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Columbia River Cold Water Refuges Plan

Prepared by:
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Region 10

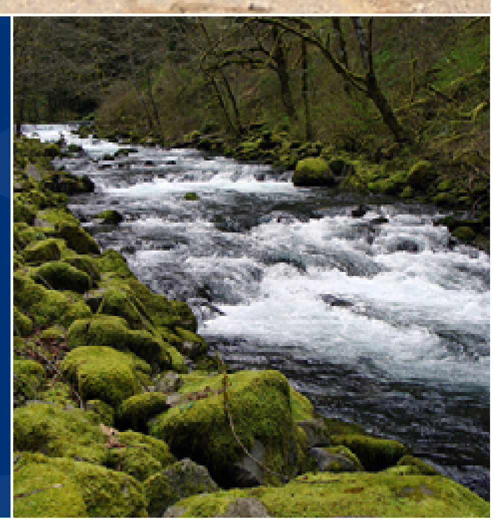

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
°C	Degrees Celsius
°F	Degrees Fahrenheit
cfs	cubic feet per second
CWR	Cold Water Refuge
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DART	Data Access in Real Time
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
HCP	Habitat Conservation Plan
ISWR	Instream Water Right
LCFRB	Lower Columbia Fish Recovery Board
NHD	National Hydrography Dataset
NMFS	National Marine Fisheries Service
NorWeST	Northwest Stream Temperature database
NPCC	Northwest Power and Conservation Council
ODEQ	Oregon Department of Environmental Quality
ODF	Oregon Department of Forestry
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department
PIT-tag	Passive Integrated Transponder-tag
SWSL	Surface Water Source Limitation
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USBR	United State Bureau of Reclamation
USFS	United States Forest Service
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WQMP	Water Quality Management Plan
WRIA	Water Resource Inventory Area

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EPA Region 10 CWR Team: John Palmer (Lead), Dru Keenan, Jenny Wu, Peter Leinenbach, Ben Cope, Rochelle Labiosa, Gretchen Hayslip, Alexandra Clayton, Jonell Deacon, Keyyana Blount, Martin Merz, Miranda Magdangal, David Gruen, Dylan Laird, Martin Jacobsen, Abigail Conner, Lindsay Guzzo, Sally Goodman, Andrea Lindsay, Mary Lou Soscia, Jennifer Byrne, Christine Psyk, and Angela Chung

EPA Office of Research and Development CWR Team: Joe Ebersole, Marcia Snyder, Nathan Schumaker, Randy Comeleo, and Jonathan Halama (Corvallis, OR); Naomi Detenbeck, and Matthew Fuller (Narragansett, RI)

Contributors: Matt Keefer (University of Idaho); Debra Sturdevant, James McConaghie, Don Butcher, Gene Foster, Bonnie Lamb, Smita Mehta, Tonya Dombrowski (Oregon Department of Environmental Quality); Melissa Gildersleeve, Chad Brown, Ben Rau, Jim Pacheco, Paul Pickett, Mike Gallagher (Washington Department of Ecology); Ritchie Graves, Blane Bellerud, Anne Mullan, Josie Thompson, Spencer Hovekamp, and Scott Carlon (National Marine Fisheries Service); Dan Isaak, Brian Staab, Diane Hopster, Robin Shoal, Bengt Coffin (United States Forest Service); Art Martin, Rod French, Tucker Jones, Anna Stevenson, Spencer Sawaske, Erin Andyke, Erick Van Dyke, Derrek Faber (Oregon Department of Fish and Wildlife); Dan Rawding, Thomas Beuhrens (Washington Department of Fish and Wildlife); John Plumb, Pat Connelly, Christian Torgersen, Jason Dunham, Krista Jones, and Ian Jezorek (United States Geological Survey); Brian Maschhoff; Jessica Olson (Columbia River Gorge Commission); Margaret Filardo (Fish Passage Center); Catherine Corbett, Chris Collins, and Keith Marcoe (Lower Columbia Estuary Partnership); Lynn Palensky, Laura Robinson, and Leslie Bach (Northwest Power and Conservation Council); Denis Lofman (Columbia River Estuary Study Taskforce); Lowell Dickson (Washington Department of Natural Resources); Bill Sharp, Joe Zendt, Shuba Pandit, and Tom Iverson (Yakama Nation); Laura Gephart, Dianne Barton, and Jeff Fryer (Columbia River Inter-Tribal Fisheries Commission); Scott O'Daniel, Gary James, Robin Harris (Confederated Tribes of the Umatilla Indian Reservation); Chris Brun, Brad Houslett, Ryan Gerstenberger (Confederated Tribes of the Warm Springs Reservation); David Moskowitz (The Conservation Angler); Sarah Cloud, Greg McMillan, and Ben Kirsch (Deschutes River Alliance); Nina Bell (Northwest Environmental Advocates); Miles Johnson (Columbia Riverkeeper); Scott Levy (Bluefish); Dan Turner and Mike Langeslay (United States Army Corps of Engineers); Agnes Lut (Bonneville Power Administration); Megan Hill and Lori Campbell (Portland General Electric); Tova Tilinghast (Underwood Conservation District), Jess Groves and Sally Moore (Port of Cascade Locks), Bruce Aylward (AMP Insights), Holly Coccoli, Cindy Thiemann (Watershed Council Hood River Watershed Group), Steve Hood (Sandy River Watershed Council), Dave McClure (Klickitat County), Josh Epstein and Gardner Johnston (Interfluve)

EXECUTIVE SUMMARY

The *Columbia River Cold Water Refuges Plan* focuses on the lower 325 miles of the Columbia River from the Snake River to the ocean. Cold water refuges (CWR) are locations migrating adult salmon and steelhead temporarily use to escape warm summer river temperatures. CWR serve an increasingly important role to some salmon species as the Lower Columbia River has warmed over the past 50 years and will likely continue to warm in the future. The Plan:

- Describes available CWR in the Lower Columbia River,
- Characterizes how salmon and steelhead use CWR,
- Assesses the amount of CWR needed to attain Oregon's Clean Water Act CWR narrative water quality standard,
- Identifies actions to protect and restore CWR, and
- Recommends future CWR studies.

Fish Use of CWR

Adult salmon and steelhead commonly use CWR in the Lower Columbia River from mid-July through mid-September when river temperatures typically exceed 20°C (68°F). August is the warmest month, with average river temperatures of 21-21.5°C (70-71°F); the warmest days commonly reach 22.5°C (72.5°F). Daily average river temperatures are similar throughout the entire 325-mile stretch of the Lower Columbia River, with slightly cooler temperatures near McNary Dam and the warmest temperatures near the John Day and The Dalles Dams.

CWR are found where cooler tributary rivers flow into the Columbia River. A CWR tributary is at least 2°C cooler than the Columbia River. EPA identified 23 tributaries that provide CWR. EPA defined 12 of these as "primary" CWR tributaries because of their size, accessibility, and documented or presumed use by migrating salmon and steelhead. Of the 12 primary CWR, four are below Bonneville Dam (**Cowlitz River, Lewis River, Sandy River, and Tanner Creek**); seven are between Bonneville Dam and The Dalles Dam (**Eagle Creek, Wind River, Herman Creek, White Salmon River, Little White Salmon River, Hood River, and Klickitat River**); and one is between The Dalles Dam and the John Day Dam (**Deschutes River**). There are no primary CWR between the John Day Dam and McNary Dam.

Salmon and steelhead use of the eight primary CWR above Bonneville Dam is well-documented from scientific tagging studies. Less is known about the use of the four CWR below Bonneville Dam. The largest CWR with well-documented use are the **Little White Salmon River** (Drano Lake), **Deschutes River**, **Klickitat River, Herman Creek** (Herman Creek Cove), and the **White Salmon River**.

Among the various Columbia River salmon runs, CWR are used most often by adult summer steelhead and fall Chinook salmon because their migration timing corresponds with the warmest river temperatures. Using CWR allows fish to escape warm Columbia River temperatures and complete their upstream migration when river temperatures are cooler. EPA modeling (HexSim) simulated fish migrating between Bonneville Dam and McNary Dam and showed that CWR use allows summer steelhead to reduce the time exposed to stressful temperatures by 50 percent. Other modeling studies have predicted that use of CWR by early migrating fall Chinook salmon allows them to retain enough energy to successfully spawn in the fall. Summer steelhead often will use CWR for several weeks, while fall Chinook salmon generally use CWR for a few days to a week.

EPA Findings and Recommendations

Oregon's Clean Water Act CWR narrative standard stipulates that the Lower Columbia River "*must have coldwater refugia that's sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperature elsewhere in the waterbody*," and coldwater refugia is "*at least 2°C colder*" than the river. To assess attainment with Oregon's CWR standard, EPA evaluated the total amount of CWR, the extent to which fish use CWR, the density of fish in CWR, the distribution of CWR, the health benefits of CWR use, and the overall importance of adult migration risk factors in the recovery of ESA-listed salmon and steelhead. EPA made this assessment under current Lower Columbia River temperatures, while recognizing increased use of CWR is likely to occur as the Columbia River continues to warm due to climate change. EPA has concluded that attainment of Oregon's CWR standard will depend on maintaining the volume of the 12 primary CWR and increasing CWR in the Umatilla River.

To protect the 12 primary CWR tributaries and the Umatilla River from future warming and to retain the existing CWR volume, this Plan describes an array of existing programs, plans, and regulations. These include: the aquatic protection prescriptions for timber harvest on national forest land, state forest land, and private forest land; stream buffer protections associated with the *Management Plan for the Columbia River Gorge National Scenic Area*; Wild and Scenic River management plans, county land use and shoreline regulations; established minimum flow requirements; and state water quality provisions to protect existing cold water.

This Plan highlights recommended restoration actions found in the Northwest Power and Conservation Council subbasin plans, salmon recovery plans, TMDL implementation plans, and water management plans. Such plans exist for all of the 12 primary CWR tributaries and the Umatilla River. Implementation of these plans will help reduce river temperatures in their watersheds. The identified restoration actions serve to improve fish habitat and to cool river temperatures that will help maintain CWR volume in light of predicted tributary warming due to climate change.

Recommended restoration actions to maintain and increase CWR include:

- Restoring riparian vegetation to provide river shading,
- Restoring stream morphology and floodplain connectivity to reduce channel widths and create pools and groundwater connectivity, and
- Restoring summer river flows that are more resistant to warming and increase CWR volume.

To address identified uncertainties, this Plan recommends future studies to track fish use of CWR, to assess the benefits of CWR use, and to assess density effects and the carrying capacity of CWR. This Plan identifies immediate monitoring priorities to track CWR use, stream temperature, and flow trends, including:

- Installing PIT-tag detectors in Little White Salmon/Drano Lake and Herman Creek Cove,
- Re-establishing USGS flow gauges, including temperature gauges, near the mouth of Little White Salmon River and Wind River, and
- Installing and operating long-term annual summer temperature monitoring at or near the USGS flow gauge sites near the mouth of the Cowlitz, Lewis, Sandy, White Salmon, Hood, Klickitat, and Umatilla Rivers.

1 INTRODUCTION

Approximately 700,000 to two million adult salmon and steelhead return from the ocean and migrate up the Columbia River each year past the Bonneville Dam. Roughly 40% of these fish that migrate during the summer months when Columbia River water temperatures reach or exceed 20°C may endure adverse effects in the form of disease, stress, decreased spawning success, and lethality (EPA, 2003). To minimize their exposure to warm temperatures in the Columbia River, many salmon and steelhead temporarily move into areas of cooler water, which are called cold water refuges (CWR). In the Lower Columbia River, these CWR are primarily where cooler tributary rivers flow into the Columbia River.

This Plan characterizes Columbia River water temperatures, the amount of available CWR in the Lower Columbia River (mouth to Snake River), and the extent to which salmon and steelhead use the CWR. The plan also assesses the amount of CWR needed to support migrating adult salmon and steelhead, highlights recommended actions to protect and restore the CWR, and recommends future studies and monitoring.

1.1 REGULATORY BACKGROUND

Both the States of Oregon and Washington have established temperature water quality standards for the Lower Columbia River to protect migrating salmon and steelhead, which include a 20°C (68°F) numeric criterion[1] for limiting the maximum water temperatures. The State of Oregon also includes a narrative temperature standard that stipulates that the Lower Columbia River:

"*must have coldwater refugia that's sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body*."

Oregon standards define coldwater refugia as

"those portions of a water body where, or times during the diel temperature cycle when, the water temperature is at least 2 degrees Celsius colder than the daily maxium temperature of the adjacent well mixed flow of the water body (OAR 340-041-0002(10))."

Under the Clean Water Act, the U.S. Environmental Protection Agency must approve (or disapprove) new or revised state water quality standards. In 2004, EPA approved the State of Oregon's temperature water quality standards for the Lower Columbia River, including the 20°C maximum numeric criterion and the coldwater refugia narrative provision noted above. As part of the approval process, EPA consulted with the National Marine Fisheries Services (NMFS) per the requirements of the Endangered Species Act to ensure EPA's approval would not jeopardize the continued existence of ESA listed species.

The ESA consultation on the Oregon Lower Columbia River temperature standards noted above (among other standards) was initially completed in 2004, but was invalidated by the United States District Court of Oregon in 2012. In accordance with a court order, NMFS issued a new Biological Opinion in November 2015. In that Opinion, NMFS concluded that Oregon's Lower

[1] Oregon's 20°C numeric criterion is based on a 7-day average daily maximum. Washington's 20°C numeric criterion is based on a daily maximum.

Columbia River temperature standards are likely to jeoparize the survival and recovery of ESA listed salmon and steelhead because the coldwater refugia narrarative standard, to date, did not appear to be an effective means for minimizing the adverse effects likely to be experienced by migrating salmon and steelhead under the 20°C numeric criterion.

To avoid jeopardizing ESA listed salmon and steelhead, the NMFS 2015 Biological Opinion included a reasonable and prudent alternative for EPA to develop this *Columbia River Cold Water Refuges Plan*.

The EPA recently issued the *Columbia and Lower Snake Rivers Temperature Total Daily Maximum Load* (TMDL) (2020a) that addresses exceedances of the 20°C numeric criteria[2] on the Lower Columbia River as well as Oregon's coldwater refugia narrative criteria. The Columbia River Temperature TMDL calculates how much various sources are contributing to exceedances of the 20°C numeric criteria and establishes temperature targets for cold water refuge tributaries to attain Oregon's CWR narrative criteria. The Columbia River Temperature TMDL establishes temperature targets for cold water refuge tributaries consistent with the scientific analysis sumarized in this *Columbia River Cold Water Refuges Plan*. The states of Oregon and Washington are responsible for the development of management plans to implement the Columbia River Temperature TMDL. This *Columbia River Cold Water Refuges Plan,* specifically actions and recommendations listed in Chapters 7, 8, and 9 of the Plan, can serve as a reference to the states in the establishment of the management plans to meet the CWR targets established in the TMDL. This Plan, however, does not address actions to cool the mainstem Columbia River to attain the 20°C numeric criteria.

Lastly, EPA is issuing this Plan as a result of the reasonable and prudent alternative in the 2015 NMFS Biological Opinion. The Plan is not a regulation and does not impose binding requirements on any party, including EPA, other federal agencies, the states, or private entities.

1.2 TYPES OF COLD WATER REFUGES

Cold water refuges are created in several ways. Tributary streams that are colder than the river they flow into provide CWR for migrating fish in the confluence area of the tributary (plume CWR) and in the lower section of the tributary (stream CWR). Fish can enter these tributary areas to reside in water temperatures cooler than the river, minimizing their heat exposure. This is the main type of CWR in the Lower Columbia River.

