higher than under the No Action Alternative and would result in higher terrestrial insect availability under this alternative. This, coupled with the higher volume of the productive euphotic (surface and near surface) water, would result in a moderate benefit to the food web for bull trout.

Under the Preferred Alternative, Libby Dam would provide discharge of 20 kcfs or greater for 11 days, on average, during the spring freshet, which is 2 days less than the mean for the No Action Alternative. The mean flow rate from May 15 to June 15 under the Preferred Alternative would be slightly less than under the No Action Alternative. Similar to the No Action Alternative, this would be insufficient to mobilize or reshape tributary deltas that could prevent bull trout access during low flows in the fall spawning season. Improvements to riparian function from mitigation measures described previously on the Kootenai River would provide a minor benefit for bull trout habitat below Libby Dam.

The mean summer discharge from Libby Dam would be slightly lower under the Preferred Alternative than the No Action Alternative; these reduced flows would provide slightly more usable habitat and would be in the optimum range for bull trout food availability and off-channel inundation and connectivity.

Kootenai River White Sturgeon

The Preferred Alternative would have a negligible change to peak sturgeon flows in most water year types, but a minor beneficial increase in wet years related to the increased rate of flow in the spring. The rate of which flows decrease after reaching the highest point in the spring would be similar to the No Action Alternative, and there would be one day less floodplain connectivity for larval rearing. River temperature would be similar to the No Action Alternative. Effects of the Preferred Alternative to Kootenai River White Sturgeon would be negligible compared to those of the No Action Alternative in most water year types and minor beneficial in wet years, when the sturgeon have the best chance of recruitment.

Other Fish

As described for bull trout, there would be a moderate beneficial effect to the food web that would also benefit westslope cutthroat trout and kokanee in Lake Koocanusa. The euphotic zone would see moderate beneficial effects. Regarding benthic insect production, the minimum annual pool elevation of Lake Koocanusa under the Preferred Alternative would be approximately 3 feet lower in average years for minor adverse effects, 2 feet higher in dry years for beneficial effects, and similar to the No Action Alternative in wet years. This would result in overall negligible to minor effects to benthic insect larvae production for resident fish species. The annual maximum elevation of Lake Koocanusa under the Preferred Alternative would be about 2 feet higher than under the No Action, and would result in slightly higher terrestrial insect availability. Entrainment of kokanee would be similar to the No Action Alternative.

The Kootenai River below Libby Dam would have slightly lower discharges for the period May 15 to September 30 than the No Action Alternative, and would provide a negligible increase in usable habitat for juvenile and adult rainbow trout (less than 2 percent) than the No Action Alternative. Entrainment of kokanee would be similar to the No Action Alternative. For burbot in the reservoir, entrainment risk would be slightly lower. For burbot in the Kootenai River, the spring freshet flow increase in most years would be less than No Action Alternative for a minor adverse effect, but higher and a minor beneficial effect in wet years. The change in days of floodplain connectivity would be negligible. High and variable flows could interrupt burbot spawning migrations, while low (4 kcfs) and stable winter flows enhance the likelihood of successful burbot spawning. Median flows under the Preferred Alternative would be slightly higher than No Action Alternative, but flow variability would be similar. Burbot recruitment would be similar to the No Action Alternative. Improvements to riparian function and floodplain connectivity would provide a minor to moderate beneficial effect due to additional rearing habitat for many of these species.

HUNGRY HORSE/FLATHEAD/CLARK FORK FISH COMMUNITIES

Summary of Key Effects

The key effects under the Preferred Alternative would be very similar to the No Action Alternative, with exceptions due to the *Sliding Scale at Libby and Hungry Horse* measure. Higher reservoir elevations in the summer and into the fall months in drier years, as well as reduced summer outflows, would have minor to moderate beneficial effects to food supply, habitat suitability, and spawning fish access into tributaries, especially in dry years.

Habitat Effects Common to All Fish

In most years, the deepest draft of the reservoir would be similar to the No Action Alternative, and in dry years this lowest point of the year would be several feet higher than the No Action Alternative. Maintaining a higher elevation provides a larger pool of water. In wet and average water years the hydrograph would be similar to No Action Alternative; the reservoir would still reach near full pool (elevation 3,560 feet) by early July and be allowed to drain until the end of

September to about 3,550 feet elevation. In dry years the reservoir would approach full pool similar to No Action Alternative but would have water withdrawn, or drafted, more slowly until the end of September, ending about 6 feet higher than the No Action Alternative. Similarly, through the fall and winter months the Preferred Alternative elevations would be similar to No Action Alternative in wet and average years, and the median elevation of dry years would be about 4 feet higher than No Action Alternative. Note, in the driest years the project would be operated to meet minimum flows for resident fish downstream of the project resulting in similar drafts to the No Action Alternative.

Lake elevation in the warm summer months determines the volume of reservoir that would be available to produce plankton (euphotic zone). With higher summer elevations in dry years the euphotic zone in August and September would be 2 percent and 3 percent higher, respectively. In other months, and in all months of wet and average years the zone would be similar to the No Action Alternative volume, with less than 1 percent change. See Appendix E for a table of the calculated euphotic zone predictions of the Preferred Alternative.

Reservoir drawdowns at any time during the year affect the production of insects that live on the bottom of the reservoir. Aquatic insects are the primary food supply for fish during spring and early summer and remain important fish prey through late fall. The Preferred Alternative would draft at a lower rate than the No Action Alternative in the summer and the surface of the reservoir would remain at a higher elevation through the following fall and winter in dry years. This would result in slightly more area for benthic insect (those that live on, under, or near the reservoir floor/lake bottom) production than the No Action Alternative, particularly in the large, shallow lobes of the upper reservoir where a small change in elevation can result in a proportionally larger change in inundated/submerged lake bottom. Some of the larger aquatic insects have long life cycles that require overwintering where they are deposited; higher winter elevations would improve the survival of these important insects. Surface area can be used as an index for change in benthic area. By this measure, the Preferred Alternative surface area would be 1 to 3 percent higher than the No Action Alternative in the summer months of dry years, and similar to No Action Alternative in other years.

Finally, the reservoir surface elevation determines the surface area available for terrestrial insects to land on the water, where they become available as fish food during summer and fall. The reservoir elevation also influences the proximity of the water's edge to terrestrial vegetation and therefore, the amount of the poorly flying insects that become available to fish by passively landing on the water. In the summer months of dry years, the surface area would still decrease as the reservoir drafts, but at a lower rate than the No Action Alternative. By mid-summer there would be about 1 percent more surface area than the No Action Alternative and by late September there would be up to about 3 percent, or about 600 acres, more. See Appendix E for a table of the calculated surface area predictions of the Preferred Alternative.

Zooplankton would continue to be entrained into the South Fork Flathead River from Hungry Horse reservoir. In the long-term, repairs to the slide gates of the selective withdrawal structure, as described in the No Action Alternative measure *Hungry Horse Project Power Plant*

Modernization (and carried forward in the Preferred Alternative), would reduce the entrainment of zooplankton by allowing adjustments to take water from the zones in the reservoir that are not heavily populated with zooplankton to reach target water temperatures. Outflows, and therefore zooplankton entrainment, under the Preferred Alternative would be slightly (up to 1 percent) higher than the No Action Alternative in October through June in all year types, and 1 percent to 5 percent lower in July through September. This would provide a minor beneficial effect to reservoir food supply in the summer by reducing entrainment compared to the No Action Alternative.

Outflow patterns from Hungry Horse Reservoir can also affect how fish are entrained into the South Fork Flathead River, and the habitat conditions, such as river elevation (stage), velocities, and temperatures in the river. Slightly lower outflows in late summer would reduce entrainment of fish. The temperature control structure would still operate in the summer months as in the No Action Alternative so changes in outflows in this timeframe would not affect summer temperatures downstream.

In the Flathead River down to Flathead Lake, habitat suitability under the No Action Alternative is a key issue due to high flows during the summer and winter. Under the Preferred Alternative, summer flows would be 1 to 5 percent lower and provide a minor benefit to habitat suitability by mimicking a natural hydrograph more closely, reducing velocities compared to the No Action Alternative. Spring peak flows and winter base flows would be the same or slightly higher than the No Action Alternative. These spring flows would continue to occasionally provide flushing of sediments from gravels to maintain habitat; effects from slight flow increases in the winter would be a negligible effect to fish habitat. The winter water temperature warming influence from the contribution of the South Fork Flathead would be similar to the No Action Alternative, as would the total dissolved gas levels in the river.

The influence of Preferred Alternative changes to Flathead Lake levels and Seli'š Ksanka Qlispe' Dam operations would be minimal compared to the No Action Alternative, and habitat conditions in these areas would be similar to those described under the No Action Alternative.

Bull Trout

Summer production of zooplankton would slightly increase under the Preferred Alternative as well as surface insect landing and feeding area, and annual benthic insect populations that support the bull trout food web. Juvenile bull trout moving into the reservoir in the spring rely on eating benthic and terrestrial insects until they transition to eating fish so this would be a moderate beneficial effect to bull trout, especially in dry years. The prey items that adult bull trout eat also consume benthic insects and may be in better condition or more plentiful. This could result in slightly improved bull trout condition/health.

Higher reservoir elevations in the fall would decrease the risk and exposure to predation and angling pressure for upstream migrating bull trout. The difference between the Preferred Alternative and the No Action Alternative would be more pronounced in dry years when these issues tend to occur. The sedimentation of tributary deltas currently is unknown, but there could potentially be access to some tributaries in some years where fish would have been blocked under the No Action Alternative.

Bull trout entrainment through the dam would likely decrease under the Preferred Alternative due to slightly lower late summer outflows. Withdrawals in August and September are generally selected from fairly deep in the water column to release the target temperature, and bull trout have been documented in these strata at this time of year. Entrainment under the No Action Alternative is likely minimal, but would be expected to decrease up to about 5 percent under the Preferred Alternative as modeled.

In the South Fork Flathead River, below Hungry Horse Dam, zooplankton inputs from the reservoir may decrease slightly in summer with lower outflows, but benthic production would remain stable. Decreased late summer flows would more closely mimic a normalized hydrograph and lower velocities would result in more suitable habitat for bull trout. Overall there are few bull trout that use the South Fork Flathead River and impacts to these species would be negligible and habitat effects are minor.

Summer flows in the mainstem Flathead River would continue to meet minimum flow requirements, but are projected to be slightly lower than the No Action Alternative in some years, for a minor improvement in habitat suitability. Muhlfeld et al. (2011) found even moderate increases in summer flows resulted in substantial decreases in suitable area for bull trout, and that nighttime habitat for subadult bull trout was most sensitive. The 2 to 5 percent decrease due to Preferred Alternative operations would be a minor beneficial effect to bull trout habitat, especially for subadults. The mainstem Flathead River would be similar to the No Action Alternative in winter, with barely perceptible changes (slightly higher) from the No Action Alternative.

Operations of Seli'š Ksanka Qlispe' Dam (Flathead Lake) would be similar to the No Action Alternative, and the bull trout habitat use and life history functions in Flathead Lake, the Lower Flathead River, and Clark Fork River would be similar to the No Action Alternative.

Other Fish

Hungry Horse Reservoir favors a native fish dominated community. Juvenile bull trout and adult whitefish, northern pikeminnow, sculpins, and westslope cutthroat trout feed on zooplankton, aquatic insects, and terrestrial insects; adult bull trout prey on mountain whitefish, suckers, minnows, etc. The food web effects described above would also apply to all of these species of fish in Hungry Horse Reservoir. Slight increases in zooplankton, benthic insects, and increased summertime feeding of terrestrial insects could improve food supply, especially in dry years.

Westslope cutthroat trout and other native fish spawn in the spring (April through June), so effects on adults migrating into tributaries to spawn would differ from bull trout. Spring spawning fish migrate when reservoir levels are lower and tend to experience longer varial zones, or areas where the tributaries pass through the upper parts of the reservoirs that are only seasonally inundated during high water periods and, as such, are typically void of vegetation and of insufficient depth to provide cover. This subjects them to increased exposure to predation and angling pressure. Under Preferred Alternative operations the April and May elevations would be either the same or slightly higher than in No Action Alternative. Spring spawning fish such as westslope cutthroat trout would experience slightly fewer varial zone effects (predation and angling pressure) and access issues to spawning tributaries under the Preferred Alternative. Juveniles typically out-migrate in June when the effects would also be similar to the No Action Alternative.

Entrainment from the reservoir would also continue at unquantified levels and could decrease slightly in the summer months with lower outflows. Northern pike minnow and bull trout have been documented at the depths of late summer withdrawal and would be most susceptible to entrainment, and therefore be benefitted most by this minor effect of the Preferred Alternative. Entrainment would be expected to decrease 1 to 5 percent in the summer months and change in winter would be negligible.

Habitat suitability described for bull trout would be similar for other native fish in the mainstem Flathead River (Muhlfeld et al. 2011), with lower summer flows in the Preferred Alternative resulting in a minor increase in suitable habitat for these native fish in the summer.

Effects to fish in Flathead Lake, the lower Flathead River, and Clark Fork River would be the same as described under the No Action Alternative.

LAKE PEND OREILLE (ALBENI FALLS RESERVOIR)/PEND OREILLE RIVER

Summary of Key Effects

Hydrology modeling showed that Lake Pend Oreille elevations, inflows, and outflows would be similar to those found in the No Action Alternative. Biological relationships were dependent on these parameters, so the key effects of the Preferred Alternative for bull trout, fish habitat, and other fish species in the Pend Oreille basin would be the same as those described under the No Action Alternative. The key effects of the Preferred Alternative would be the continued effects of the No Action Alternative, many of which limit important biological processes, with a mix of effects from the measures in the Preferred Alternative. The Preferred Alternative includes operational measures that would have minor to moderate adverse and beneficial effects to resident fish compared to the No Action Alternative. The various mechanisms that affect food webs in Lake Koocanusa would realize a moderate benefit. Below Libby Dam, there would be minor adverse effects to riparian function in median years, but minor beneficial effects to riparian habitat function, fish growth, and food production in wet years. Riparian processes for cottonwood generation would be similar or slightly better than the No Action Alternative, with minor adverse effects to riparian habitat functionality and minor beneficial effects to rates of flow recession during the riparian recruitment period. Riparian function and cottonwood recruitment would benefit from mitigation measures to increase riparian vegetation. Conditions for Kootenai River white sturgeon and burbot would be variable, but overall minor beneficial effects to ecosystem productivity would be realized compared to the No Action Alternative, especially in wet years. Effects to other native fish below Libby Dam would be either negligible or minor beneficial effects. Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* would have a direct effect on Libby Dam operations and reservoir elevations. Mitigation measures included in the Preferred Alternative are *Plant Cottonwood Trees (up to 100 acres) on the Kootenai River below Libby Dam* and *Plant native wetland and riparian vegetation (up to 100 acres) on the Kootenai River downstream of Libby.*

Habitat Effects Common to All Fish

The Preferred Alternative would have slightly lower flows during the early spring freshet than the No Action Alternative, which would translate to a greater delay in growth and development of resident fish and their food sources compared to the No Action Alternative. Conversely, in wet years, there would be a beneficial effect because the flows in early spring would be higher than the No Action Alternative; the higher flows would increase productivity in the river because more river margins and floodplain areas would be inundated, allowing these habitats to become warmer and more productive sooner than in the No Action Alternative. For further description and graphic representation of the hydrograph in wet, dry, and average year types see Section 7.7.1 for Region A.

The Preferred Alternative measures would result in similar potential timeframes for cottonwood and willow seeding and recruitment compared to the No Action Alternative; on average, about half of the time winter flows would exceed a stage of 1,753 feet at Bonners Ferry (considered representative of the previous summer's seeding elevation), leading to mortality of seedlings recruited the previous spring. The potential riparian habitat area provided for seeding and recruitment would decrease by about 30 percent under the Preferred Alternative, which provides about 0.7-foot band of potential vegetation, compared to a 1.0-foot band in the No Action Alternative. However, mitigation measures would provide up to 100 acres of riparian (cottonwood) plantings large enough to withstand inundation by winter flows. Additionally, the rate of recession after the spring peak would be 60 percent slower, and would allow for greater riparian recruitment because the slower rate of recession is closer to the optimum rate for the roots of seedlings to maintain contact with the water table as it recedes. However, the slower rate is more prevalent in dry years, leading to riparian recruitment in lower elevations that are more susceptible to inundation the following winter. In wet and average years, the rate of hydrograph recession would be similar to the No Action Alternative. Considering all of these factors, the Preferred Alternative would provide a minor beneficial effect to riparian recruitment.

Bull Trout

The metrics for food productivity under the Preferred Alternative varies for different food sources, but overall the Preferred Alternative would provide moderate beneficial effects for bull trout in the reservoir. Lake Koocanusa would be above elevation 2,450 feet for 60 days, compared to only 44 in the No Action Alternative on average during the summer when productivity is critical. The increased volume of productive water would be a moderate beneficial effect to food source productivity.

The average minimum annual pool elevation of Lake Koocanusa under the Preferred Alternative would be approximately 3 feet lower in dry and average years than under the No Action Alternative. The expected result would be more area during these year types subject to annual dewatering and decreased benthic insect production. In wet years, the minimum pool elevation would be the same as the No Action Alternative. There would be a minor decrease in bull trout growth and/or survival, particularly for juveniles as they out-migrate from tributaries but before they switch to fish for prey, during dry and average years. However, the annual maximum elevation of Lake Koocanusa under the Preferred Alternative would be about 2 feet higher than under the No Action Alternative and would result in higher terrestrial insect availability under this alternative. This, coupled with the higher volume of the productive euphotic (surface and near surface) water, would result in a moderate benefit to the food web for bull trout.

Under the Preferred Alternative, Libby Dam would provide discharge of 20 kcfs or greater for 11 days, on average, during the spring freshet, which is 2 days less than the mean for the No Action Alternative. The mean flow rate from May 15 to June 15 under the Preferred Alternative would be slightly less than under the No Action Alternative, and, similar to the No Action Alternative, would be insufficient to mobilize or reshape tributary deltas that can prevent bull trout access during low flows in the fall spawning season. Improvements to riparian function from mitigation measures would provide a minor benefit to bull trout habitat in the Kootenai River.

The mean summer discharge from Libby Dam would be slightly lower under the Preferred Alternative than the No Action Alternative; these reduced flows would provide slightly more usable habitat and would be in the optimum range for bull trout food availability and off-channel inundation and connectivity.

Kootenai River White Sturgeon

The Preferred Alternative would have a negligible change to peak sturgeon flows in most water year types, but a minor beneficial increase in wet years related to the increased rate of flow on the ascending limb of the hydrograph. There would be a negligible decrease in the duration of receding limb of the hydrograph, and one day less floodplain connectivity for larval rearing. River temperature would be similar to the No Action Alternative. Effects of the Preferred Alternative to Kootenai River white sturgeon would be negligible compared to those of the No Action Alternative in most water year types and minor beneficial in wet years, when the sturgeon have the best chance of recruitment.

Other Fish

As described for bull trout, there would be a moderate beneficial effect to the food web that could benefit westslope cutthroat trout and kokanee in Lake Koocanusa. The euphotic zone would see moderate beneficial effects. Regarding benthic insect production, the minimum annual pool elevation of Lake Koocanusa under the Preferred Alternative would be approximately 3 feet lower in average years for minor adverse effects, 2 feet higher in dry years for beneficial effects, and similar to No Action Alternative in wet years. This would result in overall negligible to minor effects to benthic insect larvae production for resident fish species. The annual maximum elevation of Lake Koocanusa under the Preferred Alternative would be about 2 feet higher than under the No Action, and would result in slightly higher terrestrial insect availability. Entrainment of kokanee would be similar to the No Action Alternative.

The Kootenai River below Libby Dam would have slightly lower discharges for the period May 15 to September 30 than the No Action Alternative, and would provide negligible increase in usable habitat for juvenile and adult rainbow trout (less than 2 percent) than the No Action Alternative. Entrainment of kokanee would be similar to No Action Alternative. For burbot in the reservoir, entrainment risk would be slightly lower. For burbot in the Kootenai River, spring freshet flow increase in most years would be less than No Action Alternative for a minor adverse effect, but higher and a minor beneficial effect in wet years. The change in days of floodplain connectivity would be negligible. High and variable flows can interrupt burbot spawning migrations, while low (4 kcfs) and stable winter flows enhance the likelihood of successful burbot spawning. Median flows under the Preferred Alternative would be slightly higher than No Action Alternative, but flow variability would be similar. Burbot recruitment would be similar to the No Action Alternative overall. Improvements to riparian function and floodplain connectivity would provide a minor to moderate beneficial effect due to additional rearing habitat for many of these species.

HUNGRY HORSE/FLATHEAD/CLARK FORK FISH COMMUNITIES

Summary of Key Effects

The key effects under the Preferred Alternative would be very similar to the No Action Alternative, with exceptions due to the *Sliding Scale at Libby and Hungry Horse* measure. Higher reservoir elevations in the summer and into the fall months in drier years, as well as reduced summer outflows, would have minor to moderate beneficial effects to food supply, habitat suitability, and spawning fish access into tributaries, especially in dry years.

Habitat Effects Common to All Fish

In most years the deepest draft of the reservoir would be similar to the No Action Alternative, and in dry years this lowest point of the year would be several feet higher than the No Action Alternative. Maintaining a higher elevation provides a larger pool of water. In wet and average water years the hydrograph would be similar to No Action Alternative; the reservoir would still reach near full pool (elevation 3,560 feet) by early July and be allowed to drain until the end of September to about 3,550 feet elevation. In dry years, the reservoir would approach full pool similar to No Action Alternative but would have water withdrawn, or drafted, more slowly until the end of September, ending approximately 6 feet higher than the No Action Alternative. Similarly, through the fall and winter months the Preferred Alternative elevations would be similar to No Action Alternative in wet and average years, and the median elevation of dry years would be about 4 feet higher than No Action Alternative. Note, in the driest years the project would be operated to meet minimum flows for resident fish downstream of the project resulting in similar drafts to No Action Alternative.

Lake elevation in the warm summer months determines the volume of reservoir that would be available to produce plankton (euphotic zone). With higher summer elevations in dry years the euphotic zone in August and September would be 2 percent and 3 percent higher, respectively. In other months, and in all months of wet and average years, the zone would be similar to the No Action Alternative volume, with less than 1 percent change. See Appendix E for a table of the calculated euphotic zone predictions of the Preferred Alternative.

Reservoir drawdowns at any time during the year affect the production of insects that live on the bottom of the reservoir. Aquatic insects are the primary food supply for fish during spring and early summer and remain important fish prey through late fall. The Preferred Alternative would draft at a lower rate than the No Action Alternative in the summer and the surface of the reservoir would remain at a higher elevation through the following fall and winter in dry years. This would result in slightly more area for benthic insects (those that live on, under, or near the reservoir floor/lake bottom) production than the No Action Alternative, particularly in the large, shallow lobes of the upper reservoir where a small change in elevation can result in a proportionally larger change in inundated/submerged lake bottom. Some of the larger aquatic insects have long life cycles that require overwintering where they are deposited; higher winter elevations would improve the survival of these important insects. Surface area can be used as an index for change in benthic area. By surface area measurement, the Preferred Alternative area would be 1 to 3 percent higher than the No Action Alternative in summer months of dry years, and similar to No Action Alternative in other years.

Finally, the reservoir surface elevation determines the surface area available for terrestrial insects to land on the water, where they become available as fish food during summer and fall, as well as influencing the proximity of the water's edge to terrestrial vegetation and therefore the amount of the poorly-flying insects that become available to fish by passively landing in the water. In summer months of dry years, the surface area would still decrease through the summer as the reservoir drafts, but at a lower rate than the No Action Alternative. By mid-summer there would be about 1 percent more surface area than the No Action Alternative and by late September there would be up to about 3 percent, or about 600 acres, more. See Appendix E for a table of the calculated surface area predictions of the Preferred Alternative.

Zooplankton would continue to be entrained into the South Fork Flathead River from Hungry Horse reservoir. In the long-term, operations of the slide gates of the selective withdrawal structure, as described in the No Action Alternative measure *Hungry Horse Project Power Plant Modernization* (and carried forward in the Preferred Alternative), would reduce the entrainment of zooplankton by allowing adjustment to take water from the zones in the reservoir that are not heavily populated with zooplankton to reach target temperatures. Outflows, and therefore zooplankton entrainment, under the Preferred Alternative would be slightly (up to 1 percent) higher than the No Action Alternative in October through June in all year types, and 1 to 5 percent lower in July through September. This would provide a minor beneficial effect to reservoir food supply in the summer by reducing entrainment compared to the No Action Alternative.

Outflow patterns from Hungry Horse Reservoir can also affect how fish are entrained into the South Fork Flathead River, and the habitat conditions, such as river elevation (stage), velocities, and temperatures in the river. Slightly lower outflows in late summer would reduce entrainment of fish. The temperature control structure would still operate in the summer months as in the No Action Alternative so changes in outflows in this timeframe would not affect summer temperatures downstream.

In the Flathead River down to Flathead Lake, habitat suitability under the No Action Alternative is a key issue due to unnaturally high flows during the summer and winter. Under the Preferred Alternative, summer flows would be 1 to 5 percent lower and provide a minor benefit to habitat suitability by mimicking a natural hydrograph more closely, reducing velocities compared to the No Action Alternative. Spring peak flows and winter base flows would be the same or slightly higher than No Action Alternative. These spring flows would continue to occasionally provide flushing of sediments from gravels to maintain habitat; effects from slight flow increases in the winter would be a negligible effect to fish habitat. The winter water temperature warming influence from the contribution of the South Fork Flathead would be similar to No Action Alternative, as would the TDG in the river.

The influence of Preferred Alternative changes to Flathead Lake levels and Seli'š Ksanka Qlispe' Dam operations would be minimal compared to the No Action Alternative, and habitat conditions in these areas would be similar to those described under the No Action Alternative.

Bull Trout

Higher reservoir elevations in the summer and into the fall months in drier years, as well as reduced summer outflows, under the Preferred Alternative would slightly increase the summer production of zooplankton, surface insect landing and feeding area, and annual benthic insect populations that support the bull trout food web. Juvenile bull trout moving into the reservoir in the spring rely on eating benthic and terrestrial insects until they transition to eating fish so this would be a moderate beneficial effect to bull trout, especially in dry years. Adult bull trout prey also consume benthic insects and the prey may be in better condition or more plentiful. This could result in slightly improved bull trout condition/health.

Higher reservoir elevations in the fall would decrease the risk and exposure to predation and angling pressure for upstream migrating bull trout. The difference between the Preferred Alternative and No Action Alternative would be more pronounced in dry years when these issues tend to occur. The sedimentation of tributary deltas is not known, but there could potentially be access to some tributaries in some years where fish would have been blocked under the No Action Alternative.

Bull trout entrainment through the dam would likely decrease in the Preferred Alternative due to slightly lower late summer outflows. Withdrawals in August and September are generally selected from fairly deep in the water column to release the target water temperature, and bull trout have been documented in these strata at this time of year. Entrainment under the No Action Alternative is likely minimal but would be expected to decrease up to about 5 percent under the Preferred Alternative as modeled.

In the South Fork Flathead River, below Hungry Horse Dam, zooplankton inputs from the reservoir may decrease slightly in summer with lower outflows, but benthic production would remain stable. Decreased late summer flows would more closely mimic a naturalized hydrograph and lower velocities would result in more suitable habitat for bull trout. Overall changes in the South Fork Flathead River would be negligible for bull trout; the habitat effects are minor, and few bull trout use this area.

Summer flows in the mainstem Flathead River would continue to meet minimum flow requirements but are projected to be slightly lower than the No Action Alternative in some years, for a minor improvement in habitat suitability. Muhlfeld et al. (2011) found even moderate increases in summer flows resulted in substantial decreases in suitable area for bull trout, and that nighttime habitat for subadult bull trout was most sensitive. The 2 to 5 percent decrease due to Preferred Alternative operations would be a minor beneficial effect to bull trout habitat, especially for subadults. The mainstem Flathead River would be similar to the No Action Alternative in winter, with barely perceptible changes (slightly higher) from the No Action Alternative.

Operations of Seli'š Ksanka Qlispe' Dam (Flathead Lake) would be similar to the No Action Alternative, and the bull trout habitat use and life history functions in Flathead Lake, the Lower Flathead River, and Clark Fork River would be similar to the No Action Alternative.

Other Fish

Hungry Horse Reservoir favors a native fish dominated community. Juvenile bull trout and adult whitefish, northern pikeminnow, sculpins, and westslope cutthroat trout feed on zooplankton, aquatic insects, and terrestrial insects; adult bull trout prey on mountain whitefish, suckers, minnows, etc. The food web effects described above would also apply to all of these species of fish in Hungry Horse Reservoir. Slight increases in zooplankton, benthic insects, and increased summertime feeding of terrestrial insects could improve food supply, especially in dry years.

Westslope cutthroat trout and other native fish spawn in the spring (April through June), so effects on adults migrating into tributaries to spawn would differ from bull trout. Spring spawning fish migrate when reservoir levels are lower and tend to experience longer varial zones, or areas where the tributaries pass through the upper parts of the reservoirs that are only seasonally inundated during high water periods and, as such, are typically void of vegetation and of insufficient depth to provide cover. This subjects them to increased exposure to predation and angling pressure. Under Preferred Alternative operations the April and May elevations would be either the same or slightly higher than in No Action Alternative. Spring spawning fish such as westslope cutthroat trout would experience slightly less varial zone effects (predation and angling pressure) and access issues to spawning tributaries under the

Preferred Alternative. Juveniles typically out-migrate in June when the effects would also be similar to the No Action Alternative.

Entrainment from the reservoir would also continue at unquantified levels and could decrease slightly in the summer months with lower outflows. Northern pikeminnow and bull trout have been documented at the depths of late summer withdrawal and would be most susceptible to entrainment and therefore be benefitted most by this minor effect of the Preferred Alternative. Entrainment would be expected to decrease 1 to 5 percent in the summer months and change in winter would be negligible.

Habitat suitability described for bull trout would be similar for other native fish in the mainstem Flathead River (Muhlfeld et al. 2011), with lower summer flows in the Preferred Alternative resulting in a minor increase in suitable habitat for these native fish in the summer.

Effects to fish in Flathead Lake, the lower Flathead River, and Clark Fork Rivers would be the same as described under the No Action Alternative.

LAKE PEND OREILLE (ALBENI FALLS RESERVOIR)/PEND OREILLE RIVER

Summary of Key Effects

Hydrology modeling showed that Lake Pend Oreille elevations, inflows, and outflows would be similar to those found in the No Action Alternative. Biological relationships were dependent on these parameters, so the key effects of the Preferred Alternative for bull trout, fish habitat, and other fish species in the Pend Oreille basin would be the same as those described under the No Action Alternative.

7.7.5.2 Region B

LAKE ROOSEVELT/COLUMBIA RIVER FROM U.S.-CANADA BORDER TO CHIEF JOSEPH DAM

Summary of Key Effects

The most notable effect from the Preferred Alternative would be habitat and spawning success effects from the earlier draft of Lake Roosevelt in above average water years. There would be minor to moderate effects from increased stranding of kokanee and burbot eggs, and potential increased spawning habitat access issues for redband rainbow trout. Mitigation measures would provide a minor beneficial effect to these fish. The Preferred Alternative would have a negligible effect to white sturgeon in this reach. Minor increases or decreases in retention time in various months and year-types would result in minor adverse or beneficial effects to fish in Lake Roosevelt due to entrainment risk and food source reductions, depending on year type and time of year. The Preferred Alternative would continue to support both wild and hatchery-raised kokanee, redband rainbow trout and hatchery rainbow trout as well as non-native warmwater game species such as walleye, smallmouth bass, and northern pike. Northern pike would likely continue to increase and invade downstream, and the lake elevations could result in a minor decrease in the ability for boat-based Northern pike suppression efforts in above average water years. Rufus Woods Lake would continue to provide habitat for fish entrained from Lake Roosevelt and from limited production of shoreline spawning by some species. Fish entrainment could increase in winter and decrease in the summer months in some years. TDG would be similar or less than the No Action Alternative in most years, but maintenance operations would increase TDG in some years in the short term with long term benefits due to increased reliability. The operational measures that could impact fish include the *Update System FRM Calculation, Planned Draft Rate at Grand Coulee, Fall Operational Flexibility for Hydropower (Grand Coulee),* and *Lake Roosevelt Additional Water Supply*, as well as the *Grand Coulee Maintenance Operations* measure carried forward from the No Action Alternative, fish and wildlife mitigation measures carried forward, and new mitigation for *Spawning Habitat Augmentation at Lake Roosevelt*. Additionally, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures in the Preferred Alternative affect inflows to Lake Roosevelt.

Habitat Effects Common to All Fish

Inflows to Lake Roosevelt would be within 1 percent of the No Action Alternative, with negligible increases in winter months and decreases in spring and summer. The most notable habitat effects come from reservoir elevation changes in Lake Roosevelt. Earlier drafts (when water is drained from the reservoir) in wet years would result in the median wet year elevation at the end of February about 5 feet lower than the No Action Alternative. In addition, fall operations would differ such that completing refill to 1,283 feet (as outflows are reduced to allow the reservoir to fill) could be delayed from the end of September to the end of October, resulting in elevations about a half a foot lower through these 2 months. Mid-May through August, and December through January elevations would be the same as No Action Alternative. In the No Action Alternative the project is refilled to 1,283 feet NGDV29 by the end of September in most years (modeling assumption shows that this occurs in all years); for the Preferred Alternative the elevation at the end of September would be below 1,283 feet in 40 percent of years.

Median peak outflows under the Preferred Alternative would follow the same pattern as the No Action Alternative with minor changes, including increases in January and February (0 to 1 percent), reductions in spring and summer (up to 2 percent in April and August).

The duration that water stays in the reservoir (i.e., retention time) is a driving metric for the food web in Lake Roosevelt and influences the populations of several fish species. Under the Preferred Alternative, monthly average retention time would be within 1 percent of the No Action Alternative in most months of all water year types, with a few exceptions. In average years, it would decrease 2 percent in September and increase 2 percent in October. In dry years, it would be 2 percent higher than the No Action Alternative in October and 4 percent higher in May. In wet years, it would be 2 percent higher in October but 4 percent and 3 percent lower in February and May, respectively. Retention time is lowest in wet years because more water is moving through the system, and therefore more critical to fish effects.

Temperature in the reservoirs would be similar to the No Action Alternative. Generally speaking, water quality modeling showed the sum of operational measures would result in lower TDG than the No Action Alternative, although operations to support maintenance measures would likely increase TDG from April to July during maintenance, but may result in slight reductions in spill long-term. The *Grand Coulee Maintenance Operation* measure reduces the hydraulic capacity through the power plant in the near term; this has the potential to increase spill in some years. This impact is partially offset in wet years by the *Planned Draft Rate at Grand Coulee*. Spill and resulting TDG levels are expected to be similar to the No Action Alternative; with the potential of TDG in the reservoir and tailwater in excess of 125 percent TDG. TDG in the Grand Coulee tailwater is also a concern for fish in Rufus Woods Lake.

Bull Trout

Under the Preferred Alternative, bull trout in Lake Roosevelt could continue to move to cooler locations in the reservoir and these refuges would remain similar to the No Action Alternative. Retention time of a reservoir can influence the productivity, growth, and distribution of zooplankton which, in turn, affects fish growth, distribution, and entrainment risk. Minor changes in inflows and outflows (all less than 2 percent difference from the No Action Alternative) would be negligible for bull trout flushing and entrainment. The bull trout prey base would continue to fluctuate as the fish they eat are sensitive to changes in productivity and location of zooplankton in Lake Roosevelt that is influenced by the retention time of water in the reservoir. In dry and average years these would be negligible or minor beneficial effects with slightly higher water retention time allowing zooplankton to develop longer in the reservoir. In wet years there would be minor decreases in retention time during February and May, which would be a minor adverse effect because zooplankton would have less time to develop. Bull trout are also sensitive to contaminants that are found in this region and would continue to bioaccumulate contaminants as a top predator. Water fluctuation events that mobilize mercury would be the same as the No Action Alternative. Overall effects to bull trout would be negligible because of the small magnitude of changes and the scarcity of bull trout in Lake Roosevelt.

Other Fish

White sturgeon recruitment would be dependent on flows exceeding 200 kcfs and appropriate temperatures in late June/early July. The Preferred Alternative flows at the Canadian border in June and July would be similar to the No Action Alternative, exceeding 200 kcfs about 28 percent of the time and 9 percent, respectively, in mid-June and July. In high flow years, the Lake Roosevelt reservoir elevations would be the same as the No Action Alternative in these months. Under the Preferred Alternative, recruitment of white sturgeon would continue to be a rare event supplemented by hatchery propagation and rearing, similar to the No Action Alternative.

Wild production of native fish such as burbot, kokanee and redband rainbow trout would continue to provide valuable resources in Lake Roosevelt. As described in the common habitat effects, these fish are the most sensitive to the effects of changing retention times. Under the No Action Alternative an estimated average of over 400,000 fish annually would be entrained, with 30 to 50 percent of them being kokanee, primarily of wild origin and rainbow trout the second most entrained species. Under Preferred Alternative operations, retention time would decrease 4 percent and 3 percent, respectively, in February and May of wet years for a minor adverse effect. Changes in other months and year types would be either negligible or minor beneficial effects to fish entrainment, zooplankton entrainment, and food webs.

For tributary spawning species such as redband rainbow trout and a portion of the wild production of kokanee, tributary access at the right time of year is important. Reservoir drawdown in the spring creates barren tributary reaches through the varial zone (upper region of the reservoir that is only seasonally inundated, resulting in areas devoid of vegetation cover), which directly and indirectly impedes migration to and from tributaries and the reservoir. Redband rainbow trout need access to tributaries in the spring. Under the Preferred Alternative, reservoir elevations would be 2 to 3 feet lower than the No Action Alternative levels in the critical spawning migration time of April to May in wet years. Specific access issues are unknown, but redband rainbow trout spawn in Sanpoil River, Blue Creek, Alder, Hall Creek, Nez Perce Creek, Onion Creek, Big Sheep Creek, and Deep Creek. These tributaries higher in the basin are more susceptible to elevation changes because a smaller change in vertical lake elevation would result in a larger area of varial zone exposure than tributaries closer to the dam, due to the shallow slope of the reservoir. Migratory impacts, although not well documented, could be minor to moderate given the timing and extent of the drawdowns in the Preferred Alternative. Additionally, minor increases in exposure during migrations to these tributaries would increase the varial zone effects where migrating fish are more exposed to predation and angling due to lack of cover. The portion of kokanee that spawn in tributaries access these habitats in the fall. In some years the reservoir elevation would be slightly lower than the No Action Alternative, but would still be above the elevation of 1,283 feet that provides access for kokanee spawning under the No Action Alternative.

Species such as kokanee and burbot that spawn on shorelines in Lake Roosevelt are susceptible to eggs drying out if reservoir levels drop while eggs are still in the gravel. Kokanee spawn on shoreline gravels September 15 to October 15 and eggs incubate through February. Burbot tend to spawn successfully in depths provided by the No Action Alternative in the Columbia River and in Lake Roosevelt on shorelines near the Colville River in winter with eggs incubating through the end of March (Bonar et al. 2000). In the Preferred Alternative, the dry and average years would be similar to No Action Alternative. In wet years, however, the earlier drafting of the reservoir would strand or dewater more burbot and kokanee eggs because the reservoir elevation would be similar to No Action Alternative when eggs are deposited, but drop up to 5 feet deeper in the wet years before fry emerge. The portion of kokanee that spawn in the shallower 5 feet of elevation could have eggs desiccated when these drops occur. Due to earlier drafts, more eggs deposited in fall would also become dewatered before enough time elapses for emergence. Fry sometimes also stay in the gravels and could become stranded as well. The earlier drafts of Lake Roosevelt would be a moderate adverse effect to kokanee and redband rainbow trout. Mitigation measures to study if these operations affect these species, determine specific spawning locations, and augment spawning habitat to increase spawning at levels where eggs would be safer would be a minor beneficial effect to kokanee and burbot. Burbot spawn later in the winter, but would also be affected by the deeper draft in the reservoir. Lake elevations influence river stage up to the U.S.-Canada border but the water level changes are smaller than in the reservoir. Thus, burbot that spawn in the rivers would experience the same patterns of dewatering, but to a lesser degree.

Kokanee are very sensitive to water temperature, and during summer are found at depths below 120 m to find suitably cool water. Under the No Action Alternative, Lake Roosevelt is very weakly stratified but does have suitably cool water at this depth along with suitable levels of dissolved oxygen. Lake whitefish and mountain whitefish also likely use this cool water in the summer. Reservoir water temperatures and thermal stratification in the summer in the Preferred Alternative would be similar to the No Action Alternative.

Non-native warmwater gamefish, such as walleye, northern pike, smallmouth bass, sunfish, crappie, and others, as well as the prey fish that they eat (such as shiners, dace, and sculpins) all tolerate a wide range of environmental conditions and would continue to contribute to the fishery community under the Preferred Alternative, and continue to negatively impact native species via predation. The invasion downstream by northern pike is of concern. The Lake Roosevelt co-managers, such as the Confederated Tribes of the Colville Reservation, The Spokane Tribe of Indians and Washington Department of Fish and Wildlife, co-managers would continue to actively suppress pike populations using gillnets. The co-managers set the gillnets by boats as soon as they can get on the water in the spring until the boat ramp becomes unusable at an elevation of 1,235 feet. Under the No Action Alternative this occurs on April 15 in wet years and would not occur at all in dry and average years. Under the Preferred Alternative in wet years this would occur up to about a week sooner and preclude the ability for the pike suppression efforts for that time period. For estimation purposes, one crew typically removes about 100 pike per week and they would operate three crews (Colville Tribe unpublished data), so losing up to a week under the Preferred Alternative could result in an estimated 300 pike not removed. It should be noted that this analysis focuses on one boat ramp, but the middle of Lake Roosevelt becomes inaccessible earlier, at lake elevation of 1,245 feet. Additionally, outflows and retention time would continue to influence the entrainment and downstream invasion of non-native gamefish below Chief Joseph Dam where ESA-listed anadromous salmonids would be susceptible to predation by them. During the time when pike juveniles would be most susceptible to entrainment (May to August), retention time under the Preferred Alternative would be similar or slightly higher so entrainment risk for pike would be similar to the No Action Alternative or slightly lower. Adult pike would continue to move further downstream (similar to No Action Alternative), so minor increases in entrainment in February and May due to retention time changes would be a minor adverse effect to native fish due to minor increased risk of pike entrainment.

Once released, the net pen fish that supplement the rainbow trout fishery in Lake Roosevelt would experience similar effects as their native counterparts except for spawning and early rearing effects. In addition, the net pen locations are situated where the water quality can be affected by changes in reservoir elevations; these fish are sensitive to temperature and TDG levels. Their eventual recruitment to the fishery can be affected by retention time coupled with reservoir elevation at the time of their release (McLellan et al. 2008), which is typically in May.