CWR can also be formed by inflowing groundwater colder than the river channel, including river water that submerges into the gravels then re-emerges colder than the river (referred to as hyporheic flow) (Torgersen, C. et al. 2012). CWR can occur in stratified reservoirs, where warmer surface water can be avoided by fish residing in cooler water at depth. Additionally, if a river's temperature varies throughout the day, with warmer temperatures during the daylight hours and cooler temperatures at night due to the difference in solar heating, the cooler nighttime conditions serve as CWR relative to the warmer daytime temperatures. These other types of CWR are minor in scope in the Lower Columbia River, and there is no evidence that

[2] EPA's *Columbia and Lower Snake Rivers Temperature TMDL* also addresses exceedances of other numeric criteria in the Columbia and Snake Rivers.

they serve a significant role for salmon and steelhead in the Lower Columbia River (Appendix 12.1; High et al. 2006).

1.3 OVERVIEW OF COLUMBIA RIVER COLD WATER REFUGES PLAN

This Plan is focused on the Lower Columbia River between the mouth and river mile 309 (Oregon-Washington border), where the Oregon cold water narrative criteria applies (***Figure 1-1***). Since the Snake River entry at river mile 325 is near the Oregon-Washington border, EPA extended some of the analyses in the plan to the Snake River.

The following is a brief summary of the chapters in the plan.

- Chapter 1 provides introductory and background information.
- Chapter 2 characterizes the existing temperature conditions in the Lower Columbia River and identifies tributaries that provide CWR, including the location and size of each CWR.
- Chapter 0 describes how various salmon and steelhead species use CWR, including the Columbia River temperatures that trigger CWR use and the number of salmon and steelhead that reside in CWR during the warmest time of year.
- Chapter 4 summarizes the adverse effects warm river temperatures have on migrating adult salmon and steelhead and the relationship of river temperature to survival rates and the loss of energy reserves.
- Chapter 5 assesses how much the Columbia River has warmed over the past century and the extent to which the Columbia River is predicted to continue to warm due to climate change.
- Chapter 6 assesses whether there is a sufficient amount of CWR to support healthy salmon and steelhead populations and attain Oregon's coldwater refugia narrative criteria.
- Chapter 7 analyzes the watersheds of CWR tributaries and recommends actions to protect, restore, and enhance them.
- Chapter 8 summarizes scientific uncertainties related to CWR in the Lower Columbia River and recommends research studies to address those uncertainties.
- Lastly, Chapter 9 includes the plan's overall conclusions and recommendations.

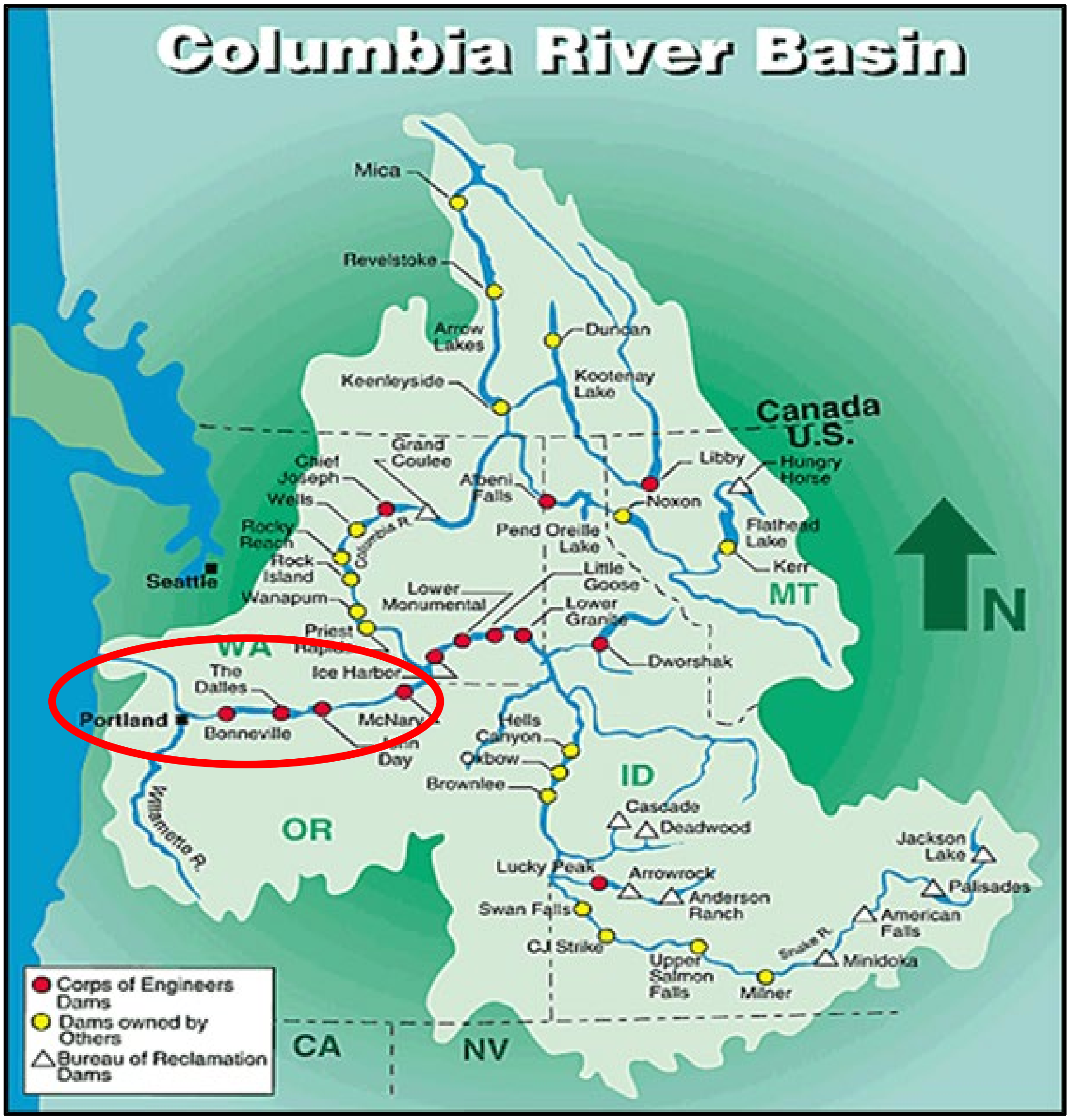

Figure 1-1 Map of the Columbia Basin, with the Columbia River Cold Water Refuges Plan scope circled in red (USACE)

2 COLD WATER REFUGES IN THE LOWER COLUMBIA RIVER

2.1 COLUMBIA RIVER TEMPERATURES

The Columbia River enters the State of Washington from Canada and warms as it moves through Washington towards the Pacific Ocean. ***Figure 2-1*** illustrates this longitudinal warming in the warm summer month of August, when river temperatures are at their seasonal peak. When the river enters Washington from Canada, average August river temperatures generally fluctuate between 17-18°C from year to year. Throughout the Lower Columbia River where the river serves as the border between Washington and Oregon, average August temperatures are between 21-22°C. This warm lower section of the river is the corridor through which all Columbia Basin salmon must begin their migration and is the focus of EPA's Cold Water Refuges Plan.

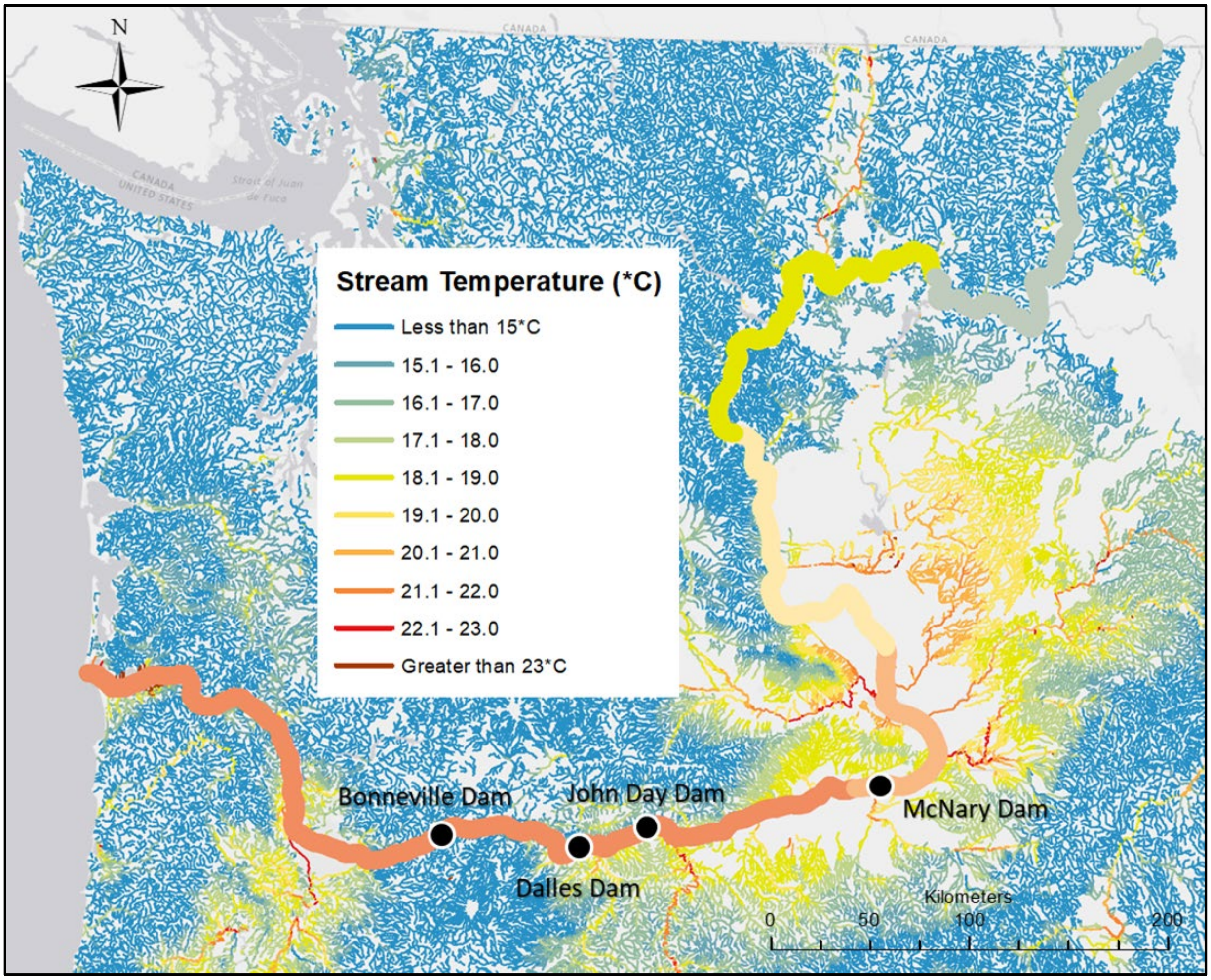

Figure 2-1 Current August mean water temperature in the Columbia River and tributaries (2011-2016) (Appendix 12.14)

Temperature data from the four Lower Columbia River dams show the longitudinal temperature regime in the Lower Columbia River (***Figure 2-2***). At McNary Dam, the most upstream of the four Lower Columbia River dams, the average August temperature is 21°C. The Columbia River then warms by 0.5°C in the 80-mile pool between McNary Dam and John Day Dam. The highest average August temperatures in the Lower Columbia River and the entire Columbia River occur near the John Day Dam, reaching 21.5°C on average in August. Temperatures decrease slightly at The Dalles Dam and the Bonneville Dam (***Figure 2-2***).

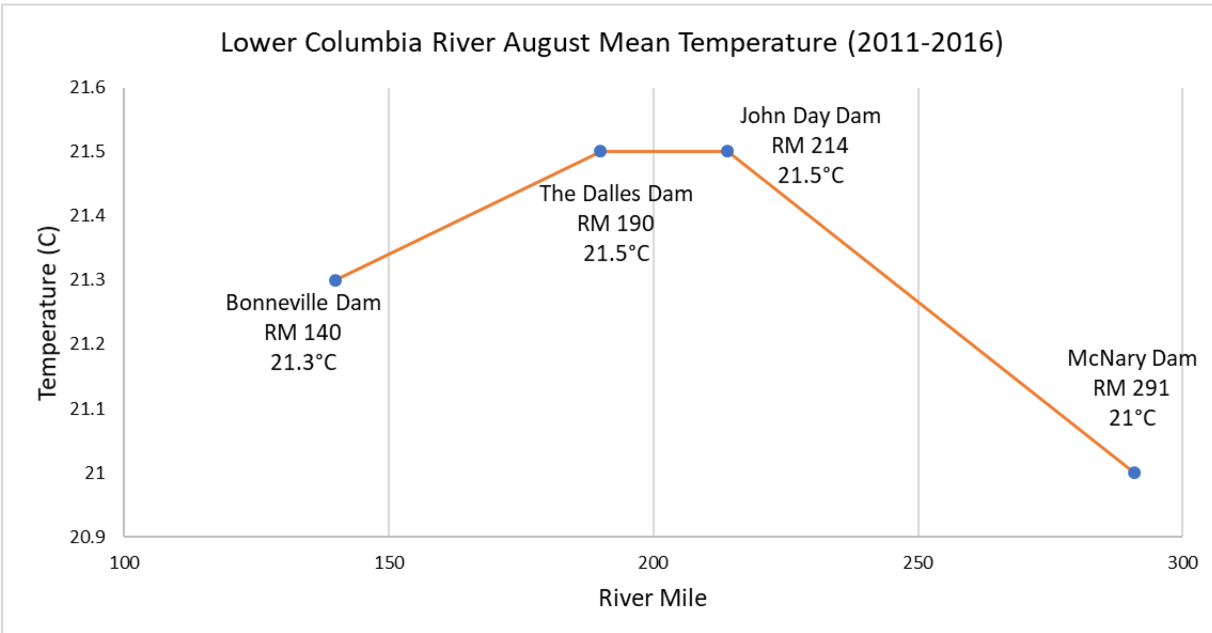

Figure 2-2 Longitudinal profile of the August mean Columbia River temperature from McNary Dam to the Bonneville Dam (DART)

Figure 2-3 illustrates the 6-year (2011-2016) daily average temperatures at the same four Columbia River dams, calculated from monitoring data downstream of the dams (tailrace or a few miles downstream). Also illustrated in ***Figure 2-3*** is the 20°C water quality standard for the Lower Columbia River, developed by both Washington and Oregon to protect migrating salmon. Daily average temperatures typically exceed 20°C for two months in a given summer on average throughout the Lower Columbia River, from the middle of July to the middle of September. Further, temperatures exceed 21°C for one month on average, generally the month of August, and peak close to 22°C during this time. As discussed above, temperatures at McNary Dam are slightly cooler than at the other three dams on average, and therefore the duration of exceeding these thresholds is slightly less than at the other three dams.

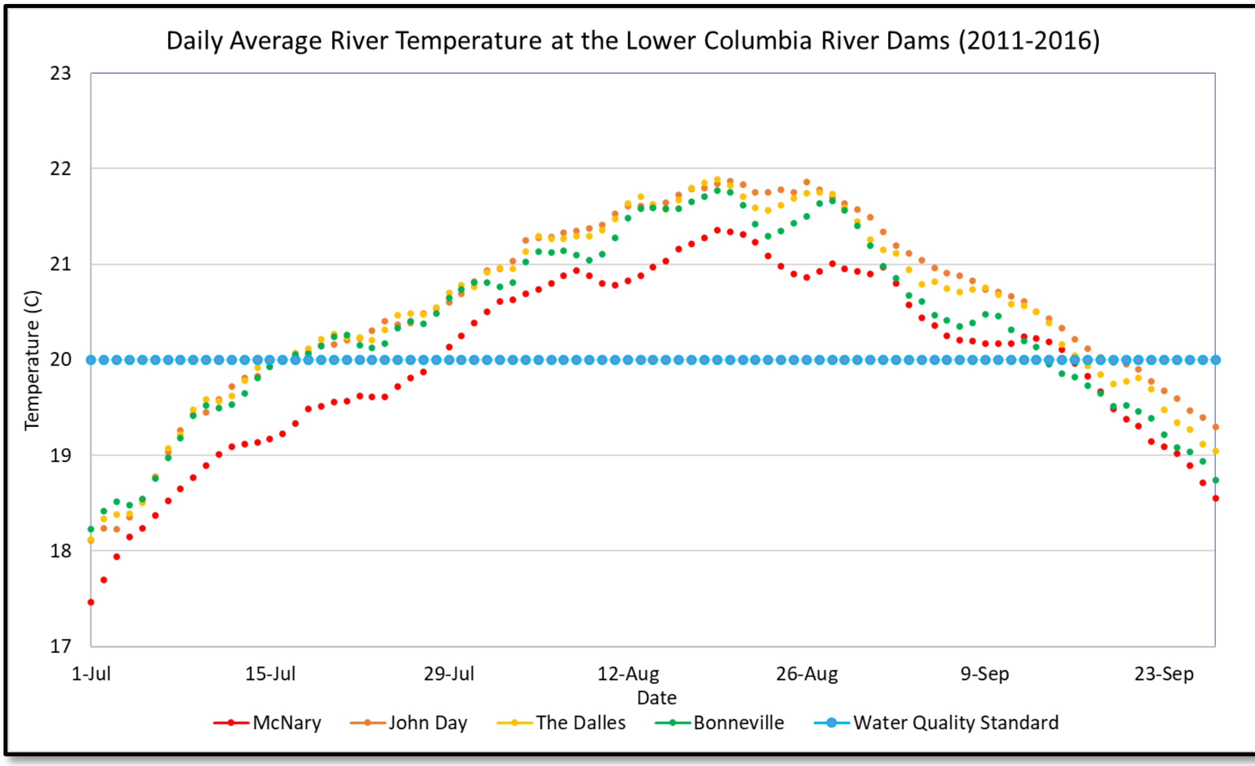

Figure 2-3 Lower Columbia River temperature from early July to mid-September, 6-year average 2011-2016 (DART)

Figure 2-1 through ***Figure 2-3*** illustrate data averaged across multiple years, which illustrate patterns for typical years but do not illustrate annual variability. The temperature regime can be very different between years primarily due to different air temperatures. ***Figure 2-4*** depicts observed data downstream of Bonneville Dam for 10 individual years (2009-2018) to illustrate the seasonal temperature range. The 10-year average of these Bonneville Dam daily average temperatures (thick black line) reaches 20°C in mid-July, rises to 21-22°C in August, then falls below 20°C in early September. The gray, red, and blue lines illustrate the variability in the Lower Columbia River temperature regime, showing that magnitude, timing, and duration of peak warming can vary between years. The red line depicts 2015 temperatures, which were unusually warm early in the summer contributing to high rates of sockeye salmon mortality.

During this 10-year timeframe, mid-July temperatures ranged from about 17.5°C in 2011 (blue line) to 22.5°C in 2015 (red line), a spread of 5°C. In mid-August, temperatures have less interannual variability, ranging from 20-22°C.

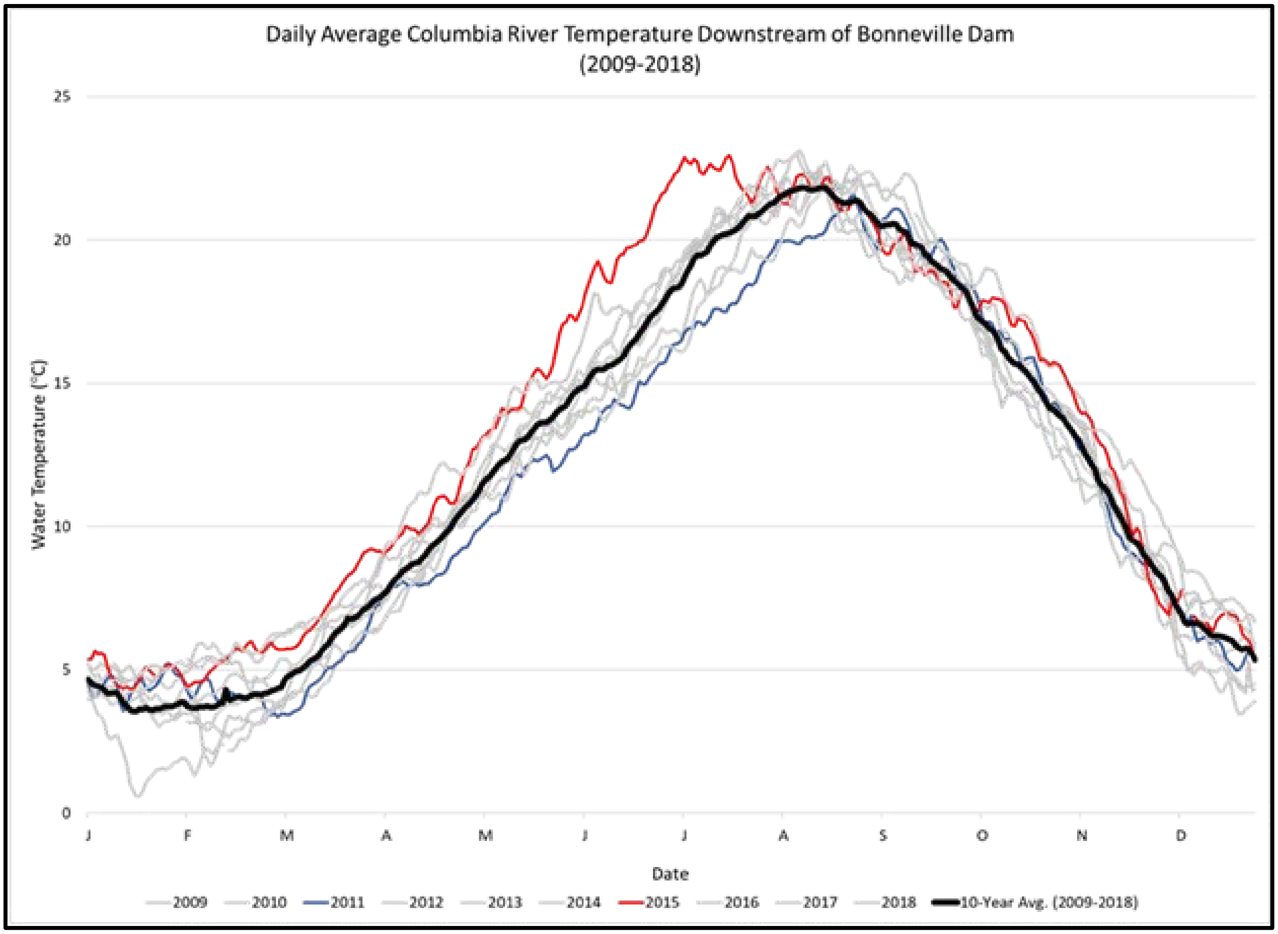

Figure 2-4 Seasonal temperature profiles downstream of Bonneville Dam, 10-year average 2009-2018 (DART)

There is little daily variation in the temperature of the Columbia River. Since the river is so large, it does not respond quickly to the air temperature differential between night and day as smaller rivers and creeks tend to do. The Lower Columbia River dams are 'run of river' so the reservoirs generally do not thermally stratify like deeper storage reservoirs. However, due to heating of the upper surface layer in the John Day and McNary Reservoirs in the summer, the upper part of these two reservoirs can be substantially warmer than the main channel temperature. During warm periods, the upper surface layer of these two reservoirs, especially near the dam forebays, can be 3-6°C warmer than the main channel temperature (Appendix 12.1).

2.2 TRIBUTARY TEMPERATURES COMPARED TO COLUMBIA RIVER TEMPERATURES

The National Hydrography Dataset (NHD) identifies 191 tributaries that flow directly into the Columbia River between the mouth of the Columbia River and the confluence with the Snake River (Appendix 12.2). Current August mean water temperatures for these rivers were obtained from a Spatial Stream Network model developed by the U.S. Forest Service (USFS) called NorWeST. The NorWeST database houses temperature data assembled from over 100 resource agencies across the western United States, and where data are unavailable, provides modeled temperature estimates based on nearby temperature measurements and other factors (Isaak et al. 2017). ***Figure 2-5*** illustrates these 191 tributary confluences (white dots) along with the predicted August mean temperature of the tributary.

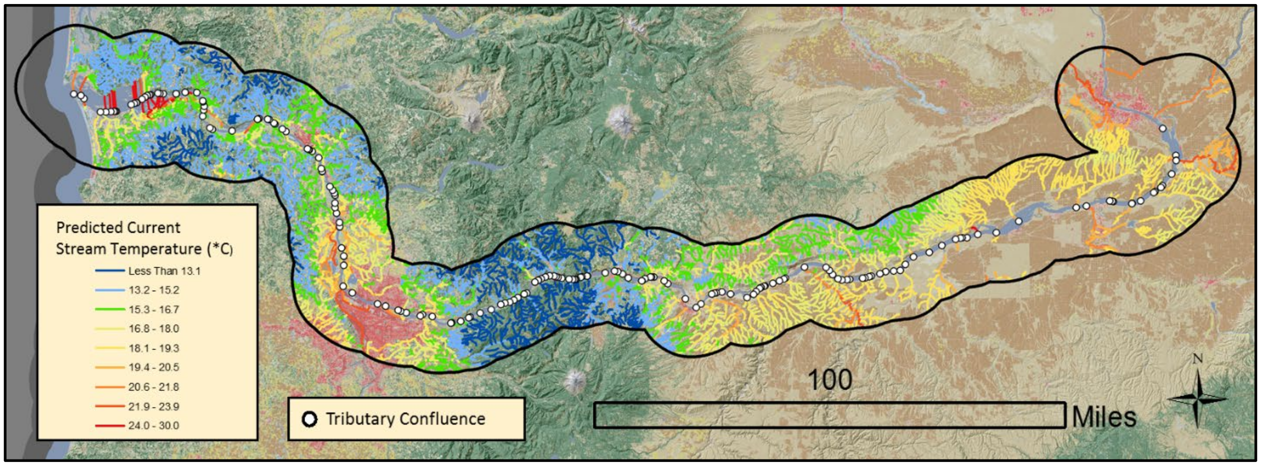

Figure 2-5 191 tributary confluences with the Lower Columbia River (white dots), with predicted stream temperatures from the NorWeST database [predicted August mean stream temperature for the 1993-2011 period]

EPA compared the predicted August mean temperature of these 191 tributaries to the August mean temperature of the Columbia River. ***Figure 2-6*** illustrates the August mean temperature difference between the Columbia River and its tributaries. The largest tributaries in ***Figure 2-6*** are displayed for geographical reference.

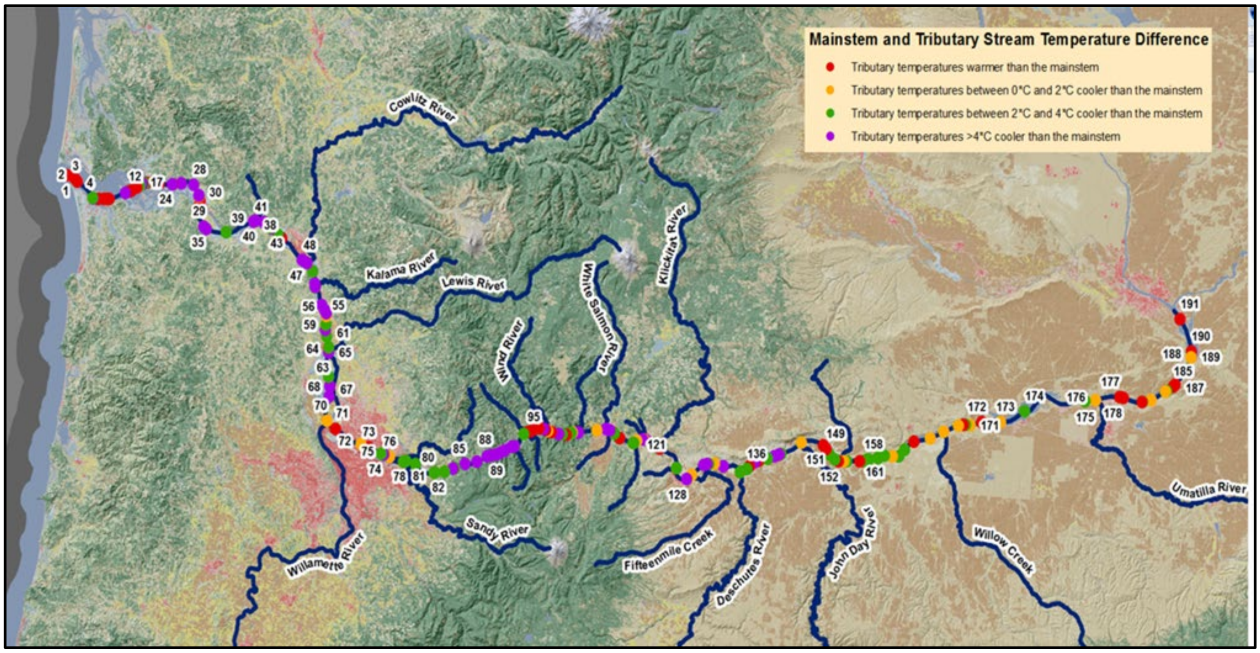

Figure 2-6 Columbia mainstem and tributary temperature difference (August mean water temperatures from USFS NorWeST)

Each of the 191 tributaries is color coded in ***Figure 2-6***, with purple identifying tributaries that are more than 4°C cooler than the Columbia River and green and yellow identifying tributaries that are between 2-4°C and 0-2°C colder than the Columbia River, respectively. Red identifies tributaries that are warmer than the Columbia River. As can be seen in the ***Figure 2-6***, most of the coolest tributaries (purple and green) are located within and downstream (west) of the Cascade mountain range.

In addition to the temperature analysis described above, the average (1971-2000) August flows for the 191 tributaries to the Lower Columbia River were derived from the Extended Unit Runoff Method model in NHDPlusV2, a national surface water database. It is important to note that there is a very large range of stream flows within these tributaries, ranging from <1 cfs to 8591cfs (August mean). ***Figure 2-7*** illustrates the relative flow (size of circle), tributary and Columbia River temperature (position along y-axis), and temperature relative to the Columbia River (color).

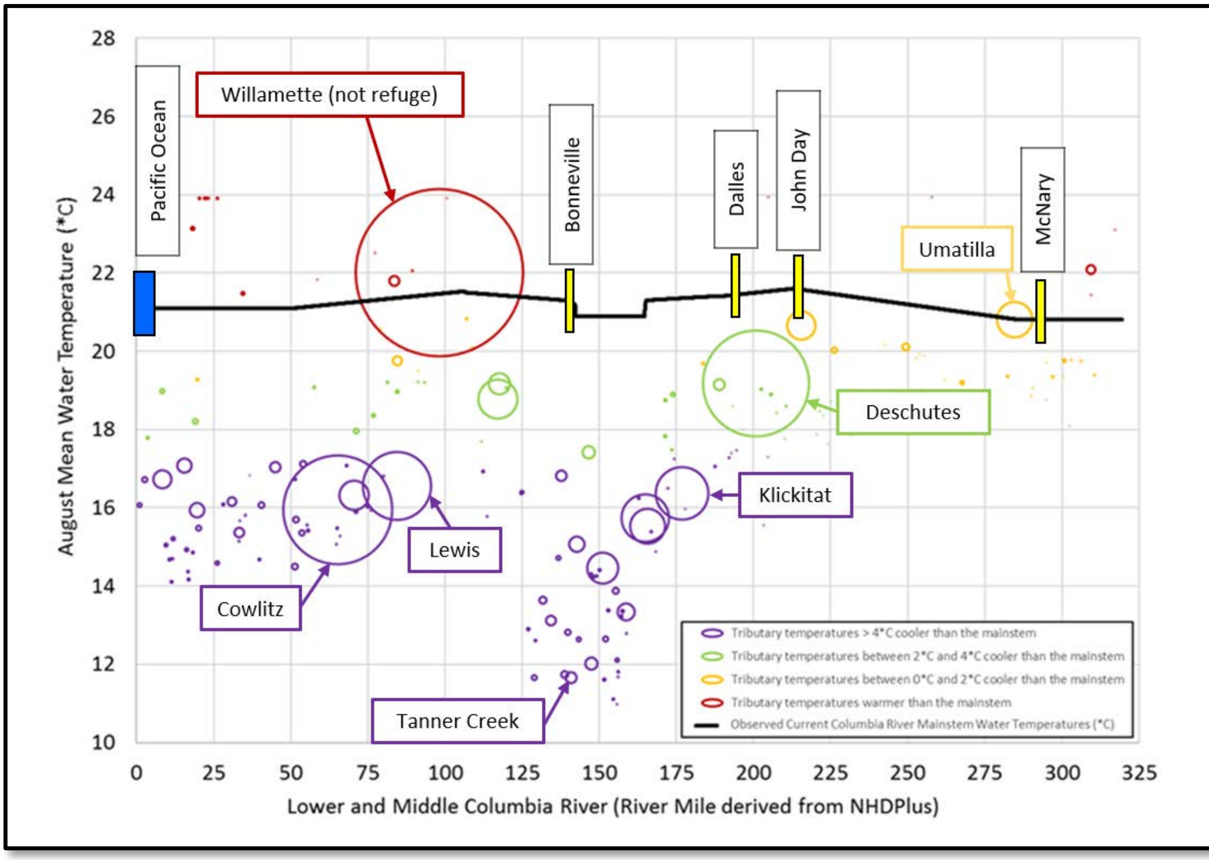

Figure 2-7 Modeled August mean stream temperatures for tributaries in the Lower Columbia River (1993-2011) (USFS NorWeST). Circle sizes illustrate relative tributary August mean flow (1971-2000) (NHDPlus).