Under the Preferred Alternative, the water quality at these locations would be similar to the No Action Alternative. In average and dry years, reservoir levels and retention time would be similar to No Action Alternative or slightly beneficial. In wet years, the reservoir would be slightly lower than No Action Alternative, and the water retention time in May would be 3 percent lower; this would be a minor adverse effect to entrainment risk for these fish. The operators strive to release these fish to coincide with the initiation of reservoir refill to reduce entrainment risk, which under Preferred Alternative would be the same as the No Action Alternative, so these fish would continue to be released when water quality conditions would be suitable.

The fish in Rufus Woods Lake would continue to be supplemented by entrained fish out of Lake Roosevelt to a large extent, with fish mostly entrained during the spring freshet and winter drawdown periods. Slightly higher flows in the winter drawdown in the Preferred Alternative may increase entrainment slightly and boost populations in Rufus Woods Lake. Minor decreases in spring freshet outflows likely would decrease entrainment during this period, but, as described in the previous paragraph, there could be slightly higher entrainment in May due to lower retention times. This lake has more riverine characteristics with steep gradients and narrow canyon walls, making it more like a river than a reservoir, with short water retention time and low productivity. High flows during late spring and early summer would continue to flush eggs and larvae from protected rearing areas similar to the No Action Alternative, but at a slightly lower magnitude.

TDG in the Grand Coulee tailwater is a concern for fish in Rufus Woods Lake as it sometimes exceeds 125 percent TDG under the No Action Alternative. Water quality modeling showed TDG under the Preferred Alternative would be similar to the No Action Alternative except for slight decreases in spring months of average years. However, maintenance operations would likely increase TDG from April to July in some years due to a reduction in the number of turbines available to pass water. On the other hand, the *Planned Draft Rate at Grand Coulee* measure could decrease potential spill during this same time and partially offset any increased TDG. As this maintenance is completed, the hydraulic capacity through the power plant and reliability should increase, which would result in decreases in forced outages and spill. This would eventually reduce TDG in comparison to the No Action Alternative. Overall, effects under the Preferred Alternative would be minor adverse to fish in Lake Rufus Woods.

7.7.5.3 Region C

SNAKE RIVER BASIN

Summary of Key Effects

Key effects from the Preferred Alternative that differ from those found under the No Action Alternative include moderate increases in spill and TDG in April through mid-June from the *Juvenile Fish Passage Spill* measure and increases in entrainment at Dworshak Reservoir in January from the *Slightly Deeper Draft for Hydropower (Dworshak)* measure. These effects would have minor adverse effects to resident fish species in Region C.

Habitat Effects Common to All Fish

Common habitat effects of the Preferred Alternative are similar to those identified for the No Action Alternative with the exception of the increased spill, elevated TDG, and increased entrainment discussed in the section above.

Bull Trout

Effects of the Preferred Alternative to bull trout within the Snake River Basin that differ from the No Action Alternative include increases in spill and TDG from April to mid-June, as well as an increase in entrainment risk at Dworshak Reservoir in January. Increased spill during the spring spill season would cause moderate increases in TDG that would likely result in minor adverse effects to bull trout using the mainstem Snake River as a migratory corridor during spring. In addition, during spring high spill bull trout are generally migrating out of the Snake River back to cooler tributary habitats. These fish may experience minor adverse effects in delay at projects while searching for fish ladder entrances. Increased spill at Dworshak in wet years would have minor adverse effects to bull trout in the form of increased risk of entrainment.

Other Fish

Effects to white sturgeon under the Preferred Alternative that differ from the No Action Alternative would include moderate increases in TDG in the lower Snake River. Water Quality data shows increases in exposure to high TDG from April through mid-June when compared with the No Action Alternative. These increases would have minor adverse effects to white sturgeon larvae and fry, particularly in a drifting life stage that occurs near the water surface.

Key effects of the Preferred Alternative relative the No Action Alternative for additional fish resources would include moderate increases in TDG from April through mid-June. Increases in spill under this alternative would increase TDG by approximately 5 percent during spring spill operations. High TDG would have minor adverse effects to early life stages of resident fish that are not able to avoid high TDG by changing depth. Other effects would be similar to the No Action Alternative.

7.7.5.4 Region D

MAINSTEM COLUMBIA RIVER FROM MCNARY DAM TO THE LOWER COLUMBIA RIVER ESTUARY

Summary of Key Effects

The key effects under the Preferred Alternative would be due to changes in TDG in the river from *Juvenile Fish Passage Spill Operations*, and changes in the John Day Reservoir operations from certain measures including *Predator Disruption Operations* and *Increased Forebay Range Flexibility*. Bull trout, white sturgeon, and other resident fish would experience intermittently higher or lower TDG levels, and the drop in the John Day reservoir could result in a minor effect of potential stranding sturgeon larvae.

Habitat Effects Common to All Fish

Outflows from McNary Reservoir influence some of the fish relationships described in this section. Peak spring flows affect habitat maintenance for some species. Modeled monthly median outflows for the Preferred Alternative would be within 2 percent of the No Action Alternative. Other flow parameters referred to in this section refer to outflows of McNary Dam, which are indicative of flows downstream through the other projects. The median outflows at McNary Dam in spring months (with change from No Action Alternative in parentheses) would be:

- April: 192 kcfs (-1 percent)
- May: 260 kcfs (0 percent)
- June: 285 kcfs (0 percent)
- July: 198 kcfs (-1 percent)

Operations changes at John Day reservoir would result in October median monthly average outflows being 2 percent higher than the No Action Alternative in October, 1 percent higher in January, February, and June; and 1 percent lower in March to May and July to September.

Water quality in Region D would experience an overall negligible change from the No Action Alternative, though there could be increases or decreases in TDG during certain times of the year due to increased spill during the spring spill season.

Bull Trout

Bull trout are known to use the mainstem Columbia River to move between tributaries and have been observed at Bonneville Dam and McNary Dam in the spring and summer (Barrows et al. 2016). Water temperature is the most important habitat factor for bull trout in the mainstem Columbia; temperature would not change under the Preferred Alternative. TDG levels in the winter, when most bull trout would be using the river, would also be similar to the No Action Alternative.

Adult bull trout move downstream during fall and overwinter in reservoirs (October to February) (Barrows et al. 2016). Although bull trout successfully move between areas on the mainstem, their migration can be delayed at the dams.

Passage through turbines can cause injury or mortality, as well as migration delays. Blade strike incidence increases with increased blade size. The Preferred Alternative includes the *Improved Fish Passage Turbines at John Day* measure, which would improve survival (Deng et al. 2019). At John Day, turbine replacement would provide safer passage for any bull trout that move through the dam.

The Preferred Alternative includes *Predator Disruption Operations* that could reduce predation on bull trout and other native resident fish species, which would be a beneficial effect compared to the No Action Alternative.

Other Fish

Under the Preferred Alternative, white sturgeon spawning and recruitment would be similar to the No Action Alternative with negligible differences in the number of days with suitable flow conditions and suitable temperatures for embryo incubation. In years of low flow conditions, water temperatures could increase beyond the suitable range by early June, resulting in little or no recruitment (similar to the No Action Alternative).

White sturgeon spawning generally occurs in areas with fast-flowing waters over coarse substrates (Parsley et al. 1993). Minor changes in outflow under the Preferred Alternative would not be large enough to cause discernable velocity changes that would affect sturgeon spawning habitat.

Lack of upstream white sturgeon (juvenile and adult) passage decreases the connectivity of the population (Parsley et al. 2007). This would not change under the Preferred Alternative compared to the No Action Alternative.

As described previously, the Preferred Alternative includes the *Improved Fish Passage Turbines at John Day* measure, which would reduce injuries and mortality of juvenile sturgeon (Deng et al. 2019).

White sturgeon larvae are negatively affected by TDG. Studies have shown high rates of altered buoyancy at 118 percent TDG, and 50 percent mortality at 131 percent TDG (Counihan et al. 1998). Under the Preferred Alternative, there would be negligible increases in TDG overall, with periods of time where it could be increased due to increased spill. During these times, there would be minor adverse effects to juveniles and larvae, depending on their ability to move to deeper depths. Adults are more able to compensate for increased TDG by moving to lower depths, but larvae in shallow water are not able to compensate and would be more affected.

Under the Preferred Alternative, lower flows at Bonneville during dry years in May and August could potentially increase pinniped predation rates, but it is also likely that sturgeon are avoiding the tailrace due to predation pressure.

Resident fish such as sculpin, walleye, and smallmouth bass are predators of embryo and age-0 white sturgeon. Under the Preferred Alternative, predation would continue to affect early life stages of white sturgeon.

Reservoirs in the lower Columbia may be in maturation (meaning that as reservoirs get older they trap sediments, become shallower, and changes to biological process may occur). This could lead to sedimentation and invasive aquatic plants reducing habitat value for sturgeon through changes in predation, food availability, and suitability for invasive species. Under the

Preferred Alternative, river mechanics would be the same as the No Action Alternative, except in the John Day Reservoir, where there is the potential for a minor amount of bed sediment to become finer due to changes in operations. This would be a negligible effect to white sturgeon in the timeframe of this EIS.

Under the Preferred Alternative, no changes to resident fish communities would be expected. As shown above, outflow rates below McNary Dam would be very similar to the No Action Alternative. Water quality and food availability would also be similar to the No Action Alternative. Increased TDG would likely affect some species of resident fish.

Conditions that promote lower water temperatures and higher spring flows tend to lower the survival rates of warmwater game fish, potentially lowering populations of predators on salmon and steelhead. The Preferred Alternative would be expected to continue supporting warmwater game fish at levels similar to the No Action Alternative.

7.7.6 Macroinvertebrates

Below is a discussion of the macroinvertebrates in Regions A, B, C, and D under the Preferred Alternative. For more detailed information on the effects of the Preferred Alternative on aquatic invertebrates and implications on food web interactions see the Habitat Effects section of the respective resident fish community analyses previously described under the applicable region.

7.7.6.1 Region A

Project operations under the Preferred Alternative would affect the following aquatic environments: Hungry Horse Reservoir, South Fork Flathead River, Flathead River, Flathead Lake, lower Flathead River, Clark Fork River, Lake Pend Oreille, Pend Oreille River, Lake Koocanusa, and the Kootenai River. Specifically, these measures include the *Sliding Scale at Libby and Hungry Horse* and the *Modified Draft at Libby*.

At Hungry Horse reservoir*, Sliding Scale at Libby and Hungry Horse* is the only new measure in the Preferred Alternative that would affect operations and therefore, invertebrates. Higher elevations in the summer and into the fall months, as well as reduced summer outflows, would have minor to moderate beneficial effects to macroinvertebrates. With higher summer elevations in dry years the euphotic zone in August and September would be 2 percent and 3 percent higher, respectively, for a minor benefit to zooplankton production, which fuels the food web for aquatic macroinvertebrates, in these months during dry years. In other months (and in all months of wet and average years), the euphotic zone would be similar to the No Action Alternative, with less than 1 percent change. Zooplankton entrainment would be slightly lower than the No Action Alternative in summer months in drier years due to slightly decreased outflows. In the long term, rehabilitation of the selective withdrawal system (as part of the *Hungry Horse Project Power Plant Modernization* measure, carried forward from the No Action Alternative) would also reduce entrainment as gates could be operated to draw water from strata in the reservoir that are not densely occupied by zooplankton. The Preferred Alternative would draft at a lower rate than the No Action Alternative in the summer and would remain at a higher elevation through the following fall and winter in dry years. Using surface area as an index for benthic area, the surface area under the Preferred Alternative would be 1 to 3 percent higher than the No Action Alternative in summer months during dry years, and similar to the No Action Alternative in other years. This would result in minor to moderate beneficial effects to benthic macroinvertebrates compared to the No Action Alternative, particularly in the large, shallow lobes of the upper reservoir. In these aquatic habitats, a small change in elevation can result in a proportionally larger change in inundated lake bottom. Some of the larger aquatic insects have long life cycles that require overwintering where they were deposited; higher winter elevations would improve the survival of these species.

In the South Fork Flathead and mainstem Flathead Rivers, slight decreases in summer flows in the Preferred Alternative would cause a slight decrease in habitat for macroinvertebrate production, although minimum flows would continue to protect these habitats, and lower summer flows than the No Action alternative are closer to normalized flow regimes. The Preferred Alternative would result in negligible changes to invertebrate communities in Flathead Lake, the lower Flathead River, and the Clark Fork River.

The operations of Albeni Falls Project would be similar to the No Action Alternative operations and would result in negligible effects to Lake Pend Oreille or the Pend Oreille River. Negligible effects are expected to the macroinvertebrate communities in those habitats.

In the Kootenai basin, Lake Koocanusa would be held above an elevation of 2,450 feet more than twice as many days as the No Action Alternative, which would increase the overall productivity of zooplankton and macroinvertebrates in the system and be a moderate benefit to macroinvertebrates. Regarding benthic insect production, the minimum annual pool elevation of Lake Koocanusa under the Preferred Alternative would be approximately 3 feet lower in average years for minor adverse effects, 2 feet higher in dry years for beneficial effects, and similar to No Action Alternative in wet years. This would result in overall negligible effects to benthic invertebrate production. Below Libby Dam, outflows would be slightly lower than the No Action Alternative in summer months causing a minor reduction in habitat for invertebrates, but flow variability would be similar to the No Action Alternative so survival of these organisms would not change.

7.7.6.2 Region B

The Columbia River from Canada to Lake Roosevelt would continue to produce benthic aquatic insects such as stonefly, caddisfly and mayfly larvae, with negligible to minor adverse effects from the Preferred Alternative. The operational measures in the Preferred Alternative that could affect macroinvertebrates include the *Update System FRM Calculation, Planned Draft Rate at Grand Coulee, Fall Operational Flexibility for Hydropower (Grand Coulee)*, and *Lake Roosevelt Additional Water Supply*, as well as the *Grand Coulee Maintenance Operations* carried forward from the No Action Alternative. There would also be fish and wildlife mitigation measures carried forward from the No Action Alternative, and new mitigation for *Spawning Habitat Augmentation at Lake Roosevelt.*

Operations under the Preferred Alternative would result in minor changes in river elevations at the U.S.-Canada border in the months September and October, as the fall operation of the reservoir would result in median river stage (elevation) of about 2 feet lower than the No Action Alternative by the end of September, with minor decreases in macroinvertebrate habitat. Otherwise the Preferred Alternative would have a similar stage as the No Action Alternative in the Columbia River near the international border. Further downstream, as reservoir influences are more noticeable, the Preferred Alternative would have this same fall pattern of minor reductions in stage. There would also be minor decreases in river stage from earlier drafts of the reservoir (resulting in lower elevations compared to the No Action Alternative) in January and February of wet years. This would reduce habitat, as well as increase the risk of dewatering macroinvertebrates in the winter. In these months, the reservoir would be up to 5 feet lower than the No Action Alternative by the end of February, and the decreased levels would continue until refill would begin in early May. This change in elevation represents the vertical feet, actual habitat dewatered, and proportion of macroinvertebrates affected, which would vary depending on habitat used and the slope of the riverbanks at various locations throughout the reservoir. The subsequent reduction in habitat and additional dewatering would be a minor to moderate effect, depending on year type. *Spawning Habitat Augmentation at Lake Roosevelt* would provide up to 100 acres of additional gravel substrate in areas more protected from dewatering events that would provide minor beneficial effects to macroinvertebrate production and survival.

In Lake Roosevelt, the production, distribution and persistence of zooplankton is highly variable and sensitive to retention time of water in the reservoir, which is a function of inflows, reservoir volume, and outflows. Under the Preferred Alternative, monthly average retention time would be within 1 percent of the No Action Alternative in most months of all water year types, with a few minor exceptions. In average years, it would decrease 2 percent in September and increase 2 percent in October. In dry years, it would be 2 percent higher than the No Action Alternative in October and 4 percent higher in May. In wet years, it would be 2 percent higher in October but 4 percent and 3 percent lower in February and May, respectively. During wet years, retention time is lowest because more water is moving through the system. With lower retention times under the Preferred Alternative in these 2 months, when retention times are already fairly low, there would be increased entrainment of zooplankton out of Lake Roosevelt.

Downstream of Grand Coulee Dam, Rufus Woods Lake has more riverine characteristics with steep gradients and narrow canyon walls, making it more like a river than a reservoir, with short water retention time and low productivity. Aquatic insect production and survival in Lake Rufus Woods would be similar to the No Action Alternative, but there would be minor increases in zooplankton inputs in February and May of wet years, as described above. There would be negligible change to these communities. In some years in the short-term, *Grand Coulee Maintenance Operations* may result in increased TDG exposure as maintenance activities reduce turbines available and spill may increase. In the long term, TDG would be decreased as the units become more reliable. This would be a minor effect to invertebrate populations that are generally more resistant than fish to effects from elevated TDG (Ryan et al. 2002), and it would occur infrequently. Effects due to TDG under the Preferred Alternative to macroinvertebrates would be negligible.

7.7.6.3 Region C

Effects of the Preferred Alternative to macroinvertebrates in Region C that differ from the No Action Alternative would include effects from the *Slightly Deeper Draft for Hydropower at Dworshak,* which would result in increased entrainment in Dworshak Reservoir during January of wet years. This would also lead to faster refill at Dworshak on dry years, as well as elevated TDG downstream of Lower Granite Dam on the Snake River due to *Juvenile Fish Passage Spill*. In addition, increased entrainment during the winter months would have minor adverse effects to zooplankton populations in Dworshak Reservoir as portions of these populations would be entrained from the reservoir and into the Clearwater River. Conversely, on wet years the reservoir would refill earlier and would stay near full pool for a longer period of time, providing a minor beneficial effect to invertebrate populations that colonize these substrates.

Under the Preferred Alternative TDG would increase by approximately 5 percent from April through mid-June. This increase in TDG would have minor effects to invertebrate populations that are generally more resistant to effects from elevated TDG (Ryan et al. 2002).

The macroinvertebrate community of the lower Snake reservoirs and river would continue similar to the No Action Alternative. Siberian prawns and opossum shrimp would continue to increase in the reservoir environments. The reservoirs would continue to provide habitat for clams, mussels, and other invertebrates, as in the No Action Alternative, and crayfish would continue to find suitable habitat in the rock and riprap of reservoirs.

7.7.6.4 Region D

The Preferred Alternative would not differ from the No Action Alternative in its effects to flows or water temperatures. Effects to invertebrates that differ from the No Action Alternative would include reservoir elevation manipulations at John Day Reservoir to dissuade nesting of Caspian Terns that consume juvenile salmon and steelhead as part of the *Predator Disruption Measure*.

Under the Preferred Alternative, pool elevations would be about 1 foot higher in the John Day Reservoir from late March through early June, and then drop in early June by about 2 feet before returning to base elevations in September. During the period of March through early June, aquatic macroinvertebrates could colonize the additional benthic substrate and shallow water habitat afforded by the higher pool elevation, but could then be stranded or desiccated when levels drop in June. The other run of river dams would continue to be operated at stable elevations that would continue production of these aquatic macroinvertebrates.

7.7.7 Vegetation, Wildlife, Wetlands, and Floodplains

7.7.7.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

There are two measures in the Preferred Alternative that would be implemented in Region A: the *Modified Draft at Libby* and the *Sliding Scale at Libby and Hungry Horse* that differ from the No Action Alternative. Under the Preferred Alternative, both these measures would directly affect operations and reservoir levels at Libby. The *Sliding Scale at Libby and Hungry Horse* measure would directly impact Hungry Horse outflows. The Preferred Alternative water management and operational measures in Region A would have negligible effects on Albeni Falls Dam outflow and Lake Pend Oreille elevation compared to the No Action Alternative.

The *Modified Draft at Libby* causes the spring reservoir elevation at Lake Koocanusa to be lower than the No Action Alternative when the seasonal water supply forecast is less than 6.9 Maf. Deeper drafts would increase the barren zone width around Lake Koocanusa providing greater surface area of exposed soils for potential colonization by invasive species. The barren zone causes a hydrologic disconnect between the reservoir and tributary confluences, like the Tobacco River. The biologically rich transition zone between emergent herbaceous, and forested and scrub-shrub wetlands would shift having minor impacts on wildlife habitat.

In average and high water years, reservoir elevations are up to 4 feet lower in winter and spring. By summer, reservoir elevations are up to 1 foot higher than No Action Alternative in average years, and up to 5 feet higher in wet years in May through October. In dry years, reservoir elevations are up to 12 feet lower in fall and slightly lower in summer by several feet. These reservoir elevation changes in Lake Koocanusa would cause minor shifts in transition zones between uplands and emergent and forested wetlands. In August and September, the reservoir elevation would be about 1-4 feet higher than the No Action Alternative due to *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures.

Libby Dam outflow under the Preferred Alternative is impacted by the *Modified Draft at Libby and Sliding Scale at Libby and Hungry Horse*. Monthly average outflow in average to dry years increases in January, February, and March, followed by a reduction in April and May as refill begins caused by the *Modified Draft at Libby*. In dry years, Libby releases higher flows in June, July, and August. Conversely, in wet years, Libby releases higher flows in late April, and lower flows in late June, July and August. In typical to wet years, reduced outflow starts in June through September resulting from the *Sliding Scale at Libby and Hungry Horse*.

Under existing conditions, Libby Dam maintains higher flows to inundate the channel during the most biologically productive time of the year, May 15 through September 30. While operations at this location are primarily fish focused, wildlife habitats and wildlife populations would continue to benefit from increased water availability downstream. The small wetland fringe in areas where the reservoir converges with small tributaries would continue to be inundated and benefit from operations. Under the Preferred Alternative operations during wet years, would reduce outflows to the Kootenai River from June to September potentially reducing ecological productivity in the river. Regardless of the water year, the transition zone between wetlands and uplands in the Kootenai may be altered under the Preferred Alternative, resulting in the loss of wildlife habitat if not mitigated.

Under the Preferred Alternative, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures affect flows at Bonners Ferry to a smaller degree than outflows at Libby Dam due to dilution effects of major tributaries downstream. In wet years, flows are higher in October and April, and lower in August. In average years, flows are higher in January-March, and lower in April-September. In dry years, flows are lower in November and May, and higher in January, and June-August.

Ongoing trends of reduced riparian vegetation establishment due to higher winter flows would be expected to continue. Winter flows can inundate and scour river banks, destroying tree and shrub saplings like cottonwoods and willows that have not yet developed sufficient root structures to withstand high winter flows or the spring freshet. The gradual loss of deciduous woody plant communities and conversion to coniferous uplands and forested and scrub-shrub wetlands could lead to a loss of biodiversity and degraded ecosystem function in the Libby Dam study area (Kootenai Tribe of Idaho [KTOI] 2013). At Libby Dam and downstream along the Kootenai River, because high winter releases scour seedlings, some riparian cottonwood communities could continue to decline in some locations due to altered hydrological conditions if not mitigated.

Streambank erosion and bank sloughing would potentially increase in the Preferred Alternative due to higher winter outflows at Libby Dam. Shoreline erosion in Bonner's Ferry, Idaho, caused by frozen banks suddenly drawn down due to reduced flows, would continue to maintain the trend of wildlife habitat reduction relative to the No Action Alternative, if not mitigated.

For Hungry Horse, the *Sliding Scale at Libby and Hungry Horse* would have direct effects on reservoir elevations and outflows during most years, with the largest differences from the No Action Alternative occurring in dry years. Winter water levels are slightly lower (typically less than a foot) than the No Action Alternative in most years but can be several feet lower in the driest years. Summer water levels can be several feet lower in the driest 25 percent of years. This change would have negligible effects to minor beneficial effects to vegetation surrounding the reservoir. The higher water elevation would increase soil moisture and reduce the extent of exposed barren zone in the fall. This would maintain vegetation communities around the reservoir. Wildlife would experience a smaller barren zone compared to the No Action Alternative. This would benefit smaller prey species, but the effects would be negligible.

The *Sliding Scale at Libby and Hungry Horse* measures would also affect Hungry Horse Dam outflows, causing slight increases in the winter and early spring (up to 2 percent) and slight decreases July through September (3 percent typical). The decreases in summer flows can result in a decrease in water levels in the Flathead River of 0.1 feet. These changes in outflow and river elevation would have no effects to negligible effects on vegetation along the South Fork Flathead and Flathead rivers. The diversity, quantity, and quality of vegetation and wildlife habitat on the South Fork Flathead and Flathead rivers would not change as a result of the Preferred Alternative.

The Preferred Alternative measures would not impact the annual peak reservoir levels in the Albeni Falls Dam reservoir, or impact timing of refill or drawdown. Results from modeling and analysis show that reservoir elevations in most water years would remain consistent with the No Action Alternative. The differences in monthly reservoir elevations during most water years and months is within the expected range of natural variability. Thus, negligible impacts to vegetation communities and wildlife habitat are expected from the implementation of this proposed measure. Undercutting of banks and erosion resulting from reservoir operations, boat wakes, and wind-wave erosion would be expected to continue under the Preferred Alternative.

The Preferred Alternative would affect the monthly average outflow of Albeni Falls Dam. In higher flow years, the outflow in the summer months would be similar to No Action Alternative. In low water years, outflow would be several hundred cfs lower in August (-1 percent) and September (-2 percent). The Preferred Alternative measures would have negligible downstream impacts on vegetation communities and habitat. The Preferred Alternative measures are not anticipated to increase invasive species colonization in the Hungry Horse and Albeni Falls Dam study areas.

Invasive species management within the Corps-managed lands would continue under the No Action Alternative. Invasive species in the affected environment include Russian olive, Canadian thistle, flowering rush, and false indigo bush. The *Modified Draft at Libby* causes the spring reservoir elevation at Libby Dam to be lower than the No Action Alternative. Deeper drafts would increase the barren zone width around Lake Koocanusa providing greater surface area of exposed soils for potential colonization by invasive species. Invasive species spread in the Lake Koocanusa drawdown zone may have downstream effects when plant seeds that enter the reservoir are washed downstream in the Kootenai.

The seasonal wetlands within the Kootenai Wildlife Refuge are drained in spring and summer to promote emergent vegetation for waterfowl food sources. Under the No Action Alternative current operations of Libby Dam adversely affect wetland management capability, reducing availability of forested and scrub-shrub and emergent herbaceous wetlands (USFWS 2015). Under the Preferred Alternative, the Modified Draft at Libby would result in lower flows in late April and May, and higher flows in June, July, and August in dry years. Excess water in the summer would have a minor adverse effect on the wildlife refuge limiting the ability to modify water levels.

Operational changes at Libby Dam under Preferred Alternative would cause water level fluctuations at the Kootenai Falls Wildlife Management Area. However, these fluctuations would not have measurable impacts on wildlife habitat.

Similar to the No Action Alternative, the Pend Oreille Wildlife Management Area would be inundated for approximately 4 to 5 months each year. Habitat types range from exposed mudflats during winter reservoir drawdown to submerged lands with rooted aquatic plants and forested uplands. During the summer, the Wildlife Management Area contains emergent marsh habitat with an average water depth of 2 to 4 feet surrounded by a narrow zone of sedges, cottonwoods, and willows. In low water years, outflow would be several hundred cfs lower in

August (-1 percent) and September (-2 percent). Therefore, the Preferred Alternative is anticipated to have no effect on the Pend Oreille Wildlife Management Area.

The *Modified Draft at Libby* causes the spring reservoir elevation at Libby Dam to be lower than the No Action Alternative when the seasonal water supply forecast is less than 6.9 Maf. A larger transition zone devoid of vegetative cover would expose wildlife to increased rates of predation. For wildlife, the barren zone represents an area that smaller wildlife species, such as rodents or snakes, must navigate to reach water in the reservoir. Crossing wide barren zones with no cover poses a risk of predation for prey species, which is a detriment to them, while conversely providing a benefit to predators.

Reservoir levels in July, August and September are higher in dry, average, and high water years. In August and September, the reservoir elevation would be about 1-4 feet higher than the No Action Alternative due to *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures. Changes in reservoir elevation in Lake Koocanusa during summer may have minor impacts to nesting waterfowl.

Libby Dam releases lower flows in late June, July and August in typical to wet years resulting from the *Sliding Scale at Libby and Hungry Horse*. Shallow backwater habitat may become intermittently dry as river elevations decrease, causing immotile amphibian eggs and tadpoles, like those of the western toad and northern leopard frog, to desiccate.

Aquatic invertebrates, like caddisflies and stoneflies, would experience similar interruptions in life cycle, which could lead to changes in the food web and a corresponding decrease in food availability to wildlife such as swallows and flycatchers (See Section 3.5, *Aquatic Habitats, Aquatic Invertebrates, and Fish*). Western grebes are abundant on portions of the Pend Oreille Wildlife Management Area. Denton Slough is a shallow bay with a large quantity of submerged plants used by western grebe to construct their nests from May through September (Idaho Department of Fish and Game [IDFG] 1999). The Preferred Alternative is not expected to impact nesting birds in the Albeni Falls Dam study area.

Operational changes at Libby Dam from the Preferred Alternative would also be evident in downstream reaches of the Columbia River, as discussed below.

7.7.7.2 Region B Grand Coulee and Chief Joseph

Under the Preferred Alternative, the *Update System FRM Calculation*, *Planned Draft Rate at Grand Coulee*, F*all Operational Flexibility for Hydropower (Grand Coulee)*, and *Lake Roosevelt Additional Water Supply* measures would directly affect outflows from Grand Coulee Dam. In addition, the *Modified Draft at Libby* and *Sliding Scale at Libby and Hungry Horse* measures from Region A upstream would affect inflows and outflows at Grand Coulee Dam. The outflows from Grand Coulee Dam would differ from the No Action Alternative depending on the time of year. In almost every month of the year, the outflow from Grand Coulee Dam under the Preferred Alternative would differ from the No Action Alternative due to various measures at Grand Coulee Dam and in Region A upstream. However, these changes are relatively small, with median monthly average flows typically within 1 percent of those under the No Action Alternative. The pattern of flow changes from Grand Coulee Dam outflow would continue through the middle Columbia River under the Preferred Alternative. The middle Columbia River monthly average flows for the Preferred Alternative (as change from No Action Alternative) shows minor changes in the median values of monthly average flows for Lake Roosevelt Inflow, Grand Coulee Dam outflow, and other dam outflow locations downstream in Region B of less than 1 to 2 percent throughout spring and summer.

Collectively, these measures only slightly influence reservoir elevations in Lake Roosevelt and downstream reaches of the Columbia River through the run of river past Chief Joseph Dam, resulting in only potentially minor changes to the quantity, quality, and distribution of habitats in the study area. However, even minor changes to wildlife habitats could have a corresponding effect on wildlife populations in the study area. During the spring, the potential to have a minor decrease in water elevation, even only 1 to 2 percent, could affect the growth of emergent vegetation on the shoreline and cause a minor increase in the barren strip of land immediately adjacent to the water. The frequency and duration of drying conditions could slightly increase for areas with emergent herbaceous and forested and scrub-shrub wetlands, and these habitats could transition into upland habitats, or plant communities in these habitats would transition to predominantly species more tolerant of dry conditions. This could change plant composition and distribution, or reduce the overall quantity of wetland acreage. The amount of impacts, however, are very likely to be minor, given the small percentage of water elevation changes throughout an average year under the Preferred Alternative when compared to the No Action Alternative.

7.7.7.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and ice Harbor Dams

Structural measures in the Preferred Alternative in Region C include the *Lower Granite Trap Modifications*, *Lamprey Passage Ladder Modifications*, *Fewer Fish Screens*, and *Turbine Strainer Lamprey Exclusion* measures. These measures would collectively improve conditions for ESA-listed fish and lamprey passage and survival. Structural measures would be limited to the immediate vicinity of the project dams on the lower Snake and Columbia Rivers and construction-related effects would not result in widespread effects to wildlife habitats or populations.

Operational measures associated with the Preferred Alternative in Region C include the *Deeper Draft for Hydropower at Dworshak, Increased Forebay Range Flexibility, Juvenile Fish Passage Spill (Operations), Early Start Transport, Contingency Reserves in Fish Spill, Zero Generation Operations, Above 1% Turbine Operations,* and *Increased Forebay Range Flexibility* measures. Collectively, these measures could improve fish passage times and increase abundance of juvenile fish transported to the estuary, increase capacity and provide flexibility for hydropower generation, shape hydropower generation, and maintain grid reliability, and decrease avian predation of juvenile salmon and steelhead.

Under the Preferred Alternative, the *Slightly Deeper Draft for Hydropower at Dworshak* measure would allow for additional hydropower generation and hydropower flexibility by drafting to reservoir elevations lower than what is required for FRM purposes. This measure would result in lower water levels than the No Action Alternative in larger forecast years in the months of January, February, and March, and then similar water levels for the rest of the year. By the end of February, only the wettest 10 percent of years would have deeper drafts than the No Action Alternative, but the difference could range from 2 to 35 feet. By the end of March, reservoir levels are effectively the same as the No Action Alternative, typically less than a foot lower.

This measure would not result in changes to the quantity, quality, and distribution of habitats in the Dworshak Reservoir. Changes to wildlife habitats have a corresponding effect on wildlife populations in the study area. However, lower water levels in January, February, and March would have a minor adverse effect on elk migration patterns, when ice is present on the reservoir. When ice is present, elk may cross the reservoir to reach their south-facing winter range on the northern end of the reservoir. In winters when snow accumulates on thin ice, elk and deer may fall through the ice and die. Migration across the ice occurs frequently when ice and snow conditions permit. Drawdown of the reservoir effects ice thickness (Huokuna et al. 2017).

Downstream of Dworshak Reservoir, this measure would not result in changes to the quantity, quality, and distribution of habitats in the Clearwater River. Changes to wildlife habitats have a corresponding effect on wildlife populations in the study area. There would be no net loss or reduction in the quality and distribution of existing emergent herbaceous and forested and scrub-shrub wetlands under the Preferred Alternative, when compared to the No Action Alternative. Existing wetlands would continue to be productive habitats supporting breeding amphibians, reptiles, mammals, and birds during the spring and summer breeding season.

Under the Preferred Alternative, operating reservoir elevation restrictions at the four lower Snake River dams would be changed to provide operating flexibility during the fish passage season April 3 through August 15 (August 15–31 becomes minimum spill operations) due to the *Increased Forebay Range Flexibility* measure. At all four projects, the seasonal MOP range is increased from a 1.0-foot range to a 1.5-foot range, each with a 0.5-foot increase in the upper end of the range. Any fluctuations in water elevations would be approximately 0.5 feet higher than the No Action Alternative and the range of natural variability for daily operations. Therefore, the Preferred Alternative may affect the quantity, quality, or distribution of existing habitat types by making them slightly wetter than the No Action Alternative. However, the overall effect would be negligible.

Emergent herbaceous wetlands may become established in new areas where water depth and inundation patterns support establishment of wetland vegetation and soil conditions, increasing the overall quantity and quality of wetlands in the area. There would be no reduction in the quality and distribution of existing emergent herbaceous and forested and scrub-shrub wetlands under the Preferred Alternative, when compared to the No Action Alternative.

Existing wetlands would continue to be productive habitats supporting breeding amphibians, reptiles, mammals, and birds during the spring and summer breeding season.

The Preferred Alternative is not anticipated to result in new exposed soil. Therefore, invasive species colonization is unlikely to expand within Region C. Invasive species management efforts are anticipated to continue similar to the No Action Alternative.

The *Early Start Transport* measure would reduce the quantity of juvenile salmonid and steelhead available to avian and mammalian predators similar to MO1, MO2, and MO4. There would be fewer juvenile salmonids in the system between collection points in the lower Snake and release points below Bonneville Dam between April 15 and October 31. Decreasing the number of juvenile salmonids above Bonneville Dam would decrease overall prey resources supporting a variety of wildlife populations at higher trophic levels above Bonneville Dam, specifically colonial nesting terns, gulls, and pelicans. These colonies prey heavily on juvenile salmonids and fewer fish would likely force birds to transition to other prey resources, delay nesting, or relocate breeding activities to other areas on the Columbia Plateau where prey resources are more widely available (Meyer et al. 2016). Consistent or long-term delays in nest initiation would decrease overall reproductive success for the colony, reducing the overall fecundity and potentially leading to a long-term reduction in regional populations.

The changes proposed as part of the Preferred Alternative, specifically the *Early Start Transport* measure, would offset impacts to juvenile salmonids by transporting individuals through the lower Snake and Columbia Rivers. As a result, it is assumed that the abundance and condition of juvenile salmon and steelhead entering the estuary would similarly increase the prey base available to colonial nesting waterbirds in the estuary. An increase in the prey base would support reproductive success of these colonies, providing long-term benefits to regional populations.

7.7.7.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

Structural measures in the Preferred Alternative in Region D include the *Lamprey Passage Structures*, *Turbine Strainer Lamprey Exclusion*, *Modify Bonneville Ladder Serpentine Weir*, *Bypass Screen Modifications for Lamprey*, *Closable Gates*, *Improved Fish Passage Turbines at John Day Dam*, *Fewer Fish Screens*, and *Lamprey Passage Ladder Modifications* measures. These measures would collectively improve conditions for ESA-listed fish and lamprey passage and survival. Structural measure effects would be limited to the immediate vicinity of the project dams on the lower Snake and Columbia Rivers and construction-related effects would not result in widespread effects to wildlife habitats or populations.

Operational measures associated with the Preferred Alternative in Region D include the *Juvenile Fish Passage Spill (Operations)*, *Early Start Transport*, *Contingency Reserves in Fish Spill*, *Above 1% Turbine Operation*s, *Predator Disruption Operations*, *Increased Forebay Range Flexibility*, and *John Day Full Pool* measures. Collectively, these measures would improve fish passage times and increase abundance of juvenile fish transported to the estuary, increase capacity and provide flexibility for hydropower generation, shape hydropower generation, maintain grid reliability, and decrease avian predation of juvenile salmon and steelhead.

Under the Preferred Alternative, there would be no changes to the reservoir elevations at McNary, The Dalles, or Bonneville Dam and river elevations would remain consistent with the No Action Alternative. Any fluctuations in water elevations would be within the normal operating range for daily operations. The Preferred Alternative is anticipated to have a similar level of effect to the quantity, quality, or distribution of existing habitat types and there would be no additional effects to vegetation communities or wildlife habitat at these projects. Similarly, wetland habitats downstream of Bonneville Dam, such as Franz Joseph, Pierce, Steigerwald, Ridgefield, Julia-Butler Hansen, and Lewis and Clark National Wildlife Refuges, would remain consistent with existing conditions despite minor changes in water surface elevations. Any changes in river elevations downstream of Bonneville Dam from implementing the Preferred Alternative would become progressively muted and would not result in measurable changes in effects to wildlife populations or their habitats downstream of Bonneville Dam.

At John Day Dam, the *John Day Full Pool*, *Predator Disruption Operations*, and *Increased Forebay Range Flexibility* measures change reservoir operating ranges compared to the No Action Alternative. As described in Section 3.6.2, *Affected Environment*, and the No Action Alternative, there are regionally important forested and scrub-shrub and emergent herbaceous wetlands in the John Day Dam study area, including the extensive wetland complex at the Umatilla National Wildlife Refuge. The *John Day Full Pool* and *Increased Forebay Range Flexibility* measures of the Preferred Alternative would change operational limits on reservoir elevations, inundating wetland habitats between 0.5 to 2.5 feet vertically. Increasing the duration and extent of inundation could shift wetland species composition from facultative species to a greater dominance by obligate species. Despite the increased duration of inundation under the Preferred Alternative, the temporary nature of inundation is not expected to result in functional changes to wetland habitats in Lake Umatilla.

Emergent herbaceous wetlands may become established in new areas where water depth and inundation patterns support establishment of wetland vegetation and soil conditions, increasing the overall quantity and quality of wetlands in the area. There would be no reduction in the quality and distribution of existing emergent herbaceous and forested and scrub-shrub wetlands under the Preferred Alternative, when compared to the No Action Alternative. Existing wetlands would continue to be productive habitats supporting breeding amphibians, reptiles, mammals, and birds during the spring and summer breeding season. These wetland habitats would continue to support regionally important migratory waterfowl overwintering in the Umatilla National Wildlife Refuge by providing forage opportunities and prey resources.

The Preferred Alternative is not anticipated to result in new exposed soil. Therefore, invasive species colonization is unlikely to expand within Region D. Invasive species management efforts are anticipated to continue similar to the No Action Alternative.

Habitat conditions in Lake Wallula, Lake Celilo, and Lake Bonneville are not expected to change under the Preferred Alternative. Consequently, there would be no measurable impacts to wildlife populations using these habitats under the Preferred Alternative. In locations where ODFW or WDFW manage wetland habitats for wildlife, operations and maintenance actions under the Preferred Alternative are assumed to continue similar to current practices under the No Action Alternative, including actions at Klickitat Wildlife Area and Sondino Ponds in Washington for western pond turtle. It is assumed that wildlife concentrations and use of habitats in the lower Columbia River estuary would not change under the Preferred Alternative from current conditions as described in the No Action Alternative.

The *Early Start Transport* measure would reduce the quantity of juvenile salmonid and steelhead available to avian and mammalian predators under the Preferred Alternative, similar to MO1, MO2, and MO4. There would be fewer juvenile salmonids in the system between collection points in the lower Snake and release points below Bonneville Dam between April 15 and October 31. Decreasing the number of juvenile salmonids above Bonneville Dam would decrease overall prey resources supporting a variety of wildlife populations at higher trophic levels above Bonneville Dam, specifically colonial nesting terns, gulls, and pelicans. These colonies prey heavily on juvenile salmonids and fewer fish would likely force birds to transition to other prey resources, delay nesting, or relocate breeding activities to other areas on the Columbia Plateau where prey resources are more widely available (Meyer et al. 2016). Consistent or long-term delays in nest initiation could decrease overall reproductive success for the colony, reducing the overall fecundity and potentially leading to a long-term reduction in regional populations.

Avian populations would also experience additional impacts from changes in the availability of nesting habitat. Nesting habitat on Badger Island, Foundation Island, and Crescent Island would be similar to the No Action Alternative due to consistent reservoir elevations in Lake Wallula. However, less habitat would be available in Lake Umatilla as a result of the *Predator Disruption Operations* measure. As described for the No Action Alternative, several islands in Lake Umatilla are used by colonial nesting waterbirds, including the Blalock Islands, and these sites would be inundated during the breeding season under the Preferred Alternative. Because the *Predator Disruption Operations* measure could reduce the overall quantity and availability of habitat in Lake Umatilla prior to the breeding season, nesting waterbirds would likely delay nest initiation until late June and July, forego nesting, or relocate to other areas.