2.3 TRIBUTARIES PROVIDING COLD WATER REFUGE

Whether a tributary will provide cold water refuge (CWR) depends upon its temperature relative to the Columbia River and the size and accessibility of its confluence area to migrating salmon and steelhead. Using the information described in section 2.2 and other information noted below, EPA conducted a screening analysis to identify tributaries that provide CWR for salmon and steelhead in the Lower Columbia River. The first screen in the analysis was based on: 1) the tributary's August mean temperature being 2°C colder than the Columbia River; and 2) the tributary's August mean flow being greater than 10 cubic feet per second (cfs). EPA used 10 cfs as an approximate minimum flow needed to form a cool water plume in the Columbia River, which would attract salmon and steelhead use (Appendix 12.3).

From this list of tributaries, EPA excluded tributaries that were inaccessible to migrating salmon and steelhead and excluded several tributaries where field flow data indicated flow was significantly less than 10 cfs. EPA added the Umatilla River to the list, because although its August mean temperature difference is less than 2°C cooler than the Columbia River, it is 2°C cooler in late August/September and is the only CWR in the John Day Reservoir, so its location is important. EPA also included two tributaries (Germany Creek and Bridal Veil Creek) on the list with August mean flows between 7-10 cfs that are especially cold. This screening approach resulted in listing 23 tributaries that currently provide CWR in the Lower Columbia River, as noted in ***Table 2-1*** (Appendix 12.3).

In ***Table 2-1*** the August mean Columbia River mainstem temperatures (2005-2014) reflect data in DART from the nearest mainstem dam. The August mean tributary temperatures are from the NorWeSt model (1993-2011).The tributary flows are either from NHD Plus (1971-2000), or if available, USGS gauge data. Although this information has varying time frames due to the availablity of the data, these data are intended to represent long term average temperature and flow conditions.

Tributary Name	River Mile	August Mean Mainstem Temperature (DART)	August Mean Tributary Temperature (NorWeST)	August Mean Temperature Difference	August Mean Tributary Flow (NHD & USGS*)
		°C	°C	°C	cfs
Skamokawa Creek (WA)	30.9	21.3	16.2	-5.1	23
Mill Creek (WA)	51.3	21.3	14.5	-6.8	10
Abernethy Creek (WA)	51.7	21.3	15.7	-5.6	10
Germany Creek (WA)	53.6	21.3	15.4	-5.9	8
Cowlitz River (WA)	65.2	21.3	16.0	-5.4	3634
Kalama River (WA)	70.5	21.3	16.3	-5.0	314*
Lewis River (WA)	84.4	21.3	16.6	-4.8	1291*
Sandy River (OR)	117.1	21.3	18.8	-2.5	469
Washougal River (WA)	117.6	21.3	19.2	-2.1	107*
Bridal Veil Creek (OR)	128.9	21.3	11.7	-9.6	7
Wahkeena Creek (OR)	131.7	21.3	13.6	-7.7	15
Oneonta Creek (OR)	134.3	21.3	13.1	-8.2	29
Tanner Creek (OR)	140.9	21.3	11.7	-9.6	38
Bonneville Dam					
Eagle Creek (OR)	142.7	21.2	15.1	-6.1	72
Rock Creek (WA)	146.6	21.2	17.4	-3.8	47
Herman Creek (OR)	147.5	21.2	12.0	-9.2	45
Wind River (WA)	151.1	21.2	14.5	-6.7	293
Little White Salmon River (WA)	158.7	21.2	13.3	-7.9	248*
White Salmon River (WA)	164.9	21.2	15.7	-5.5	715*
Hood River (OR)	165.7	21.4	15.5	-5.9	374
Klickitat River (WA)	176.8	21.4	16.4	-5.0	851*
The Dalles Dam					
Deschutes River (OR)	200.8	21.4	19.2	-2.2	4772*
John Day Dam					
Umatilla River[1] (OR)	284.7	20.9	20.8	-0.1	87*
McNary Dam					

[1] The Umatilla is 2°C cooler than the Columbia River in late August and September.

Table 2-1 23 tributaries providing cold water refuge in the Lower Columbia River

EPA estimated the volume in cubic meters (m^3) of water that is at least 2°C colder than the Columbia River for each of the 23 tributaries listed in ***Table 2-1***. The purpose of estimating the CWR volume is to compare the relative size and importance of the refuges and to assess the density of fish in CWR. EPA used a combination of monitoring and modeling techniques to estimate the volume of CWR in tributary confluence areas (plume CWR) and in the lower portion of the CWR tributaries (stream CWR) used by salmon and steelhead. As part of estimating the stream CWR volume in the lower portion of a given CWR tributary, EPA estimated how far upstream salmon or steelhead are likely to go when using it as a CWR. These 'upstream extent' estimates are based on Passive Integrative Transponder-tag (PIT-tag) and radio tag information, discussions with field biologists, stream depth measurements, satellite images, and field observations (Appendix 12.4). To estimate the volume of the plume extending into the Columbia River that remained 2°C colder than the Columbia River itself (plume CWR), EPA used a CORMIX plume model or in some cases (Herman Creek Cove, Little White Salmon (Drano Lake), and the Wind River delta) took direct measures of embayment areas to calculate the volumes (Appendix 12.5 through 12.11). The 23 tributaries and their associated plume CWR and stream CWR are listed in ***Table 2-2***.

Tributary Name	River Mile	August Mean Mainstem Temperature (DART)	August Mean Tributary Temperature (NorWeST)	August Mean Temperature Difference	August Mean Tributary Flow (NHD & USGS*)	Plume CWR Volume (> 2°C Δ)	Stream CWR Volume (> 2°C Δ)	Total CWR Volume (> 2°C Δ)
		°C	°C	°C	cfs	m³	m³	m³
Skamokawa Creek (WA)	30.9	21.3	16.2	-5.1	23	450	1,033	1,483
Mill Creek (WA)	51.3	21.3	14.5	-6.8	10	110	446	556
Abernethy Creek (WA)	51.7	21.3	15.7	-5.6	10	81	806	887
Germany Creek (WA)	53.6	21.3	15.4	-5.9	8	72	446	518
Cowlitz River (WA)	65.2	21.3	16.0	-5.4	3634	870,000	684,230	1,554,230
Kalama River (WA)	70.5	21.3	16.3	-5.0	314*	14,000	27,820	41,820
Lewis River (WA)	84.4	21.3	16.6	-4.8	1291*	120,000	493,455	613,455
Sandy River (OR)	117.1	21.3	18.8	-2.5	469	9,900	22,015	31,915
Washougal River[1] (WA)	117.6	21.3	19.2	-2.1	107*	740	32,563	33,303
Bridal Veil Creek (OR)	128.9	21.3	11.7	-9.6	7	120	0	120
Wahkeena Creek (OR)	131.7	21.3	13.6	-7.7	15	220	0	220
Oneonta Creek (OR)	134.3	21.3	13.1	-8.2	29	820	54	874
Tanner Creek (OR)	140.9	21.3	11.7	-9.6	38	1,300	413	1,713
Bonneville Dam								
Eagle Creek (OR)	142.7	21.2	15.1	-6.1	72	2,100	888	2,988
Rock Creek[1] (WA)	146.6	21.2	17.4	-3.8	47	530	1,178	1,708
Herman Creek (OR)	147.5	21.2	12.0	-9.2	45	168,000	1,698	169,698
Wind River (WA)	151.1	21.2	14.5	-6.7	293	60,800	44,420	105,220
Little White Salmon River (WA)	158.7	21.2	13.3	-7.9	248*	1,097,000	11,661	1,108,661
White Salmon River (WA)	164.9	21.2	15.7	-5.5	715*	72,000	81,529	153,529
Hood River (OR)	165.7	21.4	15.5	-5.9	374	28,000	0	28,000
Klickitat River (WA)	176.8	21.4	16.4	-5.0	851*	73,000	149,029	222,029
The Dalles Dam								
Deschutes River (OR)	200.8	21.4	19.2	-2.2	4772*	300,000	580,124	880,124
John Day Dam								
Umatilla River[1] (OR)	284.7	20.9	20.8	-0.1	87*	0	10,473	10,473
McNary Dam								

[1] Only provide intermittent cold water refugia; CWR volume represents volume when river is greater than 2°C colder than Columbia River.

Table 2-2 Estimates for the volume of water in tributary confluence areas that is more than 2°C cooler than the Columbia River

2.4 TWELVE PRIMARY COLD WATER REFUGES

Of the 23 tributaries in ***Table 2-1*** and ***Table 2-2***, EPA identified 12 as particularly important primary CWR areas based on CWR volume, stream temperatures, field observations, and documented or presumed use by salmon and steelhead (Appendix 12.5). The 12 primary CWR are bolded in ***Table 2-3*** and displayed in ***Figure 2-8***. In both ***Table 2-3*** and ***Figure 2-8***, primary CWR tributaries that are >4°C cooler than the Columbia are highlighted in purple, and primary CWR tributaries with temperatures 2-4°C cooler than the Columbia are highlighted in green.

The 12 primary tributaries constitute 98% of the total CWR volume in the Lower Columbia River, are easily accessible, are sufficiently deep to provide cover, and have documented or presumed use by migrating salmon and steelhead. The other 11 non-primary CWR tributaries have small CWR volume (less than 2,000 m^3), have substantial periods of time when the tributary is less than 2°C cooler or even warmer than the Columbia River, and/or are shallow and exposed. Additionally, the extent of use by salmon and steelhead in these 11 non-primary CWR tributaries is unknown and likely is limited due to one or more of the characteristics noted above (Appendix 12.5).

Tributary Name	River Mile	August Mean Mainstem Temperature (DART)	August Mean Tributary Temperature (NorWeST)	August Mean Temperature Difference	August Mean Tributary Flow (NHD & USGS*)	Plume CWR Volume (> 2°C Δ)	Stream CWR Volume (> 2°C Δ)	Total CWR Volume (> 2°C Δ)
		°C	°C	°C	cfs	m^3	m^3	m^3
Skamokawa Creek (WA)	30.9	21.3	16.2	-5.1	23	450	1,033	1,483
Mill Creek (WA)	51.3	21.3	14.5	-6.8	10	110	446	556
Abernethy Creek (WA)	51.7	21.3	15.7	-5.6	10	81	806	887
Germany Creek (WA)	53.6	21.3	15.4	-5.9	8	72	446	518
Cowlitz River (WA)	65.2	21.3	16.0	-5.4	3634	870,000	684,230	1,554,230
Kalama River[2] (WA)	70.5	21.3	16.3	-5.0	314*	14,000	27,820	41,820
Lewis River (WA)	84.4	21.3	16.6	-4.8	1291*	120,000	493,455	613,455
Sandy River (OR)	117.1	21.3	18.8	-2.5	469	9,900	22,015	31,915
Washougal River[1] (WA)	117.6	21.3	19.2	-2.1	107*	740	32,563	33,303
Bridal Veil Creek (OR)	128.9	21.3	11.7	-9.6	7	120	0	120
Wahkeena Creek (OR)	131.7	21.3	13.6	-7.7	15	220	0	220
Oneonta Creek (OR)	134.3	21.3	13.1	-8.2	29	820	54	874
Tanner Creek (OR)	140.9	21.3	11.7	-9.6	38	1,300	413	1,713
Eagle Creek (OR)	142.7	21.2	15.1	-6.1	72	2,100	888	2,988
Rock Creek[1] (WA)	146.6	21.2	17.4	-3.8	47	530	1,178	1,708
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Wind River (WA)	151.1	21.2	14.5	-6.7	293	60,800	44,420	105,220
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White Salmon River (WA)	164.9	21.2	15.7	-5.5	715*	72,000	81,529	153,529
Hood River (OR)	165.7	21.4	15.5	-5.9	374	28,000	0	28,000
Klickitat River (WA)	176.8	21.4	16.4	-5.0	851*	73,000	149,029	222,029
Deschutes River (OR)	200.8	21.4	19.2	-2.2	4772*	300,000	580,124	880,124
Umatilla River[1] (OR)	284.7	20.9	20.8	-0.1	87*	0	10,473	10,473

[1] Only provides intermittent cold water refugia; CWR volume represents volume when river is greater than 2°C colder than Columbia River.
[2] Tidally influenced and may be inaccessible during low tides.

Table 2-3 Twelve primary CWR tributaries (highlighted in bold and color)

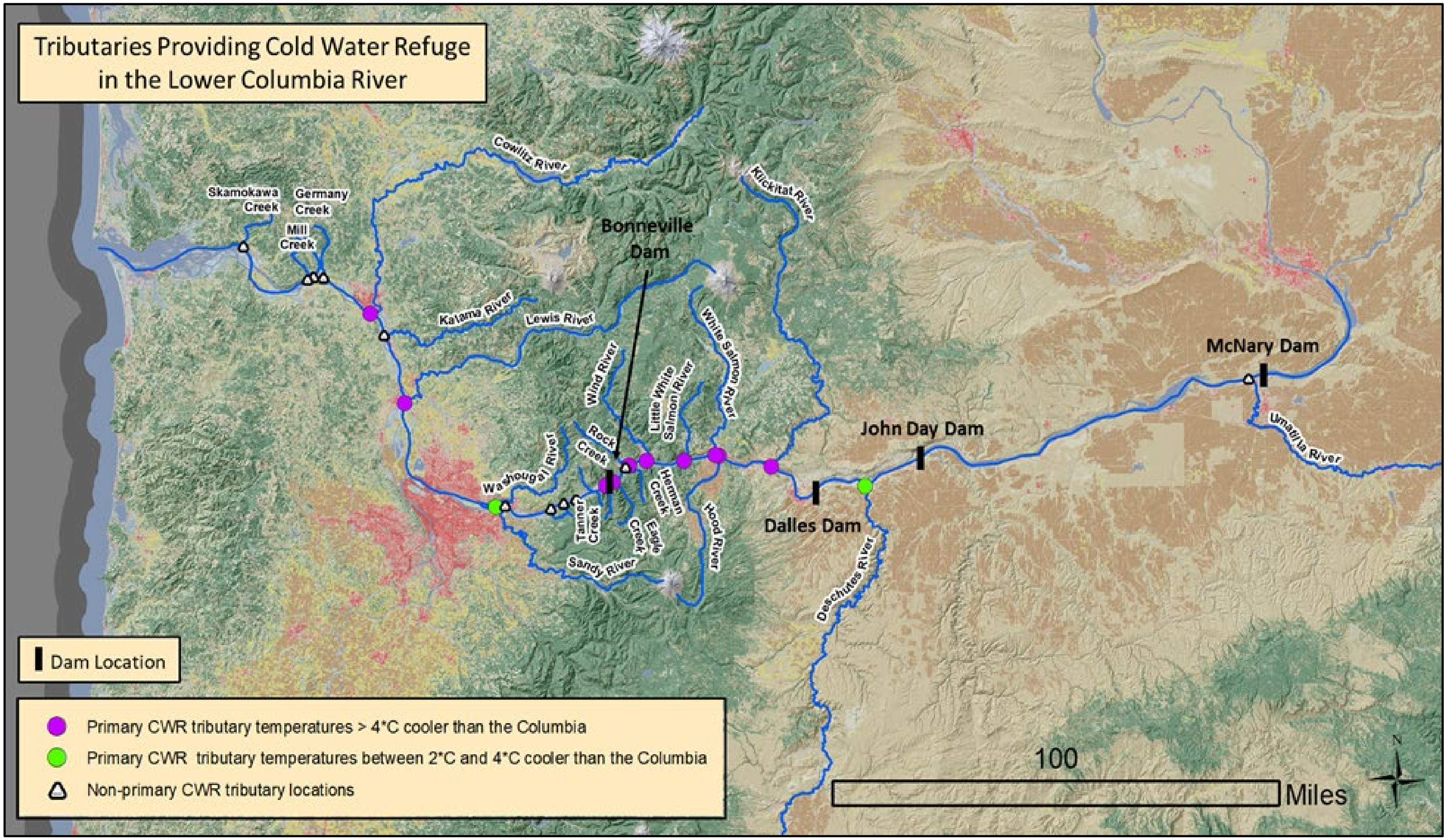


Figure 2-8 Twelve primary cold water refuge tributaries (purple and green) to the Lower Columbia River as well as the 11 non-primary cold water refuge tributaries (white)

Four of the 12 primary CWR tributaries are below Bonneville Dam, seven are between the Bonneville Dam and The Dalles Dam, and only one, the Deschutes River, is upstream of The Dalles Dam. The two largest CWR are the Cowlitz River confluence area CWR and the Little White Salmon River CWR, which drains into Drano Lake prior to entering the Columbia River. The total volume of all 23 CWR is roughly 5 million cubic meters, which is equivalent to 2,000 Olympic-sized swimming pools. The 12 primary CWR constitute an estimated 98% of the total CWR volume in the Lower Columbia River.

Each of the 12 primary CWR tributaries is shown in ***Figure 2-9*** through ***Figure 2-20***. On each figure is a yellow pin showing the ‘upstream extent,’ which signifies how far upstream EPA estimates salmon and steelhead will swim up the tributary when using it as a CWR (Appendix 12.4). Each figure includes the daily average temperature profile of both the Columbia River (black) and the tributary (purple or green) to illustrate the difference in water temperatures over time between the two (see Appendix 12.12 for location of temperature monitors). The bars associated with the temperature profiles reflect the average diurnal range in temperature. Some of the figures include a pink pin, which is the location of a PIT-tag antenna that records fish with inserted PIT-tags if they swim past the receiver.