Avian predators displaced from nesting habitat in Lake Umatilla under the Preferred Alternative would be expected to relocate to other islands and continue to forage within the Columbia River Basin. Alternatively, birds would move to alternate nesting locations in Lake Celilo (i.e., Miller Rocks) or Lake Wallula (i.e., Badger or Foundation Island), where habitat availability would remain consistent with the area currently available under the No Action Alternative. As discussed in Section 3.6.3.2, Caspian terns are highly mobile during the breeding season and move between breeding colonies in a given year and between years, demonstrating a willingness to nest away from the Columbia River while still foraging on juvenile salmonids (Corps 2014, 2018, 2019). It is also possible that some birds would move outside of the

Columbia River Basin in response to *Predator Disruption Operation* measure and nest in colonies in northern California, southern Oregon, or along the Oregon and Washington coasts.

The changes proposed as part of the Preferred Alternative, specifically the *Early Start Transport* measure, would offset impacts to juvenile salmonids by transporting individuals through the lower Snake and Columbia Rivers. As a result, it is assumed that the abundance and condition of juvenile salmon and steelhead entering the estuary would similarly increase the prey base available to colonial nesting waterbirds in the estuary. An increase in the prey base would support reproductive success of these colonies, providing long-term benefits to regional populations.

This measure would increase the survival and condition of juvenile fish entering the estuary. As described in Section 3.5, the expected impact in smolt-to-adult returns and overall abundances of adult salmon and steelhead would increase the prey base available to marine mammals foraging downstream of Bonneville Dam or offshore from the mouth of the Columbia River, such as seals, sea lions, and other predators. In addition, it is assumed that the abundance and condition of juvenile salmon and steelhead entering the estuary would similarly increase in the prey base available to nesting waterbirds, which would be a moderately beneficial impact to the size and reproductive success of these colonies.

Management activities implemented at and immediately downstream of John Day Dam, The Dalles Dam, and Bonneville Dam to reduce avian predation on juvenile salmonids by gulls and terns under the No Action Alternative are expected to continue under the Preferred Alternative. These activities include the maintenance of avian wires spanning the river in an effort to minimize large concentrations of birds congregating at juvenile bypass outfalls, where they can more easily prey upon juveniles exiting the bypass systems. Similar to the No Action Alternative, no management actions would occur under the Preferred Alternative at Miller Island in Lake Celilo to limit or preclude nesting habitat for colonial nesting birds.

7.7.8 Special Status Species

This section discusses the potential effects of implementing Preferred Alternative on ESA-listed plant and animal species that may occur in the study area.

Table 7-28 provides details about ESA-listed wildlife species that are known or likely to occur in the study area and the potential effects to these species or their critical habitats in response to Preferred Alternative implementation. Similar to the No Action Alternative, it is assumed that those species Federally-listed and present in the study area will remain listed, and existing regulatory and best management practices would reduce the likelihood that populations would continue declining or become extinct. It is assumed that neither grizzly bear critical habitat nor whitebark pine would be listed, and their presence and population in, or in the vicinity of, the study area would remain relatively stable.

The impacts to wildlife from adult salmon and steelhead returning to the Columbia River estuary is described in Section 3.5. The CSS model is indicating a major increase of smolt-to-adult returns and the overall abundance of adult salmon and steelhead returning to the estuary increases. However, the NMFS LCM model is indicating a negligible decrease in smolt-to-adult returns. This represents a negligible adverse decrease to moderate increase in Chinook salmon populations that would return to the Columbia and Snake rivers. Therefore, the prey base available to marine mammals foraging downstream of Bonneville Dam and offshore from the mouth of the Columbia River, such as seals and sea lions, may be negligibly lower to moderately higher and the Preferred Alternative, which could have long-term, beneficial impacts on wildlife downstream of Bonneville Dam. Alternatively, fish populations could decrease negligibly and the overall abundance of salmon and steelhead returning to the Columbia River estuary could decrease. This would have negligible effects to marine mammal populations.

An increase in Chinook salmon returns could cause an increase in sea lions around the Bonneville and The Dalles dam. Hazing would continue and may increase around these dams. In addition, the southern resident killer whales may have a slight increase in available food around the mouth of the Columbia River. However, this increase in food availability would have a negligible effect on killer whales, given that the Snake River and Columbia Chinook populations constitute a small portion of their overall diet. Fish hatchery production would continue at similar rates to the No Action Alternative into the future and the change in Chinook salmon abundance influenced by the Preferred Alternative would be negligible.

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Table 7-28. Sensitive Species Effects for Preferred Alternative

Common Name	Scientific Name	Status of Species and Critical habitat	Projects Where Species Occurs	Effects of Preferred Alternative
Mammals				
Grizzly bear	*Ursus arctos horribilis*	ESA status: T CH: Proposed	Libby Hungry Horse	Construction of structures on the dams: No effect. Hydrology: Negligible effect on habitat. Hydrograph would not be beneficial to establishment of cottonwood seedling or a benefit to riparian species. Conclusion: Negligible effect. Preferred Alternative would have a negligible benefit to the grizzly bear from No Action Alternative conditions. Riparian mitigation is proposed in the form of cottonwood plantings. The Preferred Alternative is not likely to adversely affect grizzly bears.
Columbian white-tailed deer	*Odocoileus virginianus leucurus*	ESA status: T CH: None	Downstream of Bonneville Dam	Construction of structures on the dams: No effect. Disturbance would not extend to suitable habitat, no individuals or habitat affected. Hydrology: Negligible effect. Virtually no change in river elevation within range of Columbian white-tailed deer. No change is suitable habitat or probability of flooding individuals. Conclusion: Negligible effect to Columbian white-tailed deer from Preferred Alternative. The Preferred Alternative is not likely to adversely affect Columbian white tailed deer.
California sea lion	*Zalophus californianus*	ESA status: None CH: None Marine Mammal Protection Act	Downstream of Bonneville Dam, occasionally seen at The Dalles Dam	Construction of structures on dams: Negligible, temporary effect. Minimal visual and noise disturbance, potentially resulting in avoidance of the area. Prey availability: Negligible Effect. Smolt-to-adult survivorship varies between the two models. These models predict a negligible decrease to major increase in Chinook salmon returns. This would be a minor change in prey availability in comparison from No Action Alternative conditions. Conclusion: Negligible effect. Numbers of California sea lions could increase under Preferred Alternative and may be slightly higher based on increases of the available fish. Hazing would continue under the Preferred Alternative. California sea lion populations would remain stable.
Steller sea lion	*Eumetopias jubatus*	ESA status: None CH: None Marine Mammal Protection Act	Downstream of Bonneville Dam	Construction of structures on dams: Temporary. Negligible effect. Minimal visual and noise disturbance, potentially resulting in avoidance of the area. Prey availability: Negligible Effect. Smolt-to-Adult survivorship varies between the two fish models. These models predict a negligible decrease to major increase in Chinook salmon returns. This would result in a minor change in prey availability in comparison from No Action Alternative conditions. Conclusion: Negligible effect. Numbers of Steller sea lions could increase under the Preferred Alternative and may be slightly higher based on increases of the available fish. Hazing would continue under the Preferred Alternative. Steller sea lion populations would remain stable.
Southern Resident killer whale Distinct Population Segment	*Orcinus orca*	ESA status: E CH: None	None	Construction of structures on the dams: No effect. Disturbance would not extend to suitable habitat for Southern Resident killer whale, no individuals or habitat affected. Prey Availability: Negligible effect. Smolt-to-Adult survivorship varies between the two fish models. These models predict a negligible decrease to major increase in Chinook salmon returns. This would result in a minor change in prey availability in comparison from No Action Alternative conditions. Conclusion: Negligible effect. The southern resident killer whale population would remain similar to the No Action Alternative based on the fact that the Columbia and Snake River chinook salmon are a small percentage of the overall diet for the population. Some prey may be more available or there may be a slight decrease in available fish. The fish hatchery production will continue at similar rates into the future. The Preferred Alternative is not likely to adversely affect the southern resident killer whale population.
Birds				
Yellow-billed cuckoo	*Coccyzus americanus*	ESA status: T CH: Proposed	Study area is within the range of yellow-billed cuckoo.	Construction of structures on the dams: No effect. Disturbance would not extend to suitable habitat, no individuals or habitat affected. Hydrology: Negligible effect. Preferred Alternative is unlikely to have any impact on yellow-billed cuckoo due to infrequent sightings of the birds near the study area. Long-term effects of decreased riparian vegetation along the Kootenai River (Plant Cottonwood Trees [up to 100 acres] near Bonners Ferry and Plant Native Wetland and riparian vegetation [up to 100 acres] on the Kootenai River downstream of Libby) may equate to decreased acreages of suitable habitat for the western yellow-billed cuckoo. Mitigation efforts may offset these impacts. Conclusion: Negligible effect. There would be some continued loss of habitat at the Libby area for cottonwood recruitment, similar to the No Action Alternative. Overall, cottonwoods may continue to decline in areas where they are established. The Preferred Alternative is not likely to adversely affect the yellow-billed cuckoo.
Bald eagle and golden eagle	*Haliaeetus leucocephalus* *Aquila chrysaetos*	Bald and Golden Eagle Protection Act	Throughout the study area.	Construction of structures on the dams: No effect. Hydrology: Negligible effect. Preferred Alternative operations would continue trends in reducing riparian habitat along the Kootenai River. Mitigation efforts may offset these impacts. Conclusion: Negligible effect. Forested areas should remain forested along the riparian system. Riparian plantings are proposed under the Preferred Alternative. Therefore, the impact to bald and golden eagles should be negligible in compared to No Action Alternative.
Streaked horned lark	*Eremophila alpestris strigata*	ESA status: T CH: Designated	Downstream of Bonneville Dam	Construction of structures on the dams: No effect. Disturbance would not extend to suitable habitat, no individuals or habitat affected. Hydrology: No Effect. Virtually no change in river elevation below RM 123. Not likely to convert suitable habitat or flood individuals. Conclusion: The Preferred Alternative is not likely to adversely effect to the streaked horned lark.

Common Name	Scientific Name	Status of Species and Critical habitat	Projects Where Species Occurs	Effects of Preferred Alternative
Plants				
Ute ladies'-tresses	*Spiranthes diluvialis*	ESA status: T CH: None	Grand Coulee Chief Joseph	Construction of structures on the dams: No effect. Disturbance would not extend to suitable habitat, no individuals or habitat affected. Hydrology: Negligible Effect. Changes in reservoir elevations could alter regions along the water margins where the plant occurs. The general trend toward lower reservoir elevations throughout most of the year due to the large deviation at Grand Coulee would have a negative impact on the plant, if the plant were to grow along the banks and margins of Lake Roosevelt. Conclusion: Negligible effect. There would be low impact to this species if the plant were to grow along the banks and margins of Lake Roosevelt. The Preferred Alternative is not likely to adversely affect the Ute Ladies' Tresses.

Effects to floodplains were also evaluated. For the Preferred Alternative, changes in flood elevations are expected to be similar to those predicted for MO 1 and 2. Flood elevation changes would typically be negligible (absolute value less than 0.3 feet) with minor reductions (absolute value less than 1 foot) in flood elevations predicted in Region D for the Columbia River below Bonneville Dam for floods with moderate to low frequencies (Annual Exceedance Probability values from 15 to 2 percent). The annual average probability of inundation under the Preferred Alternative would remain unchanged from current conditions in most of the basin, with minor reductions in inundation frequency below Bonneville Dam.

7.7.9 Power Generation and Transmission

This section evaluates effects on hydropower under the Preferred Alternative. Overall, hydropower would decrease relative to the No Action Alternative under the Preferred Alternative. However, because of the shape of the remaining hydropower generation in the Preferred Alternative, the LOLP was essentially the same as that of the No Action Alternative; therefore, potential replacement resources that would maintain LOLP at No Action Alternative levels were not evaluated. Absent offsetting cost reductions, the effects of decreased hydropower generation would result in upward pressure on electricity rates under the Preferred Alternative relative to No Action Alternative. Over the past 2 years, Bonneville and its partners have taken steps to offset the costs of reduced hydropower generation resulting from the flexible spill agreement. The co-lead agencies expect that the conditions that drive the flexible spill operation value for power would evolve with changes in energy markets and the resource mix. For example, as coal plants are retired and likely replaced with renewable resources, the price of electricity may fluctuate more over the day than it does today. This could improve the value of the increased-power-generation periods within flex spill if there are greater spreads in power prices throughout the day. Similarly, increased access to different markets and the evolution of the power markets may increase Bonneville's ability to take advantage of price values through power trading with adjacent regions (e.g., California). The spill operations contained in the Preferred Alternative are intended to test the potential biological benefits of significantly increased spill while maintaining cost neutrality for regional electricity ratepayers relative to the 2018 spill injunction.

7.7.9.1 Changes in Power Generation

Table 7-29 and Figure 7-20 present the generation for the No Action Alternative and Preferred Alternative and their differences by month. Overall, generation from the CRS projects would drop from 8,300 aMW under the No Action Alternative, on average, over all water years, to 8,140 aMW under the Preferred Alternative. This represents a decrease of 160 aMW, which is about a 2 percent decrease in generation on average. (The decrease in generation from all Northwest U.S. projects including the non-Federal projects that are affected by changes in the CRS projects is 160 aMW.) The reduction in critical water generation from the Preferred Alternative is even greater. The critical water year generation of the CRS projects would decrease by about 5 percent (300 aMW) thus decreasing the amount of firm power used to supply Bonneville's long-term contracts.

Table 7-29. Monthly Electricity Generation at the Columbia River System Projects under Preferred Alternative (aMW)

Month	No Action Alternative	Preferred Alternative Generation Difference	Preferred Alternative % Difference
October	5,500	153	2.8%
November	7,400	-47	-0.6%
December	8,300	16	0.2%
January	9,500	278	2.9%
February	9,700	190	2.0%
March	8,800	-96	-1.1%
April I[1/]	7,800	-845	-10.8%
April II[1/]	8,200	-1,100	-13.9%
May	10,000	-1,400	-13.3%
June	11,000	-490	-4.5%
July	8,800	31	0.3%
August I[1/]	7,600	-19	-0.3%
August II[1/]	6,500	731	11.3%
September	5,800	90	1.5%
Annual Average	**8,300**	**-160**	**-1.9%**

1/ HYDSIM uses a 14-period time step. April and August are split into two half-month periods because these months tend to have significant natural flow differences between their first and second halves. Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.
Source: HYDSIM results (November 2019)

The measure that appears to have the largest impact on generation is *the Juvenile Fish Passage Spill Operations* measure that reduces generation in the spring. There would be slight increases in generation in the winter, primarily from the *Slightly Deeper Draft for Hydropower at Dworshak* measure and in the second half of August from the summer spill timing in the *Juvenile Fish Passage Spill Operations* measure. For generation in the critical water year, the largest impact would be from the *Juvenile Fish Passage Spill Operations* measure. Additionally, the *Sliding Scale at Libby and Hungry Horse* measure contributes to reductions in summer generation. The generation at Grand Coulee would be reduced in January.

While there would be a decrease in generation, the largest decrease would be in the spring when the region often has surplus power. With the 1937 water year baseline comparison, there would be a decrease in July and early August. However, the slight increase in generation in the winter and late August compared to the No Action Alternative would offset the impact on power system reliability from the spring and summer generation loss. The result would be an LOLP for the Preferred Alternative that is essentially the same as the No Action Alternative (6.5 percent for the Preferred Alternative compared to 6.6 percent for the No Action alternative).

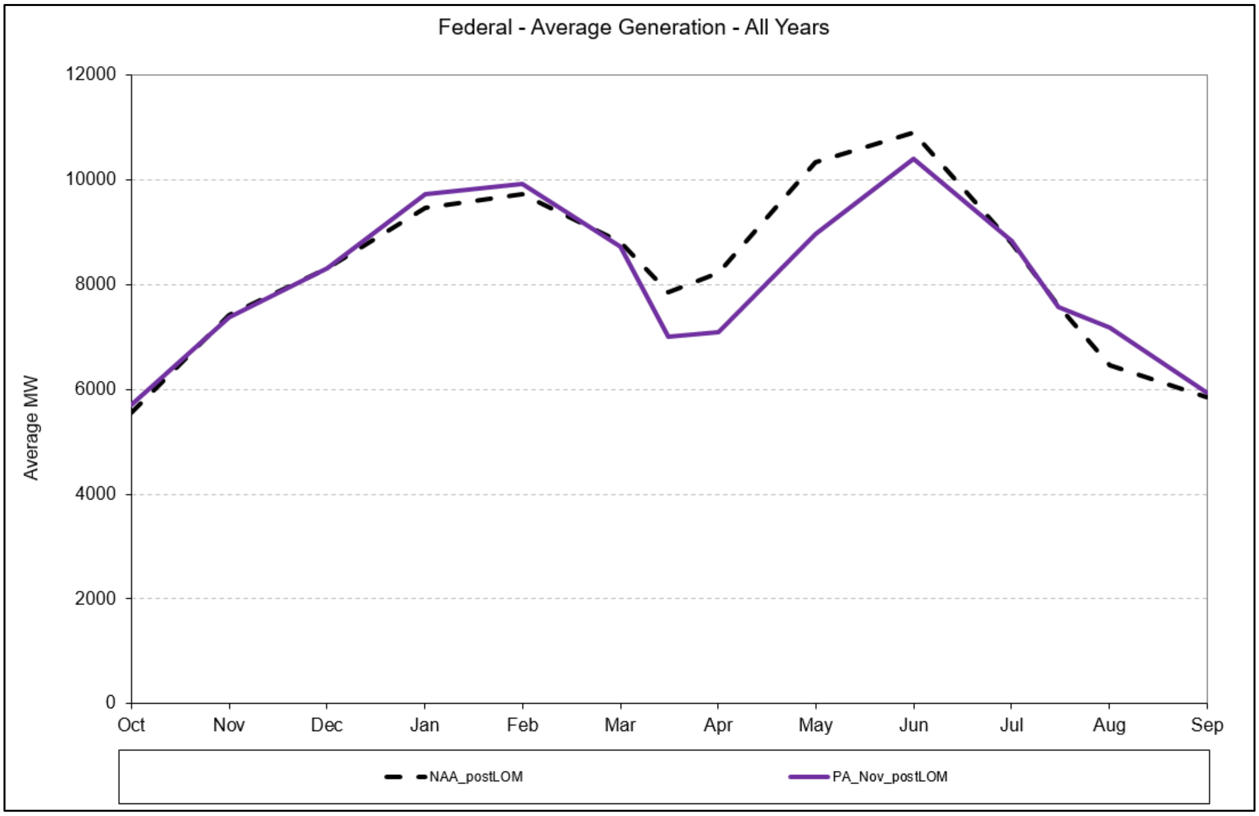

Figure 7-20. Monthly Hydropower Generation at the CRS Projects, No Action and Preferred Alternative, in aMW, for the Base Case without Additional Coal Plant Retirements

The ability of CRS projects to meet peak-periods would decrease by 1.2 percent, relative to the No Action Alternative. Based on a qualitative assessment of the alternative, the Preferred Alternative has some measures that would increase the flexibility of operating the CRS projects while the *Juvenile Fish Passage Spill Operations* measure would decrease the flexibility of the hydrosystem. Thus, the Preferred Alternative might increase the ability to integrate other renewable resources into the power grid in some seasons while decreasing this capability in the spring.

Other non-Federal regional hydropower projects that are located downstream of CRS projects (such as the Mid-Columbia hydropower projects) would experience similar trends as the CRS projects in the winter from flow changes upstream of these projects. However, the non-Federal projects would not be affected by the changes in fish passage spill in the Preferred Alternative or flow changes at Dworshak. The regional generation including these non-Federal projects would generate on average 13,200 aMW, which is a decrease of approximately 1 percent (approximately 200 aMW) relative to the No Action Alternative (at 13,400 aMW). The CRS projects account for almost all of the hydropower generation decrease under the Preferred Alternative.

EFFECTS ON POWER SYSTEM RELIABILITY

Despite the reduction in annual average hydropower generation under the Preferred Alternative, the LOLP would be 6.5 percent, which would be 0.1 percentage points lower than the LOLP in the No Action Alternative, which has a LOLP of 6.6 percent. This difference is not statistically significant. The slight reduction in LOLP occurs even with the loss of generation because of the shape of the remaining generation in the Preferred Alternative. The largest reductions in annual average hydropower generation occur in periods when the system is generally surplus (spring) and loads are easier to meet, while smaller reductions would also occur in July and the first half of August. The Preferred Alternative increases generation in late August and in the winter, which generally offsets these reductions, returning LOLP to essentially the same level of the No Action Alternative.

As described in Chapter 3.7, these LOLP estimates rely on the assumption that 4,246 MW of coal generating capacity would continue to serve regional loads (primarily investor-owned utility loads, not public utility loads) over the study period. In future scenarios with limited and no coal capacity, the LOLP under the Preferred Alternative would decrease by 3 percentage points and 4 percentage points, respectively, compared to the No Action Alternative. This would result in absolute LOLP percentage values of 24 percent in a limited coal capacity scenario (whereas the No Action Alternative is 27 percent), and 59 percent without any regional coal capacity (whereas the No Action Alternative is 63 percent). The LOLP for No Action (6.6 percent) without the additional coal retirements is already above the Northwest Power and Conservation Council target of 5 percent, and the Preferred Alternative is essentially the same at 6.5 percent. However, the difference between the two alternatives does become more significant with additional coal plant closures, largely due to the Preferred Alternative having slightly more generation than the No Action Alternative in the winter and late-August.

POTENTIAL REPLACEMENT RESOURCES AND ASSOCIATED COSTS

Because the Draft Preferred Alternative has essentially the same power supply adequacy and system reliability as the No Action Alternative, the analysis did not identify a need for replacement resources (as was the case with MO1, MO3, and MO4). In contrast, MO1, MO3, and MO4 decreased the regional power system reliability (and required replacement resources to maintain system reliability), and MO2 increased system reliability compared to No Action (and did not require replacement resources).

The LOLP for the No Action Alternative (6.6 percent) without the additional coal retirements is already above the NW Council target of 5 percent, indicating a need for the region to add new resources to meet the NW Council target.

For the scenario with limited or no coal capacity, the No Action Alternative has a significantly higher LOLP, and new resources will be needed to maintain the current level of reliability (Table 7-30). In these scenarios, for the Preferred Alternative no additional zero-carbon resources would be needed to restore the regional LOLP to the No Action Alternative level. That is, if the Preferred Alternative is adopted, and either the Limited Coal Capacity scenario occurred or the No Coal scenario occurred, the region would not need to acquire any more resources for the Preferred Alternative than it would have otherwise acquired under the No Action Alternative.

In fact, the Draft Preferred Alternative would reduce the need for new resources to replace retired coal capacity. In scenarios with limited coal generation capacity and assuming no new gas plants are built, restoring LOLP to 6.6 percent would require 200 MW fewer zero-carbon replacement resources under the Preferred Alternative, relative to the No Action Alternative, as summarized in Table 7-30. Under a no-coal future, the Draft Preferred Alternative would require 1,000 MW fewer zero-carbon replacement resources than the No Action Alternative. The reason for this change is related to the seasonality of the LOLP. In the base case without additional coal retirements, the Preferred Alternative has about the same LOLP as the No Action Alternative measured annually. However, The No Action Alternative has a higher LOLP in January and February, while the Preferred Alternative has a higher LOLP June through August. As coal plants are retired, the replacement resources may consist of large quantities of new solar power. Because solar is more effective in the summer, it takes slightly less solar power for a limited or no coal scenario for the Preferred Alternative with a larger summer LOLP than for the No Action Alternative with a larger winter LOLP.

Table 7-30. Coal Capacity Assumptions Zero-Carbon Replacement Resources

Alternative	Base Case Coal Capacity Assumption in EIS (4,246 MW)			More Limited Coal Capacity (1,741 MW)			No Coal Capacity (0 MW)		
	Pre-Resource Build LOLP	Zero-Carbon Resource Build (MW)	Change from No Action (MW)	Pre-Resource Build LOLP	Zero-Carbon Resource Build (MW)	Incremental Resource Build for Preferred Alternative as Impacted by Additional Coal Retirements (MW)	Pre-Resource Build LOLP	Zero-Carbon Resource Build (MW)	Incremental Resource Build for Preferred Alternative as Impacted by Additional Coal Retirements (MW)
No Action	6.6%	0	0	27%	8,800	N/A	63%	28,000	N/A
Draft Proposed Action	6.5%	0	0	24%	8,600	0	59%	27,000	0

Note: The replacement resources for the No Action Alternative include demand-response, wind, and solar.

EFFECTS ON TRANSMISSION FLOWS, CONGESTION, AND THE NEED FOR INFRASTRUCTURE

Bonneville interconnections

Under the Preferred Alternative, no new transmission interconnections or reinforcements would be required.

Bonneville transmission reliability and operations

Under the Preferred Alternative, Bonneville would continue to meet its transmission system reliability requirements. There could be an increase in generation from the Lower Snake and Lower Columbia projects during the last half of August relative to the No Action Alternative. This generation would provide additional flexibility that could provide operational benefits for the transmission system. As a result, no additional reinforcements have been identified beyond those that are a part of Bonneville's regular system assessments.

Regional transmission system congestion effects

Under any runoff condition, small changes in the number of congestion hours relative to the No Action Alternative would occur on the majority of north to south paths. The Pacific DC Intertie (PDCI) and the South of Custer interfaces would experience increases of 40 and 38 hours relative to the No Action Alternative under low runoff conditions and smaller changes under other runoff conditions. Other north to south paths would see changes of 30 congestion hours or less.

In high runoff conditions, some west to east paths would experience a higher number of congested hours as additional hydro generation is exported. The largest increases would be on the Hemingway to Summer Lake[9] path (61 hours) and the Idaho to Northwest path (52 hours). Under median runoff there would be a reduction of approximately 54 congestion hours relative to the No Action Alternative for the Hemingway to Summer Lake path and about 107 congestion hours for the Idaho to Northwest path. See Appendix H, *Power and Transmission,* for more detailed congestion graphs.

Changes in the patterns of CRS generation under the Preferred Alternative would have a minor impact on congestion for Pacific Northwest transmission paths.

[9] The Hemingway – Summer Lake transmission line component of both the Hemingway – Summer Lake and Idaho to Northwest transmission paths.

CHANGES IN ELECTRICITY RATES

Bonneville Wholesale Power Rates

Overview

This section describes the effects of the Preferred Alternative on Bonneville's wholesale power rate pressure. The methodology used in this section is the same methodology used to evaluate the wholesale power rate effects of the MOs, which is described in detail in Chapter 3.7.3.1 of this DEIS. In summary, the power rate pressure effects analysis for the Preferred Alternative is comprised of four components: (1) a Base Case Analysis; (2) a Rate Sensitivity Analysis; (3) a summary of the total effects on Bonneville wholesale power rate pressures of the Preferred Alternative (i.e., Base Case Analysis plus Rate Sensitivity Analysis); and (4) an Other Regional Cost Pressure analysis. A table identifying each element of this analysis is provided below followed by a brief description of each component in Table 7-31.

To the extent that the Preferred Alternative increases the cost of power generation and transmission (e.g., if Bonneville or other entities need to acquire new sources of power or construct transmission infrastructure), the increased costs would place upward pressure on wholesale and retail electricity rates. The term "upward rate pressure" indicates the potential for increases in rates resulting from the added costs of generating and transmitting power; upward rate pressure could lead to increased rates absent the ability of Bonneville or other entities to balance out the added costs. Likewise, "downward rate pressure" indicates the potential for reductions in rates resulting from decreased costs of generating and transmitting power.

The *Base Case Analysis* estimates the impacts of the Preferred Alternative using information available at the time of the development of the Base Case. This analysis uses certain assumptions regarding resource availability, resource costs, demand response, construction costs, coal plant retirements, carbon policies, and other factors that affected the output of the resulting power rates analysis. The *Base Case Analysis* represents the "base line" power rate pressure effect of the Preferred Alternative using the best available information at the time the analysis was performed.

The *Rate Sensitivity Analysis* builds off of the *Base Case Analysis* by updating certain assumptions that have changed (or are likely to change) and adding new considerations that have arisen since the original analysis was performed. Many of the assumptions underlying the *Rate Sensitivity Analysis* were either unknown or speculative at the time the *Base Case Analysis* was developed. For that reason, these assumptions and considerations were not included in the *Base Case Analysis,* but instead were appended to the wholesale power rate analysis as a range of sensitivities. Six specific sensitivities were considered: (1) Fish and Wildlife Costs; (2) Hydro Flexibility; (3) Resource Financing; (4) Construction Contingencies (Cost Uncertainties); (5) Demand Response; and (6) Oversupply. An in-depth description of each of these sensitivities is provided in Chapter 3.7.3.1, under the heading "Rate Sensitivity Analysis."

Table 7-31. Change in Bonneville's Priority Firm Tier 1 Rate, Bonneville Finances

Change in Bonneville's Priority Firm Rate, Bonneville Finances

		Zero-Carbon Portfolio		Conventional Least-Cost Portfolio	
		$ rate pressure	change from NAA	$ rate pressure	change from NAA
	Base-Case Analysis (annual cost in $ millions unless noted otherwise)				
1	Base Rate	Base Case Analysis		$ /MWh	$ /MWh
2	Change from NAA due to Costs	$	%	$	%
3	Change from NAA due to Load		%		%
4	**Total Base Change in Rate**		**%**		**%**
	Rate Sensitivities (annual cost in $ millions)				
5	Fish and Wildlife Costs	$ to $	% to %	$ to $	% to %
6	Integration Services	$ to $	% to %	$ to $	% to %
7	Resource Financing Assumptio	$ to $ Rate Sensitivity Analysis	% to %	$ to $	% to %
8	Resource Cost Uncertainties	$ to $	% to %	$ to $	% to %
9	Demand Response	$ to $	% to %	$ to $	% to %
10	Oversupply	$ to $	% to %	$ to $	% to %
11	**Total Rate Sensitivities**	**$ to $**	**% to %**	**$ to $**	**% to %**
12	**Total Base Effect + Sensitivities**	**Base Case + Rate Sensitivity Analysis** $ to $	**% to %**	**$ to $**	**% to %**

Other Regional Cost Pressure (annual cost in $ millions)

		Zero-Carbon Portfolio		Conventional Least-Cost Portfolio	
		$ pressure	change from NAA	$ pressure	change from NAA
	Other Regional Cost Pressure				
13	Regional Cost of Carbon Compliance	$ to $		$ to $	
14	Regional Coal Retirements (capital)	$ to $		$ to $	
15	Regional Coal Retirements (other)	$ to $		$ to $	

The *Other Regional Cost Pressure* analysis addresses two additional potential cost impacts that have been identified but remain speculative and uncertain at this time. These cost impacts include (1) the potential incremental costs associated with policies to reduce greenhouse gas emissions that place a direct or indirect price on carbon, and (2) the potential incremental costs associated with accelerated Coal Retirements (capital and other costs [e.g., market price effects]). These variables are presented at the end of the wholesale power rates analysis as a source of additional cost pressures to regional utilities. These costs would not all be directly assignable to Bonneville's power rates. However, it is possible that in some instances the regional costs identified in this section could affect Bonneville's cost of power (such as compliance price on carbon), while in other instances the effect would be indirect (such as through market price impacts arising from the accelerated retirement of coal).

Summary of the Preferred Alternative Impacts on Bonneville's Wholesale Power Rate and Other Regional Cost Pressure

Under the Preferred Alternative, the average wholesale Priority Firm (PF) power rate would experience upward rate pressure relative to the No Action Alternative. Should the upward rate pressure lead to rate increases (i.e., if Bonneville or other entities were unable to balance the additional costs), the average PF power rate would be $35.47/MWh, which represents an increase of $0.90/MWh or a 2.7 percent increase relative to the No Action Alternative in the base case, without accounting for additional coal plant retirements. Note, the wholesale rate represents the average rate paid by Bonneville's preference customers as calculated for the

Preferred Alternative using the methodology and assumptions established for this EIS and is a useful comparison to the calculated rate for the No Action Alternative. It does not represent the effective rate paid by a particular Bonneville customer[10] and it is not an actual or forecast rate in Bonneville rate cases.

Summary results for power rate pressures are presented in Table 7-32. The table is the projected change in the Bonneville Wholesale Power Rate for the base analysis followed by a discussion of additional changes in costs that could affect the rate.

Table 7-32. Average Bonneville Wholesale Power Rate ($/MWh), for the Base Case without Additional Coal Plant Retirements as well as the Rate Pressures Associated with Additional Sensitivity Analysis

Change in Priority Firm Rate, Preferred Alternative

		Zero-Carbon Portfolio	
		$ rate pressure	change from NAA
	Base-Case Analysis (annual cost in $ millions unless noted otherwise)		
1	Base Rate	$35.47 /MWh	$0.90 /MWh
2	Change from NAA due to Costs	$11	0.5%
3	Change from NAA due to Load		2.2%
4	**Total Base Change in Rate**		**2.7%**
	Rate Sensitivities (annual cost in $ millions)		
5	Fish and Wildlife Costs	-$47 to $0	-2.3% to 0%
6	Integration Services		
7	Resource Financing Assumptions		
8	Resource Cost Uncertainties		
9	Demand Response		
10	Oversupply	-$1 to $0	0% to 0%
11	**Total Rate Sensitivities**	**-$48 to $0**	**-2.3% to 0.0%**
12	**Total Base Effect + Sensitivities**	**-$37 to $11**	**0.4% to 2.7%**

Other Regional Cost Pressure (annual cost in $ millions)

		Zero-Carbon Portfolio	
		$ pressure	change from NAA
13	Regional Cost of Carbon Compliance	**$9 to $47**	
14	Regional Coal Retirements (capital)	**$0 to $0**	
15	Regional Coal Retirements (other)	too uncertain to estimate	

Note: Line 3 represents the effect of Bonneville selling less power through its long-term contracts to its preference customers. As volume of these sales decrease, Bonneville's fixed costs (e.g., for energy efficiency or fish and wildlife) are recovered from a smaller pool of sales, leading to upward pressure on the wholesale rate.

[10] The effective rates paid by each customer are different due to the specifics of a particular customer, such as its load profile and the products and services it purchases from Bonneville.

Base Case

The Base Case rates analysis results show upward rate pressure of 2.7 percent relative to the No Action Alternative (lines 1-3). In this alternative, no replacement resources were needed to return the region to the No Action Alternative level of reliability (i.e., a Loss of Load Probability (LOLP) of 6.6 percent).[11] Approximately 0.5 percent of the rate pressure occurs because of expected cost increases of $11 million per year (2019 dollars) primarily due to higher capital costs associated with the structural measures described in Section 7.7.21. The remaining 2.2 percent of rate pressure occurs as a result of the loss of firm generation, which reduces the amount of firm power Bonneville is able to sell to its customers at the Tier 1 System Rate. With less firm power to sell, Bonneville must collect more of its costs over a smaller pool of firm power sales, resulting in the 2.2 percent of rate pressure.

Rate Sensitivity Analysis

The *Rate Sensitivity* analysis is presented in lines 5 through 11 to provide quantitative estimates described in the *Additional Rate Sensitivities,* in Chapter 3.7.3.1.

Fish and Wildlife Cost Sensitivities

In 2016, the Bonneville Fish and Wildlife Program budget was $267,000,000, and the LSRCP budget was $32,303,000. When these budgets are adjusted to represent 2019 dollars, they become $281,536,000 and $34,062,000, respectively. These values were modeled as part of the Base Case rate analysis, which is consistent with the approach taken for the No Action Alternative. However, over the last 3 years, Bonneville has adjusted the Fish and Wildlife Program budget to $249 million and the LSRCP budget to $30.5 million, changes that are captured within the rate sensitivity analysis. As a result, Bonneville does not anticipate additional reductions to the Fish and Wildlife Program or LSRCP with the implementation of the Preferred Alternative at this time.

Other Sensitivities

Because no replacement resources were needed to maintain an LOLP of 6.6 percent, no sensitivities for resource acquisitions were analyzed. Oversupply Management Protocol costs associated with oversupply events could be $1 million per year lower due to increased spill and less generation in the spring.

Other Regional Cost Pressures

The *Other Regional Cost P*ressures analysis reflects the potential regional costs associated with greenhouse gas emission reduction policies that directly or indirectly put a price on carbon and accelerated coal retirements under the Preferred Alternative. This analysis does not calculate the potential impacts of these factors on Bonneville's power rates. Rather, this analysis

[11] See Chapter 3.7.3.2, where regional power reliability is described as maintaining the current LOLP of 6.6 percent.

estimates the regional impact of the Preferred Alternative (lines 13 and 14), a portion of which may directly or indirectly affect Bonneville in the future. Effects associated with greenhouse gas emission reduction laws are not fully known given states are actively developing these policies in order to reduce greenhouse gas emissions in the electricity sector and across the economy, e.g., pending current legislation in Oregon and the currently in-progress rulemaking for Washington's Clean Energy Transformation Act (a 100 percent carbon-free standard) as discussed in the Additional Rate Sensitivities section in Chapter 3.7.3.1.

Recent trends in state legislation and policies are directed at decarbonizing the electric grid, suggesting that in the future there may be a price associated with most or all fossil fuel generation located or serving load in the Pacific Northwest. The Preferred Alternative reduces the amount of hydropower production in the region as compared to the No Action Alternative, which in turn could affect compliance costs for utilities, and ultimately ratepayers, under policies that mandate a price on greenhouse gas emissions. Applying the same methodology as applied in Chapter 3.7.3.1, this analysis estimates that, in 2030, the reductions in hydropower generation in the Preferred Alternative would increase the cost of compliance with greenhouse gas emission reduction policies in the Pacific Northwest between $9 and $47 million per year.

As described in Sections 3.7.3.1 ("Availability of Coal Resources"), and in 3.7.3.2 ("Effects on Power System Reliability"), regional utilities would need to add 8,800 MW of additional zero carbon resources in the limited coal capacity scenario and 28,000 MW of additional zero carbon resources in the no coal scenario to maintain regional LOLP at the No Action Alternative levels (6.6 percent). The Preferred Alternative has a similar or slightly lower (better) LOLP than the No Action Alternative, so no additional resources are needed for the Preferred Alternative in these scenarios besides the resources needed for the No Action Alternative.

For the limited coal capacity scenario under the PA, a minimum of 8,600 MW of zero-carbon resources would need to be added by the region to maintain regional LOLP at the No Action Alternative level of 6.6 percent before the coal-plant retirements. For the no coal scenario under the PA, a minimum of 27,000 MW of zero-carbon resources would be needed to maintain regional LOLP to the No Action Alternative levels before the coal-plant retirements. Because both of these starting values are below the No Action Alternative's 8,800 MW (for limited coal) and 28,000 MW (for no coal), no incremental zero-carbon resource costs would be incurred as a result of the PA under either a limited or no coal scenario.

Market Prices

The average market price for power in the Pacific Northwest (mid-Columbia trading hub) would be expected to increase under the Preferred Alternative to $19.27/MWh. This represents an increase of $0.19/MWh or 1.0 percent relative to the No Action Alternative. The decrease in hydropower generation decreases the amount of power sold into and/or increases amount of power purchased from the market relative to the No Action Alternative, leading to increases in the market price. Figure 7-21 presents the CRS projects' generation and the market prices under the Preferred Alternative for the average of the 80 historical water years. Prices would peak in August and December when demand is relatively high compared to generation, but would be slightly lower under the Preferred Alternative due to a slight increase in hydropower generation compared to the No Action Alternative., Conversely, prices would be lowest in June when generation exceeds 10,000 aMW, but would be increase in April through June under the Preferred Alternative. The spring price increase results from decreased generation resulting primarily from increased spill.

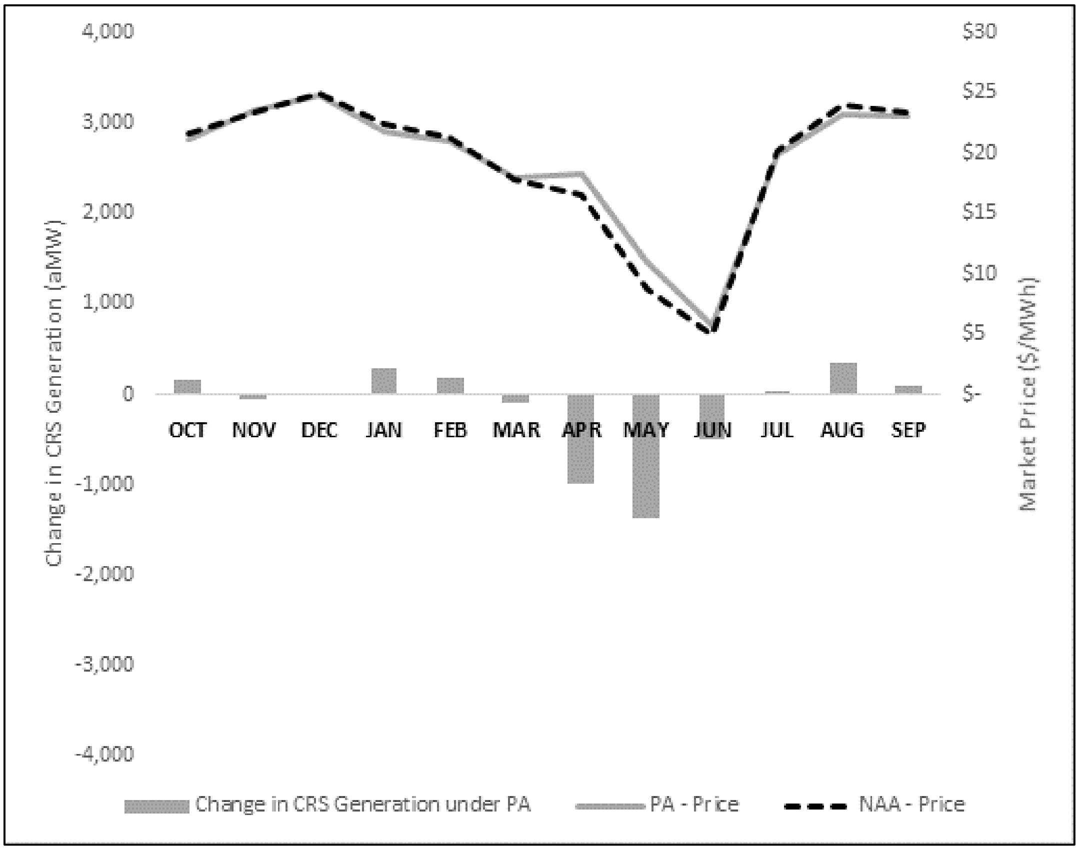

Figure 7-21. Market Prices and Average CRS Hydropower Generation under the Preferred Alternative for the Base Case without Additional Coal Plant Retirements

Note: The right hand axis is the market price ($/MWh). The left hand axis is generation from the CRS projects by month (aMW).