**Yellow pin is estimated CWR upstream extent*

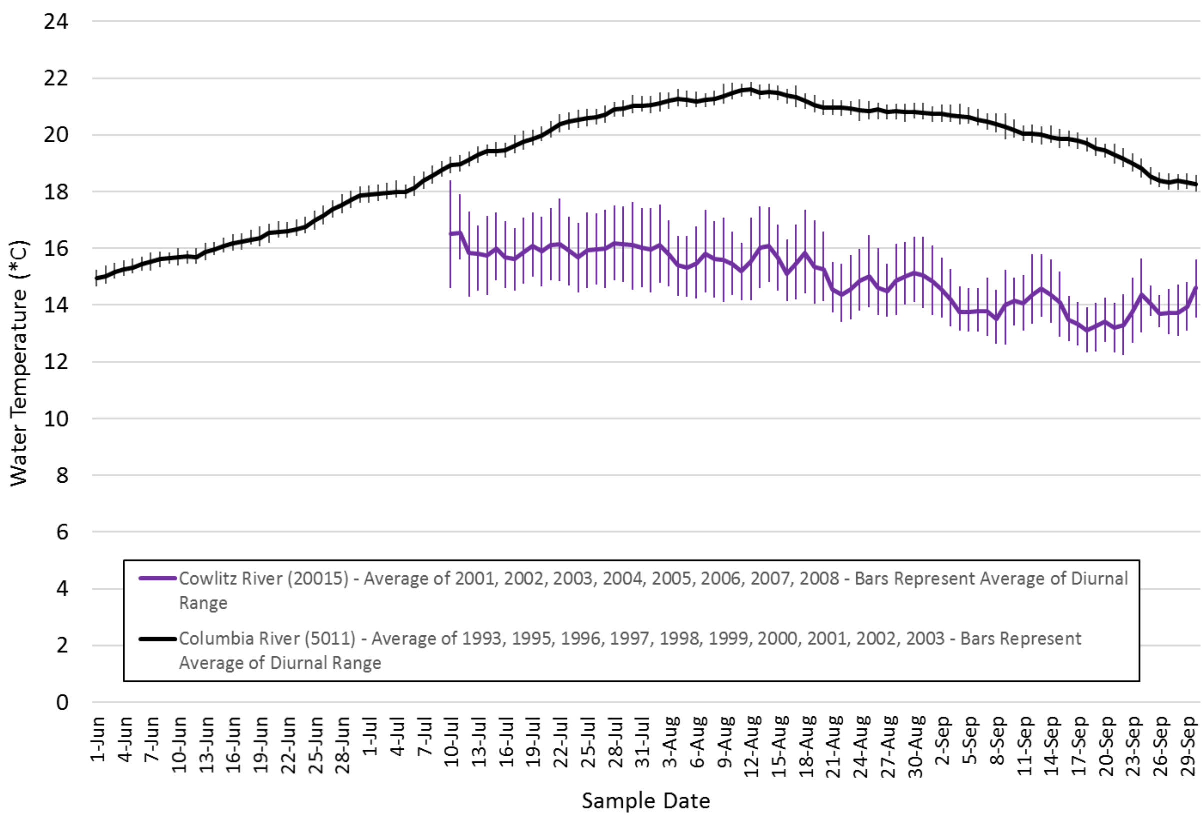


Figure 2-9 Cowlitz River Cold Water Refuge and Associated Temperatures

**Yellow pin is estimated CWR upstream extent*

Figure 2-10 Lewis River Cold Water Refuge

**Yellow pin is estimated CWR upstream extent*

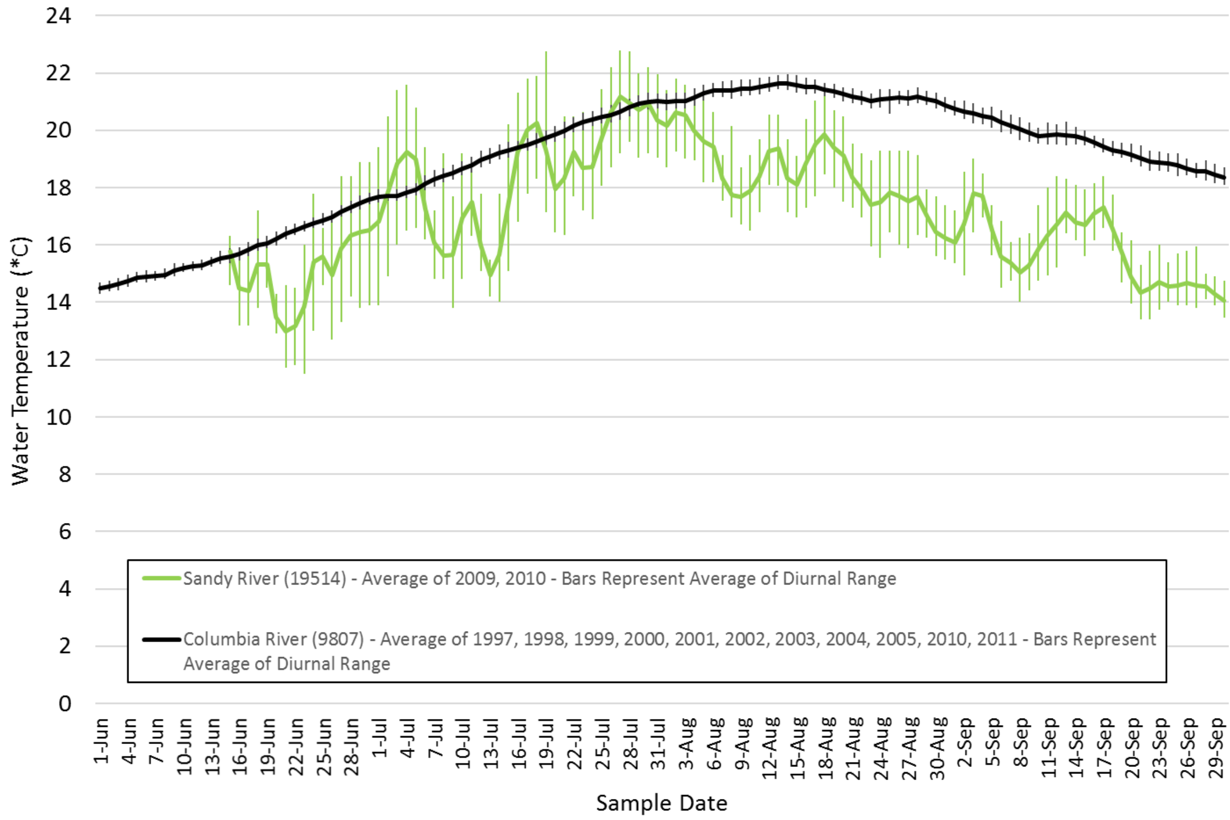


Figure 2-11 Sandy River Cold Water Refuge and Associated Temperatures

Yellow pin is estimated CWR upstream extent

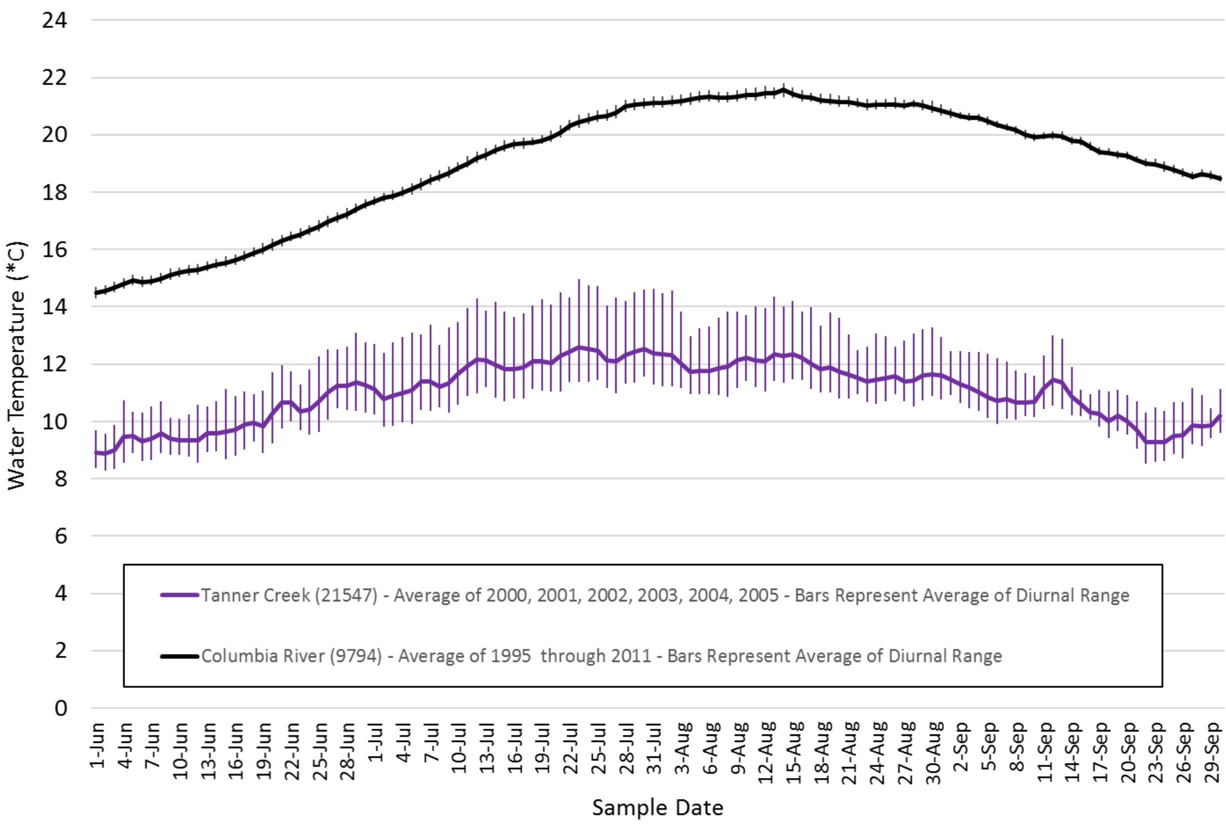


Figure 2-12 Tanner Creek Cold Water Refuge and Associated Temperatures

**Yellow pin is estimated CWR upstream extent*

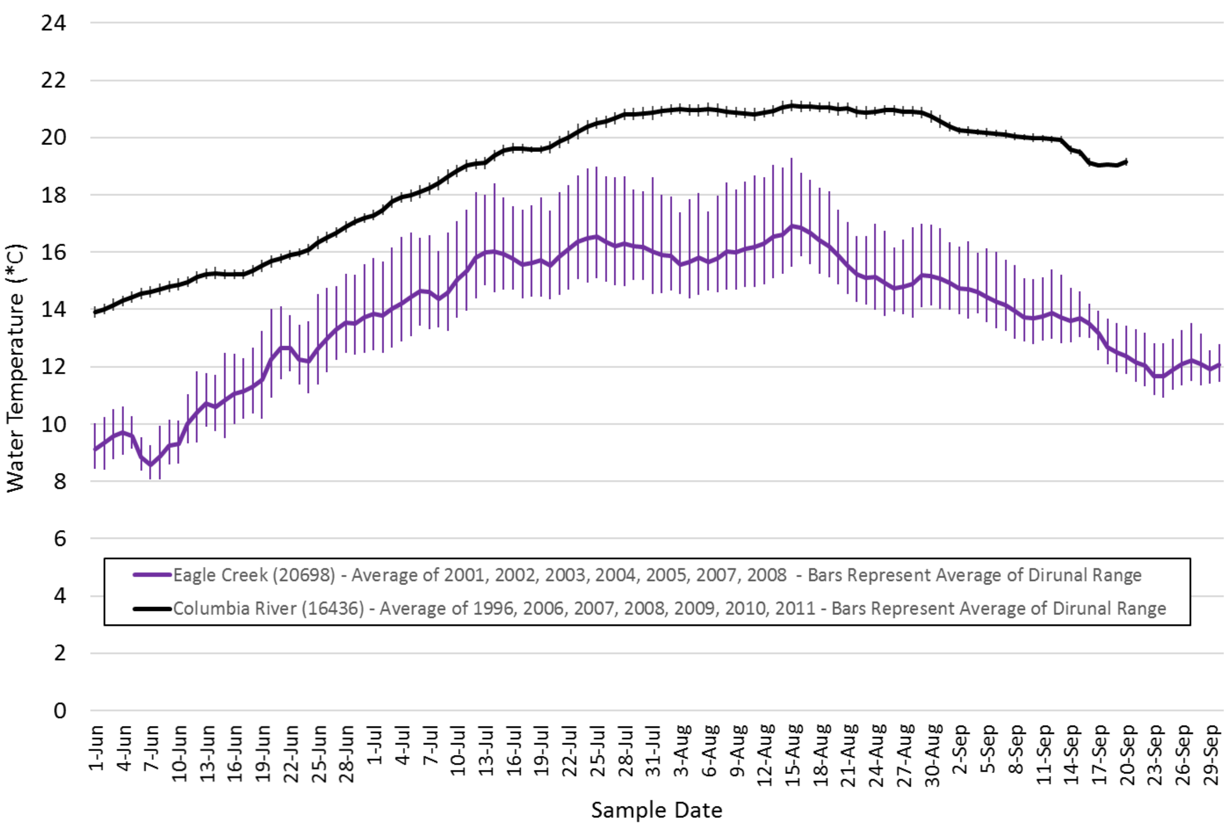


Figure 2-13 Eagle Creek Cold Water Refuge and Associated Temperatures

**Yellow pin is estimated CWR upstream extent*

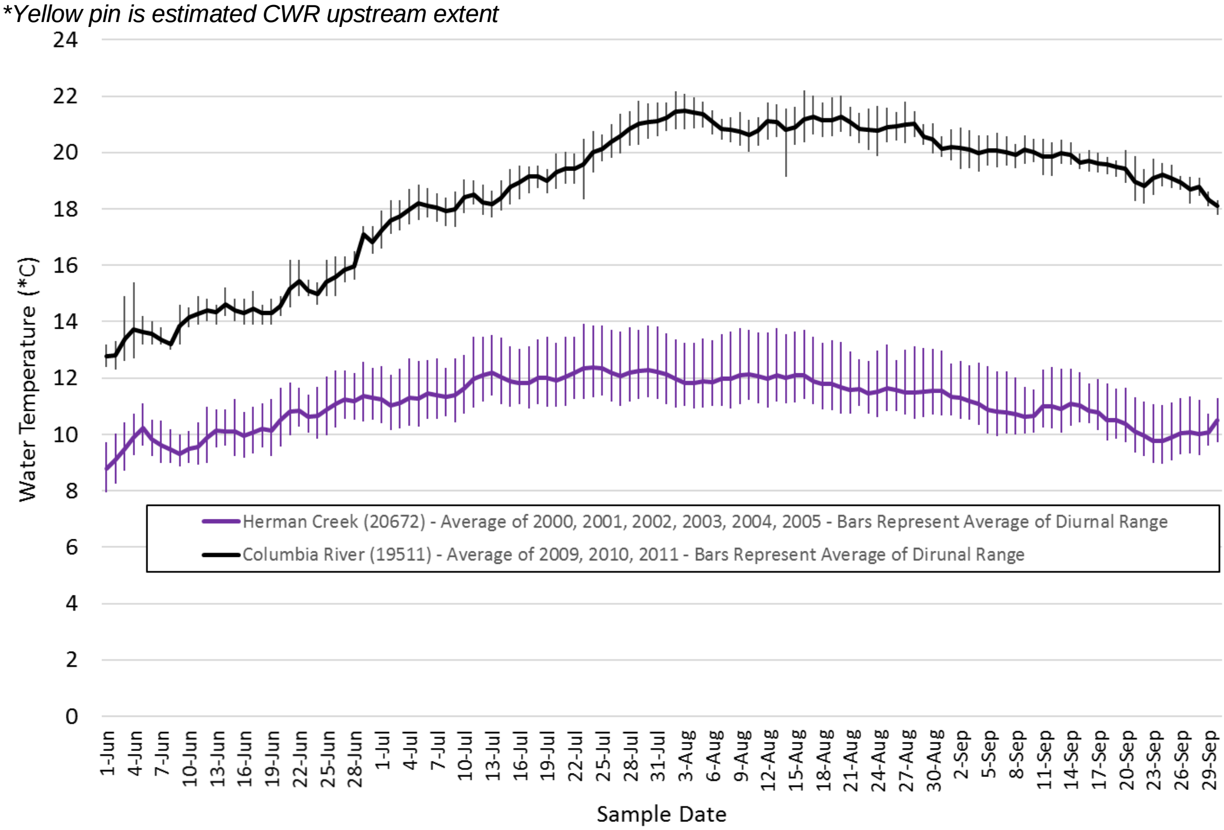


Figure 2-14 Herman Creek and Cove Cold Water Refuge and Associated Temperatures

**Yellow pin is estimated CWR upstream extent*

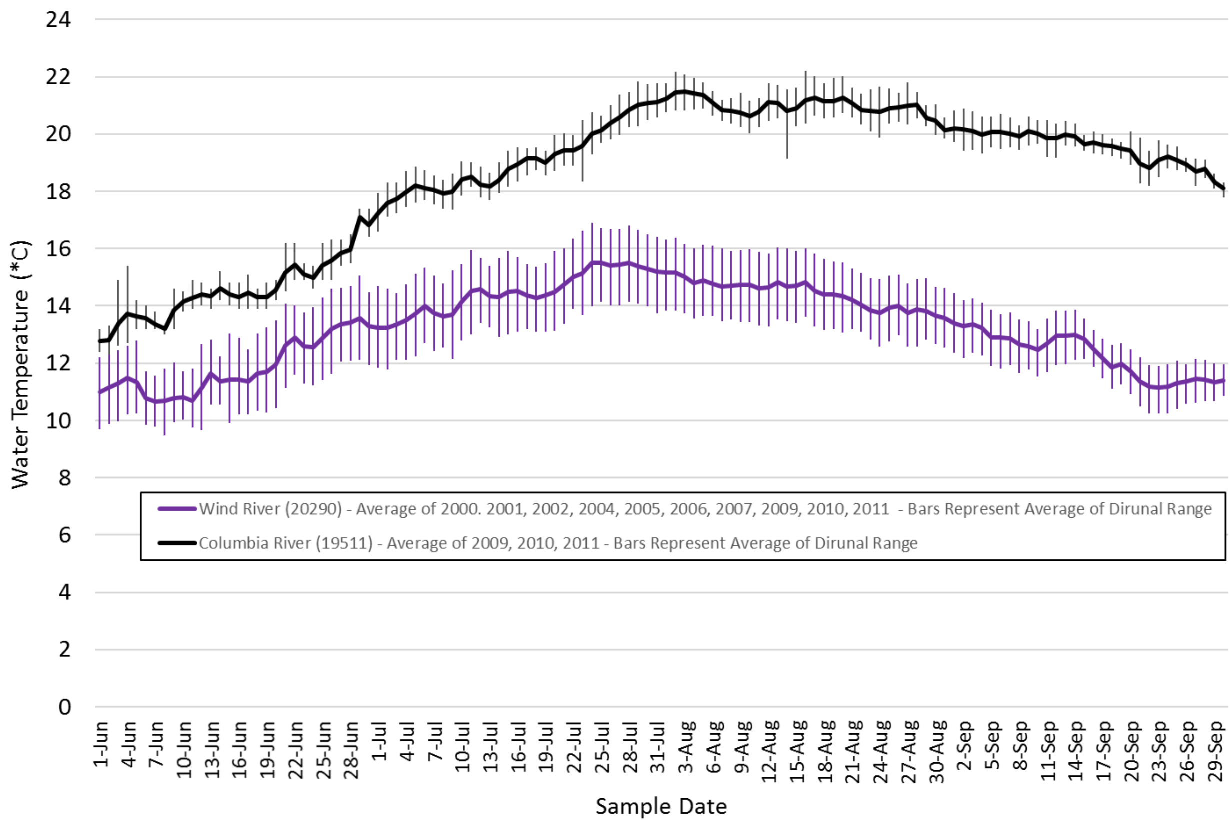


Figure 2-15 Wind River Cold Water Refuge and Associated Temperatures

*Yellow pin is estimated CWR upstream extent

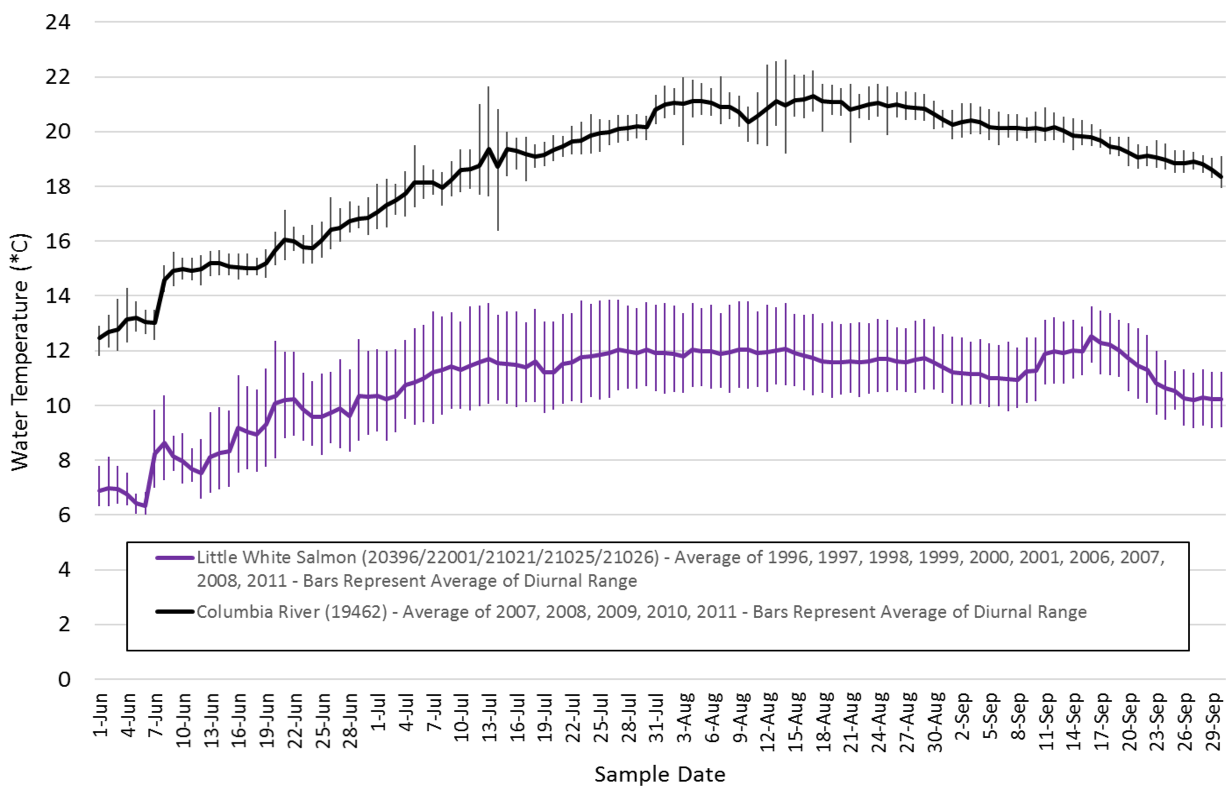


Figure 2-16 Little White Salmon River and Drano Lake Cold Water Refuge and Associated Temperatures