Transmission Rate Pressure

Under the Preferred Alternative, there would be no changes in capital investments or long-term transmission sales. Upward transmission rate pressure would be about 0.09 percent annually (0.7 percent cumulatively over an 8-year period) relative to the No Action Alternative because transmission short-term sales would likely decrease as a result of the changes in hydropower generation and associated market pricing. For specific customers and product choices, the annualized upward rate pressure would range from 0.04 percent to 0.18 percent relative to the No Action Alternative.

Retail Rate Effects

Under the Preferred Alternative, retail electricity rates (paid to individual utilities) would be similar to the No Action Alternative. Most counties would experience slight upward rate pressure on the electricity retail rate. Should the upward rate pressure lead to increases in rates, across the Pacific Northwest, residential retail rates could range from an increase of less than 0.01 cents/kWh to an increase of 0.10 cents/kWh (in percentage terms this represents an increase of less than 0.1 percent to an increase of 1.1 percent). For commercial end users, rate pressure effects could lead to an increase in rates of less than 0.01 cents/kWh to an increase of 0.10 cents/kWh (an increase of 0.0057 percent to an increase of 1.3 percent), and for industrial customers, from an increase of less than 0.01 cents/kWh to an increase of 0.10 cents/kWh (an increase of less than 0.01percent to an increase of 1.9 percent). The rate pressure effects would be larger for customers of utilities that receive power from Bonneville and smaller for customers whose electricity is not supplied by Bonneville.

Bonneville Financial Analysis

The purpose of the financial analysis is to enable comparisons between alternative investment opportunities. The financial analysis quantifies the expected stream of cash inflows and outflows over time and then discounts those cash flows over time to produce a single net present value (NPV) representing how much an investment is worth at a specific point in time. Discounting accounts for the time-value of money; a dollar received today is worth more than a dollar received in 10 years. Present value calculations are therefore sensitive to the discount rate used.

For the Preferred Alternative, the NPV of the cash flow effects are described in Table 7-33 below. This NPV analysis is Bonneville specific and does not capture wider societal impacts. This Bonneville NPV analysis uses a risk-adjusted discount rate of 7.9 percent and a 30-year timeframe.[12] The financial analysis includes only those cash flows that differ between the Preferred Alternative and the No Action Alternative. Ultimately, these cash flows determine revenue requirements and lead to changes in power and transmission rate pressures.

The sensitivities in this analysis are described in the Power Rates section, above.

Table 7-33. Bonneville Financial Analysis Results Incremental Compared to No Action Alternative

Type	Preferred Alternative (Millions of 2019 dollars)
Power	($290)
Transmission	($4)
Total Base Impact – Bonneville	**($294)**

Notes: Discount Rate: Risk Adjusted rate of 7.9 percent (2019 assumptions), 30-year timeframe
Analysis does not account for the cost uncertainty as risk is captured in the discount rate, rather than the cash flows

[12] A risk-adjusted discount rate is used for making investment decisions. It includes a risk premium, resulting in a higher discount rate that has the effect of reducing the present values of riskier investments for which the expected return-on-investment is increasingly uncertain over time. The Bonneville risk-adjusted discount rate of 7.9 percent represents the BPA average cost of debt at 3.9%, then a 4% risk premium adder to account for cost uncertainty over the term of the analysis.

SOCIAL AND ECONOMIC EFFECTS OF CHANGES IN POWER AND TRANSMISSION

Social Welfare Effects

From an economic perspective, the conceptual basis for measuring economic value is society's "willingness-to-pay" (WTP) for a good or service.[13] Absent data to directly measure WTP, it is common to estimate WTP based on additional indicators of value, including market prices and replacement costs. This analysis applies two separate methods to estimate social welfare values of the changes in power generation and transmission. Both methods are consistent with the Corps' guidance for valuing social welfare effects of changes in power, and are presented as changes relative to the No Action Alternative for the base case (i.e., not accounting for the rate sensitivities and the additional coal plant retirements).[14]

Table 7-34 presents the market value of the decrease in Pacific Northwest hydropower generation under the Preferred Alternative as compared with the No Action Alternative. Based on the market price method, the average annual economic effect of the Preferred Alternative is a $6.7 million cost. This is based on the 160aMW reduction in regional hydro power priced at the average monthly market prices, resulting in a net loss compared to the No Action Alternative.

Table 7-34. Average Annual Social Welfare Effect of the Preferred Alternative Based on the Market Price of Changes in Pacific Northwest Hydropower Generation

Change in Generation (aMW)	Change in Generation (MWh)	Average Annual Social Welfare Effect (2019 dollars)
-160	-1,400,000	**-$6,700,000**

Note: Estimates are rounded to two significant digits. Negative values in the table represent a net loss in social welfare.

Table 7-35 evaluates the social welfare effects of the Preferred Alternative based on the additional costs of providing power to meet demand given the reduction in hydropower generation. That is, the social welfare effects quantified based on the production cost method are estimated on the marginal increase in the cost of producing power to maintain power system reliability. The social welfare effects based on the production cost method reflect the potential for: increased fuel costs, operations and maintenance costs, start-up costs and carbon emissions penalties (in California) for fossil fuel-based generation. The change in these variable costs reflect changes across the entire Western Interconnection. Replacement resources are not required under the Preferred Alternative and the value of the slightly improved level of power system reliability is not quantified; the resource portfolio that would be equivalent to

[13] WTP measures the maximum amount that an individual (or population) would be willing to pay rather than do without a good or service above and beyond what the individual (or population) does pay.

[14] The Corps' guidance describes the following: "Primary benefit measure for hydropower: Market value of output, or alternative cost of providing equivalent output when market price does not reflect marginal costs." (Source: U.S. Army Corps of Engineers Institute for Water Resources. June 2009. National Economic Development Procedures Manual.)

the improvement in power system reliability under the Preferred Alternative would likely be small. Based on this approach, the social welfare effect of the Preferred Alternative is an average annual cost of $25 million.[15]

Table 7-35. Average Annual Social Welfare Effect of the Preferred Alternative based on the Increased Cost of Producing Power to Meet Demand

Production Cost Factor	Average Annual Social Welfare Effect (2019 dollars)
Annualized Fixed Cost of Replacement Resources	$0
Annualized Fixed Cost of Transmission Infrastructure	$0
Average Annual Variable Costs	-$25,000,000
Average Annual Social Welfare Effects	**-$25,000,000**

Notes: Estimates are rounded to two significant digits. The negative numbers in this table represent net costs (positive numbers would reflect net benefits).

Regional Economic Effects

Under the Preferred Alternative, the Pacific Northwest would generally experience slight upward retail electricity rate pressure relative to the No Action Alternative, though effects range by household and by commercial or industrial business.

Residential Effects

A large portion of the counties in the Pacific Northwest would experience slight upward residential retail rates pressure under the Preferred Alternative. Residential retail rate pressure under the Preferred Alternative would range from a less than 0.01 percent increase to 1.1 percent increase across the region. In addition, in the scenarios with limited or no coal in the region, the rate pressure might be slightly lower in the Preferred Alternative relative to the No Action Alternative due to the benefit to the power system of additional system reliability that would reduce the need to build new generating capacity.

Both urban areas and rural areas would experience slight upward rate pressure under the Preferred Alternative (Table 7-36). On average, all CRSO regions experience rate pressure of less than 0.5 percent, with Regions A and D experiencing the highest average rate pressure as the utilities serving these areas purchase more power from Bonneville.

Figure 7-22 maps potential residential retail rate pressure effects by county for the Preferred Alternative relative to the No Action Alternative. As illustrated in this figure, counties would generally experience slight upward residential retail rate pressure across the region with three counties experiencing a larger increase (1.0 to 2.5 percent increases).

[15] Note that this welfare estimate does not consider the benefits of increased power system reliability under the Draft Preferred Alternative.

Table 7-36. Average Residential Rate Pressure Effects by Columbia River System Operations Region under the Preferred Alternative

CRSO Region	Average Residential Rate Pressure Relative to No Action
Region A	0.34%
Region B	0.24%
Region C	0.21%
Region D	0.44%
Other	0.34%

Note: The “Other” region encompasses the counties outside of the four CRSO EIS regions but within the Bonneville service area. See Chapter 3.7.1.3 for the definition of the area of analysis as well as the map of the Bonneville service area and CRSO regions.

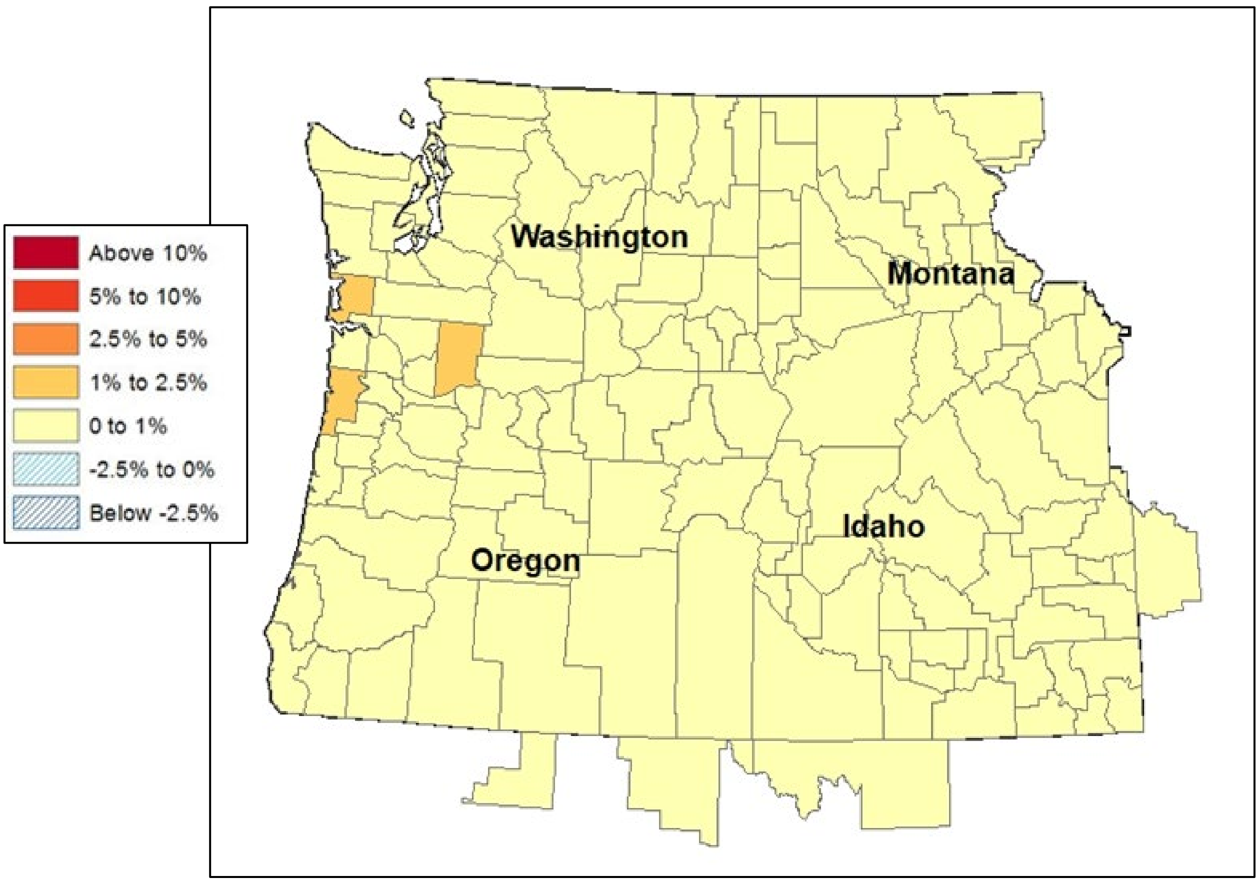

Figure 7-22. Residential Rate Pressure Effects under the Preferred Alternative Relative to the No Action Alternative

Given rate pressure over time, the upward rate pressures would increase faster under the Preferred Alternative relative to the No Action Alternative, stabilizing around an average effect of 0.40 percent compared to the No Action Alternative by 2041.

To the extent that the upward rate pressure leads to changes in rates, end users would increase spending on electricity (See Table 7-37). Ninety-nine percent of all households in the region would pay between zero and 1 percent more for electricity per year. Less than 1 percent of households would pay between 1 percent and 2.5 percent more for electricity, while the rest of regional households would pay between zero and 1 percent more for electricity, assuming these additional costs were passed on directly to end users.

Table 7-37. Percentage of Residential End Users who may Experience Changes in Electricity Expenditures by Size of Expenditure Change under the Preferred Alternative

Sector	Change in Household Spending on Electricity	Percent of Households
Residential	>+10%	0%
	+5% to 10%	0%
	+2.5% to 5 %	0%
	+2.5% to 1%	0.66%
	+0% to 1%	99%
	Decrease	0%

Note: Estimates are rounded to two significant digits and may not sum to 100 percent due to rounding.

Given the relatively small upward rate pressure under the Preferred Alternative, the effects on the demand for electricity would also likely be small. Residential end users could adjust their consumption based on changes between less than 0.01 percent and 1.1 percent, varying by the county rate effect. On average, households would experience a less than 1 percent change.

If the upward rate pressure results in increased retail rates for electricity, average annual household spending on electricity as a percentage of median household income region-wide could increase very slightly from 1.69 percent under the No Action Alternative to 1.70 percent under the Preferred Alternative. This equates to a total increase in household spending on electricity across all Pacific Northwest households of $19 million per year.

This analysis considers how the region-wide changes in household spending on electricity could affect demand for other goods and services across the region. That is, increased spending on electricity may reduce spending on other items, affecting regional economic productivity. This analysis applies IMPLAN to model the increased spending on electricity as a reduction in household income (direct effect), and quantifies the multiplier effects on interrelated economic sectors (indirect and induced effects). This analysis finds that, assuming upward retail rate pressure reduces regional spending on other goods and services, regional economic impacts across the Pacific Northwest could be on the order of $20 million reduction in regional output (sales) and 130 jobs (Table 7-38).

These estimates are a 1-year snapshot of the potential impacts and do not account for broader adjustments in regional economic activity that may occur over time that would offset these impacts. Furthermore, the estimated effects, while likely focused most in Washington and Oregon, would be distributed over a broad geographic area, including all of Washington, Oregon, Idaho, and parts of Montana and Nevada. Of note, the impacts presented in Table 7-38 are conservative (i.e., more likely to overestimate than underestimate the regional economic impacts) given assumptions that the upward rate pressure would increase retail rates, and that the retail rate effects would in turn affect household spending patterns.

Table 7-38. Regional Economic Effects from Changes in Household Spending on Electricity

Effect	Annual Impact of the Preferred Alternative
Output	-$20 million
Value Added	-$12 million
Labor Income	-$6.7 million
Employment	-130 jobs

Note: Negative values in the table represent a net loss in output (sales) and employment for the regional economy

Commercial and Industrial Effects

Under the Preferred Alternative, commercial and industrial rates would also experience upward rate pressure. The average upward rate pressure effects for commercial and industrial end users would be 0.35 percent and 0.46 percent, respectively. The counties with the largest number of commercial entities would experience rate pressure effects between a 0.18 percent and a 1.0 percent commercial rate change.

Table 7-39 presents the fraction of commercial and industrial end users (i.e., businesses) that would experience upward rate pressure potentially leading to increases in expenditures on electricity. Under the Preferred Alternative, 98 percent of commercial businesses in the Pacific Northwest could increase spending on electricity by less than 1 percent. Another 2.1 percent could increase spending by 1 percent to 2.5 percent.

Additionally, 90 percent of industrial businesses in the Pacific Northwest could increase spending on electricity by less than1 percent. Another 10 percent could increase spending by 1 percent to 2.5 percent.

Table 7-39. Percentage of Commercial and Industrial End Users who Experience Changes in Electricity Expenditures by Size of Expenditure Change under the Preferred Alternative

Sector	Change in Spending on Electricity	Percentage of Businesses
Commercial	>+10%	0%
	+5% to 10%	0%
	+2.5% to 5%	0%
	+2.5% to 1%	2.1%
	+0% to 1%	98%
	Decrease	0%
Industrial	>+10%	0%
	+5% to 10%	0%
	+2.5% to 5%	0%
	+2.5% to 1%	10%
	+0% to 1%	90%
	Decrease	0%

Note: Estimates are rounded to two significant digits and may not sum to 100 percent due to rounding.

Under the Preferred Alternative, the upward rate pressure across commercial businesses in the Pacific Northwest could result in increased spending on electricity of $6.3 million. This analysis uses the IMPLAN model to quantify the multiplier effects of the change in commercial sector productivity (Table 7-40). The multiplier effects reflect how the increased costs of doing business may affect demand for inputs to production across commercial businesses. This analysis finds that regional economic impacts across the Pacific Northwest could result in the loss of $10 million in regional output (sales) and 70 jobs. As described above, the estimated regional economic impacts reflect conservative assumptions that the increased rate pressure would increase the cost of electricity to end users, and reduce commercial sector spending on other regional goods and services. The majority of regional economic effects would occur in Washington and Oregon.

Table 7-40. Regional Economic Effects from Changes in Commercial Business Spending on Electricity

Effect	Annual Impact of the Preferred Alternative
Output	-$10 million
Value Added	-$6.5 million
Labor Income	-$3.3 million
Employment	-70 jobs

Note: Negative values in the table represent a net loss in output (sales) and employment for the regional economy

Under the Preferred Alternative, upward rate pressure across industrial businesses in the Pacific Northwest could result in increased spending on electricity of $23 million. Like the commercial spending analysis, the IMPLAN model is used to quantify the multiplier effects of the change in industrial sector productivity (Table 7-41). This analysis finds that regional economic impacts across the Pacific Northwest could result in the loss of $37 million in regional output (sales) and 240 jobs. As described above, the estimated regional economic impacts reflect conservative assumptions that the increased rate pressure would increase the cost of electricity to end users, and reduce industrial sector spending on other regional goods and services. The majority of regional economic effects would occur in Washington and Oregon.

Table 7-41. Regional Economic Effects from Changes in Industrial Business Spending on Electricity

Effect	Annual Impact of the Preferred Alternative
Output	-$37 million
Value Added	-$24 million
Labor Income	-$12 million
Employment	-240 jobs

Note: Negative values in the table represent a net loss in output (sales) and employment for the regional economy.

Tribal Interests

Many tribes in the study area receive electricity through Bonneville. Some have tribal utilities that get power directly from Bonneville and some are served by public utilities that get power from Bonneville. Therefore, any upward or downward movement in power rate pressures would directly affect tribes. The Confederated Tribes of the Colville Reservation (CTCR) and the Spokane Tribe of Indians (likely starting in 2021) receive annual payments from Bonneville as compensation for tribal lands inundated by Lake Roosevelt. The payment is based on annual average generation produced at Grand Coulee Dam as well as the power used to pump water to Banks Lake for irrigation. Based on the combination of changes in generation (reduced), at Grand Coulee, and market prices of power, the Preferred Alternative results in upward payment pressure of about 1 percent relative to the No Action Alternative.

Other Social Effects

Under the Preferred Alternative, household spending on electricity would generally increase slightly. This change would be unlikely to create a burden on household end users and would not be expected to cause households to reduce electricity consumption due to changes in electricity bills. The Preferred Alternative would not reduce power system reliability; the slight increase in power system reliability (i.e., reduction in LOLP) would potentially slightly reduce the risk of safety concerns related to power outages relative to the No Action Alternative.

SUMMARY OF POWER AND TRANSMISSION EFFECTS UNDER THE PREFERRED ALTERNATIVE

Under the Preferred Alternative, hydropower generation would decrease relative to the No Action Alternative, and the FCRPS would lose 304 aMW of firm power available for long-term firm power sales (roughly the amount of power consumed by about 250,000 Northwest homes in a year).

The decrease in hydropower generation across the Pacific Northwest (an average decrease of 160 aMW including Federal and non-Federal projects) results in social welfare costs ranging between $6.7 million and $25 million. These values are estimates of the net economic cost of the Preferred Alternative from a national societal perspective. In addition, the Preferred Alternative would result in additional cost of compliance with greenhouse gas emission reduction programs in the region of between $9 and $47 million per year.

Residential, commercial, and industrial end users would experience slight upward retail rate pressure. In the scenarios with limited or no coal, the rates would likely be lower than the No Action Alternative. Regional utilities that purchase most or all of their power from Bonneville would experience larger effects than Investor Owned Utilities (IOUs) or other public utilities that do not purchase Bonneville power directly.

Assuming the upward rate pressure would slightly increase the costs of living (residential rate pressure) and doing business (commercial and industrial rate pressure), and reduce regional spending on other goods and services, combined regional economic impacts across the Pacific

Northwest could result in approximately $68 million in lost output (sales) and approximately 440 jobs. As previously described, these estimates reflect conservative assumptions about the likelihood that upward rate pressures would reduce regional spending on other goods and services across the region. They are a 1-year snapshot of the potential impacts and do not account for broader adjustments in regional economic activity that may occur over time that would offset these impacts. Furthermore, the estimated effects, while focused in Washington and Oregon, would be distributed over a broad geographic area, including all of Washington, Oregon, Idaho, and parts of Montana and Nevada (Table 7-42).

Table 7-42. Summary of Effects under the Preferred Alternative Without Additional Coal Plant Closures

Effect	No Action Alternative[/1]	Effects of the Preferred Alternative Relative to No Action
CRSO Hydropower Generation (aMW)	8,300	-160
Firm power of FCRPS (aMW)	7,100	-300
LOLP	6.6%	-0.1 LOLP %
Replacement Resources to return LOLP to No Action Alternative level	——[/1]	——[2]
Replacement Resource Cost to return LOLP to No Action Alternative level (annual cost)	——[/1]	——[3]
Transmission Infrastructure to return LOLP and/or transmission system reliability to No Action Alternative level (annualized reinforcement and/or interconnection cost)	——[/1]	——[3]
Average Bonneville wholesale power rate pressure (base analysis) Potential Bonneville wholesale power rate ($/MWh) Potential range of Bonneville wholesale power rate including rate sensitivities	$34.56 ——[/1]	+2.7% $35.49 0.4% to 2.7%
Annualized Transmission Rate Pressure relative to No Action Alternative (%)	——[/1]	+0.087%
Average Annual Social Welfare Effects ($): Market Price Method Estimate	——[/1]	-$6.7million
Average Annual Social Welfare Effects ($): Production Cost Method Estimate	——[/4]	-$25 million
Average Residential Rate, weighted average and range (cents/kWh)	10.21	+0.33% (less than +0.01% to +1.1%)
Commercial Rate, weighted average and range (cents/kWh)	8.89	+0.36% (less than +0.01% to +1.3%
Industrial Rate, weighted average and range (cents/kWh)	7.25	+0.47% (less than +0.01% to +1.9%)
Regional Economic Productivity Effects: Change in Output	——[/1]	-$68 million/year
Regional Economic Productivity Effects: Change in Employment	——[/1]	-440 jobs

Effect	No Action Alternative[/1]	Effects of the Preferred Alternative Relative to No Action
Share of households experiencing >5% increase in rates relative to No Action Alternative, highest across scenarios	——[/1]	0%
Share of businesses with >5% increase in rates relative to No Action Alternative, highest across scenarios	——[/1]	0%
Regional Cost of Carbon Compliance	——[/1]	+$9-47 million/year

The estimated LOLP effect and resulting social welfare and rate effects rely on the best available information regarding planned coal plant retirements as of 2017 when the modeling efforts began for this analysis. Based on regional energy policy developments and expected coal plant closures as of 2019, Chapter 3.7.3.1 discusses the sensitivity of the results of the analysis to these revised assumptions.

/1 The analysis of the No Action Alternative for these effect categories provides a baseline against which the action alternatives are compared. Thus, the No Action Alternative results presented in this table describe the baseline magnitude of power and transmission values (e.g., for LOLP and rates) and the Preferred Alternative results describe the change relative to the No Action Alternative. A "——" indicates an effect category that is not relevant to the No Action Alternative because it only occurs as a result of implementing the action alternatives (e.g., the need for new generation and transmission infrastructure and associated costs).

/2 Because the Preferred Alternative has essentially the same power supply adequacy and system reliability as the No Action Alternative, the analysis did not identify a need for replacement resources.

/3 The social welfare value presented is an estimate of the economic value of hydropower generated by the U.S. System (hydropower projects in the U.S. portion of the Columbia River system [Federal plus non-Federal projects]) under the No Action Alternative.

/4 The production cost method for valuing social welfare effects of the Preferred Alternatives and MOs relies on information regarding the changes in the fixed and variable costs of the system. Negative values in the table represent an increase (net cost) in the cost of producing power. These costs are not relevant to the No Action Alternative.

7.7.10 Air Quality and Greenhouse Gases

Consistent with Chapter 3, due to the reduction in hydropower generation, air quality would most likely be degraded slightly and greenhouse gas emissions would most likely increase by an estimated 0.54 MT per year (or 0.33 percent) relative to the No Action Alternative across the Western Interconnection. In the Pacific Northwest region, greenhouse gas emissions would increase by 0.26 MMT (or 0.70 percent) compared to the No Action Alternative. Other emissions sources (e.g., navigation, construction, fugitive dust) are most likely to have a negligible effect on air quality and greenhouse gas emissions relative to the No Action Alternative across the basin. Effects to air quality are expected to be negligible across the basin including any potential impacts to non-attainment or maintenance areas. Most effects related to construction activities at the projects are expected to be temporary and short-term.

7.7.11 Flood Risk Management

This section describes changes in flood risk that would be anticipated under the Preferred Alternative, as measured in terms of changes in Annual Exceedance Probability (AEP). A discussion of the methodology employed to evaluate flood risk is provided in Section 3.9.4.1. A more detailed presentation of quantitative results for alternatives including the Preferred Alternative are provided in Appendix K.

7.7.11.1 Region A – Libby, Hungry Horse, and Albeni Falls Dams

There is little change anticipated to AEP in Region A under the Preferred Alternative. As discussed in Section 3.9, AEP is a measurement of the likelihood that established flood risk thresholds would be exceeded. In Region A, flow conditions measured at some locations, indicate flood risk is anticipated to decrease (refer to Table 6 in Appendix K, Flood Risk Management).

No effect is anticipated to flood risk in the Kootenai River reach within Region A under the Preferred Alternative. Under typical to lower annual peak flow conditions, flood risk is anticipated to decrease in probability under this alternative. In particular, the probability of flooding at Bonners Ferry, Idaho, is anticipated to decrease by 6 percent under the Preferred Alternative at the action stage. This is due to a combination of operational measures at Libby Dam including the *Modified Draft at Libby* measure that would result in deeper drafts earlier in the spring. There are negligible changes to the probability of higher flood stage at the Bonners Ferry gage that would result in no effect to flood risk conditions. Likewise, since the Canadian border is downstream of Bonners Ferry no effect to Canada is expected under the Preferred Alternative.

No change in flood risk is anticipated to occur on the Flathead River below Hungry Horse Dam. No change in flood risk is anticipated to occur at the Clark Fork reach near Plains, Montana.

7.7.11.2 Region B – Grand Coulee and Chief Joseph Dams

No changes to flood risk are anticipated in Region B under the Preferred Alternative.

7.7.11.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

No changes to flood risk are anticipated in Region C under the Preferred Alternative.

7.7.11.4 Region D – McNary, John Day, The Dalles, and Bonneville Dams

No changes to flood risk are anticipated in Region D under the Preferred Alternative.

7.7.11.5 Summary of Effects

No increase in flood risk is anticipated under the Preferred Alternative. As described above, Region A could experience a slight decrease in flood risk, particularly in areas around Bonners Ferry, Idaho. But in general, the measures and system operations included under the Preferred Alternative meet the overall goal of not increasing flood risk associated with the system.

7.7.12 Navigation and Transportation

In Region A, there would likely be no effects to navigation from reservoir elevation changes. In Region B, the effects to the operation of the Inchelium-Gifford Ferry resulted in minor effects due to the *Planned Draft Rate at Grand Coulee* measure and would be addressed by extending the boat ramp for the Inchelium-Gifford Ferry in Lake Roosevelt. Ferry operations on Lake Roosevelt could be affected under the Preferred Alternative due to anticipated drawdowns in wet years, the wettest 20 percent of years as measured at The Dalles. In the median wet years, when Lake Roosevelt's draw down for flood risk management begins sooner than for No Action Alternative, the Inchelium-Gifford Ferry on Lake Roosevelt would not be able to operate for approximately 31 days in the year, which is four additional days than would have been anticipated under the No Action Alternative at this location. Effects would primarily occur on the Confederated Tribes of the Colville Reservation. Other operational measures within the Preferred Alternative may have notable effects on water levels and flow in upstream regions, but these flow changes are increasingly attenuated as they reach the mainstem Columbia River.

The planned structural measures under the Preferred Alternative are unlikely to have measurable impacts to commercial navigation or cruise lines in the Columbia-Snake Navigation System (CSNS) because they do not affect flow or elevation of water. Some of the operational measures have the potential to affect operations on the CSNS. In particular, *Summer Spill Stop Trigger, Modified Dworshak Summer Draft,* and *Planned Draft Rate at Grand Coulee* measures may alter reservoir levels or the quantity or the timing of the flows in the Snake River and lower Columbia River (or both) and have the potential to impact how vessels move on the CSNS. It is expected that higher spill and variable timing of the spill over the course of a day due to the *Juvenile Fish Passage Spill* measure could result in changes to the tailraces at Lower Monumental and Lower Granite projects. The Corps would monitor the tailrace at each project to track changes that could affect safe navigation. If changes to the tailrace warrant action, coffer cells to dissipate energy may be constructed in the tailrace at either of the projects.

7.7.12.1 Social Welfare Effects

COMMERCIAL NAVIGATION AND TRANSPORTATION SYSTEMS

The hydrology & hydraulics data used as input into the SCENT model, as presented in Table 7-43, show that the Preferred Alternative could result in approximately a 1 day per year decrease in navigable days under low flow conditions when compared to the No Action Alternative, and approximately a 1-day increase in navigable days during normal flow conditions. In all other flow conditions there would be negligible or no effect compared to the No Action Alternative.

Table 7-44 presents anticipated changes in average annual operating costs that would occur under the Preferred Alternative as a result of flow changes. Costs of operations under normal flow range categories would not be affected under the Preferred Alternative.

Table 7-43. Changes in Average Commercial Navigation Flow Days Under the Preferred Alternative Relative to No Action Alternative, over 50 years

River Segment	Number of Days Under Various Flow Condition (Days Per Year)					Number of Days Experiencing Draft Restriction (Days Per Year)					
	Low	Normal	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft
Shallow[16]	-1.2	1.2	–	<0.1	–	–	–	–	–	–	–
Deep Draft	-1.2	1.2	<-0.1	–	–	–	–	–	–<0.1	–	< -0.1

Source: SCENT modeling

The average annual extra transportation costs for transportation in the Deep Draft segment are estimated to be $93,000 less under the Preferred Alternative than under the No Action Alternative. The reason for the minor decrease in costs is that there would be slightly fewer days of low flow under this alternative related to the *John Day Full Pool* measure. The average annual change in transportation costs under the Preferred Alternative in the Columbia-Snake Shallow segment is estimated to be $4,000 higher than the No Action Alternative due to the *Slightly Deeper Draft for Hydropower (Dworshak)*. In the spring in the Deep draft the slight increase in cost would occur from a combination of upstream measures, primarily at Grand Coulee and Libby Dams. As shown in Table 7-44, the total decrease in average annual costs to commercial navigation operations would be approximately $93,000.

[16] The Columbia-Snake Shallow category refers to traffic that traveled on both the Columbia and Snake Rivers while the Columbia Shallow presents the impact to traffic only traveling on the Columbia River.

Table 7-44. Changes in Average Annual Costs of Commercial Navigation Operations Under the Preferred Alternative Relative to No Action Alternative (2019 dollars), over 50 years

	Change in Costs Associated with Flow Range Categories				Changes in Costs Associated with Draft Restrictions						
River Segment	**Low**	**High**	**Very High**	**Too High**	**37 ft**	**38 ft**	**39 ft**	**40 ft**	**41 ft**	**42 ft**	**Total**
Columbia-Snake Shallow	–	$1,000	$1,000	$1,000	–	–	–	–	–	–	$4,000
Columbia Shallow	–	-$1,000	$1,000	$1,000	–	–	–	–	–	–	–
Deep Draft	**-$118,000**	**-$1,000**	**$4,000**	**$14,000**	**$1,000**	**-$2,000**	**$1,000**	**$1,000**	**$3,000**	**–**	**-$97,000**
Total	**-$118,000**	**-$1,000**	**$6,000**	**$16,000**	**$1,000**	**-$2,000**	**$1,000**	**$1,000**	**$3,000**	**–**	**-$93,000**

Note: These effects are all within one standard deviation of the No Action Alternative conditions. Costs of operations under normal flow range categories are not anticipated to be affected under any alternatives and are therefore excluded from the table. Numbers may not sum due to rounding.

Source: SCENT modeling.

7.7.13 Recreation

The environmental consequences analysis for recreation evaluates how changes in reservoir, river, and habitat conditions under the MOs and the Preferred Alternative could affect visitation, recreational opportunities, and the value of the recreation experience. The Preferred Alternative includes operational changes to Libby, Hungry Horse, Grand Coulee, Dworshak, and John Day dams. The anticipated changes in reservoir elevations at Lake Koocanusa (Libby Dam), Lake Roosevelt (Grand Coulee Dam), and Dworshak Reservoir (Dworshak Dam) could affect boat ramp accessibility for some periods of time during the year, and hence, access and visitation for some water-based visitors. Water quality and fishing conditions within reservoirs, as well as in some stream reaches below reservoirs, may also be affected under the Preferred Alternative. The effects of the Preferred Alternative on recreation are described for each region.

7.7.13.1 Social Welfare Effects

The focus of effects on water-based visitation in this section is described as annual effects that would occur after implementation of the Preferred Alternative. Over time, visitors may adjust their behavior to adapt to changes in accessibility and site quality, such as utilizing different sites on the system. These long-term adaptations could reduce effects on recreation.

REGION A – LIBBY, HUNGRY HORSE, AND ALBENI FALLS DAMS

Under the Preferred Alternative, measures impacting recreation in Region A include the *Sliding Scale at Libby and Hungry Horse* and *Modified Draft at Libby* measures. Because no structural measures are planned for Region A under the Preferred Alternative, the effect on recreation is directly tied to changes in water elevations and flows related to operational changes. These changes in recreational visitation would be negligible compared to the No Action Alternative. However, as noted above, recreationists may adjust their behavior over time, which could reduce effects on project visitation.

Water-based Recreational Visitation

Anticipated changes in reservoir elevations under the Preferred Alternative would affect boat ramp accessibility and visitation relative to the No Action Alternative at Lake Koocanusa (Libby Dam) in Region A for some periods of time in a typical year. Changes in water levels at other reservoirs in the region would not affect accessibility and visitation. Due to changes in project outflows, recreational activities occurring in river reaches downstream of Libby Dam could cause both beneficial effects or adverse localized effects, or both, depending upon the river-based recreation activity.

At Lake Koocanusa, median reservoir elevations would be higher for most of the year under the Preferred Alternative relative to the No Action Alternative, but would be lower by 1 to 4.5 feet in a typical water year from February through June. The reservoir elevations in March through May under the Preferred Alternative would fall below the minimum usable elevations at some boat ramps, causing a decrease in boat ramp accessibility at the reservoir relative to the No Action Alternative. No accessibility effects are expected in February or June. Due to minor decreases in boat ramp accessibility (e.g., some Lake Koocanusa boat ramps would remain usable), water-based recreational visitation is estimated to decrease slightly (by less than 1 percent, or approximately 416 visits). In a high-water year, water-based visitation would not change relative to the No Action Alternative. In a low-water year, water-based visitation would decrease slightly (about 1 percent) relative to the No Action Alternative. The change in social welfare value associated with the change in visitation at Lake Koocanusa would be negligible, about $4,000 in a typical year.

In addition to changes in reservoir elevations, river flows and stages in the region would change relative to the No Action Alternative. Under the Preferred Alternative, there would be a decrease of 14 percent in monthly median outflow in May from Libby Dam relative to the No Action Alternative. This may reduce water turbidity and beneficially affect nearby in-river recreational fishing activities. Smaller changes in river flows and stages (less than 10 percent) would occur during peak recreation season at Libby Dam under the Preferred Alternative. Rafting and paddling activities may be adversely affected. The small changes in the river flows and reservoir elevations at Hungry Horse Dam are not anticipated to affect recreation at the reservoir. These changes are not expected to affect downstream reaches including the Pend Oreille Lake and River.

Quality of Recreational Experience

Changes in the quality of recreational experience are anticipated to be negligible in Region A under the Preferred Alternative. In Region A, as described in Section 7.7.5, *Resident Fish*, effects to resident fish at Libby are expected to have both minor adverse effects due to higher river elevations during the winter and minor beneficial effects due to the changes in reservoir elevation, downstream water temperatures, and restoration of native riparian vegetation. Effects at Hungry Horse are expected to be minor beneficial due to higher reservoir levels in late summer. None of these changes would likely be noticeable to recreational anglers.

REGION B – GRAND COULEE AND CHIEF JOSEPH DAMS

For Region B under the Preferred Alternative, the effect on recreation is directly tied to changes in reservoir elevations and flows related to operational changes upstream in Region A and in Region B. These changes in recreational visitation are negligible compared to the No Action Alternative. However, as noted above, recreationists may adjust their behavior over time, which could reduce estimated effects on visitation.

Water-based Recreational Visitation

Anticipated changes in reservoir elevations under the Preferred Alternative would affect boat ramp accessibility at Lake Roosevelt in Region B relative to the No Action Alternative. Other reservoirs in the region would not be affected. Relative to the No Action Alternative, anticipated reservoir elevations would be the same or higher for the majority of a typical year, though decreases of 1 to 2 feet would occur in September and October. These changes in reservoir elevations would result in decreased boat ramp accessibility in September and October, but increases in accessibility in May and June.

Due to minor changes in monthly boat ramp accessibility (both decreases and increases), water-based visitation is estimated to increase slightly by less than 0.1 percent (approximately 171 visits) in a typical year. In a high-water year, visitation would increase by less than 1 percent relative to the No Action Alternative. In a low-water year, visitation would decrease by less than 1 percent relative to the No Action Alternative. Changes in social welfare value associated with the visitation change in a typical year would be about $3,000. A negligible effect on water-based reservoir recreation is expected.

Changes in river flows and stages between dams would be minor (less than 10 percent) relative to the No Action Alternative, and therefore, would not be expected to affect river recreation.

Quality of Recreational Experience

Changes in the quality of recreational experience are anticipated to be negligible in Region B under the Preferred Alternative, as described in Section 7.7.4, *Anadromous Fish*. These effects are expected to be negligible due to minor changes in operations. As described in Section 7.7.5, *Resident Fish*, there would be minor to moderate adverse effects to Kokanee, burbot, and redband rainbow trout from operations and minor benefits from mitigation. And as described in the Section 7.7.7, *Vegetation, Wildlife, Wetlands, and Floodplains*, under the Preferred Alternative in Region B, changes would be minimal. As such, there could be negligible changes in the recreational experiences for anglers, hunters and wildlife viewers in Region B under the Preferred Alternative.

REGION C – DWORSHAK, LOWER GRANITE, LITTLE GOOSE, LOWER MONUMENTAL, AND ICE HARBOR DAMS

Under the Preferred Alternative, operational measures impacting recreation in Region C include the *Slightly Deeper Draft for Hydropower (Dworshak)* measure. As discussed previously, recreationists may adjust their behavior over time, which would reduce effects on visitation.

Structural measures impacting recreation in Region C include the *Additional Powerhouse Surface Passage*, *Upgrade to Adjustable Spillway Weirs*, *Lower Granite Trap Modifications*, and *Lower Snake Ladder Pumps* measures. The structural measures could have localized, short-term effects to recreation during the anticipated 2-year period when construction occurs in proximity to the recreation sites close to dams. Effects could include disruption at project sites, noise, potential traffic congestion, and access limitations during the construction period.

Water-Based Recreational Visitation

Anticipated changes in reservoir elevations under the Preferred Alternative would not affect boat ramp accessibility in most years at reservoirs in Region C relative to the No Action

Alternative. In years where high run-off is projected (i.e., wet years), there would be decreased reservoir elevations in January through March that could affect boat ramp accessibility relative to the No Action Alternative. Water-based visitation would decrease by less than 1 percent at Dworshak Reservoir relative to the No Action Alternative, or 1,286 visits, during these years when high run-off is projected. Other reservoirs in the region would not be affected. Reductions in social welfare associated with the visitation change are anticipated to be about $14,000 in these wet years when high run-off is projected.

Changes in river flows and stages between dams would be minor (less than 10 percent) relative to the No Action Alternative, and therefore, would not be expected to affect river recreation.

Quality of Recreational Experience

Changes in the quality of recreational experience are anticipated to be moderate adverse to major beneficial in Region C under the Preferred Alternative. As described in Section 7.7.4, *Anadromous Fish*, effects to anadromous fish in Regions C and D have the potential to range from moderate adverse impact to a major beneficial impact. The range in potential effects are due to uncertainty and spread between modeled estimates. Resident fish in the lower Snake River reservoirs would see minor effects under the Preferred Alternative from elevated TDG, but populations would be similar to the No Action Alternative, as described in Section 7.7.5 *Resident Fish*. These would be minor changes that would not likely be noticeable to most recreational anglers.

REGION D – MCNARY, JOHN DAY, THE DALLES, AND BONNEVILLE DAMS

Under the Preferred Alternative, operational measures impacting recreation in Region D include the *Increased Forebay Range Flexibility* measure and the *Predator Disruption Operations* measure. Structural measures that could impact recreation in Region D include the *McNary Turbine Replacement*, *Improved Fish Passage Turbines at John Day*, *Additional Powerhouse Surface Passage*, and *Modify Bonneville Ladder Serpentine Weir* measures. Similar to Region C, structural measures included for Region D projects could have localized, short-term effects to recreation during the anticipated 2-year period when construction occurs in proximity to the recreation sites close to dams. Effects could include disruption at project sites, noise, potential traffic congestion, and access limitations during the construction period.

Water-based Recreational Visitation

Changes in reservoir elevations and river flows are expected to be minor and are not anticipated to affect recreational access and visitation at recreation sites at the four reservoirs and river reaches in Region D.

Quality of Recreational Experience

Changes in the quality of recreational experience are anticipated to be minor adverse to moderate beneficial in Region D under the Preferred Alternative. As described in Section 7.7.4, *Anadromous Fish*, effects to anadromous fish in Region D have the potential to range from moderate adverse impact to a major beneficial impact. The range in potential effects are due to uncertainty and spread between modeled estimates. Resident fish in the lower Columbia River would see minor effects under the Preferred Alternative but populations would be similar to the No Action Alternative, as described in Section 7.7.5, *Resident Fish*. These would be minor effects from elevated TDG that would not likely be noticeable to most recreational anglers.

REGIONAL ECONOMIC EFFECTS

As a result of changes in boat ramp accessibility in a typical year, recreational expenditures associated with non-local visitation at Lake Koocanusa in Region A would decrease annually by $18,000 under the Preferred Alternative. Recreational expenditures associated with non-local visitation at Lake Roosevelt in Region B would increase annually by $7,000 in a typical year under the Preferred Alternative. No changes to visitation are anticipated in Region C or Region D in a typical year. The changes in Regions A and B represent less than 0.1 percent of non-local recreational expenditures in the basin under the No Action Alternative. Overall, the change in regional expenditures and the regional economic implications of those changes would be negligible. Over time, visitors would likely adjust their behavior to adapt to the minor anticipated changes in accessibility, such as utilizing different sites on the system. These long-term adaptations would reduce effects to visitation.

OTHER SOCIAL EFFECTS

Because of the modest anticipated changes to visitation described in the social welfare evaluation and the moderate adverse impact to a major beneficial impact to fish anticipated under the Preferred Alternative, other social effects associated with the well-being of recreationists, particularly those who value recreational fishing, changes are anticipated to range from no or negligible change to recreation fishing (primarily for resident fishing) to moderate adverse to major beneficial under the Preferred Alternative.

SUMMARY OF EFFECTS – PREFERRED ALTERNATIVE

Table 7-45 presents a summary of the Preferred Alternative effects, including the anticipated changes in average annual recreational visitation, social welfare, and regional economic effects by region and in total relative to the No Action Alternative. Across the study area, total recreational visitation and associated social welfare effects are anticipated to decrease by less than 0.1 percent annually (approximately 250 visits and $2,000) in a typical year associated due to changes in boat ramp access. Expenditures associated with non-local visitation would decrease by $12,000 annually across the study area, a change of less than 0.1 percent compared to the No Action Alternative. Regional economic effects of this change in expenditures would be negligible. Effects to the quality of hunting, wildlife viewing, swimming, and water sports at river recreation sites in the study area would be generally negligible under the Preferred Alternative.

Table 7-45. Changes in Economic Effects of Recreation Under the Preferred Alternative Relative to the No Action Alternative

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A decrease of approximately 400 water-based recreational visits would occur at Lake Koocanusa (less than 1.0 percent of water-based visitation at the site) in a typical year associated with changes in boat ramp access. In high-water-level years, water-based visitation would not change at Lake Koocanusa and would decrease by about 1.0 percent in low-water-level years. Annual social welfare benefits would decrease by $4,300 in a typical year. Negligible effects to the quality of recreation experiences would occur.	Expenditures associated with non-local recreational visits would decrease by $18,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change resulting in no noticeable effect to recreationist well-being when compared to the No Action Alternative.
Region B	An increase of approximately 200 water-based visits at Lake Roosevelt (less than 0.1 percent of water-based visitation at the site) would occur in a typical year. In years with high or low water, visitation would decrease by less than 1.0 percent. Annual social welfare benefits would increase by approximately $2,600 in a typical year. Negligible effects to the quality of recreation experiences would occur.	Expenditures associated with non-local recreational visits would increase by $7,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change resulting in no noticeable effect to recreationist well-being when compared to the No Action Alternative.
Region C	No changes in reservoir visitation associated with changes in boat ramp access in a typical year or high-water-level year. A reduction of approximately 1,300 water-based visits at Dworshak Reservoir (less than 1 percent of water-based visitation at the site) would occur in a low-water-level year. Annual social welfare benefits would not change in typical or high-water-level years, but would decrease by about $14,000 in a low-water-level year. Moderate adverse to major beneficial effects to quality of fishing may occur. Impacts to hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions are likely to be negligible.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access in most years. Regional effects of potential changes in expenditures during low-water-levels years would be negligible.	No change to visitor well-being associated with access to reservoir-based recreation. Moderate adverse to major beneficial change in recreationist well-being when compared to the No Action Alternative.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region D	No changes in reservoir visitation associated with changes in boat ramp access. Moderate adverse to major beneficial effects to quality of fishing may occur. Effects to hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions are likely to be negligible.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access.	No change to visitor well-being associated with access to reservoir-based recreation. Moderate adverse to major beneficial change in recreationist well-being when compared to the No Action Alternative.
Total	Negligible effects to reservoir visitation (reduction of 250 visits, representing less than 0.1 percent of total visitation compared to the No Action Alternative) in a typical year, with decreases in social welfare of approximately $2,000 annually associated with changes in boat ramp access. Negligible to minor effects in most areas to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions may occur. There is the potential for minor adverse effects to moderate beneficial effects in recreational fishing conditions along in Regions C and D.	Expenditures associated with non-local recreational visits would decrease by $12,000 across the study area (a change of less than 0.1 percent from No Action) in a typical year associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Recreation would continue to provide other social effects associated with considerable recreational opportunities in the study area. Continued operation of the system would provide benefits to community well-being and identity. Negligible change from No Action in most locations, with the exception of potential moderate beneficial social effects to anglers in Regions C and D.

7.7.14 Water Supply

Consistent with Chapter 3, the Preferred Alternative is not expected to change the ability to deliver existing water supply as compared to the No Action Alternative because the changes in flow and reservoir elevations are expected to be negligible. In addition, the operation of withdrawals is timed to minimize impacts to flows. The additional 45 kaf from Lake Roosevelt proposed for storage in this measure is expected to increase water supply in Region B, but is not expected to affect other regions.

7.7.15 Visual

Effects to visual resources from structural measures for Regions A and B would be negligible because they would not substantially differ from the No Action Alternative. There would be minor, short-term visual effects for viewers in the vicinity of projects in Regions C and D because of increased construction activity from implementing structural measures such as new fish-passage structures, modifications to fish ladders, and changes to spillway weirs, but these measures would not contribute to a substantial visual change in the landscape surrounding those projects. To the extent operational or structural measures affect the viewshed, this can have unique effects on spiritual practices for tribes. Because operational measures across all regions would result in minor changes in pool elevation management, carrying out those measures would have a minor effect on the viewshed and viewers in the vicinity of changes in duration and timing of reservoir elevations compared to the No Action Alternative.

7.7.16 Noise

Sound levels in the vicinity of the projects throughout all regions would be similar to the No Action Alternative with the exception of temporary increases in sound levels from the construction of structural measures at projects in Regions A, C and D, which would result in minor, short-term construction-related noise effects. In all regions, there would be negligible noise effects from those changes compared to the No Action Alternative because the seasonal timing or duration of spill levels would change under the operational measures.

7.7.17 Fisheries and Passive Use

The effects from the Preferred Alternative on anadromous fish are expected to be negligible in Region B downstream of Chief Joseph Dam, but have the potential to range from moderate adverse effects to major beneficial effects in Regions C and D (direction and magnitude of effects is dependent upon the model used and the relevant ESU/DPS). To the extent that increases or decreases in fish abundance occur as a result, this could result in a minor decrease to a potentially major increase in opportunities for commercial and ceremonial and subsistence fishing for anadromous species, such as salmon and steelhead throughout the Columbia River Basin.

The effects for resident fish range from moderate adverse to moderate beneficial. These effects could result in abundance changes, which could affect resident ceremonial and subsistence fisheries depending on the region and species.

7.7.18 Cultural Resources

Cultural resources were evaluated for effects to four categories: archaeological resources, traditional cultural properties, the built environment, and sacred sites. Consistent with Chapter 3, sacred sites were identified after discussions with the tribes and based on these discussions, evaluated at Albeni Falls and Grand Coulee.

The following discussion focuses primarily on the differences between the storage reservoirs and the run-of-river projects, as opposed to a region-by-region organization.

7.7.18.1 Archaeological Resources

EXPOSURE

Table 7-46 shows the number of acre-days that archaeological resources would be exposed if the Preferred Alternative was selected. Exposure amounts for the other alternatives are also provided to facilitate comparison. Table 7-47 expresses the differences as a percentage relative to the No Action Alternative. For example, if there was an increase in the amount of archaeological resource exposure under the Preferred Alternative at a reservoir, this is indicated as a positive percentage. If there is a reduction in the amount of exposure, this is shown as a negative percentage. The methodology behind this analysis is provided in Section 3.16.

Table 7-46. Effects to Archaeological Resources – Acre-Day Calculations by Reservoir and Alternative

Reservoir	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
John Day	135,000	132,000	135,000	135,000	166,000	135,000
Lower Granite	26,000	26,000	26,000	265,000	27,000	24,000
Dworshak	112,000	112,000	127,000	111,000	111,000	113,000
Grand Coulee	315,000	348,000	355,000	314,000	463,000	316,000
Albeni Falls	141,000	141,000	142,000	141,000	152,000	141,000
Libby	16,000	16,000	18,000	18,000	16,000	17,000
Hungry Horse	38,000	44,000	40,000	45,000	47,000	37,000

Note: Values have been rounded to the nearest thousand.

Table 7-47. Effects to Archaeological Resources – Increases or Decreases in Exposure of Archaeological Resources by Reservoir and Multiple Objective Alternatives

Reservoir	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
John Day	0%[1/]	-3%[1/]	0%[1/]	0%[1/]	23%[3/]	-18%[4/]
Lower Granite	0%[1/]	0%[1/]	0%[1/]	915%[3/]	4%[1/]	-7%[4/]
Dworshak	0%[1/]	0%[1/]	13%[3/]	-1%[1/]	-1%[1/]	1%[1/]
Grand Coulee	0%[1/]	10%[3/]	13%[3/]	0%[1/]	47%[3/]	0%[1/]
Albeni Falls	0%[1/]	0%[1/]	0%[1/]	0%[1/]	7%[2/]	0%[1/]
Libby	0%[1/]	-1%[1/]	8%[2/]	8%[2/]	-2%[1/]	4%[1/]
Hungry Horse	0%[1/]	17%[3/]	6%[2/]	18%[3/]	23%[3/]	-3%[1/]

Note: Values have been rounded to the nearest whole percent. A positive value indicates an increase in exposure (an adverse effect), while a negative value indicates a decrease in exposure (a beneficial effect).
1/ Percentage change indicates a ±5% change in the amount of exposure and is considered negligible.
2/ Percentage change indicates an increase in amount of exposure between 5% and 10% and is a moderate adverse effect.
3/ Percentage change indicates an increase in the amount of exposure greater than 10% is considered a major adverse effect.
4/ Percentage change indicates a reduction in the amount of exposure greater than 5% and is considered a beneficial effect.

As illustrated in Table 7-47, the Preferred Alternative would not result in any major increases in the acre-days exposure of archaeological resources. The biggest increase is seen at Libby, where the change in operations under the Preferred Alternative would result in an increase of about 4 percent. At three of the projects (John Day, Lower Granite, and Hungry Horse), the Preferred Alternative would result in a reduction of exposure of archaeological resources, largely as a result of retention of greater amounts of water in these reservoirs than under the other action alternatives. Downstream of Dworshak, exposure of archaeological resources would decrease under the Preferred Alternative due to changes in outflow from Dworshak as compared to the No Action Alternative. While there would still be ongoing adverse effects, the Preferred Alternative would be expected to lessen some impacts at these three projects in comparison to the No Action Alternative.

EROSION

Because of the lack of a means of estimating the amount of shoreline erosion that would take place along the reservoirs under these various alternatives, three proxy measures of erosion have been adopted: changes in the frequency of reservoir elevation changes, changes in the amplitude of reservoir elevation changes, and the frequency of relatively high draft rate events. Repeated monitoring of archaeological sites along the project reservoirs has shown that, as these three variables are increased, it tends to increase the rate at which archaeological resources erode. The methodology behind this analysis is provided in Section 3.16.

Table 7-48, Table 7-49, and Table 7-50 provide a percentage comparison between each of the action alternatives and the No Action Alternative. If there is an increase in one of these statistics relative to the No Action Alternative (and thus an increase in the factors that tend to promote archaeological resource erosion), then there will be a positive percentage. If there is a decrease in one of these statistics (and thus a decrease in the factors that promote erosion), there will be a negative percentage.

Table 7-48. Effects to Archaeological Resources – Average Frequency of Reservoir Elevation Change by Alternative

Project	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Albeni Falls	0%[4/]	0%[4/]	0%[4/]	0%[4/]	1%[3/]	0%[4/]
Dworshak	0%[4/]	-1%[5/]	3%[3/]	1%[3/]	1%[3/]	-2%[5/]
Grand Coulee	0%[4/]	32%[1/]	26%[1/]	-4%[5/]	24%[1/]	0%[4/]
Hungry Horse	0%[4/]	4%[3/]	-5%[6/]	4%[3/]	8%[2/]	-2%[5/]
Libby	0%[4/]	-1%[5/]	0%[4/]	0%[4/]	9%[2/]	0%[4/]

Note: Values have been rounded to the nearest whole percent. A positive value indicates an increase in the average frequency of reservoir elevation changes, which is an adverse effect. A negative value indicates a decrease in the average frequency of reservoir elevation changes, which is a beneficial effect.
1/ Increase is greater than 10% relative to the No Action Alternative and is considered moderate adverse.
2/ Increase is between 5% and 10% and is considered minor adverse.
3/ Increase is between 0% and 5% is considered negligible.
4/ No difference between the No Action Alternative and the alternative.
5/ Decrease between 0% and 5% is considered negligible.
6/ Decrease between 5% and 10% and is considered minor beneficial.
7/ Decrease is greater than 10% relative to the No Action Alternative is considered a moderate beneficial.

Table 7-49. Effects to Archaeological Resources – Changes in Average Amplitude of Reservoir Elevation Change by Alternative

Reservoir	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Albeni Falls	0%[4/]	0%[4/]	0%[4/]	0%[4/]	0%[4/]	0%[4/]
Dworshak	0%[4/]	0%[4/]	28%[1/]	0%[4/]	0%[4/]	0%[4/]
Grand Coulee	0%[4/]	1%[3/]	0%[4/]	1%[3/]	9%[2/]	-1%[5/]
Hungry Horse	0%[4/]	10%[2/]	13%[1/]	11%[1/]	10%[2/]	-1%[5/]
Libby	0%[4/]	4%[3/]	3%[3/]	3%[3/]	-1%[5/]	5%[2/]

Note: Values have been rounded to the nearest whole percent. A positive value indicates an increase in the average amplitude of reservoir elevation changes, which is an adverse effect. A negative value indicates a decrease in the average amplitude of reservoir elevation changes, which is a beneficial effect.
1/ Increase is greater than 10% relative to the No Action Alternative and is considered moderate adverse.
2/ Increase is between 5% and 10% and is considered minor negative.
3/ Increase is between 0% and 5% is considered negligible.
4/ No difference between the No Action Alternative and the alternative.
5/ Decrease between 0% and 5% is considered negligible.
6 Decrease between 5% and 10% and is considered minor positive.
7 Decrease is greater than 10% relative to the No Action Alternative is considered a moderate beneficial.

Table 7-50. Effects to Archaeological Resources – Changes in the Average Frequency of High Draft Rate Events by Reservoir and Alternative

Reservoir	No Action Alternative	MO1	MO2	MO3	MO4	Preferred Alternative
Albeni Falls	0%[4/]	1%[3/]	0%[4/]	0%[4/]	-4%[5/]	0%[4/]
Dworshak	0%[4/]	126%[1/]	-25%[7/]	0%[4/]	1%[3/]	-2%[5/]
Grand Coulee	0%[4/]	1%[3/]	3%[3/]	7%[2/]	8%[2/]	6%[2/]
Hungry Horse	0%[4/]	-19%[7/]	71%[1/]	-18%[7/]	-26%[7/]	4%[3/]
Libby	0%[4/]	-66%[7/]	88%[1/]	78%[1/]	-59%[7/]	-34.2%[7/]

Note: Values have been rounded to the nearest whole percent. A positive value indicates an increase in the average frequency of high amplitude of reservoir elevation changes, which is an adverse effect. A negative value indicates a decrease in the average frequency of high amplitude of reservoir elevation changes, which is a beneficial effect.

1/ Increase is greater than 10% relative to the No Action Alternative and is considered moderate adverse.
2/ Increase is between 5% and 10% and is considered minor adverse.
3/ Increase is between 0% and 5% is considered negligible.
4/ No difference between the No Action Alternative and the alternative.
5/ Decrease between 0% and 5% is considered negligible.
6/ Decrease between 5% and 10% and is considered minor beneficial.
7/ Decrease is greater than 10% relative to the No Action Alternative is considered a moderate beneficial.

Review of the three tables regarding proxy measures of shoreline erosion show that the Preferred Alternative would tend to minimize those conditions that foster erosion, especially in comparison to the other action alternatives. Experience has shown that, as reservoir elevations fluctuate more frequently, erosion also tends to accelerate. Comparison of the Preferred Alternative to the No Action Alternative with regard to the frequency of reservoir elevation changes shows that the Preferred Alternative would result in negligible or neutral effects (Table 7-48). Similarly, erosion tends to increase as the average amplitude of reservoir elevation changes increase. For the storage reservoirs, only Libby shows an increase when the Preferred Alternative is compared to the No Action Alternative (Table 7-49). That is, the average amplitude of reservoir elevation changes would increase by about 5 percent at Libby, suggesting that erosion may be accelerated, but this is considered negligible; neutral effects are seen at the other reservoirs. The third proxy measure of erosion is the average frequency of high draft rate events. This measure is based on the observation that erosion, particularly bank slumping, tends to accelerate as reservation elevations are dropped more quickly. Slow drawdowns, on the other, tend to minimize slumping. Under the Preferred Alternative, Grand Coulee and Hungry Horse would see some increase in high draft rate events (Table 7-50), suggesting that erosion would accelerate. That said, these effects are expected to be minor at Grand Coulee and negligible at Hungry Horse.

When viewed from an overall perspective, the Preferred Alternative would result in less adverse effects to archaeological resources than the other action alternatives, especially when compared to the No Action Alternative. Except for Lake Koocanusa, the Preferred Alternative is neutral or even slightly better than the No Action Alternative. This does not mean that the Preferred Alternative would eliminate the ongoing adverse effects of operating the reservoirs, but there may be a slight reduction in the rate at which archaeological sites decay. The adverse impacts at Libby to archaeological resources resulting from the Preferred Alternative are minor.

TRADITIONAL CULTURAL PROPERTIES

As with the other alternatives, and similar to archaeological resources, TCPs would continue to experience major effects associated with the operations and maintenance of the CRS. These effects that have occurred and would continue to occur under the Preferred Alternative are summarized in Chapter 3.16 and listed in Table 3-268. However, based on available information, and with reference to the assumptions and constraints previously described for TCPs, the Preferred Alternative would likely not result in an appreciable increase in effects relative to the No Action Alternative. As previously noted, the co-lead agencies do not have geospatial data available for TCPs at the Libby Project. Due to available information, the co-lead agencies do not expect effects, but if new information becomes available, the agencies would evaluate it to determine if their effect analysis needs to be updated.

ELEMENTS OF THE BUILT ENVIRONMENT

There would be several structural modifications constructed at various projects as part of the Preferred Alternative. A few of these modifications would have an effect on the built resources. As Bonneville Dam is a built resource more than 50 years old and a National Historic Landmark, any modification, including the gatewell orifice and ladder serpentine weir structural modifications, would potentially be an effect to a built resource. At both McNary and Ice Harbor dams, proposed structural measures include replacing the turbines, which is an adverse effect to a built resource as the structures are more than 50 years old. The power plant at Hungry Horse Dam began an extensive modernization effort in fiscal year 2018. This work would update the facilities to current industry standards. It would include the full overhaul or replacement of governors, exciters, fixed-wheel gates, and turbines; a generator rewind; overhaul of the selective withdrawal system; and recoating the penstocks. In addition, cranes that service the power plant would be refurbished or replaced, and the powerplant would meet modern fire protection standards. The replacement of original components of the project would be an effect to built resources by affecting the historic integrity. All other structural measures to the existing projects would have no effect to built resources.

In addition to structural measures, there are planned operations that may impact built resources. Water level changes at Grand Coulee could be more or less rapid. Where reservoir elevation change rapidly, it could cause landslides and erosion, which could cause minor to moderate effects to built resources. There could also be structural stabilization issues, especially to roads and bridges that could be caused by water undercutting these resources. Similar to the No Action Alternative, this change could impact built resources, such as ferry terminals, recreational facilities, and irrigation infrastructure. If water levels are too low, these resources could be unusable in their current condition. To make them usable, portions of the resources may need to be modified, which would affect the historic value of the built resources.

SACRED SITES

Consistent with the sacred sites identified for Chapter 3, the Preferred Alternative evaluates effects to two sacred sites. Operational changes at Grand Coulee and Albeni Falls as described for the Preferred Alternative would be negligible when compared to the No Action Alternative. The quantitative analysis discussed above shows that the period of site exposure at Kettle Falls and Bear Paw Rock would not increase. Other metrics indicative of the potential for increased erosion (i.e., frequency of reservoir elevation changes, amplitude of reservoir elevation changes, and frequency of high draft rate events) are also consistent with the assessment that the Preferred Alternative is not likely to result in increased erosion in comparison the No Action Alternative. Based on the similarity between the Preferred Alternative and the No Action Alternative, the effects to sacred sites under the Preferred Alternative are negligible.

7.7.19 Indian Trust Assets, Tribal Perspectives, and Tribal Interests

No direct or indirect effects to Indian Trust Assets were identified for any of the alternatives, including the Preferred Alternative. Trust lands identified during the geospatial database query and tribal outreach are located outside of any direct or indirect effects identified in the alternatives. These include lands from the Confederated Tribes of Warm Springs Reservation, the Yakama Nation, and the Kootenai Tribe of Idaho, as well as the following Indian reservations: The Confederated Tribes of the Colville Indian Reservation; Spokane Tribe of Indians; Kootenai Tribe of Idaho; Nez Perce Tribe; and The Confederated Salish & Kootenai Tribes of the Flathead Reservation.

The co-lead agencies reviewed the Tribal Perspectives (Appendix P) provided from 11 tribal governments (also see Section 3.17.2). Based on the wide distribution of issues discussed in these submissions, the co-lead agencies considered each Tribal Perspective while developing the Preferred Alternative. For more information on the Tribal Perspectives from these tribes see Appendix P, Tribal Perspectives.

Effects to tribal interests under the Preferred Alternative would be negligible for most resources (Vegetation, Wildlife, Wetlands, and Floodplains, Air Quality and Greenhouse Gases, Power Generation, Flood Risk Management, Navigation and Transportation, and Recreation).

The Preferred Alternative also includes measures to benefit ESA-listed juvenile adult salmon and steelhead and resident fish as well as to improve conditions for Pacific lamprey within the CRS. As with salmon and steelhead, Pacific lamprey is a species that is important to many tribes. The Preferred Alternative includes structural modifications to infrastructure at the dams to benefit passage of adult salmon and steelhead, as well as Pacific lamprey. Ongoing actions to benefit resident fish would be continued into the future. The *Juvenile Fish Passage Spill* measure in the Preferred Alternative builds off the successful collaboration of the *2019-2021 Spill Operation Agreement* and includes an updated approach to adaptively implementing flexible spill.

There is a range of expected effects, including minor beneficial effects such as those from the updated operations in Region A, and potentially minor adverse effects to resident fish in Lake Roosevelt due to deeper drawdowns in high water years. However, mitigation incorporated into the Preferred Alternative includes spawning habitat augmentation to offset these adverse effects. The expected ranges of impacts to fish is described in more detail in Sections 7.5.4 and 7.5.5. Ongoing fish and wildlife programs are expected to continue under the Preferred Alternative. The effects to water quality and fisheries (both anadromous and resident fish) would result in benefits to tribal interests. These effects could mitigate this impact if overall, longer term benefits to fish are realized in terms of productivity and improvements in fish stocks.

Extending the boat ramp at Inchelium Ferry would mitigate some of the drawdown effects at Grand Coulee, including accessibility to the Inchelium-Gifford ferry.

7.7.20 Environmental Justice

According to the Council on Environmental Quality (CEQ) guidance for implementing Executive Order 12898 under NEPA, "[a]gencies should consider the composition of the affected area, to determine whether minority populations, low-income populations, or Indian tribes are present in the area affected by the proposed action, and if so whether there may be disproportionately high and adverse human health or environmental effects on minority populations, low-income populations, or Indian tribes" (CEQ 1997). Consistent with Chapter 3 and based on the effects analysis for the Preferred Alternative, there is not likely to be a disproportionately high and adverse effect on low income, minority or tribal populations.

- **Fish.** As discussed in Sections 7.5.4 and 7.5.5, the Preferred Alternative would have effects ranging from negligible to minor adverse up to major beneficial effects on fish, depending on species, ESU/DPS and model assumptions and location. The Preferred Alternative has the potential to affect the availability of fish for harvest for low-income populations, minority populations or Indian tribes participating in these activities. These effects to environmental justice populations are not substantially different than the effects in the No Action Alternative.
- **Power generation and transmission**. As discussed in Section 7.7.9, increases to power and transmission rates from the Preferred Alternative would occur across the region. For the Preferred Alternative, the co-lead agencies expect that the Settlement payments to the Confederated Tribes of the Colville Reservation and the Spokane Tribe of Indians would be 1 percent higher than under the No Action Alternative.
- **Navigation and transportation**. As discussed in Section 7.7.12, Ferry operations on Lake Roosevelt could be affected under the Preferred Alternative due to anticipated drawdowns in wet years. In wet years, Lake Roosevelt is drawn down for flood risk management earlier and for a longer duration than under the No Action Alternative. Due to this earlier and longer duration draft, the Inchelium-Gifford Ferry on Lake Roosevelt would not be able to operate for approximately 31 days in the year, which is four additional days than occurs under the No Action Alternative. The co-lead agencies are proposing a mitigation measure

to extend the boat ramp for the Inchelium-Gifford Ferry in Lake Roosevelt, which would avoid the additional effects to local access compared to the No Action Alternative.

- **Cultural Resources.** As discussed in Section 7.7.18, implementation of the Preferred Alternative is expected to adversely affect cultural resources through increasing exposure and erosion of reservoir areas associated with increased reservoir level fluctuations. Specifically, the Preferred Alternative is expected to increase the exposure of archaeological resources at Lake Roosevelt in Region B and the Dworshak Project in Region C. However, these impacts would be mitigated through the FCRPS Cultural Resource Program.

7.7.21 Costs

As shown in Table 7-51, the estimated total cost for operating and maintaining the CRS under the No Action Alternative is approximately $1.06 billion annually. As described in Section 3.19.2, the CRS costs for the No Action Alternative and MOs include capital, operations and maintenance (O&M), and mitigation costs. Mitigation costs include the Bonneville F&W Program; Bonneville's funding of U.S. Fish and Wildlife Service for the Lower Snake River Compensation Plan (LSRCP); the Corps' Columbia River Fish Mitigation (CRFM) costs; and Reclamation's ESA-related costs. Note: this discussion of costs in Section 7.7.21 represents only direct expenditures. It does not represent costs to Bonneville in the form of lost revenues from reduced hydropower generation (discussed in Section 7.7.9).

The Preferred Alternative is estimated to cost from $6 million more annually (+0.6 percent) to $41 million less than the No Action Alternative (-3.9 percent) (Table 7-51). Present value of the structural measure costs for the Preferred Alternative are estimated to be $104 million, and when amortized over the 50-year period of analysis, the annual equivalent cost is approximately $4.0 million. Most of the costs of the structural measures would occur at the Bonneville project for the Lamprey passage structures and the ladder serpentine weir and at Lower Granite and Little Goose projects associated with the bypass screen modifications for Lamprey. Additionally, there could be slight decreases in capital and O&M costs under the Preferred Alternative driven by ceasing installation of fish screens at Ice Harbor, McNary and John Day. The timing for ceasing the installation of these screens would be coordinated with NMFS. However, the changes in CRS capital and O&M costs compared to the No Action Alternative would be negligible.

Funding decisions for the Bonneville F&W Program are not being made as part of the CRSO EIS process. However, a range of potential F&W Program costs are included to inform the broader cost analysis for each alternative in the EIS, which is discussed in Section 3.19. Future budget adjustments would be made in consultation with the region through Bonneville's budget-making processes and other appropriate forums and consistent with existing agreements. In the case of the Preferred Alternative, Bonneville included a range of potential F&W Program costs to acknowledge the possibility that the Preferred Alternative could provide biological benefits to anadromous fish species (see Section 7.7.4) and that this could, in turn, reduce the need for some offsite mitigation funded through the Bonneville F&W Program. By analyzing a range of costs, Bonneville reflects the year-to-year fluctuations related to managing its program and also acknowledges the uncertainty around both the magnitude of biological benefits and the potential impacts on funding, including the timing of funding decisions. In 2016, Bonneville's F&W Program budget was $267,000,000, and the LSRCP budget was $32,303,000. When these budgets are adjusted to represent 2019 dollars, they become $281,536,000 and $34,062,000, respectively, which are the budgets used under the No Action Alternative.

For the Preferred Alternative, Bonneville would continue funding the operations and maintenance of the LSRCP facilities, consistent with the No Action Alternative. Bonneville's F&W Program costs under the Preferred Alternative are estimated to range from no change from the No Action Alternative to a decrease of approximately 17 percent, or approximately $47 million, annually. Bonneville's fiscal year 2020 decisions to adjust the F&W Program budget to $249 million and the LSRCP budget to $30.5 million (BP-18 Rate Case) are consistent with the range of costs analyzed for the Preferred Alternative. As a result, Bonneville does not anticipate additional reductions to the F&W Program or Bonneville's direct-funding of USFWS's LSRCP with the implementation of the Preferred Alternative at this time.

The CRFM, F&W O&M, and the Reclamation ESA-related mitigation would remain the same as under the No Action Alternative. The Preferred Alternative would include additional mitigation measures, estimated to cost approximately $2 million, annually (see Section 7.6.4 and Annex B of the Cost Analysis appendix for additional details).

In addition, as part of the ESA process, the Preferred Alternative is being coordinated for consultation with the USFWS and NMFS. Section 7.6.4.3 describes the specific preliminary measures proposed for ESA compliance. A number of the ESA measures would be implemented through existing funding mechanisms, for example, through the Bonneville F&W Program or the CRFM program, while others would require additional appropriations or funding sources. Therefore, it is expected that there would be some small additional annual costs for these ESA measures. These costs would occur under the Preferred Alternative as well as under the other MOs.[17]

[17] The costs of the ESA measures were not included in Table 7-51 (below) because a number of the measures would be implemented under existing programs and funding sources and the specific implementation of the measures have not been identified. In addition, the ESA-compliance measures could be similar for the Preferred Alternative and the other MOs, but the final measures would need to be determined through consultation with USFWS and NMFS.

Table 7-51. Annual-Equivalent Costs and Change in Costs for the Preferred Alternatives (2019 dollars)

Alternative	Construction Costs of Structural Measures (present value)	Construction Costs of Structural Measures (annual)	Capital Costs (annual)	O&M Costs (annual)	Mitigation Costs (Low F&W Program Costs) (annual)	Mitigation Costs (High F&W Program Costs) (annual)	Annual-Equivalent Costs (Low F&W Program Costs)	Annual Equivalent Costs (High F&W Program Costs)
NAA	NA	NA	$245,000,000	$478,000,000	$332,000,000	$332,000,000	$1,055,000,000	1,055,000,000
Preferred Alternative	$104,000,000	$4,000,000	$245,000,000	$478,000,000	$287,000,000	$334,000,000	$1,014,000,000	$1,061,000,000
Change in Costs Compared to the NAA	$104,000,000	$4,000,000	$0	$0	-$45,000,000	$2,000,000	-$41,000,000	$6,000,000
Percentage Change in Costs from NAA	NA	NA	0%	0%	-13.6%	0.6%	-3.9%	0.6%

7.8 POTENTIAL CLIMATE EFFECTS BY RESOURCE

Warming temperatures and changes in precipitation trends are likely to result in declining snowpack, higher average fall and winter flows, earlier peak spring runoff, and longer periods of low summer flows. In the timeframe of this EIS, these changes in climate are expected to have negligible to moderate impacts on resources. The analysis described below of climate effects by resource is consistent with the analysis contained in Chapter 4.

7.8.1 Hydrology & Hydraulics

It is expected that climate change may result in moderate changes in seasonal flow volume and timing, resulting in higher and more variable winter flows. Reservoirs may refill early but draft deeper, and there may be lower flows during summer months across all regions. The effects to hydrology and hydraulics for the Preferred Alternative are expected to be negligible. Potential changes in climate could exacerbate this effect leading to moderate effects.

7.8.2 River Mechanics

Relative to the No Action Alternative, the effects to geomorphological processes for the Preferred Alternative are expected to be negligible. It is unknown to what degree climate change, increased demand for water, and other cumulative actions may impact future sediment processes. However, changes in climate not directly associated with the Preferred Alternative could potentially influence these processes, leading to moderate or major effects as described below.

Changes in climate have the potential to influence erosion, sediment transport, and sediment deposition throughout the CRS regions. The increase in summer warm and dry cycles would result in reduced soil moisture content, and widening gaps in rock and soil. Vegetative land cover is a key component of erosion resistance and vegetation stress caused from increased warm and dry cycles would likely correspond with increased disturbance events (wildfires, insects, disease) or water stress. A reduction in vegetative cover can increase surface erosion during rain events and elevate soil moisture resulting in reduced stability and greater landslide susceptibility. Following wildfires, soils have the decreased ability to absorb water, leading to increased surface runoff, surface erosion, and sediment transport. Summer water demands on the CRS that increase draft elevation would increase shoreline exposure and erosion processes and increase head of reservoir sediment mobilization. Increased winter temperatures would reduce snowpack and increase the amount of time that underlying erodible soils are exposed to surface erosion. Increased winter precipitation and flows would increase surface runoff and watershed sediment loads delivered into river systems and could increase river erosion, potentially resulting in geomorphic change.

7.8.3 Water Quality

It is expected that climate change may result in moderate decreases in summer flow and increased summer air temperature that would likely lead to warmer summer water temperatures across all regions. The decreases in summer flow volumes could make meeting the spill targets in Regions C and D harder because there would be less total flow to pass over the spillways and still provide minimum turbine generation. Deeper reservoir drafts and higher outflows may cause suspended solids to move further down into the reservoir and downstream of Libby Dam, and potentially increase water temperature downstream of Libby Dam. Thus, the effects to water temperature from the Preferred Alternative, which range from no change in Regions B and D to negligible in C and minor in A could be exacerbated by climate change, leading to increased effects.

7.8.4 Anadromous Fish

Because temperature is such a critical factor to anadromous fish habitat, increases in stream temperature due to increased air temperature and changes in hydrology, including declining snowpack, could further impact fish in all regions. Increased water temperatures could also increase suitable habitat for invasive species (e.g., shad and small mouth bass) that could have adverse impacts to native anadromous fish. Positive effects for anadromous species in this Preferred Alternative could be offset by adverse effects from changes in flow and increased stream temperature due to climate change.

7.8.5 Resident Fish

It is expected that climate change may result in increases in stream temperature and impact food supply. Increased water temperatures could also increase suitable habitat for invasive species (e.g., shad and small mouth bass) that could have adverse impacts. The timing of outflows could result in an increased risk of entrainment that could exacerbate negative effects to resident fish and zooplankton.

7.8.6 Vegetation, Wildlife, Wetlands, and Floodplains

It is expected that changes in climate may result in higher inflows and deeper drafts that could increase erosion and expose barren zones in Regions A, B and C. It could also increase suitable habitat for invasive plant species across all regions. For floodplains, it is expected that changes in precipitation coupled with warming temperatures could result in increased frequency and magnitude of winter floods across all regions. Increases in winter precipitation coupled with projected increases in spring temperature could also lead to increased snowmelt flooding in the spring, particularly in high elevation regions. Thus, climate change could exacerbate the effects from the Preferred Alternative on vegetation, wetlands, wildlife, and floodplains.

7.8.7 Power Generation and Transmission

Similar to the analysis in Chapter 4.2.5, climate change is likely to add additional uncertainty to the annual magnitude of total hydropower generation, and uncertainty to the monthly magnitude of generation impacts associated with the Preferred Alternative as compared to the No Action Alternative. However, it is not likely to change the relative conclusions from the power analysis for the Preferred Alternative relative to other alternatives in this EIS. Increasing temperatures and loads in July and the first half of August are likely to exacerbate reliability concerns in those months. Conversely, the increased reliability in late August could potentially ameliorate projected power shortages in that period due to increasing temperatures and loads. During the winter months, increasing temperatures and decreasing loads are likely to at least partially ameliorate power shortages in those months.

7.8.8 Air Quality and Greenhouse Gases

It is expected that greenhouse gas emissions would increase for the Preferred Alternative due to the reduction in hydropower, but the impact is expected to be negligible. Climate change is not expected to have additional effects.

7.8.9 Flood Risk Management

Projected changes in precipitation coupled with warming temperatures could result in increased frequency and magnitude of winter floods. Increases in winter precipitation coupled with projected increases in spring temperature could also lead to increased snowmelt flooding in the spring, particularly in high elevation regions.

7.8.10 Navigation and Transportation

It is expected that changes in climate may result in changes in streamflow, which could result in an increased frequency of shallow river conditions and may impact navigation at some locations. Projected higher flows and higher extreme flows in November to March could slow or interrupt barge traffic more frequently in Regions C and D. Climate change could reduce the amount of time Lake Roosevelt is drafted to an inoperable range thereby reducing the effects to the operation of the Inchelium-Gifford Ferry, an improvement over the Preferred Alternative impact without mitigation. Thus, climate change could exacerbate certain effects from the Preferred Alternative on navigation and transportation, but potentially reduce the effects on the Inchelium-Gifford Ferry.

7.8.11 Recreation

It is expected that changes in climate may result in earlier reservoir refill, which could shift the seasonal period for recreational activities that depend on high lake levels for water access earlier in the year, and potentially lengthen the reservoir recreation season depending upon later summer and fall conditions. Decreased summer and fall flow volume could potentially lead to lower reservoir outflows that could affect river recreation (e.g., river kayaking, boating, etc.). Changes in flow volume and/or increased water temperatures could decrease recreational fishing opportunities. Impacts to water-based recreation under the Preferred Alternative are expected to be negligible, but the impacts from climate change could exacerbate the effects from the Preferred Alternative particularly for river recreation.

7.8.12 Water Supply

The Preferred Alternative is not expected to change the ability to meet existing water supply obligations because the changes in flow and reservoir elevations are expected to be negligible. In addition, the operation of withdrawals is timed to minimize impacts to flows. The impacts from climate change are expected to be negligible, so the impacts on water supply from the Preferred Alternative coupled with climate change would remain negligible.

7.8.13 Visual

Climate change is not expected to ameliorate or exacerbate effects to visual resources.

7.8.14 Noise

Climate change is not expected to ameliorate or exacerbate effects to noise.

7.8.15 Fisheries and Passive Use

Changes in flow and increased stream temperature due to climate change could adversely affect anadromous and resident fish species within the Columbia River Basin. Increased water temperatures could also increase suitable habitat for invasive species (e.g., shad and small mouth bass) that could have adverse impacts to native anadromous and resident fish. Climate effects that result in reduced abundance of anadromous and resident fish species of commercial and ceremonial and subsistence value could result in decreased fishing opportunity for those species.

7.8.16 Cultural Resources

In Regions A, B, and C the impacts from deeper drafts, combined with projected increases in precipitation, could result in greater exposure and erosion, which could accelerate decay of cultural resources while the impacts in Region D are expected to be negligible. Climate change may have additional minor effects due to changes to reservoir elevations.

7.8.17 Indian Trust Assets, Tribal Perspectives, and Tribal Interests

"Climate change impacts have the potential to affect the entire Basin and resources the Tribes stewarded from time immemorial. The change has the potential to impact both aquatic systems across the Basin and the generation of electricity from the System." (Shoshone-Bannock Tribes Tribal Perspective Submittal; see Section 3.17.2.2).

The Tribes of the Pacific Northwest are focused on the challenges posed by the projected changes in climate. These changes have the potential to adversely affect tribal culture given the relationship these cultures have with the natural environment. For many tribes, their culture of stewardship is an effort to restore the ecosystem to its natural condition. This is considered an essential element in their fight against, and to counteract the effects of climate change. Climate change presents a threat to critical cultural resources, thereby also threatening the lifeways and wellbeing of the Tribes. Some tribes view the CRS, particularly its reservoirs and loss of riverine ecosystem structure and function, as a contributor to climate change.

7.8.18 Environmental Justice

Climate change can exacerbate impacts on minority populations, low-income populations, and Indian tribes. At the same time, these populations are often less able to adapt or recover from these impacts (EPA 2016). Based on the effects analysis (including the potential impacts from climate) on fish, power generation and transmission, navigation and transportation, and cultural resources as well as the addition of applicable mitigation, it is not expected that there would be any disproportionately high and adverse human health or environmental effects on minority populations, low-income populations, or Indian tribes.

7.9 CUMULATIVE EFFECTS OF THE PREFERRED ALTERNATIVE

CEQ NEPA regulations require an assessment of cumulative effects. CEQ defines a cumulative effect as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions” (40 C.F.R. § 1508.7). This section describes the methods for identification of cumulative actions and presents the results of the cumulative impacts analysis.

7.9.1 Analysis Approach

The cumulative action analysis methods are described in Chapter 6 and follow CEQ guidance, which includes establishing the geographic and temporal boundaries of the analysis, identifying applicable cumulative actions, identifying affected resources and direct/indirect impacts, and analyzing the cumulative impacts.

This section uses the effects of the Preferred Alternative and additionally considers the cumulative effects of reasonably foreseeable future actions. Climate change, for example, can be considered an effect of past, present, and future actions that may have a cumulative effect on certain resources in the analysis area. This section discusses the potential climate change effects described in Section 7.8 that may be additive to the direct and indirect effects from the Preferred Alternative.

7.9.2 Geographic and Temporal Scope

As discussed in Chapter 6, the geographic boundary for each resource considered in this cumulative effects analysis is referred to as the Cumulative Impact Analysis Area (CIAA). The CIAA follows the geographic boundaries of direct and indirect impacts for each resource described in Section 7.7. Additionally, as in Chapter 6, the temporal boundaries for cumulative effects in this analysis have three components; past, present, and future. Relevant past actions are discussed in Section 6.1.3.1 for the MOs, and this information was used to inform the past actions analysis for the Preferred Alternative. Similarly, ongoing and present actions and reasonably foreseeable future actions are discussed in Chapter 6.1.3.2 and 6.1.3.3, respectively, and this same information informed the cumulative effects analysis for the Preferred Alternative.