*Yellow pin is estimated CWR upstream extent

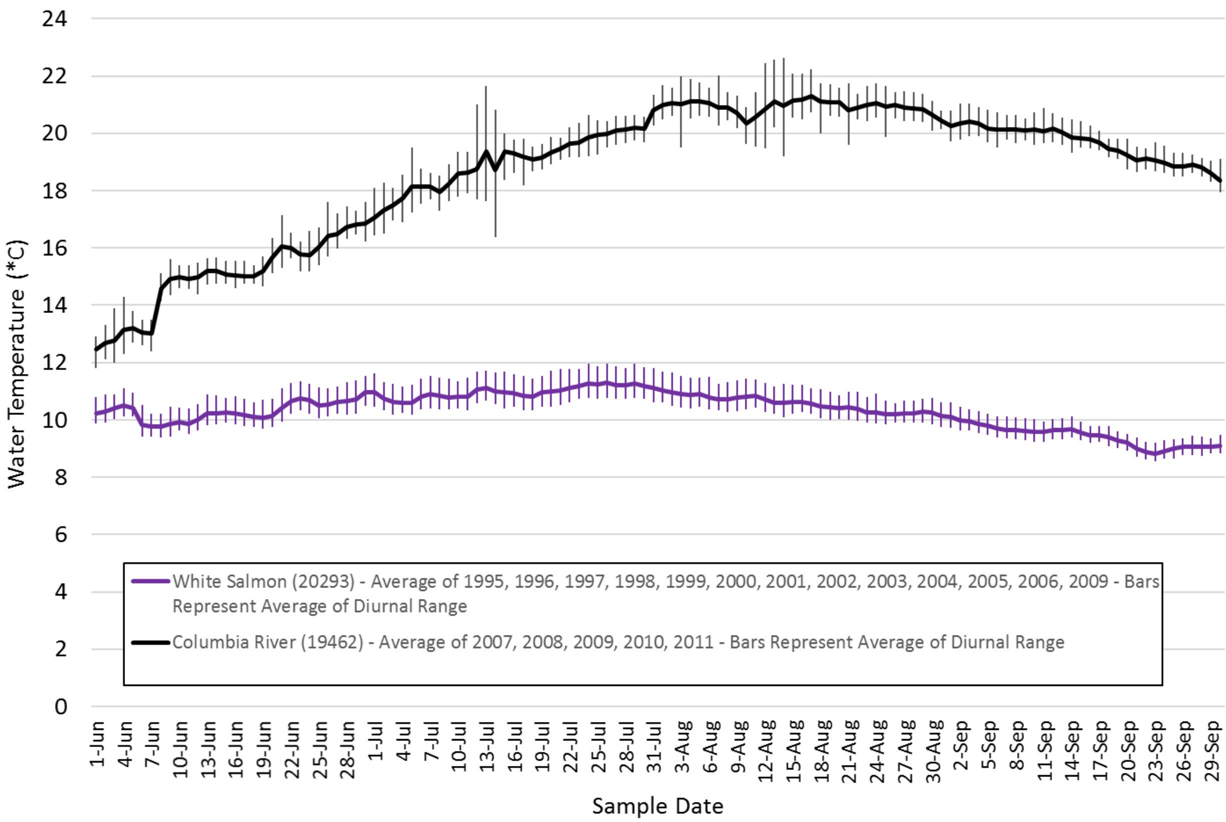


Figure 2-17 White Salmon River Cold Water Refuge and Associated Temperatures

**Yellow pin is estimated CWR upstream extent*

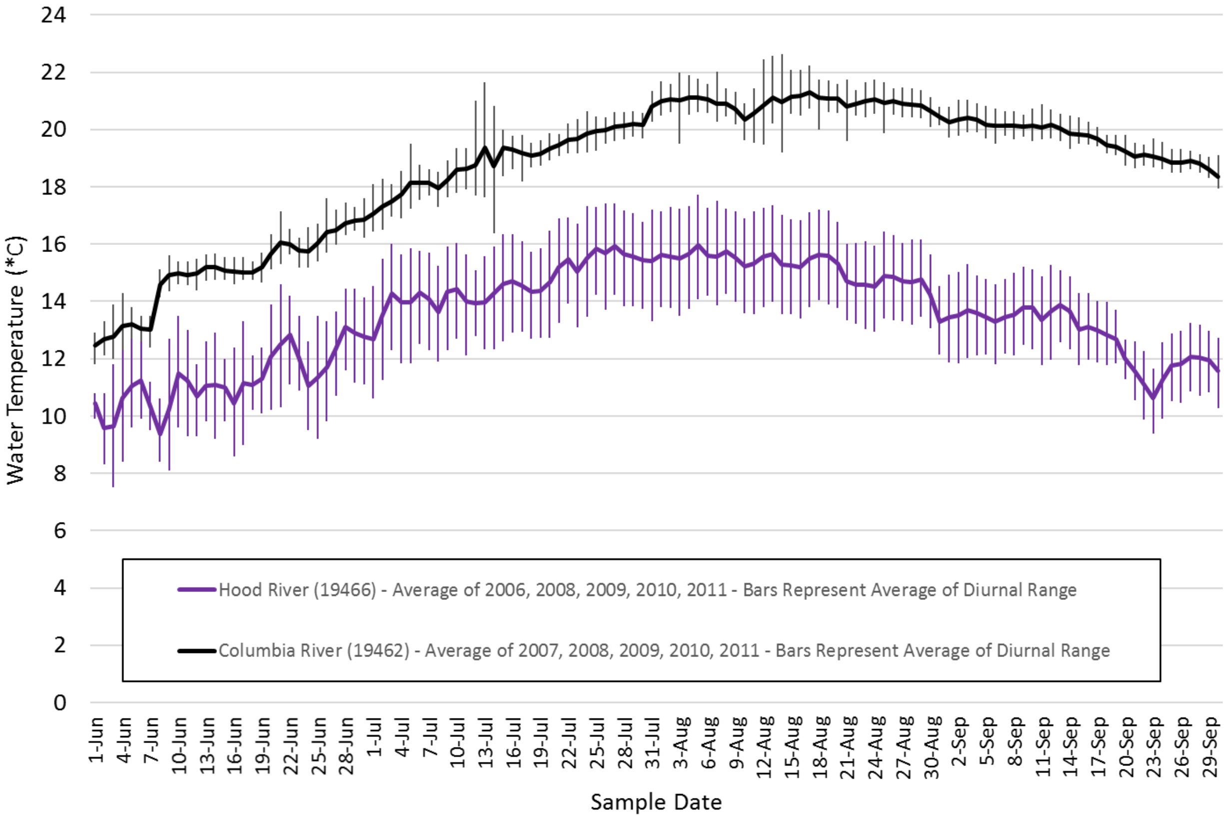
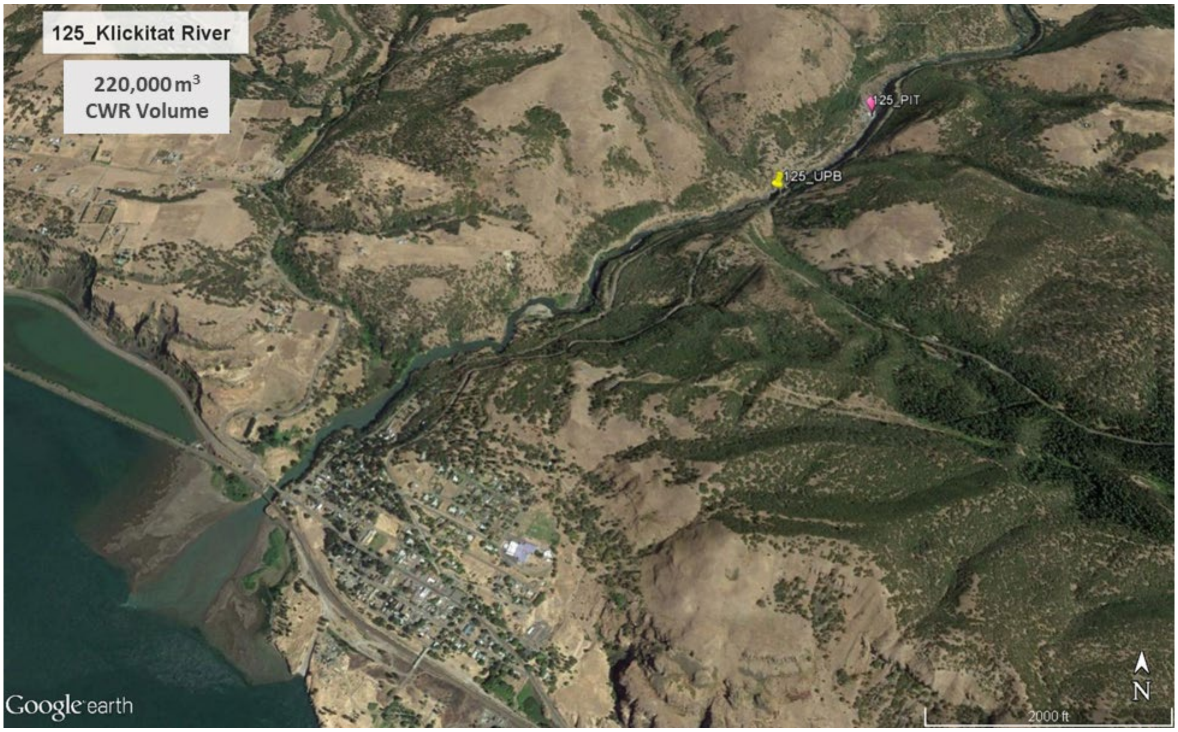


Figure 2-18 Hood River Cold Water Refuge and Associated Temperatures



**Yellow pin is estimated CWR upstream extent*

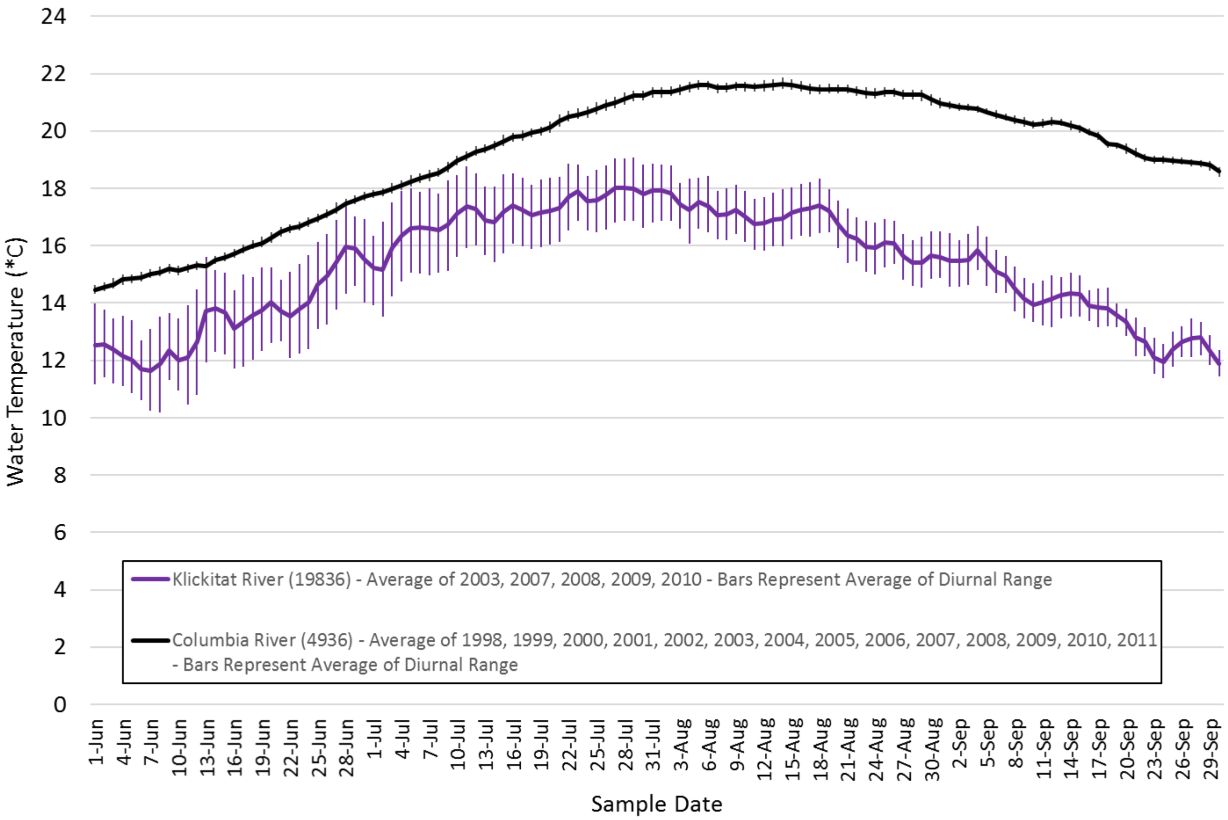


Figure 2-19 Klickitat River Cold Water Refuge and Associated Temperatures

Yellow pin is estimated CWR upstream extent

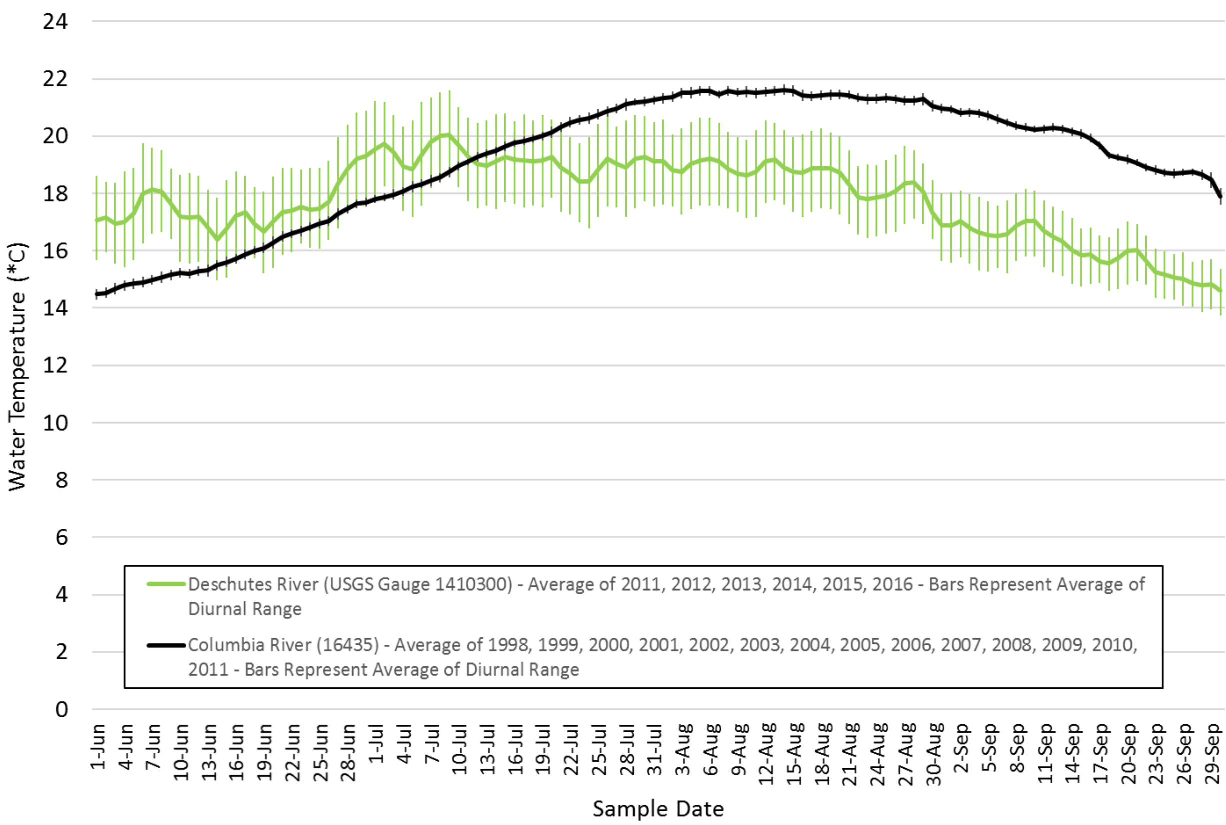


Figure 2-20 Deschutes River Cold Water Refuge and Associated Temperatures

3 SALMON AND STEELHEAD USE OF COLD WATER REFUGES

3.1 SALMON AND STEELHEAD MIGRATION TIMING AND COLUMBIA RIVER TEMPERATURES

The date when fish migrate through the Lower Columbia River and the associated water temperatures are significant factors in whether or not fish will use cold water refuges (CWR). The migration timing of the salmon and steelhead species that migrate up the Columbia River and pass Bonneville Dam each summer is displayed in ***Figure 3-1*** along with the average Columbia River temperature during that time. On average, temperatures in the Lower Columbia River exceed 20°C from mid-July through mid-September and reach peak temperatures of about 22°C in mid-August. The bulk and peak of the summer steelhead run (purple line) migrate past Bonneville Dam during the two-month period when Columbia River temperatures exceed 20°C. The first half of the fall Chinook run (blue line) migrates past Bonneville Dam when temperatures are above 20°C (fall Chinook are defined as Chinook passing Bonneville Dam after August 1st). Accordingly, steelhead and fall Chinook are the species that most often encounter warm Lower Columbia River temperatures and, as discussed later in this chapter, are the species that use CWR the most to escape warm Columbia River temperatures.

Most of the sockeye (green line) and summer Chinook (yellow line) generally pass Bonneville Dam and swim through the Lower Columbia River in June and early July, prior to the onset of warm temperatures (summer Chinook are defined as Chinook passing Bonneville Dam between June 1 and July 31). Accordingly, sockeye and summer Chinook are less likely to use CWR and typically swim continuously through the Lower Columbia River. When the river does warm earlier, coinciding with sockeye and summer Chinook fish runs, as it did in 2015, the use of CWR is seen as an ineffective migration strategy for these fish. This appears to be because delayed upstream migration by holding in CWR results in exposure to warmer mainstem temperatures during their continued upstream migration as river temperatures continue to heat up from early to mid-summer.

Due to their extensive use of CWR, this chapter focuses on characterizing summer steelhead and fall Chinook use of CWR in the Lower Columbia River.

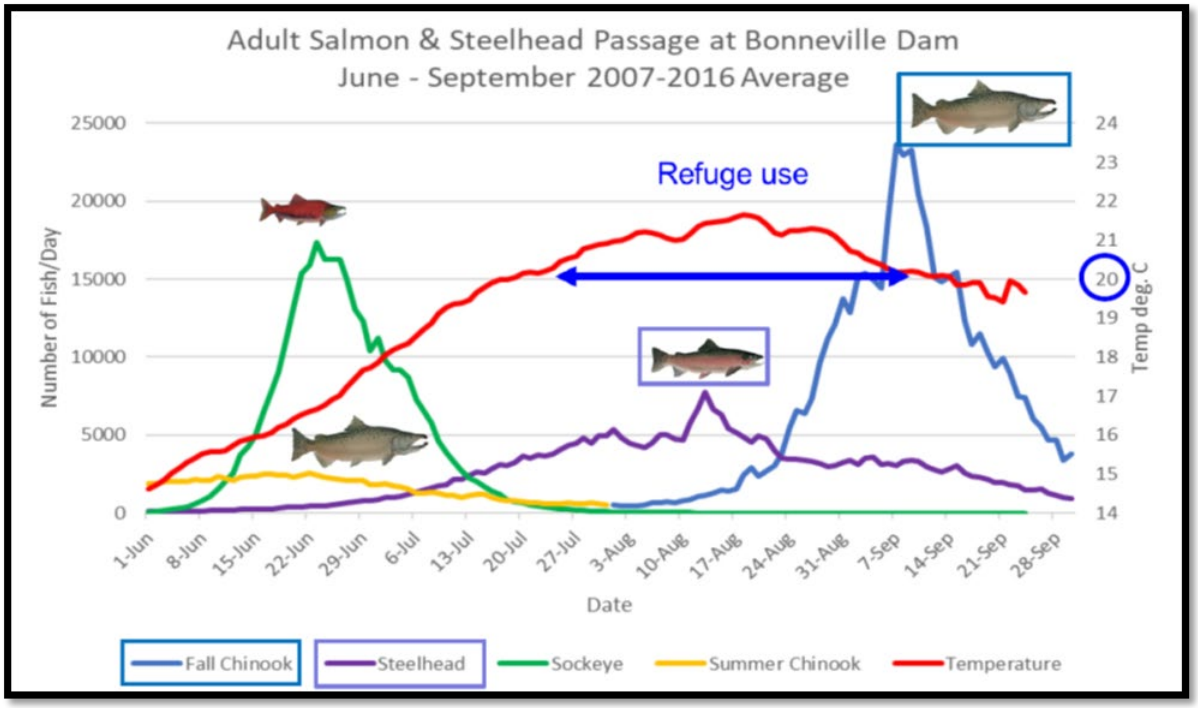


Figure 3-1 Salmon and steelhead Bonneville Dam passage and temperature (DART)

3.2 COLUMBIA RIVER TEMPERATURES THAT TRIGGER COLD WATER REFUGE USE

In the early 2000s, the University of Idaho's Department of Fish and Wildlife Sciences and NMFS, under contract with the U.S. Army Corps of Engineers, conducted a series of salmon and steelhead studies using radio-tagged fish to track movement and temperature during migration up the Columbia River. These studies characterized salmon and steelhead use of CWR in the Lower Columbia River. The study results have been summarized in several scientific journals (Goniea et al. 2006, High et al. 2006, Keefer et al. 2009, Keefer et al. 2018) and in the USACE 2013 Report titled "Location and Use of Adult Salmon Thermal Refugia in the Lower Columbia and Snake River" (USACE 2013).