7.9.3 Cumulative Actions Scenario

Consistent with Chapter 6, the same cumulative action scenario was applied to the No Action Alternative and all Action Alternatives, including the Preferred Alternative. The cumulative actions scenario focuses on the actions and trends (i.e., Reasonably Foreseeable Future Actions [RFFAs]) that were not proposed by one of the MOs but are overlapping in space and time and may contribute to cumulative impacts in combination with direct and indirect impacts of the Preferred Alternative (Table 7-52 and Table 7-53).

The co-lead agencies expect there would be a range of cumulative impacts to affected resources from the addition of the past, present and reasonably foreseeable future impacts to the impacts from the Preferred Alternative. As a reminder, the list of RFFAs is provided below, and Section 6.2 provides a brief description of each RFFA.

Table 7-52. Reasonably Foreseeable Future Actions

RFFA ID	RFFA Description
RFFA1	Population Growth and Urban, Rural, Commercial, Industrial, and Agricultural Development
RFFA2	Water Withdrawals for Municipal, Agricultural, and Industrial Uses
RFFA3	New and Alternative Energy Development
RFFA4	Increasing Use of Renewable Energy Sources, Industrial and Vehicle Emissions Reductions, and Decarbonization
RFFA5	Federal and State Wildlife and Lands Management
RFFA6	Increase in Demand for New Water Storage Projects
RFFA7	Fishery Management
RFFA8	Bycatch and Incidental Take
RFFA9	Bull Trout Passage at Albeni Falls
RFFA10	Ongoing and Future Habitat Improvement Actions for Bull Trout
RFFA11	Resident Fisheries Management
RFFA12	Fish Hatcheries
RFFA13	Tribal, State, and Local Fish and Wildlife Improvement
RFFA14	Lower Columbia River Channel Maintenance Plan
RFFA15	Snake River Sediment Management Plan
RFFA16	Seli’š Ksanka Qlispe’ Dam (Formerly Kerr Dam)
RFFA17	Invasive Species
RFFA18	Marine Energy and Costal Development Projects
RFFA19	Climate Change
RFFA20	Clean Water Act–Related Actions
RFFA21	Idaho Power Hells Canyon Complex Mercury Contamination Issues/Remediation
RFFA22	Idaho Power Hells Canyon Complex Temperature Issues
RFFA23	Mining in Reaches Upstream of CRSO Dams
RFFA24	Hanford Site
RFFA25	Columbia Pulp Plant
RFFA26	Middle Columbia Dam Operations

Table 7-53. Reasonably Foreseeable Future Actions and Potentially Affected Resources Matrix Under the Preferred Alternative (Pending Analysis)

RFFA ID	Hydrology and Hydraulics	River Mechanics	Water Quality	Anadromous Fish	Resident Fish	Vegetation, Wildlife, Floodplains and Wetlands1/	Power Generation and Transmission	Air Quality and GHGs	Flood Risk Management	Navigation and Transportation	Recreation	Water Supply	Visual	Noise	Fisheries and Passive Use	Cultural Resources	Indian Trust Assets, Tribal Perspectives and Tribal Interests[1/]	Environmental Justice
RFFA1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RFFA2	X	X	X	X	X	X			X	X	X	X			X	X	X	X
RFFA3	X		X	X	X	X	X	X	X				X	X		X	X	X
RFFA4	X		X			X	X	X	X					X		X	X	X
RFFA5		X		X	X	X		X							X	X	X	X
RFFA6	X	X		X	X	X			X		X	X				X	X	X
RFFA7				X	X	X					X				X		X	X
RFFA8				X	X										X			
RFFA9					X										X	X	X	X
RFFA10					X										X	X	X	X
RFFA11					X						X				X		X	X
RFFA12				X	X	X					X		X		X	X	X	X
RFFA13				X	X	X					X				X	X	X	X
RFFA14		X	X	X	X	X				X	X						X	X
RFFA15		X	X	X	X	X				X						X	X	X
RFFA16					X	X											X	X
RFFA17				X	X	X									X	X	X	X
RFFA18						X											X	X
RFFA19	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
RFFA20		X	X	X	X												X	X
RFFA21			X														X	X

RFFA ID	Hydrology and Hydraulics	River Mechanics	Water Quality	Anadromous Fish	Resident Fish	Vegetation, Wildlife, Floodplains and Wetlands1/	Power Generation and Transmission	Air Quality and GHGs	Flood Risk Management	Navigation and Transportation	Recreation	Water Supply	Visual	Noise	Fisheries and Passive Use	Cultural Resources	Indian Trust Assets, Tribal Perspectives and Tribal Interests1/	Environmental Justice
RFFA22			X	X	X												X	
RFFA23		X	X	X	X												X	X
RFFA24			X													X	X	X
RFFA25			X			X						X	X	X		X	X	X
RFFA26				X										X				X

1/ Not every RFFA affects each resource; please see resource section below for more information.

7.9.4 Hydrology and Hydraulics

The impacts from the Preferred Alternative to hydrology and hydraulics are closer to the No Action Alternative than any other alternative. It is expected to have minor effects to hydrology and hydraulics in Region A and B due to changes in reservoir elevation and negligible effects to Regions C and D due to changes in flow and reservoir elevation. Because the impacts are similar to the No Action Alternative, the co-lead agencies used the cumulative effects information in Chapter 6.3.1.1, to determine which RFFAs would likely impact hydrology and hydraulics. These include RFFAs 1, 2, 3, 4, 6, and 19. While the Preferred Alternative's direct and indirect effects to hydrology and hydraulics would be negligible to minor compared to the No Action Alternative, the cumulative effects from population growth, changes in energy sources and consumption, climate change, increased water withdrawals to support municipal, agricultural, and industrial uses, and potential for an increase in new storage projects could exacerbate direct and indirect effects that are attributable to lower flows and reservoir elevations in the Preferred Alternative.

7.9.5 River Mechanics

Based on available information, the impacts from the Preferred Alternative on River Mechanics vary by region, reach and sub-reach due to changes in the magnitude, range and duration of flow and stage as detailed in Appendix C. The effects to the storage projects are expected to be negligible in Region A with the exception of the Kootenai River entering Lake Kookanusa upstream of Libby Dam where there is potential for a minor change in depositional patterns with temporary head-of-reservoir deposits shifting downstream. In Regions B and C, the Preferred Alternative effects to River Mechanics are estimated to be negligible. For the CRS projects in Region D, the effects to River Mechanics are expected to be negligible except for minor impacts in the John Day Reservoir where there is potential for a minor amount of bed sediment fining due to changes in reservoir stage relative to the No Action Alternative. Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 5, 6, 14, 15, 19, 20, and 23 would likely impact River Mechanics. While the Preferred Alternative's direct and indirect effects to River Mechanics would be negligible to minor, the cumulative effects from actions that could affect sediment processes, such as population growth, increased water withdrawals to support municipal, agricultural, and industrial uses, ongoing dredging activities, climate change, mining and potential for an increase in new storage projects, could exacerbate direct and indirect effects that are attributable to the Preferred Alternative.

7.9.6 Water Quality

Changes to water temperature ranged from no change in Regions B and D, to negligible in Region C and minor in Region A. TDG analysis found no change in Region A. Conversely, in some high flow years, additional spill would occur due to the operational constraints for ongoing Grand Coulee maintenance. This additional spill would increase TDG in Region B, mostly in the reach downstream of Grand Coulee, and potentially downstream of Chief Joseph Dam. As this maintenance is completed, it would eventually reduce TDG in comparison to the No Action Alternative. Operations to provide additional spill for juvenile fish up to 125 percent TDG at the lower Snake River and lower Columbia River projects would lead to major increases in TDG in Regions C and D. These effects would be monitored, and the spill operations could be modified to be consistent with state water quality standards. The effects to other water quality processes were minor across all regions except for Region D, where the effects are expected to be negligible because of changes in flow relative to the No Action Alternative.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 4, 14, 15, 19, 20, 21, 22, 23, 24, and 25 would likely impact water quality. There could be minor adverse cumulative impacts to temperature and TDG and negligible impacts to other water quality processes when the impacts from the RFFAs are added to the impacts of the Preferred Alternative. For TDG, higher winter flows due to climate change could lead to increased TDG in the winter and early spring. For temperature, the cumulative effects from actions that could affect water quantity, such as population growth, increased water withdrawals to support municipal, agricultural, and industrial uses, climate change, mining, and potential for an increase in new storage projects, could exacerbate direct and indirect effects that are attributable to the Preferred Alternative. There would also be decreases in summer flow volumes and increased summer air temperatures leading to warmer summer water temperatures. Warmer summer water temperatures expected from climate change are likely to exacerbate the effects from the Preferred Alternative. For other water quality processes, actions that affect flows, such as climate change, could lead to greater cumulative impacts than anticipated under the Preferred Alternative.

7.9.7 Anadromous Fish

There are no anadromous fish in Region A and upstream of Chief Joseph Dam in Region B under the Preferred Alternative. The effects of the Preferred Alternative on anadromous fish are expected to be negligible in Region B downstream of Chief Joseph Dam due to minor changes in operations. Depending on which model is used (LCM or CSS), the effects to anadromous fish in Regions C and D would likely have the potential to range from a major adverse effect to a major beneficial effect. These results also vary by ESU and DPS.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 5, 6, 7, 8, 12, 13, 14, 15, 17, 19, 20, 22, 23 and 26 would likely impact anadromous fish. RFFAs that have the potential to increase TDG, water temperatures, variability of flow, and reduce water levels in the future, such as population growth and development, changes in land use, water withdrawals, new storage projects in the mid-Columbia basin, habitat degradation, and climate change, which could adversely impact anadromous fish, but it is uncertain to what degree. Some of these adverse effects could be partially alleviated by other actions that have the goal of benefiting anadromous species (i.e., RFFA 13 Tribal, State, and Local Fish and Wildlife Improvement projects) as identified in Chapter 6.

7.9.8 Resident Fish

The impacts from the Preferred Alternative on Resident Fish vary by region due to changes in flow and elevation. In Region A, effects to resident fish at Libby are expected to have both minor adverse effects due to higher river elevations during the winter and reduced benthic insect production in Lake Koocanusa and minor to moderate beneficial effects due to increased zooplankton productivity from the changes in reservoir elevation, more suitable downstream water temperatures, and restoration of native riparian vegetation. Effects at Hungry Horse are expected to be minor and beneficial due to higher reservoir levels in late summer increasing productive and lower summer outflows improving habitat suitability. In Region B, resident fish in Lake Roosevelt at Grand Coulee are expected to have minor to moderate adverse effects. This is due to increased kokanee and burbot egg stranding as well as decreased tributary access because of changes in reservoir levels, but minor beneficial effects to burbot and kokanee due to spawning habitat augmentation. In Region C, the *Slightly Deeper Draft for Hydropower (Dworshak)* measure is expected to have minor adverse effects to bull trout and kokanee because of increased entrainment risk and increased drawdown that may isolate fish from tributaries. In both Regions C and D, the Preferred Alternative is expected to have minor adverse effects on resident fish due to the higher TDG from the *Juvenile Fish Passage Spill Operations* measure.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 22, and 23 would likely impact resident fish. RFFAs that have the potential to cause cumulative impacts to resident fish when added to the direct and indirect impacts from the Preferred Alternative include climate change and water withdrawals if they cause lower water levels in the summer or if RFFAs, such as climate change, exacerbate TDG. RFFAs that have the potential to increase TDG levels, water temperatures, variability of flow, and reduce water levels in the future, such as population growth and development, changes in land use, water withdrawals, new storage projects in the mid-Columbia basin, habitat degradation, and climate change, which could adversely impact resident fish, but it is uncertain to what degree. In Region A, minor to moderate benefits from the Preferred Alternative could be offset by certain RFFAs, such as climate change and water withdrawals that may affect reservoir levels and outflows. In Region B, effects from egg stranding and spawning habitat access could be exacerbated by RFFAs that from changes (e.g., steeper) reservoir drawdowns. In Regions C and D, minor adverse effects to resident fish due to TDG levels that could be slightly increased by RFFAs. Some of these adverse effects could be partially mitigated by other RFFAs that have the goal of benefiting resident species (i.e., RFFA 13 Tribal, State, and Local Fish and Wildlife Improvement projects) as identified in Chapter 6.

7.9.9 Vegetation, Wildlife, Wetlands, and Floodplains

The impacts from the Preferred Alternative on vegetation, wildlife, wetlands, and floodplains vary by region due to changes in flow and elevation. Consistent with Chapter 3, the effects to vegetation and wildlife were minor at the storage reservoirs in Regions A and C due to deeper drafts, and negligible in Region B and at the run-of-river dams on the lower Snake and lower Columbia Rivers. *Slightly Deeper Drafts at Dworshak* in the winter may have a minor effect elk migration across the frozen reservoir. Overall there was no change from the No Action Alternative for the following ESA-listed species: southern resident killer whale (*Orcinus orca*), grizzly bear (*Ursus arctos horribilis*), yellow-billed cuckoo (*Coccyzus americanus*), and Ute lady's-tresses (*Spiranthes diluvialis*).

The Preferred Alternative's impacts on floodplains are expected to be similar to those predicted under MOs 1 and 2, with negligible effects for most of the basin and minor impacts below Bonneville Dam. Flood elevation changes would typically be negligible (absolute value less than 0.3 feet) with minor reductions (absolute value less than 1 foot) in flood elevations predicted in Region D for the Columbia River below Bonneville Dam for floods with moderate to low frequencies (Annual Exceedance Probability values from 15 to 2 percent). The annual average probability of inundation under the Preferred Alternative would remain unchanged from current conditions in most of the basin, with minor reductions in inundation frequency below Bonneville Dam.

The effects to wetlands from the Preferred Alternative are expected to be similar to MO1 in Regions B and C. In Region A, the refined *Modified Draft at Libby* measure is expected to result in water surface elevations similar to the No Action Alternative, and therefore, would have negligible effects on wetlands downstream of the Libby project. At Umatilla Reservoir (John Day Reservoir) in Region D, the *Predator Disruption Operations* measure is expected to increase reservoir elevations higher than MO1 from April 10 to June 15. This increase is expected to alter the wetlands in Umatilla Reservoir including at the Umatilla National Wildlife Refuge because the increase in reservoir elevation would be during the growing season. In addition, this increase would potentially alter other vegetation habitats along the reservoir's shoreline and Blalock Islands.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 4, 5, 6, 7, 12, 13, 14, 15, 16, 17, 18, 19, 25, and 26 would likely impact vegetation, wildlife, floodplains and wetlands. Actions that have the potential to cause cumulative impacts to vegetation, wildlife, floodplains and wetlands when added to the direct and indirect impacts from the Preferred Alternative include climate change and increased water withdrawals if they cause lower water levels and cause habitat conversion from existing vegetation types to drier habitat types (e.g., convert wetlands to uplands). Habitat conversion can negatively impact wildlife that may not be able to adapt to this change, thus, cumulative effects to wildlife could occur. Several RFFAs, including RFFAs 1, 2 and 6, could reduce instream flow potentially affecting floodplain inundation timing and magnitude; thus, the impacts from the Preferred Alternative on floodplains added to the impacts from the RFFAs could lead to minor cumulative impacts on floodplains.

7.9.10 Power Generation and Transmission

Hydropower generation under the Preferred Alternative would decrease relative to the No Action Alternative, and the FCRPS would lose an average of 160 aMW of power and 304 aMW of firm power available for long-term firm power sales (roughly the amount of power consumed by about 250,000 Northwest homes in a year). Due to changes in the seasonal shape of hydropower under the Preferred Alternative, the reliability of the Northwest power system would be about the same as the No Action Alternative, despite an overall decrease in generation.

Bonneville would continue to meet its transmission system reliability requirements. There could be an increase in generation from the lower Snake and lower Columbia River projects during the last half of August relative to the No Action Alternative. This generation would provide additional flexibility that could provide operational benefits for the transmission system. As a result, no additional reinforcements have been identified beyond those that are a part of Bonneville's regular system assessments. Additionally, changes in the patterns of CRS generation under the Preferred Alternative would have a relatively small impact on congestion for Pacific Northwest transmission paths.

Moreover, Bonneville's wholesale power rate would experience an upward rate pressure of 2.7 percent. For transmission, there would be no changes in transmission capital investments or long-term transmission sales under the Preferred Alternative. Upward transmission rate pressure would be about 0.09 percent annually (0.7 percent cumulatively over an 8-year period) relative to the No Action Alternative because transmission short-term sales would likely change as a result of the changes in hydropower generation and associated market pricing. For specific customers and product choices, the annualized upward transmission rate pressure would range from 0.04 percent to 0.18 percent relative to the No Action Alternative. Retail rate pressure (paid to individual utilities) would be similar to the No Action Alternative. Most counties would experience small amounts of upward pressure in their electricity retail rates. Across the Pacific Northwest, changes to the residential retail rate would range from a reduction of 0.068 cents/kWh to an increase of 0.11 cents/kWh (in percentage terms this represents a reduction of 0.94 percent to an increase of 1.2 percent). For commercial end users, rate effects range from a reduction of 0.081 cents/kWh to an increase of 0.11 cents/kWh (a reduction of 1.1 percent to an increase of 1.3 percent), and for industrial customers, from a reduction of 0.072 cents/kWh to an increase of 0.11 cents/kWh (a reduction of 1.3 percent to an increase of 2.0 percent). The rate effects would be larger for customers of utilities that receive power from Bonneville and smaller for customers whose electricity is not supplied by Bonneville.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 3, 4, and 19 would likely impact power and transmission. Cumulative effects from RFFA1, RFFA3, and RFFA4, in combination with the power and transmission impacts analyzed under the Preferred Alternative are expected to be similar to that of the No Action Alternative. Moreover, the cumulative effects of other non-Federal hydroelectric projects and projected scenarios for coal power plant retirements are captured within the analysis of direct and indirect effects for power and transmission. The Preferred Alternative would reduce overall hydropower generation, which would exacerbate the regional need for more power generation resulting from coal plant retirements and electrification of transportation. Under the Preferred Alternative, there would be a cumulative benefit to power system flexibility with the addition of hydropower measures to increase flexibility with the cumulative effect of more new hydrosystem flexibility being available to integrate renewable power generation (especially wind and solar) being constructed in the region. The cumulative effects to power and transmission resources as a result of climate change are likely to affect generation under the Preferred Alternative relative to the No Action Alternative roughly the same on an annual basis.

Finally, Bonneville would continue to meet its transmission system reliability requirements, but may experience shifts in regional congestion patterns or need to add reinforcements to accommodate changes in power generation beyond that identified in the planning base cases captured within the analysis of direct and indirect effects for power and transmission.

7.9.11 Air Quality and Greenhouse Gases

The impacts from the Preferred Alternative on air quality and greenhouse gases suggest air quality effects would be minor across Regions A, B, C and D based on increased greenhouse gas emissions due to the reduction in hydropower generation. Other emissions sources (e.g., navigation, construction, fugitive dust) are most likely to have a negligible effect on air quality and greenhouse gas emissions. Specifically, under the Preferred Alternative, energy sector greenhouse gas emissions would increase by 0.7 percent across the Pacific Northwest. Most effects related to construction of structural measures in Regions A, C and D are expected to be temporary and short term.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 3, 4, 5, and 19 would likely impact air quality and greenhouse gas emissions. Overall, hydropower generation would decrease under the Preferred Alternative, and climate change is likely to add additional uncertainty to the annual magnitude of generation, and uncertainty to the monthly magnitude. This reduction in hydropower combined with RFFAs, such as increased human development and resulting demand for energy could lead to a minor cumulative impact on air quality and greenhouse gas emissions.

7.9.12 Flood Risk Management

Flood risk management was evaluated for the Preferred Alternative to determine if there would be a change in flood hazards faced by communities, property, infrastructure or levees along the Columbia River System. Based on this analysis, flood risk management under the Preferred Alternative is expected to be consistent with conditions under the No Action Alternative as described in Section 3.9. The Preferred Alternative has the potential for a slight decrease in flood risk in Region A under lower annual peak flow conditions, as well as slight decreases under higher peak flow conditions near Spalding, Idaho in Region C.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 4, 6, and 19 would likely affect flood risk management. Actions such as climate change (higher winter and spring runoff) and population growth and development, may adversely affect flood risk in the future, but the extent of those impacts is uncertain. Since the Preferred Alternative would have no direct or indirect adverse impacts to flood risk management when compared to the No Action Alterative, the addition of cumulative effects from RFFAs 1, 2, 3, 4, 6 and 19 could cause negligible impacts.

7.9.13 Navigation and Transportation

Potential effects to navigation and transportation systems including ferries and cruise lines were evaluated for the Preferred Alternative. Commercial navigation on the Columbia River System, occurs in Regions C and D. Under the Preferred Alternative, there could be an approximately one day per year decrease in navigable days under low flow conditions, when compared to No Action Alternative, and approximately a one day per year increase in navigable days during typical water year conditions. No change from the No Action Alternative is expected during high flow conditions. In Region B, Lake Roosevelt water elevations would be sufficient to allow operation of the Inchelium-Gifford Ferry operations every day out of the year under the Preferred Alternative during typical water years as well as in dry water years. Ferry operations during high water years could be affected slightly more under the Preferred Alternative than under the No Action Alternative meaning the ferry would not be able to operate for approximately 31 days in the year, which is four additional days than under the No Action Alternative.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 14, 15 and 19 would likely affect navigation and transportation. Future higher winter and spring runoff volumes due to climate change could increase the direct and indirect effects of the Preferred Alternative on the Inchelium-Gifford Ferry operations because of the need to vacate reservoir space to manage flood risk, especially during high water years, but it is not known to what extent. This effect could be mitigated by the extension of boat ramp for the ferry. Overall, there would likely be negligible to minor cumulative effects when the impacts from the Preferred Alternative are added to impacts from other RFFAs, such as climate change.

7.9.14 Recreation

The recreation analysis assessed effects from the Preferred Alternative focused primarily on water-based recreation access at system reservoirs and river reaches. The effects in Region A vary from no change at Albeni Falls similar to the No Action Alternative to negligible difference from No Action at Lake Koocanusa, where there could be up to a 1 percent decrease in recreation visitor days due to decreased water-based recreation access. Additionally, the river reach downstream of Libby Dam could benefit from a decrease of 14 percent in monthly median outflow in May from Libby Dam, decrease water turbidity and benefitting nearby in-river recreational fishing activities.

Effects in Region B at Grand Coulee and Chief Joseph are also expected to be negligible based on changes to accessibility of water-based recreation facilities such as boat ramps driven by changes in reservoir elevations. For example, water surface elevations at Lake Roosevelt could be the same or higher for the majority of a typical year, when compared to the No Action Alternative, but decreases of 1 to 2 feet could occur in September and October. Due to minor changes in monthly boat ramp accessibility (both decreases and increases), water-based visitation is estimated to increase slightly by less than 0.1 percent (approximately 171 visits) in a typical year. In Region C, minor effects are expected at Dworshak due to the change in reservoir elevations and negligible effects at the lower Snake River projects. In Region D, the effects are also expected to be negligible. Effects to hunting, wildlife viewing, swimming, and water sports at river recreation sites for the Preferred Alternative would be negligible; however, there could be minor to moderate impacts to wildlife viewing at John Day Reservoir due to changes in water elevations. Finally, the Preferred Alternative is expected to improve fish survival and abundance through both operational and mitigation actions. To the extent that increases in abundance occur, this would increase opportunities for recreational (as well as tribal and commercial) fishing throughout the region on the Columbia River. Recreational wildlife watching opportunities could increase if these species experience benefits associated with an increase in anadromous fish abundance. This would result in beneficial effects for recreational fishing. In particular, the presence of additional fish may improve the quality of existing recreational fishing trips (e.g., through increased catch rates), resulting in additional value (consumer surplus) for anglers (i.e., a higher UDV). An increase of fish may also generate additional trips as more anglers could be supported.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 6, 7, 11, 12, 13, 14, and 19 would likely impact recreation. In the future, there could be reduced boat ramp accessibility for some periods of time during the year due to an overall reduced volume of available water from increased demand and from the effects of climate change, causing lower summer volumes. When the impacts from the preferred alternative are added, this has the potential to increase the impacts to recreation from negligible to minor to minor to moderate. See the cumulative effects analysis for anadromous and resident fish above for additional information.

7.9.15 Water Supply

The effects from the Preferred Alternative on water supply is not expected to change the ability to deliver existing water supply as compared to the No Action Alternative because the changes in flow and reservoir elevations are expected to be negligible for water supply purposes. In addition, the operation of withdrawals is timed to minimize impacts to flows. The additional 45 kaf from Lake Roosevelt is expected to increase available water supply in Region B, but is not expected to affect other regions.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 6, 19, and 25 would likely impact water supply. The cumulative effects of tributary water diversions added to Federal CRS water diversions are expected to continue in the future over the study period under the Preferred Alternative. Tributary diversions could negatively impact CRS water supply into the future by removing water supplies before they reach the mainstem of the Columbia and Snake Rivers, where CRS water diversions occur.

7.9.16 Visual

The effects from the Preferred Alternative on visual resources are expected to be minor due to deeper drafts at the storage reservoirs in Regions A and C, and negligible across Regions B and D. Effects to visual resources from structural measures for Regions A and B would be negligible because they would not substantially differ from the No Action Alternative. There would be minor, short-term visual effects for viewers in the vicinity of projects in Regions C and D because of increased construction activity from implementing structural measures such as new fish passage structures, modifications to fish ladders, and changes to spillway weirs, but these measures would not contribute to a substantial visual change in the landscape surrounding those projects. To the extent operational or structural measures affect the viewshed, this can have unique effects on spiritual practices for tribes. Because operational measures across all regions would result in minor changes in pool elevation management, carrying out those measures would have a minor effect on the viewshed and viewers in their vicinity from changes in duration and timing of reservoir elevations compared to the No Action Alternative. Informed by Chapter 6, the co-lead agencies determined RFFAs 1, 3, 12, and 25 would likely impact visual resources. Minor adverse visual effects from the Preferred Alternative due to deeper drafts at reservoirs could be exacerbated by cumulative actions such as climate change, increased water withdrawals to support municipal, agricultural, and industrial uses and ongoing land-based activities; however, the cumulative impact to visual resources would likely be minor.

7.9.17 Noise

The effects from the Preferred Alternative on noise are expected to be negligible in Regions A, B, C and D, with most effects from noise concentrated at the dam and reservoir projects in Regions A, C and D where structural measures would be constructed. These impacts are expected to be minor and short-term and dissipate based on distance from the project. In addition, because the seasonal timing or duration of high-flow and high-spillway-noise levels would change under the operational measures, there would be negligible effects to noise in Regions A, B, C and D. Informed by Chapter 6, the co-lead agencies determined that ongoing activities, such as driving and farming, development near the projects or along the reservoirs would continue. Also consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 3, 4, 25 and 26 would likely impact noise. In addition, no impacts to noise are anticipated from climate change (see Chapter 4.2). Overall, the impacts from the Preferred Alternative in combination with past, present, and reasonably foreseeable future actions would result in negligible cumulative impacts to noise, but these impacts are expected to be short-term and dissipate based on distance from the projects.

7.9.18 Fisheries and Passive Use

The effects from the Preferred Alternative on fisheries are expected to improve fish survival and abundance through both operational and mitigation actions. To the extent that increases in abundance occur, this would increase opportunities for tribal, commercial, and recreational fishing throughout the Columbia River Basin.

The impacts from the Preferred Alternative on anadromous fisheries are expected to be negligible in Region B below Chief Joseph Dam, but have the potential to range from moderate adverse effects to potentially major beneficial effects in Regions C and D. The predicted effects on anadromous fish could result in changes in abundance and harvest opportunities in commercial and ceremonial and subsistence fisheries for anadromous species. Effects from the Preferred Alternative on ceremonial and subsistence fisheries for resident fish range from moderate adverse to moderate beneficial effects, depending on the region and species.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 5, 7, 8, 9, 10, 11, 12, 13, 17, 18 and 19 would likely affect fisheries. Under the Preferred Alternative, the extent to which changes in the abundance of various fish populations result in changes in fisheries is driven by fishery management decisions that determine how much, when, and by whom fish can be caught. There are numerous past, present, and reasonably foreseeable future actions that could both beneficially and adversely affect species important to commercial and ceremonial and subsistence fisheries.

7.9.19 Cultural Resources

The impacts from the Preferred Alternative on cultural resources are grouped into three property-based categories: archaeological sites, traditional cultural properties (TCPs), and historic built resources. Effects to archaeological resources and TCPs were similar to the analysis for the No Action Alternative in Chapter 3.16 at all projects, with a few exceptions. At Libby and Dworshak, it is expected that the Preferred Alternative would result in negligible effects as compared to the No Action Alternative. In addition, the Preferred Alternative is expected to cause negligible beneficial effects for archaeological resources at Lower Granite, John Day, and Hungry Horse. At Bonneville Dam, McNary Dam, Ice Harbor Dam, and Hungry Horse Dam, proposed structural measures would have a negligible effect to the historic built resources by degrading their historic integrity through alteration or replacement of original components. For sacred sites, ongoing activities, such as recreation activities in Lake Roosevelt and Lake Pend Oreille would continue under all of the alternatives, including the Preferred Alternative.

Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 4, 5, 6, 9, 10, 12, 13, 15, 17, 19, 24, and 25 would likely affect cultural resources. RFFAs that could potentially decrease the amount of water in the future, such as increased development and associated water withdrawals, climate change, and increases in future storage projects, could lead to greater cumulative impacts than anticipated under the Preferred Alternative.

7.9.20 Indian Trust Assets, Tribal Perspectives, and Tribal Interests

The effects from the Preferred Alternative on Indian Trust Assets (ITA), Tribal Perspectives, and Tribal Interests vary. No direct or indirect effects to ITAs were identified from the Preferred Alternative. Trust lands identified during the geospatial database query and tribal outreach are located outside of any direct or indirect effects identified from the alternatives. These include lands from the Confederated Tribes of Warm Springs Reservation, the Yakama Nation, and the Kootenai Tribe of Idaho, as well as these Indian reservations: The Confederated Tribes of the Colville Indian Reservation; Spokane Tribe of Indians; Kootenai Tribe of Idaho; Nez Perce Tribe; and The Confederated Salish & Kootenai Tribes of the Flathead Reservation.

Effects to tribal interests under the Preferred Alternative would be negligible for most resources (e.g., Vegetation, Wetlands, Wildlife, and Floodplains; Air Quality and Greenhouse Gases; Power and Transmission; Flood Risk Management; Navigation and Transportation; and Recreation). There is a range of expected effects, including minor beneficial effects such as those from the refined operations in Region A, and potentially minor adverse effects to resident fish in Lake Roosevelt due to deeper drawdowns in high water years. However, mitigation incorporated into the Preferred Alternative includes spawning habitat augmentation to offset these effects. The expected range of impacts to fish is described in more detail in the anadromous fish, resident fish, water quality, and fisheries sections above. Additionally, ongoing Fish and Wildlife programs would continue under the Preferred Alternative, and extending the boat ramp at the Inchelium-Gifford ferry would mitigate some of the operational effects at Grand Coulee, including accessibility.

Consistent with Chapter 6, RFFAs 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 19, 20, 21, 22, 23, 24, 25, and 26 would likely affect Indian Trust Assets, Tribal Perspectives, and Tribal Interests. Ongoing activities on Indian Trust lands, for example, would be expected to continue under all of the alternatives. Since the alternatives would not have direct or indirect impacts on Indian Trust Assets, there would be no change in effects to these assets, and thus there would be no cumulative impacts to Indian Trust Assets. Cumulative effects to tribal interests are provided above for Anadromous Fish; Resident Fish; Water Quality; Vegetation, Wetlands, Wildlife, and Floodplains; Air Quality and Greenhouse Gases; Power and Transmission, Flood Risk Management; Navigation and Transportation, and Recreation.

7.9.21 Environmental Justice

The effects from the Preferred Alternative are not likely to cause a disproportionately high and adverse effect on low income, minority, or tribal populations (see Section 7.7.20). Consistent with Chapter 6, the co-lead agencies determined RFFAs 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, and 26 would likely impact environmental justice populations. Reasonably foreseeable future actions, such as climate change, could mean refill is initiated earlier more frequently, reducing the amount of time that Lake Roosevelt is drafted to inoperable range, and thus potentially reducing the impacts to the Inchelium-Gifford Ferry, including impacts to the Confederated Tribes of the Colville Reservation. As a result, effects to the ferry could be less than anticipated under the Preferred Alternative.

7.10 UNAVOIDABLE ADVERSE EFFECTS

Unavoidable adverse effects are those effects that cannot be avoided or fully mitigated should the alternatives be implemented. Although adverse effects could be avoided, minimized, or mitigated by the measures described in Section 7.6.4 some effects would remain. The effects of the Preferred Alternative are described in Section 7.7 and some of them may not be fully avoided, as identified in CEQ regulations (40 C.F.R. § 1502.16). Location and intensity of unavoidable effects would vary by alternative.

Physical laws and processes make erosion and sedimentation unavoidable. If storage reservoirs are operated according to their intended function, with drafting and refilling cycles, the reservoir elevations may fluctuate substantially, reservoir shorelines would be exposed, and islands could be bridged. Unavoidable effects from storage reservoir operations include blowing dust from exposed sediments, diminished visual quality, damage to archaeological sites, and some degree of disruption to resident fish spawning and food availability. Seasonal limitations on use of recreation facilities could be avoided by modifying the facilities, but it would be impractical to eliminate all elevation-based recreation effects. Large changes in elevation are not normal operating conditions at the run-of-river projects. Several types of effects are nevertheless unavoidable with the current configuration of the system, such as some degree of disruption to anadromous and resident fish spawning and food availability. Projected effects at the CRS projects would result from operational changes that disrupt established uses dependent upon certain elevation patterns. If operations change those elevation patterns, some degree of effect to the established uses is unavoidable.

7.11 RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

This analysis looks at the relationship between short-term uses of environmental resources and the maintenance and enhancement of long-term productivity. CRS operations may cause both short-term and long-term effects to the affected environment that cannot be mitigated. All of the alternatives would cause some mix of short-term effects, including soil erosion, dust generation, degradation of water quality, loss of riparian or wetland vegetation, disruption of fish and wildlife habitat, disruption of recreational use, degradation of visual quality, and effects to cultural resources.

In general, the extent these would be long-term effects would depend upon how long a given operation was continued. Some of the short-term changes could soon lead to long-term decreases in productivity. For example, periodic drawdowns to levels below those required for irrigation pumps could result in long-term agricultural productivity losses, if irrigators do not modify their pumps. The short-term and long-term uses of the environment for CRS operations could have some beneficial effects on long-term productivity. The continued availability of power should help maintain the region's reliability. Operations intended to benefit anadromous and resident fish should contribute to the survival and recovery of ESA-listed species and to the maintenance of other stocks. Some of the alternatives would improve conditions for anadromous and resident fish and wildlife, and this could improve the long-term productivity of these resources.

7.12 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Irreversible and irretrievable commitments generally affect environmental resources such as soils, wetlands, and riparian areas, but can involve financial resources. Such commitments are considered irreversible and irretrievable because their implementation would affect a resource that has deteriorated to the point that renewal can occur only over a long period or at a great expense, or because they would cause the resource to be destroyed or removed.

Because the adoption of the Preferred Alternative involves operation of existing facilities and not construction of new facilities, few of the operational effects identified would be irreversible or irretrievable. Loss of soil due to erosion is an irreversible and irretrievable commitment. Because all of the alternatives, including current operations, involve reservoir fluctuation at some of the projects, erosion would occur at these projects under all of the alternatives.

Greater reservoir fluctuations at storage reservoirs would result in more erosion generally than at the run-of-river reservoirs.

The abundance and quality of wetland and riparian habitat depend on water levels and timing. The desiccation of wetland plants due to drafting at storage reservoirs in some cases would be an irreversible commitment. The desiccation of submerged aquatic plants and mud-dwelling fauna and gradual loss of emergent marsh and riparian vegetation is also an irreversible and irretrievable commitment. These resources could conceivably be restored with higher water levels and replanting, but the existing resources would be lost.

Loss of cultural resources resulting from accidental damage or vandalism would be an irreversible and irretrievable commitment. All of the alternatives, including current operations, would expose substantial percentages of known archaeological sites to such damage or vandalism.

7.13 INTENTIONAL DESTRUCTIVE ACTS

Bonneville, like other utilities and government agencies, experiences incidents of criminal activity such as vandalism, theft, and burglary. Some of these incidents cause substantial operational and financial impacts to the agency. Between 2007 and 2009, Bonneville experienced approximately 128 incidents of burglary, theft, and vandalism. These incidents cost the agency approximately $1,624,110. The Bonneville Security and Emergency Response Office works closely with Federal Law Enforcement Agencies, and local and state police to ensure all incidents are appropriately reported, investigated, and prosecuted. This effort has resulted in the return of BPA property and in court ordered restitution to be paid by the convicted parties.

Issues concerning international terrorist activity, domestic terrorism and sabotage remain a significant concern for Bonneville and other critical infrastructure operators. Bonneville maintains close liaisons with Federal Law Enforcement Agencies, Department of Homeland Security, and Local jurisdictions to ensure effective communication of information and intelligence. The impacts from vandalism, theft, and burglary, though expensive, do not generally cause a disruption of service to the area. Stealing equipment from electrical substations, however, can be extremely dangerous. Federal and other utilities use physical deterrents such as fencing, cameras, and warning signs to help prevent theft, vandalism, and unauthorized access to facilities. In addition, through its Crime Witness Program, Bonneville offers up to $25,000 for information that leads to the arrest and conviction of individuals committing crimes against Bonneville facilities. Anyone having such information can call Bonneville's Crime Witness Hotline at (800) 437-2744. The line is confidential, and rewards are issued in such a way that the caller's identity remains confidential.

Acts of sabotage or terrorism on electrical facilities in the Pacific Northwest are rare, though some have occurred. These acts generally focused on attempts to destroy large transmission line steel towers. Depending on the size and voltage of the line, destroying towers or other equipment could cause electrical service to be disrupted to utility customers and end users. The effects of these acts would be as varied as those from the occasional sudden storm, accident or blackout and would depend on the particular configuration of the transmission system in the area.

When a loss of electricity occurs, all services provided by electrical energy cease. Illumination is lost. Lighting used by residential, commercial, industrial and municipal customers for safe movement and security is affected. Residential consumers lose heat. Electricity for cooking and refrigeration is also lost, so residential, commercial, and industrial customers cannot prepare or preserve food and perishables. Residential, commercial, and industrial customers experience comfort/safety and temperature impacts, increases in smoke and pollen, and changes in humidity, due to loss of ventilation. Mechanical drives stop, causing impacts as elevators, food preparation machines, and appliances for cleaning, hygiene, and grooming are unavailable to residential customers. Commercial and industrial customers also lose service for elevators, food preparation, cleaning, office equipment, heavy equipment, and fuel pumps. In addition, roadways experience gridlock where traffic signals fail to operate. Mass transit that depends on electricity, such as light rail systems, can be impacted. Sewage transportation and treatment can be disrupted.

A special problem is the loss of industrial continuous process heat. Electricity loss also affects alarm systems, communication systems, cash registers, and equipment for fire and police departments. Loss of power to hospitals and people on life-support systems can be life-threatening.

While the likelihood for sabotage or terrorist acts on the Preferred Alternative, No Action Alternative or Multiple Objective Alternatives is difficult to predict given the varied nature and wide geographic scope of the project, it is unlikely that such acts would occur. If such an act did occur, it could have a significant impact on electrical service because of the integral role these projects play in hydropower generation in the Pacific Northwest. The Department of Energy, including Bonneville, the Corps and Reclamation as well as public and private utilities, and energy resource developers include the security measures mentioned above and others to help prevent such acts and to respond quickly if human or natural disasters occur.

7.14 CONCLUSION

The Preferred Alternative contains a variety of measures to meet the Purpose and Need Statement and objectives developed for the EIS. Many of the new measures are intended to improve conditions for ESA-listed fish and lamprey. The remaining measures are intended to provide more flexible ways for the co-lead agencies to meet water demands for fish and wildlife, flood risk management, water supply, and hydropower in the Columbia Basin. Where appropriate, mitigation measures have been incorporated into the Preferred Alternative to offset new adverse impacts when compared to the No Action Alternative. Ongoing programs, operation and maintenance activities would continue from 2016 unless otherwise described. Preliminary measures agreed to by the co-lead agencies for compliance with the ESA Section 7(a)(2) are also included. These may be modified or added to as the ESA consultation process is currently ongoing.

CHAPTER 8 - COMPLIANCE WITH ENVIRONMENTAL LAWS, REGULATIONS, AND EXECUTIVE ORDERS

This section addresses Federal environmental laws, implementing regulations, and executive orders potentially applicable to the Preferred Alternative. The applicable environmental statutes are summarized below with a brief description of the law, regulations, and executive orders and status of compliance starting at Section 8.1.

8.1 NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) of 1969 (42 United States Code [U.S.C.] § 4321 et seq.) provides a commitment that Federal agencies will consider, document, and publicly disclose the environmental effects of their actions. NEPA documents must provide detailed information regarding the purpose and need statement, the proposed action and alternatives, including the No Action Alternative, the environmental impacts of the alternatives, appropriate mitigation measures, and any adverse environmental impacts that cannot be avoided if the proposal is implemented. Agencies are required to demonstrate that decision makers have considered these factors prior to undertaking actions, which is outlined in a decision document like a Record of Decision for an environmental impact statement (EIS) such as this one.

This EIS is the primary vehicle to achieve NEPA compliance for the proposed project. Before preparing this document, the co-lead agencies published a Notice of Intent to prepare an EIS in the Federal Register on September 30, 2016, and held 16 public scoping meetings and two webinars. The 45-day public review period on the draft EIS provides disclosure of the environmental effects of the alternatives to the public. Following the 30-day public review of the final EIS, the co-lead agency decision makers would sign Records of Decision, outlining the rationale for their decision.

8.2 ENDANGERED SPECIES ACT

The Endangered Species Act (ESA) of 1973 (16 U.S.C. §§ 1531–1544), amended in 1988, establishes a national program for the conservation of threatened and endangered species of fish, wildlife, and plants and the habitat upon which they depend. Section 7(a)(2) of the ESA requires that Federal agencies consult with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS), as appropriate, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or to adversely modify or destroy their designated critical habitats.

The co-lead agencies have been coordinating with both NMFS and USFWS throughout the development of this draft EIS. The biological assessment (Appendix V) has been sent to the NMFS and USFWS, dated December 20, 2019, to support development of biological opinions. The NMFS's and USFWS's biological opinions are anticipated to be completed prior to signing the Records of Decision. The biological opinions would be addressed in the Records of Decisions and, if adopted by the co-lead agencies, would supersede previous biological opinions.

8.3 FISH AND WILDLIFE CONSERVATION

8.3.1 Fish and Wildlife Conservation Act of 1980

The Fish and Wildlife Conservation Act of 1980 (16 U.S.C. § 2901 et seq.) acknowledges the historical focus of fish and wildlife conservation programs on recreationally and commercially important species, without provisions for the conservation and management of nongame fish and wildlife. This act encourages all Federal departments and agencies to utilize their statutory and administrative authority, to the maximum extent practicable and consistent with each agency's statutory responsibilities, to conserve and to promote conservation of nongame fish and wildlife and their habitats through the implementation of conservation plans and programs for nongame fish and wildlife. The co-lead agencies are in the process of consulting with USFWS concerning fish and wildlife resources that could be affected by the Preferred Alternative. In addition, the co-lead agencies worked with various cooperating agencies, including the Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game, and Montana Fish, Wildlife & Parks, on recommendations to avoid and minimize potential impacts to fish and wildlife resources. Mitigation designed to avoid and minimize impacts to fish and wildlife and their habitat is identified in Chapter 5.

8.3.2 Fish and Wildlife Coordination Act of 1934

The Fish and Wildlife Coordination Act of 1934, as amended (16 U.S.C. §§ 661–667e), provides authority for USFWS and NMFS involvement in evaluating impacts to fish and wildlife from proposed water resource development projects. It requires that fish and wildlife resources receive equal consideration to other development project features. It requires Federal agencies that construct, license, or permit water resource development projects to consult with the USFWS, NMFS, and state resource agencies regarding the impacts on fish and wildlife resources and measures to mitigate these impacts when waters of any stream or other body of water are "proposed . . . to be impounded, diverted . . . or . . . otherwise controlled or modified . . ." Section 2(b) requires the USFWS to produce a Coordination Act Report (CAR) that describes fish and wildlife resources in a project area, potential impacts of a proposed project, and recommendations for a project.

The U.S. Army Corps of Engineers (Corps) received the draft CAR on January 14, 2019, and it is included in Appendix U. In the draft CAR, the USFWS provided landscape findings and conservation recommendations for the No Action Alternative and the Multi-Objective Alternatives relating to: natural hydrologic regimes; habitat connectivity and fish passage; National Wildlife Refuges; habitat complexity and heterogeneity; invasive species; and monitoring and adaptive management. The co-lead agencies considered the findings and recommendations while finalizing the DEIS and, in particular, while developing mitigation measures for the effects of the alternatives (see Chapter 5). Coordination between the co-lead agencies and the USFWS regarding the draft CAR and the final CAR is ongoing. The USFWS will be updating the CAR for the preferred alternative and conservation recommendations provided therein will be considered. Further coordination with USFWS is necessary. The final CAR is expected be completed for inclusion in the final EIS.

8.3.3 Migratory Bird Treaty Act and Executive Order 13186, Responsibilities of Federal Agencies To Protect Migratory Birds

The Migratory Bird Treaty Act (16 U.S.C. §§ 703–712), as amended, protects over 800 bird species and their habitat, and implements various treaties and conventions between the United States and other countries, including Canada, Japan, Mexico, and Russia, for the protection of migratory birds. Under the act, taking, killing, or possessing migratory birds, or their eggs or nests, is unlawful. The act classifies most species of birds as migratory, except for upland and non-native birds such as pheasant, chukar, gray partridge, house sparrow, European starling, and rock dove. Executive Order 13186, dated January 10, 2001, directs Federal agencies to evaluate the effects of their actions on migratory birds, with emphasis on species of concern, and inform USFWS of potential negative effects to migratory birds.

The U.S. Department of Energy (DOE) and USFWS signed a Memorandum of Understanding (MOU), which is in the process of being renewed, that addresses migratory bird conservation in accordance with Executive Order 13186 (DOE and USFWS 2013). The MOU addresses how both agencies can work cooperatively to address migratory bird conservation and includes specific measures to consider applying during project planning and implementation. Bonneville Power Administration (Bonneville) follows this MOU to minimize potential impacts on migratory birds.

Prior to implementation of the Preferred Alternative, the co-lead agencies would coordinate with USFWS if it is determined there will be effects to migratory birds.

8.3.4 Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) of 1972 (16 U.S.C. §§ 1361–1407) prohibits the take of marine mammals, including harassment, hunting, capturing, collecting, or killing, except through permits and authorizations under the MMPA. The co-lead agencies would determine if there are effects to marine mammals prior to implementation of the Preferred Alternative.

8.3.5 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. § 1801 et seq.) requires Federal agencies to consult with NMFS on activities that may adversely affect Essential Fish Habitat (EFH). The objective of an EFH assessment is to determine whether the proposed action(s) “may adversely affect” designated EFH for relevant commercial, federally managed fisheries species within the proposed action area. EFH includes those waters and substrate necessary for fish spawning, breeding, feeding, or growth to maturity. The biological assessment (appended to this EIS) describes conservation measures proposed to avoid, minimize, or otherwise offset potential adverse effects to designated EFH resulting from the proposed action.

The co-lead agencies are in consultation with NMFS on effects to EFH in conjunction with the ESA Section 7 consultation.

8.3.6 Pacific Northwest Electric Power Planning and Conservation Act

Provisions of the Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act) (16 U.S.C. § 839 et seq.) require Bonneville to balance multiple public duties and purposes: helping to ensure the Pacific Northwest has an adequate, efficient, economical, and reliable power supply; promoting energy conservation and the use of renewable resources; and, consistent with the program developed by the Northwest Power and Conservation Council (NW Council), protecting, enhancing, and mitigating fish and wildlife to the extent affected by the development and operation of the Federal Columbia River Power System (FCRPS), which includes the Columbia River System (CRS). Bonneville complies with these provisions of the Northwest Power Act through the Fish and Wildlife Program and other actions.

Under the Northwest Power Act, Bonneville, the Corps, and the Bureau of Reclamation (Reclamation) exercise their responsibilities of operating the CRS in a manner that provides equitable treatment for fish and wildlife and with the other purposes for which CRS facilities are operated and managed. In addition, the co-lead agencies consider in their decision making the NW Council's Fish and Wildlife Program and Mainstem Amendments to the fullest extent possible.

8.3.7 Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act (16 U.S.C. §§ 668–668c) prohibits anyone without a permit issued by the Secretary of the Interior from "taking" eagles, including their parts, nests, or eggs. The act applies criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any [bald or golden] eagle alive or dead, or any part, nest, or egg thereof." The act defines "take" as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb."

Prior to implementation of the Preferred Alternative, the appropriate co-lead agency would determine if those activities would have the potential to take bald and golden eagles and coordinate with USFWS. Effects from operational measures in the Multiple Objective Alternatives (MOs) are anticipated to not exist or be negligible.

8.4 CULTURAL RESOURCES

8.4.1 National Historic Preservation Act

The National Historic Preservation Act (54 U.S.C. § 306108) and its implementing regulations, 36 Code of Federal Regulations (C.F.R.) Part 800, provides a regulatory framework for the identification, documentation, and evaluation of historic and cultural resources that may be affected by Federal undertakings. Under the act, Federal agencies must take into account the effects of their undertakings on historic properties, including resources that are listed or are eligible for listing in the National Register of Historic Places, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on such undertaking. Additionally, a Federal agency shall consult with any tribe that attaches religious and cultural significance to such properties.

After reviewing the changes in operations, maintenance, and configuration proposed as a part of the Preferred Alternative, the co-lead agencies have determined that the existing Systemwide Programmatic Agreement (SWPA) would cover the co-lead agencies' responsibilities under the National Historic Preservation Act Section 106 for all proposed operations, and many structural measures, under the Preferred Alternative. For proposed structural measures not covered by the SWPA, separate Section 106 compliance would be completed prior to construction, when sufficient, site-specific information on the undertaking becomes available.

8.4.2 Archaeological Resources Protection Act

The Archaeological Resources Protection Act (ARPA) of 1979 (16 U.S.C. §§ 470aa–470mm; Public Law 96-95, as amended) protects archaeological resources and sites on public and Indian lands and fosters increased cooperation and exchange of information between governmental authorities, the professional archaeological community, and private individuals. The act established civil and criminal penalties for the destruction or alteration of cultural resources.

Unlike the National Historic Preservation Act, ARPA does not have a general consultation requirement. Therefore, there is nothing specifically that the co-lead agencies would need to do as a part of considering these changes in operations, maintenance, or configurations. In the case of some of the proposed MOs, agencies may need to adjust their monitoring of archaeological resources to see if changes in operations increase the amount of intentional destruction, alteration, or unpermitted artifact collection by leaving the sites more exposed. For all the MOs except MO3, this monitoring could be accommodated within the existing FCRPS Cultural Resources Program. In the case of MO3, where the return of the lower Snake River to pre-reservoir conditions would likely expose hundreds of sites inundated since the late 1960s and early 1970s, additional law enforcement patrols would likely be needed in order to deter unpermitted artifact collection or other acts prohibited under ARPA. Under the Preferred Alternative, the primary land managing co-lead agencies (Reclamation, Corps) would continue to issue ARPA-related permits to outside project proponents for any professional investigations related to known archaeological sites, or surveys for unknown archaeological sites/items, occurring on their respectively managed Federal land.

8.4.3 Antiquities Act

The Antiquities Act of 1906 (54 U.S.C. §§ 320301–320303; Public Law 59-209) gives the President of the United States authority to create national monuments to protect important natural, cultural, or scientific features and resources. The act requires a permit be issued from the secretary of the department with land management responsibilities prior to any excavation of archaeological material. It further requires all material excavated as a result of an Antiquities Permit be properly housed in a museum or facility. This act is considered to be the beginning of a long tradition of cultural resources management and protection by the Federal government.

The majority of archaeological permitting now occurs under ARPA (see above), and the co-lead agencies do not anticipate taking any specific actions regarding implementation of the Antiquities Act as a part of developing this EIS, as none of the actions will likely involve specific Antiquities Act permitting actions or involve the creation of any national monuments.

8.4.4 Native American Graves Protection and Repatriation Act

The Native American Graves Protection and Repatriation Act (25 U.S.C. §§ 3001–3013; Public Law 101-601) describes the rights of Native American lineal descendants, Indian tribes, and Native Hawaiian organizations with respect to the treatment, repatriation, and disposition of Native American human remains, funerary objects, sacred objects, and objects of cultural patrimony, with which they can show a relationship of lineal descent or cultural affiliation.

This act does lay out a consultation process between Federal agencies and tribes, but these consultations are focused on how the agencies will handle human remains and other funerary and associated items in the event they are subsequently discovered. There is not a general consultation requirement triggered by changes in operations, maintenance, or configuration under the Preferred Alternative. The existing Cultural Resources Program maintained by the co-lead agencies addresses discoveries of human remains and works to repatriate remains and associated funerary objects currently held in museums, and those activities would continue under the Preferred Alternative.

8.4.5 American Indian Religious Freedom Act

The American Indian Religious Freedom Act of 1978 (AIRFA) (42 U.S.C. § 1996) establishes protection and preservation of Native Americans' rights of freedom of belief, expression, and exercise of traditional religions. These rights include, but are not limited to, access to sacred sites, freedom to worship through traditional ceremonial rites, and the possession and use of objects traditionally considered sacred by their respective cultures. The act requires policies of all governmental agencies to accommodate access to, and use of, Native American religious sites to the extent that the use is practicable and is consistent with an agency's essential missions.

The co-lead agencies do not anticipate taking any actions under the Preferred Alternative that would infringe upon the rights afforded under the AIRFA to area Native American tribes. The co-lead agencies would continue to consult and work with area tribes to protect and provide access to sacred sites on CRS Federal lands, when possible and practicable to do so.

8.4.6 Paleontological Resources Preservation Act

The Paleontological Resources Preservation Act (PRPA) was passed in 2009 as a part of the Omnibus Public Land Management Act of 2009 (16 U.S.C. §§ 470aaa - 470aaa-11; Public Law 111-11). PRPA directs the Department of Agriculture (U.S. Forest Service) and the Department of the Interior (National Park Service, Bureau of Land Management, Reclamation, and USFWS) to implement comprehensive paleontological resource management programs. It does not apply to Department of Defense lands. While opening some Federal lands to casual collecting, PRPA makes it clear that collection of vertebrate fossils from Federal land will be done under the terms of a permit only. It criminalizes collection of some paleontological resources without a permit, and also establishes civil penalties. The U.S. Forest Service has already adopted regulations implementing PRPA for use on their lands, and the Department of the Interior is nearing finalization of their regulations. Under the Preferred Alternative, Reclamation will continue to manage and protect paleontological resources as necessary.

8.4.7 Curation of Federally Owned and Administered Collections

Specific federal regulations, 36 C.F.R. Part 79 (16 U.S.C. §§ 470aa-mm, 16 U.S.C. § 470 et seq.) were promulgated by the National Park Service to create standards and guidelines for the long-term preservation and management of archaeological collections. This includes all collections recovered under the authority of the Antiquities Act (16 U.S.C. §§ 431-433), the Reservoir Salvage Act (16 U.S.C. §§ 469-469c), Section 110 of the National Historic Preservation Act (16 U.S.C. § 470h-2), or ARPA (16 U.S.C. §§ 470aa-mm). Under the Preferred Alternative, the co-lead agencies would continue to implement the existing Cultural Resources Program which ensures the ongoing responsibility of managing Federal archaeological collections generated from Federal lands as a result of project construction, operations, and maintenance.

8.5 CLEAN WATER ACT OF 1972

The Federal Water Pollution Control Act of 1972 (33 U.S.C. § 1251 et seq.) is more commonly referred to as the Clean Water Act (CWA). This act is the primary legislative vehicle for Federal pollution control programs and the basic structure for regulating discharges of pollutants into waters of the U.S. The CWA was established to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." The CWA sets goals to eliminate discharges of pollutants into navigable waters, protect fish and wildlife, and prohibit the discharge of toxic pollutants in quantities that could adversely affect the environment. The sections of the CWA that may apply to the Preferred Alternative are Section 401, regarding state water quality certifications that existing water quality standards would not be violated if a Federal permit that causes discharges into navigable waters were issued; Section 402, regarding discharges of pollutants from point sources under the National Pollutant Discharge Elimination System (NPDES); and Section 404, regarding fill material discharged into the waters of the U.S., including wetlands.

Section 401 water quality certifications would be obtained for project-specific structural measures, as required, prior to construction. Section 402 of the CWA also established the national pollutant discharge elimination system for permitting point-source discharges to waters of the U.S. The Corps and Reclamation have filed applications for Clean Water Act, Section 402 permits for nine mainstem dams on the Columbia and Snake Rivers. The permits are intended to regulate discharges of pollutants, including lubricants and heat additions from cooling water, from point sources at these dams. The permit applications have been pending since 2015, but no permits to date have been issued by the EPA or Oregon Department of

Environmental Quality. Compliance with Section 404 would be conducted prior to construction of the project-specific structural measures, if needed.

The Spill Prevention Control and Countermeasures Rule (40 C.F.R. Part 112) includes requirements to prevent discharges of oil and oil-related materials from reaching navigable waters and adjoining shorelines. It applies to facilities with total aboveground oil storage capacity (not actual gallons onsite) of greater than 1,320 gallons and facilities with belowground storage capacity of 42,000 gallons. Construction activities associated with the structural measures would comply with this rule in implementing the MOs, if needed.

8.6 CLEAN AIR ACT OF 1972

The Clean Air Act, as amended (42 U.S.C. § 7401, et seq.), requires EPA and the states to carry out programs intended to ensure attainment of National Ambient Air Quality Standards (NAAQS). EPA is authorized to establish air quality standards for six "criteria" air pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter ($PM_{2.5}$, PM_{10}), and sulfur dioxide. EPA uses these six criteria pollutants as indicators of air quality. EPA has established NAAQS for each criteria pollutant, which defines the maximum allowable concentration. If the standard for a pollutant is exceeded, adverse effects on human health may occur. When an area exceeds these standards, it is designated as a nonattainment area.

The General Conformity Requirements of the C.F.R. require that Federal actions do not interfere with state programs to improve air quality in nonattainment areas. There are several nonattainment areas in the study area, as well as several maintenance areas. Currently, the only nonattainment areas in the region are for $PM_{2.5}$ (in Oakridge County, Oregon; West Silver Valley, Idaho; and Libby, Montana), and PM_{10} (in Lane County, Oregon; Fort Hall Indian Reservation, Idaho; and multiple counties in Montana).

Of the six criteria air pollutants, PM is the main concern for the activities associated with the operation and maintenance of the CRS, including construction and navigation. PM_{10} are particles with an aerodynamic diameter smaller than 10 micrometers and include "dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust" (EPA 2003). $PM_{2.5}$ are "fine particles" with an aerodynamic diameter smaller than 2.5 micrometers. $PM_{2.5}$ particles can be "directly emitted from sources such as forest fires or they can form when gases emitted from power plants, industry and automobiles react in the air" (EPA 2006).

In the study area, authority for ensuring compliance with the Clean Air Act is delegated to the Washington Department of Ecology, Southwest Region; the Oregon DEQ; the Montana DEQ; and the Idaho DEQ. Each agency has regulations requiring all industrial activities (including construction projects) to minimize windblown fugitive dust through prevention of fugitive dust becoming airborne and by maintaining and operating sources to minimize emissions: Revised Code of Washington, Chapter 70.94 (Washington Clean Air Act) and Washington Administrative Code, Chapter 173.400 (general regulations for air pollution sources); Oregon Revised Statutes, Chapter 468a (Oregon air quality statutes) and Oregon Administrative Rules, Divisions 200–268

(Oregon air quality rules); Idaho Administrative Procedures Act 58.01.01, et seq. (Idaho air quality rules for control of air pollution in Idaho); and Montana Code Annotated 75-2-101, et seq. (Montana).

Consistent with Chapter 3, due to the reduction in hydropower generation, air quality under the Preferred Alternative would most likely be degraded slightly, and greenhouse gas (GHG) emissions would most likely increase by an estimated 0.54 metric ton per year (or 0.33 percent) across the Western Interconnection. In the Pacific Northwest region, GHG emissions would increase by 0.26 million metric ton (or 0.70 percent) compared to the No Action Alternative. Other emissions sources (e.g., navigation, construction, fugitive dust) are most likely to have a negligible effect on air quality and GHG emissions relative to the No Action Alternative across the basin. Effects to air quality are expected to be negligible across the basin, including any potential impacts to nonattainment or maintenance areas. Most effects related to construction activities at the projects are expected to be temporary and short term.

Based on available information, however, the effects from the Preferred Alternative on air quality and greenhouse gases (GHG) suggest air quality would have negligible adverse effects based on increased GHG emissions from the replacement power for hydropower generation. Other emissions sources (e.g., construction, fugitive dust) are likely to have a negligible effect on air quality and GHG emissions and are expected to be temporary and short-term.

Consistent with Chapter 6, the co-lead agencies determined Reasonably Foreseeable Future Actions (RFFAs) 1, 3, 4, 5, and 20 would likely impact air quality and GHG emissions. Overall, hydropower generation would decrease under the Preferred Alternative, and climate change is likely to add additional uncertainty to the annual magnitude of generation, and uncertainty to the monthly magnitude. This reduction in hydropower combined with RFFAs, such as increased human development and resulting demand for energy, could lead to a minor cumulative impact on air quality and GHG emissions.

8.7 FARMLAND PROTECTION POLICY ACT

The Farmland Protection Policy Act (7 U.S.C. § 4201 et seq.; 7 C.F.R. Part 658) of 1981 was authorized to minimize the unnecessary and irreversible conversion of farmland to nonagricultural use due to Federal projects. This act protects Prime and Unique farmland, and land of statewide or local importance. The Farmland Protection Policy Act protects forestland, pastureland, cropland, or other land that is not water or urban developed land. The Farmland Protection Policy Act requires a Federal agency to consider the effects of its actions and programs on the Nation's farmlands. This act is implemented by the Natural Resources Conservation Service (NRCS). The NRCS is authorized to review Federal projects to see if the project is regulated by the Farmland Protection Policy Act and establish what the farmland conversion impact rating is for a Federal project.

The co-lead agencies would coordinate with NRCS, as appropriate, prior to construction of any new structural measures under the Preferred Alternative, if needed.

8.8 FEDERAL NOXIOUS WEED ACT

This act, as amended in 2009, directs Federal agencies to manage undesirable plant species on Federal lands when management programs for those species are in place on state or private land in the same area. Undesirable plant species are defined as those that are classified as undesirable, noxious, harmful, exotic, injurious, or poisonous, pursuant to state or Federal law. A noxious weed list (7 C.F.R. § 360.200) is developed by the Secretary of Agriculture, which lists noxious weeds (as defined by the Plant Protection Act) that are subject to restrictions on interstate movement (7 U.S.C. § 7712). Construction activities associated with the structural measures would comply with this statute in implementing the Preferred Alternative, if needed. In addition, the existing invasive species management plans would continue under the Preferred Alternative.

8.9 RECREATION RESOURCES

8.9.1 Federal Water Project Recreation Act

In the planning of any Federal navigation, flood control, reclamation, or water resources project, the Federal Water Project Recreation Act, as amended (16 U.S.C. § 460l-12 et seq.) requires that full consideration be given to the opportunities that the project affords for outdoor recreation and fish and wildlife enhancement. The act requires planning with respect to development of recreation potential. Projects must be constructed, maintained, and operated in such a manner if recreational opportunities are consistent with the purpose of the project.

Effects to recreation analyzed for the Preferred Alternative are described in Section 7.7.

8.9.2 Wild and Scenic Rivers Act

The Wild and Scenic Rivers Act (16 U.S.C. § 1271 et seq.) establishes a National Wild and Scenic Rivers System to preserve, protect, and enhance the wilderness qualities, scenic beauties, and ecological regimes of rivers and streams. Any construction within 100 feet of a scenic stream requires a scenic streams permit.

The Preferred Alternative would not affect any wild and scenic rivers because there are no wild and scenic river sections in the CRS.

8.10 RIVERS AND HARBORS APPROPRIATION ACT OF 1899

Section 10 of the Rivers and Harbors Appropriation Act of 1899 (33 U.S.C. § 403 et seq.), commonly known as the Rivers and Harbors Act, prohibits the construction of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structures in any navigable water without Congressional consent or approval by the Corps. Section 10 regulates structures in or over any navigable water of the U.S., the excavating from or depositing of material in such waters, or the accomplishment of any other work affecting the course, location, condition, or capacity of such waters. Section 9 of the Rivers and Harbors Act (33 U.S.C. § 491) grants the authority to approve the construction or modification of bridges over any of the navigable waters of the U.S. to the U.S. Coast Guard. The Columbia River and its major tributaries, Snake, Clark Fork, and Kootenai Rivers, are designated navigable waters under the Rivers and Harbor Act.

Effects to navigable waters from the Preferred Alternative are described in Section 7.7. A determination of whether a Section 9 or 10 permit would be required will be made prior to construction of the project-specific structural measures. It is not anticipated that the co-lead agencies would need to obtain a Section 9 permit from the U.S. Coast Guard.

8.11 HAZARDOUS WASTE

8.11.1 Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended (42 U.S.C. § 9601 et seq.), which was later amended by the Superfund Amendments and Reauthorization Act of 1986, sets forth regulations for cleanup of hazardous substances after improper disposal; identifies federal response authority; and outlines responsibilities and liabilities of potentially responsible parties, who are past/present owners or operators of the site, a person who arranged disposal of hazardous substances at a site, or a person who transported hazardous substances to a site they selected for disposal. CERCLA also specifies where Superfund money can be used for site cleanup.

Any hazardous waste generated from the implementation of the Preferred Alternative would be properly disposed of, in accordance with applicable Federal and state laws. If contamination is found during the operations, maintenance, or construction activities associated with the Preferred Alternative, the co-lead agencies will comply with CERCLA.

8.11.2 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act, as amended (42 U.S.C. § 6901 et seq.), is designed to provide a program for managing and controlling hazardous waste by imposing requirements on generators and transporters of this waste, and on owners and operators of treatment, storage, and disposal facilities. Each treatment, storage, and disposal facility owner or operator is required to have a permit issued by EPA or the state. Construction, operation, and maintenance activities at the CRS projects could generate hazardous wastes under the Preferred Alternative. These materials would be disposed of according to the Resource Conservation and Recovery Act and applicable state law.

8.11.3 Toxic Substances Control Act

The Toxic Substances Control Act (15 U.S.C. § 2601 et seq.) is intended to protect human health and the environment from toxic chemicals. Section 6 of the act regulates the use, storage, and disposal of polychlorinated biphenyls (PCBs). Any equipment that may have PCBs that is removed from the CRS projects as part of the implementation of the Preferred Alternative will be handled according to the disposal provisions of the Toxic Substances Control Act.

8.12 EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

Executive Order 11990, dated May 24, 1977, requires Federal agencies to take action to avoid adversely impacting wetlands wherever possible, to minimize wetland destruction and preserve the values of wetlands, and to prescribe procedures to implement the policies and procedures of this executive order. In addition, Federal agencies shall incorporate floodplain management goals and wetlands protection considerations into its planning, regulatory, and decision-making processes.

Prior to any construction activities associated with the new structural measures of the Preferred Alternative, wetland surveys would be conducted to determine if there are any wetlands that would be affected. If wetlands are identified, applicable best management practices and mitigation would be implemented.

As part of the NEPA review, DOE NEPA regulations require that effects on wetlands be assessed and alternatives for protection of these resources be evaluated in accordance with the Compliance with Floodplain/Wetlands Environmental Review Requirements (10 C.F.R. § 1022.12) and Executive Order 11990 (Protection of Wetlands). An evaluation of effects of the MOs and Preferred Alternative on wetlands is discussed in more detail in Sections 3.6.3 and 7.6 of this EIS. Mitigation measures to address impacts to wetlands are found in Chapters 5 and 7.

8.13 EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT

Executive Order 11988, dated May 24, 1977, states that each Federal agency shall take action to reduce the risk of flood loss, minimize the impacts of floods on human safety, and restore and preserve the natural values of floodplains while carrying out its responsibilities for (1) acquiring, managing, and disposing of Federal lands; (2) providing Federal investments in construction and improvements; and (3) conducting activities affecting land use, including water resources planning and regulating activities. To comply with this order, each Federal agency has a responsibility to evaluate the potential effects of any actions it may take in the floodplain, to ensure its planning programs consider flood hazards and floodplain management, and to implement the policies and requirements of the order.

For the Preferred Alternative, no increase in flood risk is expected due to future operations, though decreases in flood risk may occur in some areas. The operational, maintenance, and system configuration measures considered in the MOs do not propose or support physical actions in floodplains, nor are they likely to induce development.

As part of the NEPA review, DOE NEPA regulations require that impacts on floodplains be assessed and alternatives for protection of these resources be evaluated in accordance with the Compliance with Floodplain/Wetlands Environmental Review Requirements (10 C.F.R. § 1022.12) and Executive Order 11988 (Floodplain Management). An evaluation of impacts of the

MOs on floodplains is discussed in more detail in Section 3.6.3 of this EIS. Mitigation measures to address impacts to floodplains are found in Chapters 5 and 7. As directed by the DOE regulations at 10 C.F.R. § 1022, the Floodplain Statement of Findings is provided in Section 3.6 of the EIS and would be documented in Bonneville's Record of Decision.

8.14 EXECUTIVE ORDER 12898, ENVIRONMENTAL JUSTICE

Executive Order 12898, dated February 11, 1994, requires Federal agencies to consider whether agency actions may have disproportionately high and adverse human health or environmental effects on minority populations, low-income populations, and Indian tribes. For the purpose of Executive Order 12898, minority populations include people of the following origins: African-American, American Indian and Alaska Native, Native Hawaiian or Other Pacific Islander, and Hispanic (of any race). Low-income populations are populations that are at or below the poverty line, as established by the U.S. Department of Health and Human Services.

Based on the discussion, analysis, and mitigation described in Chapters 3, 4, 5, 6, and 7, the Preferred Alternative would not cause disproportionately high and adverse effects on any environmental justice populations in accordance with the provisions of Executive Order 12898.

8.15 EXECUTIVE ORDER 13112, INVASIVE SPECIES, SAFEGUARDING THE NATION FROM THE IMPACTS OF INVASIVE SPECIES

Executive Order 13112, dated February 3, 1999, as amended December 5, 2016, under Executive Order 13751 establishes "the policy of the United States to prevent the introduction, establishment, and spread of invasive species, as well as to eradicate and control populations of invasive species that are established." Under this executive order, Federal agencies are required to employ integrated pest management practices to prevent the introduction and spread of invasive species and provide for the restoration of ecosystems that have been invaded. Under the Preferred Alternative, the existing invasive species management plans would continue.

8.16 EXECUTIVE ORDER 13007, INDIAN SACRED SITES

Executive Order 13007, dated May 24, 1996, directs Federal agencies to accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners. To the extent practicable, permitted by law, and not clearly inconsistent with essential agency functions, the co-lead agencies are to avoid adversely affecting the physical integrity of such sacred sites and to maintain the confidentiality of sacred sites when appropriate. The order encourages government-to-government consultation with tribes concerning sacred sites. Some sacred sites may qualify as historic properties under the National Historic Preservation Act.

Pursuant to the order, the co-lead agencies for the CRSO EIS contacted 19 tribes to request their assistance in identifying scared sites within the study area. Kettle Falls and Bear Paw Rock have been identified as sacred sites. The effects to these sacred sites under the Preferred Alternative are negligible as described in Section 7.7.

8.17 EXECUTIVE ORDER 11593, PROTECTION AND ENHANCEMENT OF THE CULTURAL ENVIRONMENT

Executive Order 11593, dated May 13, 1971, directs Federal agencies to provide leadership in preserving, restoring, and maintaining the historic and cultural environment of the Nation. The co-lead agencies are addressing compliance with Executive Order 11593 by complying with the National Historic Preservation Act.

8.18 EXECUTIVE ORDER 13175, CONSULTATION AND COORDINATION WITH INDIAN TRIBAL GOVERNMENTS

The United States has a unique legal relationship with Indian tribal governments as set forth in the Constitution of the United States, treaties, statutes, executive orders, and court decisions. This order directs federal agencies to formulate and establish “regular and meaningful consultation and collaboration with tribal officials in the development of federal policies that have tribal implications, to strengthen the United States government-to-government relationships with Indian tribes, and to reduce the imposition of unfunded mandates upon Indian tribes.” This consultation is meant to work toward a mutual consensus and is intended to begin at the earliest planning stages, before decisions are made and actions are taken.

Consistent with this executive order, the co-lead agencies established a three-tiered process in coordination with all 19 federally recognized tribes potentially affected by operations and maintenance of the CRS. The three tiers include staff-level technical meetings and information sharing, deputy-level policy meetings, and executive-level government-to-government meetings. Throughout development of the CRSO EIS, all three tiers of meetings were used on a regular basis to facilitate meaningful consultation. Additionally, each tribe was informed of the opportunity to request government-to-government consultation with co-lead agency leadership anytime they believed it was necessary.

8.19 SECRETARIAL ORDER 3175, U.S. DEPARTMENT OF THE INTERIOR RESPONSIBILITIES FOR INDIAN TRUST ASSETS

Secretarial Order 3175 requires U.S. Department of the Interior bureaus and offices to consult with the recognized tribal government with jurisdiction over the trust property that a proposal may affect and ensure that any anticipated effects are explicitly addressed in planning, decision, and operational documents including EISs. In compliance with Secretarial Order 3175, this EIS has analyzed potential effects to Indian Trust Assets in Sections 3.17 and 7.7.

CHAPTER 9 - COORDINATION AND PUBLIC INVOLVEMENT PROCESS

The Council on Environmental Quality's implementing regulations for the National Environmental Policy Act (NEPA) specify public involvement requirements for preparing an environmental impact statement (EIS). In response to those requirements, the co-lead agencies implemented a comprehensive public involvement plan that identified and coordinated an array of public involvement opportunities for the public to provide the co-lead agencies with information that would help define the issues, concerns, and the scope of alternatives to be addressed in the EIS. Due to the geographical scope and wide array of interests associated with the Columbia River System (CRS), the public involvement process required considerable time and resources to ensure meaningful engagement. Government-to-government consultations with tribal sovereigns and coordination with regional governments also were an integral part of the coordination process.

During the public scoping period, the co-lead agencies offered numerous educational opportunities to the public that were aimed at helping interested parties understand how the CRS currently operates. Columbia River Basin residents were encouraged to take advantage of open-house public scoping meetings to learn more about the NEPA process and about the way the co-lead agencies currently operate the CRS. Public meetings, outreach, and an interactive project website offered the public multiple opportunities to provide scoping comments that could help define the issues, concerns, and thoughts on system operations for consideration in the EIS. The co-lead agencies reviewed, evaluated and incorporated feedback from public involvement into the EIS.

Furthermore, the co-lead agencies used various communication tools throughout the process to share progress made on the EIS and build an understanding of the NEPA process. The following sections lay out the various components of the outreach efforts undertaken throughout the NEPA process for the development of this EIS.

9.1 FEDERAL REGISTER NOTICES AND PUBLIC SCOPING MEETINGS

9.1.1 Notice of Intent and Public Scoping Meetings

The Notice of Intent (NOI) to prepare the EIS provided a summary of the intent of the co-lead agencies to prepare an EIS, established a schedule of public meetings, and provided points of contact for each of the co-lead agencies. The co-lead agencies published the NOI in the Federal Register on September 30, 2016 (81 Federal Register 67,382). That same day, the co-lead agencies sent public scoping letters to interested parties and placed an announcement on the Columbia River System Operations (CRSO) website, www.crso.info. The public involvement team also distributed a news release announcing the NOI and provided dates, times, and venues for the public scoping meetings. The NOI invited anyone interested to help the co-lead agencies identify issues and concerns to be analyzed in the EIS. As stated in the NOI, the co-lead agencies used the public scoping process to gather comments on the preservation of historic properties subject to consideration under the National Historic Preservation Act.

The co-lead agencies held 16 public scoping meetings across the region and two webinars during public scoping to allow the public to ask questions in person and contribute their comments and ideas on what should be included in the EIS. The scoping comment period, which began September 30, 2016, was originally scheduled to end on January 17, 2017 (81 Federal Register 67,383). However, at the request of interested stakeholders, the co-lead agencies extended the comment period by three weeks to February 7, 2017 (82 Federal Register 137 [January 3, 2017]). Additionally, the co-lead agencies received a request to hold a public meeting in the Tri-Cities area of Washington State. The co-lead agencies considered the request and added a meeting in Pasco, Washington. The NOI for the Pasco meeting was published in the Federal Register on November 4, 2016 (81 Federal Register 214 [November 4, 2016]). The Scoping Report ("Public Scoping Report for the Columbia River System Operations Environmental Impact Statement," Appendix S [Scoping Report]) includes these NOIs, as well as detailed descriptions, times, and locations of scoping meetings.

The scoping meetings were held in an informal open-house format, with 35 poster stations staffed by technical experts from the co-lead agencies. The style of meeting was chosen to provide attendees an opportunity to ask questions, to have informal one-on-one discussions with various subject matter experts, and to comment after reviewing information about the CRS and how it is currently operated. All materials from the public meetings were available on the CRSO website so that participants could review and comment.

Two webinars were held on December 13, 2016, to accommodate individuals who were not able to attend one of the public meetings in person. The online webinars were staffed by subject matter experts who presented the same visual material provided during the open-house public meetings. Through the webinars, the public was able to submit questions and comments.

An interdisciplinary team from the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration attended all public scoping meetings to provide subject matter expertise. This included resource areas of the NEPA process, such as cultural resources, CRS operations, flood risk management, hydropower, water supply, navigation, fish and wildlife conservation, recreation, climate change, water quality, and endangered species. Project-specific experts representing each of the 14 projects were also available at each meeting to discuss features and operations of a specific dam or reservoir complex.

Meeting attendees were invited to submit public scoping comments at the meeting in numerous ways, including: (1) verbally through a stenographer, (2) online at a computer station, or (3) in hard copy form. Attendees were also advised that they could review all scoping materials, including the video, online. Public scoping attendees could submit comments via email, online using a prepared webform, or via a hard copy mailed to a post office box established specifically to collect scoping comments for this project. All meeting materials and all comments submitted during the scoping period can be viewed online at www.crso.info.

9.1.2 Public Scoping Comments

While over 2,300 people signed in at the public scoping meetings, the co-lead agencies received over 400,000 comments that reflected the full breadth and scope of most issues present in the basin. Of those, approximately 61,000 were considered unique comments. The Scoping Report was produced and made available to the public on October 24, 2017. The Scoping Report is included as Appendix S to the EIS and can be found on the project website at https://www.nwd.usace.army.mil/CRSO/SSR/.

The list of scoping comment topics included:

- NEPA Process
- Public Scoping Process
- Alternatives
- Scope of Analysis
- Impact Analysis Methodologies
- Hydrology and Hydraulics
- Climate Change
- Water Quality
- Water Supply
- Air Quality
- Anadromous and Resident Fish
- Threatened and Endangered Fish Species – Dam Configuration and Operation
- Wildlife
- Wetlands and Vegetation
- Invasive and Nuisance Species
- Cultural and Historic Resources
- Tribal Interests/Resources
- Flood Risk Management
- Power Generation/Energy
- Power Transmission
- River Navigation
- Transportation of Goods and Fish
- Recreation
- Socioeconomics and Environmental Justice
- General Opposition to EIS Development
- General Support of EIS Development

9.2 PUBLIC COMMUNICATION TOOLS

9.2.1 News Releases

The co-lead agencies issued numerous press releases intended to keep the public informed about the EIS public scoping process. The press releases also were provided on the CRSO website (https://www.nwd.usace.army.mil/CRSO/CRSO-News/). Each public meeting was announced in at least two local newspapers, with advertisements running two to three times beginning approximately two weeks prior to the meeting.

9.2.2 Mailing Lists

As indicated earlier, public scoping meeting attendees were invited to sign up for future communications about the EIS. Mailing lists were developed and maintained throughout the life of the NEPA process. Respondents were then categorized for the most efficient means for distributing information and for tailoring specific communication needs. For example, media outlets often have a general inbox for receiving news releases. While news releases were distributed to media outlets throughout the region, co-lead agency communicators would then send a copy of the news release to those reporters who signed up to receive the news release, ensuring they received it in a timely manner.

9.2.3 Website

A public website was established at the time the NOI was published to communicate and share information about the CRSO EIS: www.crso.info. The website announced public scoping meeting dates, times, and locations in addition to providing all the information shared during the public scoping meetings (e.g., overview video and posters). The public could also use the comment submission link on the website to submit comments during the public comment period. News releases, documents, and upcoming public meeting information were available to the public through the website.

9.2.4 Newsletters

Co-lead agencies produced and distributed newsletters and featured stories, such as about the NEPA process, project articles, fish passage, resources evaluated for EIS, and introducing a range of alternatives. The co-lead agencies used mailing lists and the website as the primary mechanisms for communicating with the public. Doing so allowed for timely distribution of information. All products are available on the www.crso.info website and were delivered electronically to the mailing list.

9.2.5 Webinars

Webinars offered direct contact with the public without the need for interested parties to travel to interact with the co-lead agencies. The co-lead agencies held three stakeholder meetings in October 2017 and public updates were held on December 7, 2017, and May 30, 2018. Some webinars, such as the webinar held on December 7, 2017, used a combination of in-person presentations with others participating by web interaction—an attempt to reach as many people as possible at one time. These webinars allowed for subject matter experts and policy leads to engage with the public.

9.2.6 Videos

Two videos have been produced and posted on the website (https://www.nwd.usace.army.mil/CRSO/Documents/) for audiences to view. The first video was used as an introduction to the public scoping meetings. The second video was produced to walk interested audiences through the range of alternatives and what to expect.

9.3 FEDERALLY RECOGNIZED TRIBES AND TRIBAL ENTITIES

Executive Order No. 13175, *Consultation and Coordination with Indian Tribal Governments,* calls for regular and meaningful consultation and collaboration with tribal officials in the development of Federal policies that have tribal implications and for strengthening government-to-government relationships between the United States and tribal governments. The co-lead agencies committed from the outset to consult with federally recognized tribes throughout the process. The co-lead agencies engaged with tribes in technical-level coordination, regional tribal meetings, and formal government-to-government consultation. The co-lead agencies also worked closely with tribal entities, which include multiple tribes, such as the Upper Snake River Tribes, Columbia River Intertribal Fish Commission, and the Upper Columbia United Tribes. Furthermore, tribes were able to request technical or formal government-to-government meetings at any time.

9.3.1 Tribal Engagement During Public Scoping

The co-lead agencies held a kickoff meeting to initiate discussions with potentially affected tribes during the Affiliated Tribes of Northwest Indians 2016 Annual meeting on September 28, 2016. They discussed the overall NEPA process, proposed tribal consultation, and schedule.

As part of the co-lead agencies' CRSO EIS tribal outreach, four regional tribal meetings were scheduled and took place the same days and locations as the public scoping meetings. The same content and subject matter experts were available at both the tribal and public meetings. Tribal members were welcome to attend any of the regional tribal meetings, as well as any of the public scoping meetings.

Regional tribal outreach meetings were held:

- November 14, 2016, in Spokane, Washington
- November 29, 2016, in Boise, Idaho
- December 6, 2016, in The Dalles, Oregon
- December 7, 2016, in Portland, Oregon

9.3.2 Government-to-Government Consultation and Tribal Engagement

As previously stated, part of the government's treaty and trust responsibilities is for the Federal government to consult on a government-to-government basis with Indian tribes. The government-to-government relationship and the process for developing open and transparent communication, effective collaboration, and informed Federal decision-making is described in Executive Order (EO) 13175, *Consultation and Coordination with Indian Tribal Governments*; EO 13007, *Indian Sacred Sites*; Secretarial Order 3206, *American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act*; the November 5, 2009, *Presidential Memorandum on Tribal Consultation*; and the April 29, 1994, *Presidential Memorandum on Government-to-Government Relations with Native American Tribal Governments.* In addition, Section 106 of the National Historic Preservation Act requires Federal agencies to consult with Indian tribes on undertakings on tribal lands and on historic properties of significance to the tribes that may be affected by an undertaking (36 Code of Federal Regulations [C.F.R.] § 800.2 (c)(2)). The co-lead agencies coordinated and consulted with tribal governments and engaged with tribal leaders and their staff whose interests might be affected by activities proposed in the CRSO EIS.

Government-to-government consultation was conducted throughout development of this EIS, in accordance with provisions included in the executive orders and secretarial orders listed above, and any additional applicable laws, as well as agency-specific regulations and guidance, such as the following:

- DOI, Departmental Manual (DM), *Departmental Responsibilities for Indian Trust Resources*, 512 DM 2 (1995)
- DOI, Departmental Manual, *Departmental Responsibilities for Protecting/Accommodating Access to Indian Sacred Sites*, 512 DM 3 (1998)
- Bonneville Power Administration Tribal Policy, DOE-BP/2971 (Revised 2016)
- 33 C.F.R. § 230.16 on Lead and Cooperating Agencies
- U.S. Department of Energy, 10 C.F.R. § 1021.342 on Interagency Cooperation

At the outset of the EIS, tribes were formally invited to enter into government-to-government consultation on the CRSO EIS. The letters, sent by the co-lead agencies, provided notification of the intent to prepare the CRSO EIS; initiated government-to-government consultation; and invited the tribes to identify concerns related to historic properties, including traditional cultural properties and archaeological sites, natural resources, relevant Indian Trust Assets, and other issues of importance.

In addition to tribal engagement, some tribes decided to engage in the NEPA process as cooperating agencies by entering into memoranda of understanding (MOUs) with the co-lead agencies. Tribes were offered opportunities to participate through a variety of venues. The amount of information that could be shared with tribes depended on whether the tribe was a cooperating agency and whether the information request came through a request to the co-lead agency or not. In addition, there were numerous other interactions ranging from one-on-one phone calls to technical teams to special briefings.

A description of the three tiered tribal engagement levels (technical, deputy or policy, and executive) is provided in Chapter 1.5.2.3. There were numerous technical level webinars and meetings held throughout the process to discuss scoping, alternatives development, and evaluation, as well as one-on-one meetings held to address technical considerations. Deputy and executive level regional tribal meetings were also offered to consult with individual tribes, designated as one-on-one engagements, following each regional meeting. Webinars and tribal regional meetings were open to all 19 tribes. Below is a list of organized meetings that took place throughout the NEPA process where tribes could participate in discussions about EIS development.

Deputy Level Meetings

- August 9, 2017, in Boise, Idaho
- August 10, 2017, in Spokane, Washington
- August 17, 2017, in The Dalles, Oregon
- August 18, 2017, in Portland, Oregon
- June 11, 2018, in Portland, Oregon
- June 12, 2018, in Spokane, Washington
- June 13, 2018, in Boise, Idaho

- February 2, 2019, in Grand Ronde, Oregon
- March 20, 2019, in Portland, Oregon
- April 9, 2019, in Spokane, Washington

Executive Level Meetings

- August 30, 2017, in Spokane, Washington
- August 31, 2017, in Portland, Oregon
- January 9, 2019, in Boise, Idaho
- January 10, 2019, in Spokane, Washington
- January 17, 2019, in Portland, Oregon
- November 5, 2019, in Portland, Oregon
- November 6, 2019, in Spokane, Washington
- November 7, 2019, in Boise, Idaho
- December 19, 2019, in Lapwai, Idaho

9.4 COOPERATING AGENCIES

On November 4, 2016, in accordance with Title 40 C.F.R. § 1501.6 of the Council on Environmental Quality's regulations for implementing NEPA and 43 C.F.R. § 46.225 of DOI's regulations for implementing NEPA, the co-lead agencies invited Federal, tribal, state, and local government agencies with jurisdiction over resources or areas of special expertise to participate in the development of the EIS as cooperating agencies. This was so that sovereign entities with special expertise or jurisdiction concerning the proposal, or both, could assist the co-lead agencies with various parts of EIS development. The cooperating agencies signed MOUs with the co-lead agencies to assist in the EIS development and are listed in Table 9-1.

Table 9-1. Columbia River System Operations Environmental Impact Statement Cooperating Agencies

Cooperating Agencies
Federal Agencies
U.S. Environmental Protection Agency, Region 10
U.S. Coast Guard, 13th Coast Guard District
U.S. Department of the Interior, Bureau of Indian Affairs
State Agencies
Idaho
Governor's Office of Species Conservation[1/]
Governor's Office of Energy and Mineral Resources
Department of Fish and Game
Department of Agriculture
Department of Lands
Department of Environmental Quality
Historic Preservation Office
Department of Parks and Recreation
Department of Water Resources
Idaho Transportation Department
Oregon
Department of Fish and Wildlife[1/]
Department of Energy

Cooperating Agencies
Water Resources Department
Department of Agriculture
Department of Environmental Quality
Montana
Montana Office of the Governor[1/]
Montana Fish, Wildlife and Parks
Washington
Department of Ecology
Department of Fish and Wildlife[1/]
Department of Agriculture
County Agencies
Lake County, Montana
Tribes
Confederated Tribes and Bands of the Yakama Nation
Kootenai Tribe of Idaho
Shoshone-Bannock Tribes
Nez Perce Tribe
Confederated Tribes of the Grand Ronde Community of Oregon
Spokane Tribe of Indians
Confederated Tribes of the Colville Reservation
Cowlitz Indian Tribe
Confederated Salish and Kootenai Tribes
Confederated Tribes of the Umatilla Indian Reservation
Intertribal Organization
Upper Snake River Tribes Foundation on behalf of Burns Paiute Tribe, Fort McDermitt Paiute-Shoshone Tribe, and Shoshone-Paiute Tribes of Duck Valley Reservation.

1/ Lead for that state's Memorandum of Understanding.

Cooperating agencies were given the opportunity to participate in regular meetings, workshops, and webinars related to the development of this EIS as related to their special expertise or jurisdiction. Individuals from the cooperating agencies routinely participated in various technical team meetings and activities. In addition, cooperating agencies reviewed and commented on a variety of EIS products related to the development of alternatives, analytical results, existing conditions, environmental impacts, full chapters, and lastly, reviewed and commented on the administrative Draft EIS. In addition, meetings, webinars, and workshops were conducted with cooperating agencies to assist in the refinement of initial alternatives and to provide general status updates.

On October 22, 2019, in response to feedback from the tribes and cooperating agencies, executives from the three co-lead agencies established an engagement team to provide technical support for engagement activities with senior cooperating agency officials.

CHAPTER 10 - PREPARERS

Table 10-1. Master List of Preparers

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored/Contributed
Brady Allen	Fish Biologist	19	M.S. Fisheries	Anadromous and Resident Fish	Bonneville	Resident Fish
Karl Anderson	Fish Biologist	10	M.S. Biology	Resident Fish	Corps	Resident Fish
Jim Anderson	Professor	50	Ph.D. Oceanography	Anadromous Fish/Modeling	UW	Anadromous Fish/TDG Effects
Felicia August	Technical Writer/Editor	9	B.A. Education	Technical Writer/Editor	Corps	Fish section compilation and references
W. Nicholas Beer	Research Consultant	20	M.S. Quantitative Ecology and Resource Management	Salmonid Ecology	UW	TDG Effects
Scott Bettin	Fish and Wildlife Administrator	37	B.S. Forest Science	Hydropower & Fish Passage	Bonneville	Anadromous and Resident Fish
Sue Camp	Fish Biologist	21	B.S. Fish and Wildlife Biology	Resident Fish	USBR	All Fish and Aquatic Sections
Charles Chamberlain	Fish Biologist	16	M.S. Fisheries Management	Anadromous and Resident Fish	Corps	All Fish and Aquatic Sections
Jim Faulkner	Mathimatical Statistician	19	Ph.D. Quantitative Ecology and Resource Management	Statistical Methods, Ecological modeling	NMFS	Anadromous Fish Modeling
Nancy Gleason	Fish Biologist	19	M.E.S. Environmental Studies	Salmonid Ecology	Corps	Anadromous fish, macroinvertebrates (both affected environment and environmental consequences); Adaptive Management Framework
Gregory C. Hoffman	Fishery Biologist	17	M.S. Natural Resources	Resident Fish	Corps	Kootenai Basin/Resident Fish

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored/Contributed
Michael J. Horn	Supervisory Biologist	26	Ph.D. Zoologoy	Resident/Anadromous Fish	USBR	Resident Fish upstrem Chief Joseph
Steve Juhnke	Fish Biologist	23	B.S. Wildlife Biology	Anadromous Fish	Corps	Lamprey
Amy Mai	Fish and Wildlife Administrator	23	M.S. Biological Sciences	Resident Fish	Bonneville	Resident fish, white sturgeon, eulachon
Rachel Neuenhoff	Fish Biologist	12	M.S. Wildlife and Fisheries Science	Quantitative Fisheries Stock Assessment and Population Dynamics Modeling	Corps	Anadromous Fish
Christine Petersen	Fish Biologist	14	Ph.D. Biology	Ecological modeling, oceanography, population genetics	Bonneville	Climate, Anadromous Fish
Sandra L. Shelin	Environmental Resources Specialist	41	B.S. Wildlife Science	Environmental Compliance (NEPA, CWA)	Corps	Resident Fish
Marvin Shutters	Fish Biologist	29	M.S. Fish & Wildlife Ecology	Hydropower & fish passage	Corps	Reviewed analyses and provded background
Cindy Studebaker	Fish Biologist	25	M.S. Environmental Science and Engineering B.S. Forest Resource Management, , Minor Rangeland Resource Management	ecosystem restoration, juvenile salmon ecology and life history	Corps	Lower Columbia River populations (expert panel elicitation / analysis)
Bjorn Van der Leeuw	Fishery Biologist	22	B.S. Wildlife and Fisheries Biology	Resident Fish	Corps	White Sturgeon and Resident Fish
Ricardo Walker	Fisheries Biologist	12	M.S. Environmental Science; B.S. Biology	Anadromous fish, specifically salmonids and lamprey	Corps	Assisted mainly with the lamprey impacts and mitigation
Daniel Widener	Fisheries Biologist	8	M.S. Aquatic & Fisheries Science	Ecological Modeling	NMFS	Anadromous Fish Modeling

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored/Contributed
Rich Zabel	Division Director	25	Ph.D. University of Washington	Ecological Modeling	NMFS	Anadromous Fish Modeling

Note: Bonneville = Bonneville Power Administration; Corps = U.S. Army Corps of Engineers; EIS = environmental impact statement; GHG = greenhouse gas; HEC = Hydrologic Engineering Center; MFWP = Montana Fish, Wildlife and Parks; NEPA = National Environmental Policy Act; NMFS = National Marine Fisheries Service; Reclamation = U.S. Bureau of Reclamation; TDG = total dissolved gas.

Table 10-2. List of Preparers for Fish

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Aaron King	Environmental Engineer	12	M.S. Environmental Engineering; B.S. Chemical Engineering	Water quality, contaminant fate and transport, remediation technologies, CERCLA process, aqueous geochemistry	Corps	Lower Columbia River Water Quality Affected Environment; Lower Columbia River Water Quality Alternatives Analysis
Aaron Marshall	Hydrologist	18	B.S. Geology	Reservoir Regulation, Hydrology	Corps	H&H Affected Environment and Environmental Consequences; H&H Appendix; Lower Snake & Lower Columbia reservoir operations
Aaron Quinn	Environmental Resources Specialist	15	B.S. Environmental Science M.A. Geography M.A. Environmental Law	Environmental Compliance and Restoration	Corps	Cumulative Impacts (Author)
Alexis Mills	Water Quality Specialist	5	M.S. Water Resources Engineering, B.S. Environmental Resources Engineering	Water Quality and Water Resources	Corps	Temperature model and spill allocation review

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Alisa Kaseweter	Climate Change Specialist	12	B.S. Environmental Economics, Policy, and Management; J.D.	Power sector: GHG emissions; GHG emissions reduction policy and regulation; climate change impacts	Bonneville	Power and Transmission; Climate; Hydropower Appendix Hydroregulation Appendix Air Quality Appendix
Anders Johnson	Electrical Engineer	15	B.S. Electrical Engineering M.S. Electrical Engineering	Transmission Planning, Production Cost Modeling, Power System Analysis	Bonneville	Power and Transmission
Ann Furbush, Research Analyst	Research Analyst (Consultant)	1.5	B.A. Economics	Data Analysis; economics	Industrial Economics, Inc. (IEc)	Recreation, environmental justice (for Bonneville)
Ann Miracle	Environmental Consultant	15	Ph.D. Molecular Ecology	NEPA, human health, cumulative, ecology	Pacific Northwest National Laboratory	Visual
Arun Mylvahanan	Operations Research Analyst	19	M.S. Civil Engineering, B.S. Civil Engineering, Professional Certificate in Civil Engineering (PE)	Water resource engineering, hydrology, hydraulics and environmental engineering; Hydropower modeling and planning.	Bonneville	Hydroregulation and Hydropower Appendices, Hydrology & Hydraulics Appendices
Barry Bunch	Research Civil Engineer	30	B.S., M.S. Civil Engineering, Doct of Engineering, Environmental option	Surface Water Quality Modeling	Corps, Engineering Research and Development Center, Environmental Laboratory	CE-QUAl-W2 Water Quality Modeling
Birgit G. Koehler, Ph.D.	CRSO EIS Program Manager for Power	17	Ph.D. Chemistry, A.B. Chemistry and Physics, US Global Change Distinguished Postdoctoral Fellow atmospheric	River and Hydropower operations, long-term planning, climate change, Columbia River Treaty, interdisciplinary analysis	Bonneville	Hydropower Appendix, Hydroregulation Report, Power and Transmission Appendix, Climate Change chapter, Alternatives

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
			chemistry, Professional Certificate in Tribal Relations			chapter, Preferred Alternative chapter
Blair Greimann	Hydraulic engineer	21	Civil engineer	River hydraulics and sediment transport; reservoir sedimentation; dam removal	Bureau of Reclamation	River mechanics supporting author; dam removal tech memo review
Brent Boehlert	Principal/Consultant	17	B.A. Engineering; M.S. Natural Resource Economics; Ph.D. Environmental and Water Resources Engineering	Socioeconomic analysis, water systems analysis	Industrial Economics, Inc.	Power and Transmission
Brian Krolak	Senior Modeler/Developer	22	B.S. Industrial Management; M.B.A.	Hydropower Operations Modeling; Data Analysis	HDR Engineering (Bonneville contractor)	Hydroregulation Appendix author
Bruce Glabau, P.E.	Physical Scientist (Power Operations Specialist)	35	M.S. Civil Engineering, Prof Certificate in Project Management, B.S. Geography and Env. Science	Water resource engineering and hydrology; Management of simulation and optimization models for reservoir operations and planning.	Bonneville	Hydroregulation and Hydropower Appendices, Hydrology & Hydraulics Appendices, Navigation Environmental Consequences Chapter; Affected Environment Chapter
Carolyn Fitzgerald	Hydrologic Engineer	23	M.S. Civil Engineering, B.S. Civil Engineering	Water Management	Corps	H&H Affected Environment and Environmental Consequences; H&H Appendix
Carolyn Foote	NWW Operations &	21	B.S. Civil Engineering	Civil Works funding and budget for O&M.	Corps	Cost analysis

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
	Maintenance Program Manager					
Charles E. Matthews, P.E.	Supervisory Electrical Engineer	30	B.S. Electrical Engineering M.S. Electrical Engineering	Transmission Planning	Bonneville	System reliability review EIS Affected Environment sections review
Chris Bouquot	Economist	8	M.S. Natural Resource Economics; M.E.M Resource Economics and Policy	Inland Navigation	Corps	Affected Environment / Environmental Considerations / Technical Appendix
Chris Frans	Civil Engineer	9	M.S., Ph.D. Civil Engineering, B.S. Earth Sciences	Hydrology, Climate Change	Corps	Climate Chapter, H&H Appendix (Hydrology)
Chris Nygaard	Senior Hydraulic Engineer	18	B.S. Civil Engineering	Hydrology, Open Channel Hydraulics and Sediment Transport	Corps-NWP --> Bonneville	River Mechanics Technical Lead
Christopher H. Furey	Environmental Protection Specialist	15	B.S. Environmental Studies/Biology J.D. Environmental and Natural Resources Law		Bonneville	Air Quality
Christopher McCann	Economist	8	B.A. Economics	Inland Navigation, Deepdraft Navigation and Flood Risk Management	Corps	Affected Environment / SCENT Model Documentation / Technical Appendix
Cindy Boen	Senior	20	BLA Landscape Architecture and Environmental Planning; B.S. History	Alternatives Development and Evaluation, Benefits Analysis, NEPA, Land Use Planning, Recreation Planning, Mitigation	Corps	Chapter 2 primary author, Chapter 7 co-author, Plan Formulation Appendix co-author
Corey Mize	Computer Scientist	2	Masters in Computer Science	Python Visualization Expert	ERDC-ITL	

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Craig Newcomb	Economist	33	B.A. Economics	Water Supply, Flood Risk Management, Hydropower, Dredging/Sedimentation, Recreation,	Corps	Navigation, Recreation
Daniel Turner	Water Quality Team Lead	18	M.S. Engineering	Water Quality	Corps	Water Quality
Dave Goodman	Environmental Protection Specialist			NEPA Policy	Bonneville; Pacific Northwest National Labs	NEPA Policy
Dave Kennedy	Executive Manager of NEPA Planning; CRSO Policy Co-Lead	30	B.A. Natural Resources Management	NEPA/ESA	Bonneville	NEPA Policy
David Gade	Limnologist	24	B.S. - Biology; M.S. - Environmental Science; Ph.D. - Environmental Science	Watershed, lake, and stream modeling; water quality analysis	Corps (CESWF-PEC-CI)	Model (CE-QUAL-W2, HEC-RAS) development, calibration, application, and conclusions.
Dean Holecek	Tribal Liaison	10	M.S. Environmental Science; B.S. Fisheries Science; B.S. Wildlife Science	Tribal Relations	Corps, Walla Walla District	Tribal Perspective section, Tribal Entities and Sovereigns, Preferred Alternative
Dennis Johnson	District Economist	7	B.S. Business Administration/Economics	Flood Risk Management	Corps	Flood Risk Management
Derek Nelson	Cost Engineer	9	B.S. Engineering	Cost Engineering	Corps	Cost analysis
Dorothy Welch	Deputy Vice President - Environment, Fish and Wildlife	19	BSFR - Wildlife Biology, M.S. Wildlife Biology	Fish and wildlife programs	Bonneville	Fish & Wildlife Programs

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Dr. Eric Jessup	Consultant and Director of the Freight Policy Transportation Institute and Associate Research Professor at Washington State University, School of Economic Sciences	20	Ph.D. Agricultural Economics; M.S. Agricultural Economics; B.S. Agricultural Economics	Inland navigation; freight system efficiency; transportation economics	Consultant	Navigation and transportation (Lead Autho)
Dr. Kenneth Casavant	Consultant and Professor at the School of Economic Sciences at Washington State University	48	Ph.D. Agricultural Economics; M.S. Agricultural Economics; B.S. Agricultural Economics	Inland navigation; transportation economics	Consultant	Technical advisor on navigation and transportation
Ellen Engberg	Business Line Manager/ Asset Manager	10	M.S. Geology, B.S. Geology	Hydropower budget and business line, hydropower capital work, dam safety, asset and program management	Corps	Cost analysis
Eric Glisch	Environmental Engineer	12	B.S. Civil and Environmental Engineering	Sediment and surface water quality assessment	Corps, New Orleans District	Author: Sediment Quality Standards Reviewer: Water Temperature Assessment, Water and Sediment Quality Introduction, Water and Sediment Quality Alternatives Analysis

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Eric Horsch, Senior Associate	Senior Associate (Consultant)	11	M.S. Applied Economics, B.S. Economics	Recreation Modeling and Effects Analysis	Industrial Economics, Inc. (IEc)	Recreation (Lead Author)
Eric Nielsen	Operations Research Analyst	13	B.S. Geology/Environmental Science, M.S. Geo-Hydrology	Hydropower modeling and planning. Hydropower operations	Bonneville	
Eric Novotny	Hydraulic Engineer	10	B.S. Biomedical Engineering, M.S. Civil Engineering, Ph.D. Civil Engineering	Water quality modeling, Hydraulic and Hydrologic modeling, programming, data analytics	Corps	Water Quality model data analysis
Eric Rothwell	Hydro-coordinator (or Hydrologist… whatever is preferred)	15	M.S. Hydrology; B.S. Geology	System Operations, Hydrology, Water Quality, Ecosystem Flows, Water Supply, Climate Change	Reclamation	H&H chapters and appendices, WQ chapters and appendices, parts of Climate, Water Quality, and Water Supply chapters.
Eric W. Graessley	Industry Economist	5	M.A. Applied Economics, B.S. Economics	Electric System Production Cost Modeling	Bonneville	
Erik Pytlak	Supervisory Meteorologist	30	B.S. Meteorology; M.P.A	Mteorologiy, hydrologiy and climate change science	Bonneville	Hydroregulaton and hydropower sections and relevant appendicies
Evan Heisman	Civil Engineer	9	M.S. Civil Engineering, Bachelors of Civil Engineering	Water Management, Hydrology, Reservoir Operations Modeling	Corps	H&H Appendix (Stage-Flow Transformation documentation, ResSim/WAT documentation)
Evan Heisman	Civil Engineer	9	M.S. Civil Engineering, Bachelors of Civil Engineering	Water Management, Hydrology, Reservoir Operations Modeling	Corps	H&H Appendix (Stage-Flow Transformation documentation,

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
						ResSim/WAT documentation)
Eve James	Supervisory Physical Scientist	13	M.S. Geology (Hydrogeology focus), B.S. Geology	River and Hydropower operations,mid-term planning, interdisciplinary analysis	Bonneville	Hydropower Appendix, Hydroregulation Report, Power and Transmission Appendix, Climate Change chapter, Alternatives chapter, Preferred Alternative chapter
Hannah Dondy-Kaplan	Fish and Wildlife Project Administrator	15	M.A. Environmental Planning	Environmental planning and permitting, land acquisition and management, fish and wildlife habitat restoration project management	Bonneville	Vegetation, Wetlands, and Wildlife
Hannah Hadley	Environmental Coordinator	15	B.A. Anthrology	NEPA and environmental compliance	Corps	Chapters 1 and 8 (Author)
Hans R. Moritz	Civil / Hydraulic Engineer	25	B.S. is Civil Engineering, ME in Ocean Engineering	River Engineering and Sediment Transport	Corps - NWP	Lower Columbia River Sedimentation and Dredging
Heather Baxter	Civil Engineer/Interdisciplinary	6.5	M.S. Civil Engineering, B.S. Civil Engineering	Modeling, ResOps, Hydrology	Corps	Reservoir Operations modeling
Holly Bender	Lead Regional Economist	21	Ph.D.	Economics	Corps	Primary -- Cost Analysis; Reviewed Recreation, Power and Tranmission, Navigation
Iris Maska	Economist	11	B.A.	Economics	BOR	Cost analysis
J. Paul Rinehimer	Senior Engineer	10	Ph.D.	Hydraulics, hydrology, water quality modeling	WEST Consultants, Inc.	AFD W2 modeling and results preparation. Review W2/RAS models of lower Snake River.

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
James Witherington	Cost Engineering Technicin	5	Economics		Corps	Mitigation Cost Meausres
Jane Israel	Senior Associate/Consultant	22	B.A. Math and Philosophy; M.B.A. Finance and Accounting	NEPA socioeconomic analysis, financial analysis, environmental justice	Industrial Economics, Inc.	Environmental Justice
Jason Change	Civil Engineer	9	B.S., M.S., and Ph.D. Agricultural and Biological Engineering	Hydrology and climate change	Corps	Climate Change and H&H Appendix
Jason Sweet	Supervisory Policy Analyst	19	B.S. in Fisheries Science. Minor in Wildlife Science	Analysis of the effect of hydropower operations on resident and migratory fish	Bonneville	Preferrred Alternative Chapter
Jayson Osborne	Remediation Biologist	12	M.S. Biology, B.S. Conservation Biology	Environmental Sampling and Cleanup	Corps	Sediment Quality Appendices for McNary, John Day, The Dalles, and Bonneville Reaches.
Jeanne Godaire	Geologist	20	Geosciences	Fluvial geomorphology; paleoflood hydrology; Quaternary geology	Bureau of Reclamation	River mechanics supporting author
Jeff Cavanaugh	Economist	1	B.A.	Economics	Corps	Cost analysis
Jennie Tran	Electrical Engineer	28	B.S. Electrical Engineering	Hydropower modeling, analysis, and planning	Bonneville	Hydropower Appendix, 4h10C studies, Hydro modeling support and analysis
Jennifer Bountry	Hydraulic engineer	21	Civil engineer	River hydraulics and sediment transport; reservoir sedimentation; dam removal	Bureau of Reclamation	River mechanics supporting author; dam removal tech memo review
Jennifer Gervais	Hydrologic Engineer	7	M.A.Sc. Civil Engineering; B.S. Industrial and Systems Engineering	Water Management, Hydraulics, Hydropower, Hydrology	Corps	H&H Appendix (Grand Coulee Upstream Storage Correction Method Sensitivity;

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
						ResSim/WAT documentation)
Jennifer Johnson	Supervisory Civil Engineer	16	Ph.D., Water Resources, M.Engr., Civil Engineering, B.S. Civil Engineering, B.S. Geophysics	Water Resources modeling, Groundwater, Water Supply, Climate Change	Bureau of Reclamation	Water Supply, Climate Change
Jennifer Kassakian	Senior Associate/Consultant	14	B.A. Biology; Master of Marine Affairs	Marine and aquatic resource management, fisheries management and policy	Industrial Economics, Inc.	Fisheries
Jennifer Miller	Chief, Environmental Engineering (Chicago District)	33	Ph.D. in Environmental Engineering, M.S. in Environmental Eng., B.S. in Civil Eng.	> 20 years of experience in civil works projects with Corps working on all project phases from planning thru design and construction; total 33 years experience in environmental engineering. Expertise in dredging, sediment management, contaminated sediment disposal, water chemistry. PE in environmental engineering.	Corps, Chicago District	Lower Snake River Sediment existing conditions; no action and alternative analyses for sediment
Jim Burton	Hydraulic Engineer	17	B.S. Civil Engineer	Hydrology & Hydraulics	Corps	Water Temperature Modeling
Jim Fodrea	Senior Project Manager	45	B.S. Civil Engineering	Hydropower, Reservoir Regulation	HDR Engineering (Bonneville contractor)	Hydropower Appendix author, Hydroregulation Appendix reviewer
John Anasis	Electrical Engineer, Transmission Operations	34	B.S. Electrical Engineering and Physics; M.P.A. Public Administration; Ph.D. System Science	Power System Operations and Modeling, Transmission Inventory Assessment, Transmission Tariffs and Scheduling.	Bonneville	Power and Transmission
John Hayes	Asset Manager	14	B.A. Geography	Asset Management, O&M	Corps	Cost analysis

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
John Newton	Hydraulic Engineer	14	Ph.D. Civil Engineering, B.S. Civil Engineering	Hydrology & Hydraulics	Corps-NWW	River Mechanics: Affected Environment supporting author and Snake River dredging metrics.
JR Inglis	Tribal Liaison	8	M.S. Systems Management, B.S. Math & Engineering	Tribal Relations	Northwestern Division, Corps	Co Author Tribal Perspective section 3.16, Tribal Entities and Soveriegns Sect 9.2
Julie Doumbia	Environmental Protection Specialist	8	M.S. Marine Resource Management; M.S. Environmental, Natural Resources & Energy Law	Anadromous fish and overall hysdrosystem operations	Bonneville	Anadromous fish, modeled species, some resident fish
Kari Cornelius Hay	Operations Research Analyst	8	B.A. Mathematics; Graduate Certificate of Applied Statistics	Development of modeling parameters to apply desired operations in Hydsim modelling process; coordinate technical modelling team in Hydsim process; analysis, coordination and alignment of Hydsim modelling process	Bonneville	Hydroregulation and Hydropower Appendices
Kasi Whorley	Hydrologic Engineer	13	B.S. Engineering	Water Management, Hydrology, Reservoir Operations Modeling, Floodplain Management	Corps	H&H Appendix (ResSim/WAT documentation); Reservoir Operations modeling
Kathryn Tackley	Physical Scientist	23	B.S. Physical Geograhpy and Geology	water quality monitoring and technical analysis; project management	Corps	Water Quality
Keleigh Duey	Environmental Manager	3 years	B.S. Biology	Ecology and Biodiversity	Corps	Vegetation, Wetland, and Wildlife
Kelly Baxter	Economist	15	B.A. Economics, M.S. Economics	Economics	Corps	Recreation, Navigation and Transportation,

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
						Flood Risk, and Cost Analysis
Kent Easthouse	Physical Scientist	27	M.S. Environmental Engineering-University of Washington, B.S Environmental Sciences-University of California at Davis	Water Quality and Sediment Quality	Corps, Seattle District	Libby Dam-Lake Koocanusa and Kootenai River: Water Quality and Sediment Quality. Albeni Falls Dam-Lake Pend Oreille and Pend Oreille River: Water Quality and Sediment Quality. Chief Joseph Dam-Rufus Woods Lake and Columbia River: Water Quality and Sediment Quality
Kevin Cannell	Archaeologist	26	M.A., Anthropology	Cultural resources	Bonneville	Cultural Resources
Kieran Bunting	Principal/Consultant	3	B.A. Economics; M.S. Carbon Management	Environmental economics; energy economics; data analysis	Industrial Economics, Inc.	Power and Transmission, Air Quality and GHG Emissions
Kimberly Johnson	Environmental Engineer	31	B.S. Civil Engineering	Water Quality, Air Quality, Environmental Engineering, NEPA	Bonneville	Water Quality, Air Quality
Kristen Kerns	Toxicologist	11	M.S., Environmental Health	Sediment remediation, human health risk assessment	Corps, Seattle District	sediment quality
Kristen Shacochis-Brown		19	B.S. Forestry and Wildlife Management, M.S. Ecological Restoration	Wetland Scientist, Ecological Restoration, Wildlife Management	Corps	Vegetation, Wetland, and Wildlife
Kristian Mickelson	Hydrologic Engineer	17	M.S. Civil Engineering, B.S. Civil Engineering	Water Management, Climate Change, Hydropower	Corps	H&H Affected Environment and Environmental Consequences; H&H

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
						Appendix; Climate Chapter, Hydrology Appendix, Spill, Water Quality, Hydropower, Fish
Kristine Sclanfani	Environmental Specialist				Corps	Vegetation, Wetland, and Wildlife
Lance Awsumb	Regional Economist	11	B.A. Economics	Flood Risk Management	Corps	Flood Risk Management
Laurel Hamilton	P.E., Hydraulic Engineer	12	M.S. - Environmental Engineering; B.S. - Chemistry	Hydraulics and Water Quality	Corps, Omaha District	Water Quality Appendix
Leah Hauenstein	Project Manager	10	B.S. Industrial & Systems Engineering	Project & program management in Corps Civil Works	Corps	Project manager level reviewer
Leslie Genova	Principal (Consultant)	19	M.A. Environmental Studies; B.A. Environmental Science	NEPA socioeconomic analysis, environmental impact analysis, regional economic impact analysis, cost-benefit analysis	Industrial Economics, Inc. (IEc)	Review and analysis of recreation, navigation and transportation, review of flood risk [also for Bonneville, review and analysis of environmental justice, fisheries]
Logan Osgood-Zimmerman	Hydraulic Engineer	5.5	M.S. Civil Engineering, B.S. Engineering	Water Management, Reservoir Regulation, Hydrology	Corps	Reservoir Operations modeling; H&H Environmental Consequences
Margaret C. Racht	Operations Research Analyst	12	M.S. Statistics, B.S Mathematics	Analysis, Coordination, and Post Processing Role in Hydsim Modeling Process, Conduit for Data Transfer to/from HDR and Downstream Parties	Bonneville	Hydroregulation and Hydropower Appendices
Margaret Ryan	Economist	11	B.A. Economics	Economics - Hydropower	Corps-HAC	Reviewed Power and Transmission

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
						Environmental Consequences Section
Margo L. Kelly	Business System Analyst II	19	N/a	Programming, Analysis, Coordination and Post Processing of Revenue and Expense Simulation Modeling	Contractor to Bonneville	hydropower analysis
Mariah March-Garr Brumbaugh	NEPA Regional Technical Specialist	19	B.S. Biology, M.S. Biology	Wetland Ecology, Avian Biology, Aquatic Entomology, Wildlife Habitat Management	Corps	Vegetation, Wetland, and Wildlife
Marke Paske	Regional Budget Officer	14	B.A.	Accounting	BOR	Cost analysis
Matt Fraver	Hydraulic Engineer	10	M.S. Civil Engineering, B.S. Environmental Engineering	Hydaulics, Hydrology	Corps	H&H Appendix (H&H Data Analysis). Data Analysis; reviews for water supply, socioeconomics, and wildlife
Maura Flight	Principal/Consultant	17	B.S. Environmental Science; M.S. Economics	Applied economics, NEPA socioeconomic analysis, cost-benefit analysis, ecosystem service valuation	Industrial Economics, Inc.	Power and Transmission, Air Quality and GHG Emissions, Passive Use Technical Report
Max Pangborn	Operations Research Analyst	3	M.A. Economics; B.A. Economic Theory; JD	Hydropower modeling and planning	Bonneville	Hydropower Appendix, NAA modeling, MO2 modeling, Preferred Alternative modeling, Climate Change
Melissa A. Foster	Geomorphologist	12	Geology	Quaternary geology, fluvial processes, river hydraulics, sediment transport	Bureau of Reclamation	River mechanics supporting author
Michael Poulos	Hydrologist	10	Ph.D. Geosciences	Spatial Water Rights Analyses	USBR	Water Supply & appendices

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Michael Ryan	Production Cost Modeling Analyst	42	B.A. Mathematics M.S. Physics	Power System Simulation; Analysis and Programming; Risk Management Analytics; Market Analysis	Bonneville	Power and Transmission
Michelle Eraut	CRSO EIS Policy Co-Lead	25	B.S., MPA/NEPA	NEPA Policy	Bonneville	NEPA Policy
Millie Chennell	Operations Research Analyst	7	Water Resources Management (Master of Environmental Science and Management)	Hydroregulation, Water Quality, Power Planning, Analysis, Communications	Bonneville	Water Quality, Power
Mitch Price	Senior Hydraulic Engineer	25	M.S. Civil Engineering, B.S. Civil Engineering	River Engineering, Sediment Transport and Ecosystem Restoration	Corps-NWW	River Mechanics Technical Lead.
Nancy Stephan	Management and Program Analyst	35	B.S. Atmo	Meteorology, Climate Change, River Operations	Bonneville (retired)	climate change analysis
Norman Buccola	Hydraulic Engineer	10	M.S. Civil and Environmental Engineering	Hydrology, water quality, statistics, water management	Corps	Water Quality Appendices
Pam Druliner	Natural Resource Specialist				BOR	NEPA Compliance, Resident Fish, Vegetation/Wetlands/ Wildlife
Patrick R. Rochelle, P.E.	Electrical Engineer	28	B.S. Electrical Engineering M.S. Electrical Engineering	Transmission Planning Distribution Planning Generation Engineering	Bonneville	System reliability review EIS Affected Environment sections review
Paula Engel	Economist	27	M.S. Agricultural Economics	Economics	BOR	Water Supply
Peter Stiffler	Public Utilities Specialist	15	Ph.D. Economics, M.A. Urban and Regional	Power Rates Analyst	Bonneville	Rate impacts and socioeconomic analysis

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
			Planning, B.A. Economics			
Peter Williams	Operations Research Analyst	9	Ph.D. Economics, B.S. Economics/Math	Hydropower modeling, quantitative analysis	Bonneville	Hydropower Appendix, MO4 modeling
Rafael Molano	Project Manager	15	B.S. Electrical Engineering M.S. Economics M.B.A. Finance	Transmission and generation planning; load forecasting models; production cost modeling; renewables development	Bonneville	Power and Transmission
Ray Walton	Lead Water Resources Engineer	45	Ph.D.	Hydraulics, hydrology, water quality modeling	WEST Consultants, Inc.	AFD W2 modeling and results preparation. Review W2/RAS models of lower Snake River.
Rebecca Weiss	Columbia River Basin Environmental Coordinator	19 at the corps	B.A. Anthropology, M.S. Genetics	Planning, Environmental Analysis, Environmental Compliance, Federal Water Resources Policy	Corps	Policy level Reviewer
Robert Diffely	Economist	30	M.S. Economics; B.S. Economics	Resource Adequacy, power operations and planning	Bonneville	Hydropower Appendix, Hydroregulation Report, Power and Transmission Appendix, Climate Change, Water Supply, Socioeconomics
Robert Petty	Manager, Power Operations and Planning	22	M.S. Economics, B.S. Business Management	Power operations and planning, rates, business operations, market analysis and trading	Bonneville	Alternatives chapter, Preferred Alternative chapter, Executive Summary
Ron Thomasson	Hydrologic Engineer	30	B.S. Civil Engineering	Hydrology, Reservoir Regulation, Water Management	Corps	H&H Appendix (Grand Coulee Upstream Storage Correction Method Sensitivity)

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Ross Wickham	Hydraulic Engineer	6	M.S. Civil and Environmental Engineering, B.S. Environmental Resources Engineering	Hydrology, Hydraulics, Reservoir Regulation	Corps	Spill; Water Quality; Geomorphology, Sediment Transport, Geology, and Soils
Ryan Laughery	Hydraulic Engineer	16	Civil Engineer	Fish Passage Engineering and Design	Corps	Fish/Econ
Sara Marxen	Hydraulic Engineer	20	M.S. Civil Engineering	Water Management, Hydraulics, Hydropower, Hydrology	Corps	H&H and FRM Affected Environment and Environmental Consequences; H&H Appendix (Spill Analysis, Grand Coulee Upstream Storage Correction Method Sensitivity, Hydrology)
Sarah Delavan	Civil (Hydraulic) Engineer	19	Ph.D., Civil Engineering	Hydraulic and Hyrologic modeling, Technical Writing	Corps	H&H Appendix (Hydrologic Data Development, Extended Observed Flows)
Scott Wells	Professor of Civil and Environmental Engineering	35	Ph.D., Civil and Environmental Engineering, Cornell; M.S. MIT, B.S. Tenn Tech Univ	Water quality and hydrodynamic modeling	Portland State University	
Selisa F. Rollins	General Engineer	2	M.S. Chemical Engineering; B.S. Chemical Engineering	Hydropower modeling and planning	Bonneville	Hydropower Appendix, MO3 modeling, Climate Change
Stacy Wachob	NWW Operations Division Program Analyst	11	B.A. Sociology; AAS Accounting	Budget and program analysis for NWW.	Corps	Cost analysis

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Stan Williams	Public Utilities Specialist	15	B.S. Forest Science M.S. Industrial Engineering	Resource and Transmission Planning; Production Cost Modeling; Linear Programming	Bonneville	Power and Transmission
Stanford Gibson	Senior Hydraulic Engineer	20	Ph.D. Civil & Environmental Engineering (Hydraulics), M.S. Civil & Environmental Engineering, M.S. Ecology	National, Corps, subject matter expert on sediment transport and mobile boundary modeling.	Corps-HEC	River Mechanics: Snake River dam removal modeling and Dam Removal tech memo supporting author.
Steve Bellcoff	Public Utilities Specialist	12	Civil Engineering Technology, AAS	Loads and Resources, Power Rates	Bonneville	Power Loads and Resources, Power Rates
Steve Juul	Water Quality Lead	27	Ph.D. Civil Engineering, M.S. Environmental Science, B.S. Wildlife Science	Limnology, sediment chemistry, aquatic ecosystem restoration, watershed management	Corps	Water and sediment quality, benthic macroinvertebrates
Steven Hollenback	Physical Scientist	5	M.S. Hydrology, M.S. Environmental Science, B.S. Chemistry, B.S. Biology	Physical Science	Bureau of Reclamation	Lake Roosevelt and Hungry Horse, Appendix 7 and 9.
Tammy Threadgill	Research Physical Scientist; Water Quality and Contaminant Modeling Branch	12	M.S. Computational Engineering; B.S. Mathematics (Analytical)	Water Quality Modeling; Data Analysis	ERDC, Vicksburg, M.S.	Water Quality Model Calibration Report; MO3 Report; Automation Tool Report; Visualization Report
Tanis Toland	Environmental Compliance Regional Specialist	29	M.S. Wildland Resource Science B.A. Biology	Ecology	Corps	Vegetation, Wetland, and Wildlife

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Tilak Gamage	Civil Engineer	25	M.S. in Civil Engineering	Hydraulic/Water qualiy modeling (15years+)	Corps - Seattle	Mid Columbia water quality models and associated report contents
Timothy Randle	Hydraulic engineer	40	Civil engineer	River hydraulics and sediment transport; reservoir sedimentation; dam removal	Bureau of Reclamation	River mechanics peer review
Tina Teed	Senior Planner	17	B.S. Ecology and Systematic Biology, M.S. Biology	Alternatives Development, Reservoir Regulation, NEPA Lead, Mitigation Compliance, Professional Wetland Scientist	Corps	Chapter 2 primary author, Plan Formulation Appendix primary author
Todd Steissberg	Research Environmental Engineer; Water Quality and Contaminant Modeling Branch	19	B.S., M.S., and Ph.D. in Civil and Environmental Engineering	Water Quality Modeling, Software Development, Data Analysis	ERDC, Davis, CA	Water quality modeling software development and support
Travis Ball	Hydraulic Engineer	12	M.Eng Civil Engineering	Hydraulics	Corps	H&H Appendix (Stage-Flow Transformation documentation), River Mechanics Affected Environment
Travis Foster	Hydraulic Engineer	14	M.S. Civil Engineering, B.S. Civil Engineering	Hydrology & Hydraulics	Corps-NWW	River Mechanics: Hydraulic model support.
Tyler Llewellyn	Operations Research Analyst	10	B.S and M.S. Environmental Science	Hydropower operations, loss-of-load probability, valuing hydropower	Bonneville	Hydroregulation and hydropower
Zac Corum	Senior Hydraulic Engineer	23	B.S. Civil Engineering	River Mechanics, Ecosystem Restoration, Sediment Transport & Geomorphology	Corps-NWS	River Mechanics: Affected Environment supporting author (Kootenai)

Name	Title	Years of Experience	Degree	Experience/Expertise	Agency	EIS Areas Authored
Zachary Jelenek		4	Bachelors	Water Quality	Corps	MO3 Water Quality Model
Zhong Zhang	Research Professor	25	Ph.D.	Riverine and reservoir water quality modeling development and application	Portland State University / ERDC-EL	TDG capability development in RAS and W2 and tech note for W2 TDG version/Water quality modeling review
Michael Sackschewsky	Environmental Consultant	25	Ph.D. Environmental Studies	NEPA, ecology, botany, human health	Pacific Northwest National Laboratory	Noise
Philip Meyer	Hydrologist	10	Ph.D. Hydrology	Hydrologic processes, flow and transport modeling	Pacific Northwest National Laboratory	Floodplains
Eve Skillman	Regional Outdoor Recreation Planner	22	B.S., Natural Science, Mathematics, & Biology; M.S., Zoology & Physiology		Bureau of Reclamation	Visual

Note: Bonneville = Bonneville Power Administration; Corps = U.S. Army Corps of Engineers; EIS = environmental impact statement; GHG = greenhouse gas; HEC = Hydrologic Engineering Center; MFWP = Montana Fish, Wildlife and Parks; NEPA = National Environmental Policy Act; NMFS = National Marine Fisheries Service; Reclamation = U.S. Bureau of Reclamation; TDG = total dissolved gas.

CHAPTER 11 - REFERENCES

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