Figure 3-2 and ***Figure 3-3*** show the relationship between Columbia River water temperature and CWR use for steelhead and fall Chinook salmon (USACE 2013). As shown in ***Figure 3-2***, migrating steelhead begin to use CWR when the Columbia River temperature reaches 19°C, and when temperatures are 20°C or higher, approximately 60-80% of the steelhead use CWR. As shown in ***Figure 3-3***, fall Chinook initiate use of CWR at slightly warmer temperatures (20-21°C), and about 40% use CWR when temperatures reach 21-22°C.

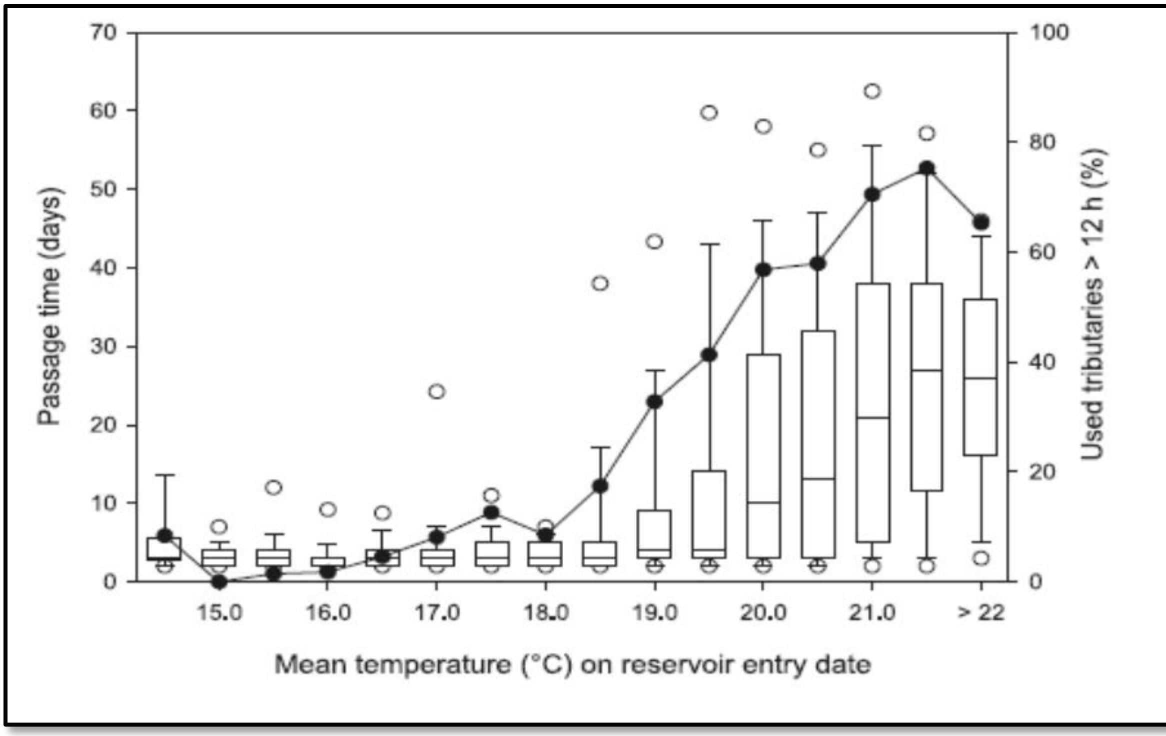


Figure 3-2 Steelhead use of cold water refuge (black dots and 'Used tributaries' axis) (Keefer et. al. 2009)

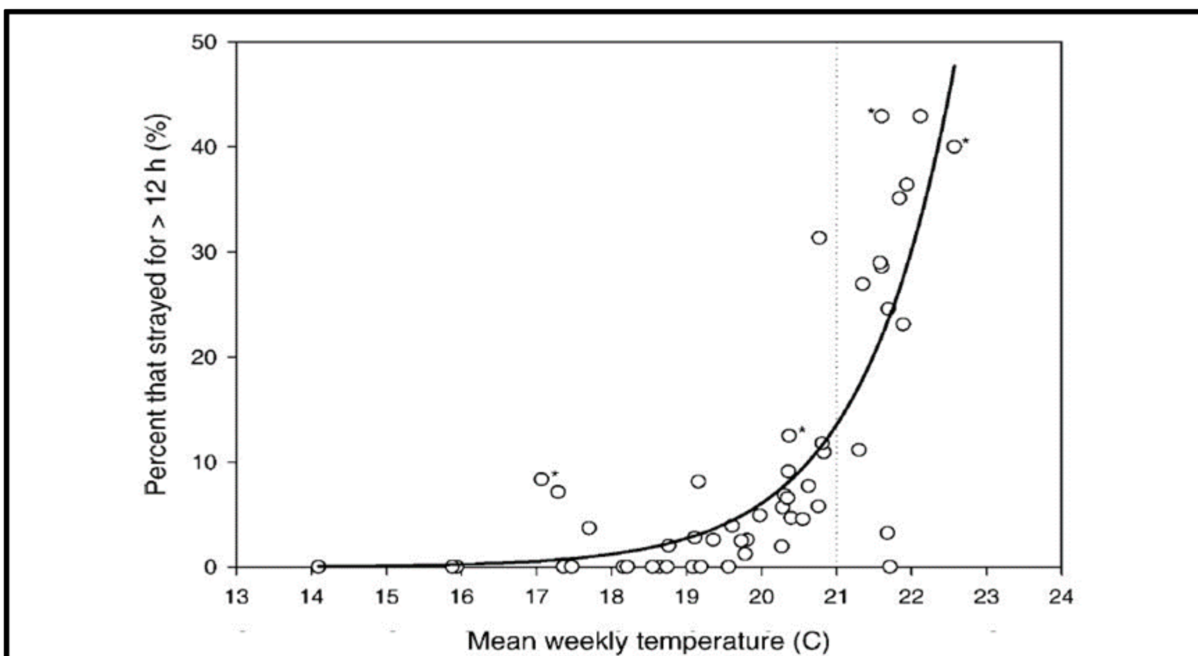


Figure 3-3 Fall Chinook use of cold water refuge (Goniea et. al. 2006)

3.3 EXAMPLES OF SALMON AND STEELHEAD USE OF COLD WATER REFUGES

It is enlightening to look at tracking study results for individual fish with internal temperature sensors to illustrate how fish use CWR. ***Figure 3-4*** shows the temperatures experienced by an individual steelhead between the Bonneville Dam and The Dalles Dam. This steelhead quickly swam from Bonneville Dam to the Little White Salmon River (Drano Lake) and stayed for approximately two weeks, then rapidly swam up the Columbia River to the White Salmon River, where it stayed for about five days before proceeding to pass The Dalles Dam. This figure provides an example of how steelhead use CWR (in this case, for approximately three weeks) to minimize their exposure to warm Columbia River temperatures as they wait for the river (gray line) to cool before they continue their upward migration to spawn. Steelhead that use CWR typically do so for 20 days in the Bonneville reservoir reach and for 2-6 days in the Dalles reservoir reach based on research done in 2000 and 2002 (Keefer and Caudill, 2017).

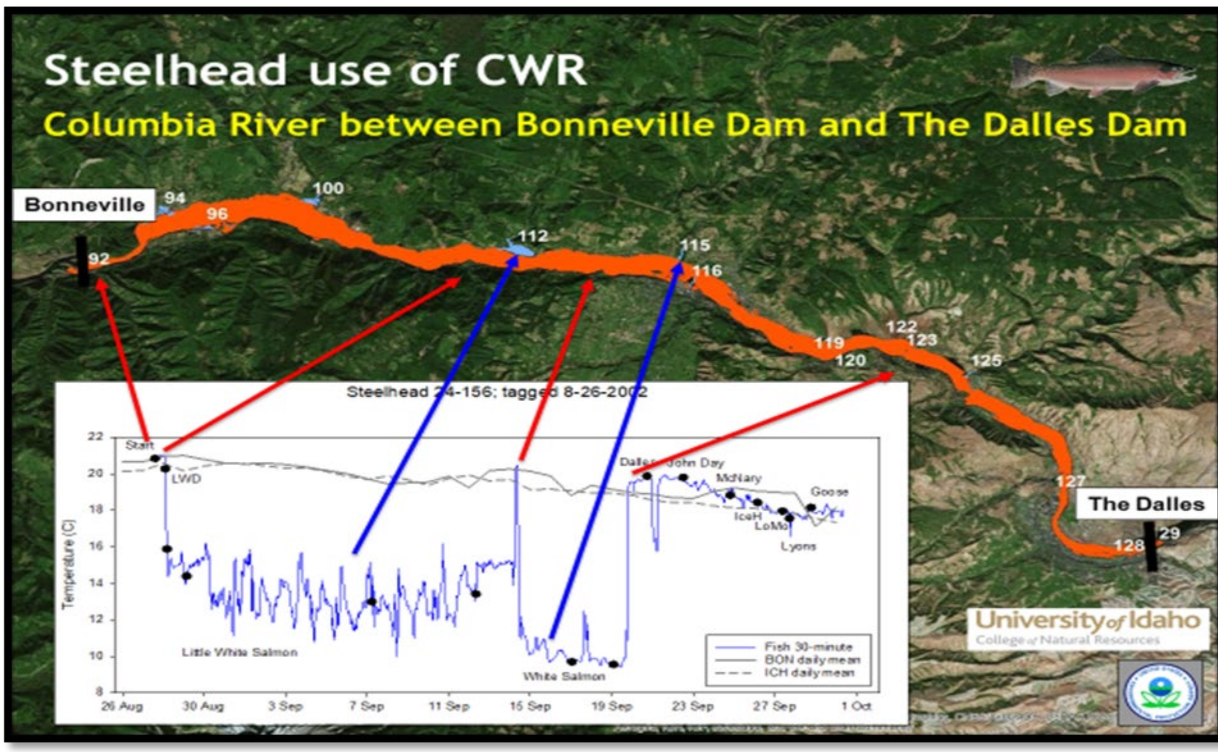


Figure 3-4 Temperature profile of a steelhead using cold water refuges (Keefer & Caudill 2017)

Figure 3-5 shows another steelhead exhibiting a similar pattern of CWR use. This steelhead used Herman Creek/Cove, the Little White Salmon River (Drano Lake), an unknown CWR (potentially the mouth of the Klickitat River) between Bonneville Dam and The Dalles Dam. It then took refuge in the Deschutes River CWR for a few days prior to proceeding up the Columbia and Snake Rivers. ***Figure 3-5*** shows how a steelhead can minimize its exposure to elevated temperatures during its upstream migration in August by residing in a CWR and continue migrating upstream in September when temperatures begin to cool.

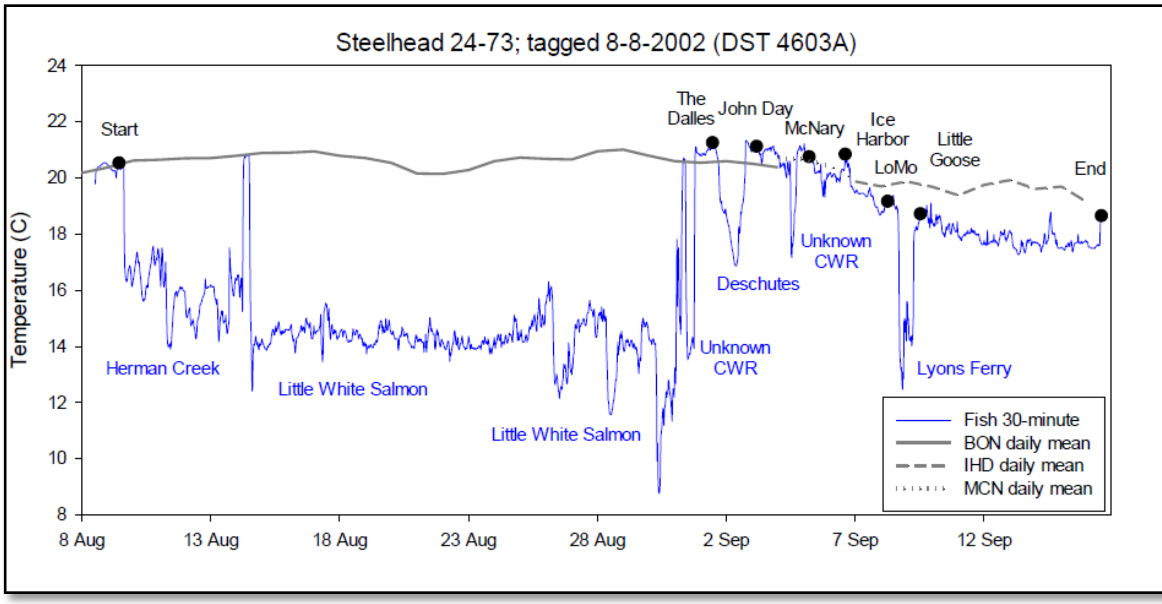


Figure 3-5 Temperature profile of a steelhead using cold water refuges (Keefer & Caudill 2017)

Figure 3-6 shows the temperature profile of a fall Chinook salmon. Fall Chinook salmon also utilize CWR as part of their migration strategy, but for shorter periods than steelhead. Scientists hypothesize that this is in part because fall Chinook spawn in the fall in upstream rivers and are genetically driven to move to their spawning grounds in time to spawn (Goniea et al. 2006). Conversely, steelhead spawn in the late winter and spring, so they have more time and flexibility in their migration to reach their upstream spawning grounds (Keefer et al. 2009 and Keefer et al. 2018). The fall Chinook in ***Figure 3-3*** used the Little White Salmon (Drano Lake), the White Salmon and an unknown CWR area (potentially the Klickitat River) for a few days between Bonneville Dam and The Dalles Dam, then found an unknown CWR area near McNary Dam. Fall Chinook that use CWR typically do so for 1-2 days in the Bonneville reservoir reach and for one day in the Dalles reservoir reach based on research done in 2000 and 2002, which were relatively cool years during the Fall Chinook run. (Keefer and Caudill, 2017).

Figure 3-7 shows the temperature profile for a summer Chinook salmon. As reflected in ***Figure 3-1***, summer Chinook salmon migrate past Bonneville Dam in June and July, typically prior to the onset of warmer Columbia River temperatures. However, summer Chinook that pass Bonneville Dam in late July, like the one shown in ***Figure 3-7***, can be exposed to warm Columbia River temperatures greater than 20°C. This summer Chinook used the Deschutes River CWR for a brief time prior to proceeding upriver, which is typical for summer Chinook CWR use (Keefer and Caudill, 2017). Summer Chinook salmon benefit less from using CWR, since they migrate when Columbia River temperatures are rising. Thus, if a summer Chinook held in a CWR, it would experience higher Columbia River temperatures during the rest of its migration. It appears to be more advantageous for summer Chinook to quickly migrate through the Lower Columbia River to avoid the warmest temperatures that generally occur in late July and August. However, brief respites in CWR could provide some physiological benefit to summer Chinook.

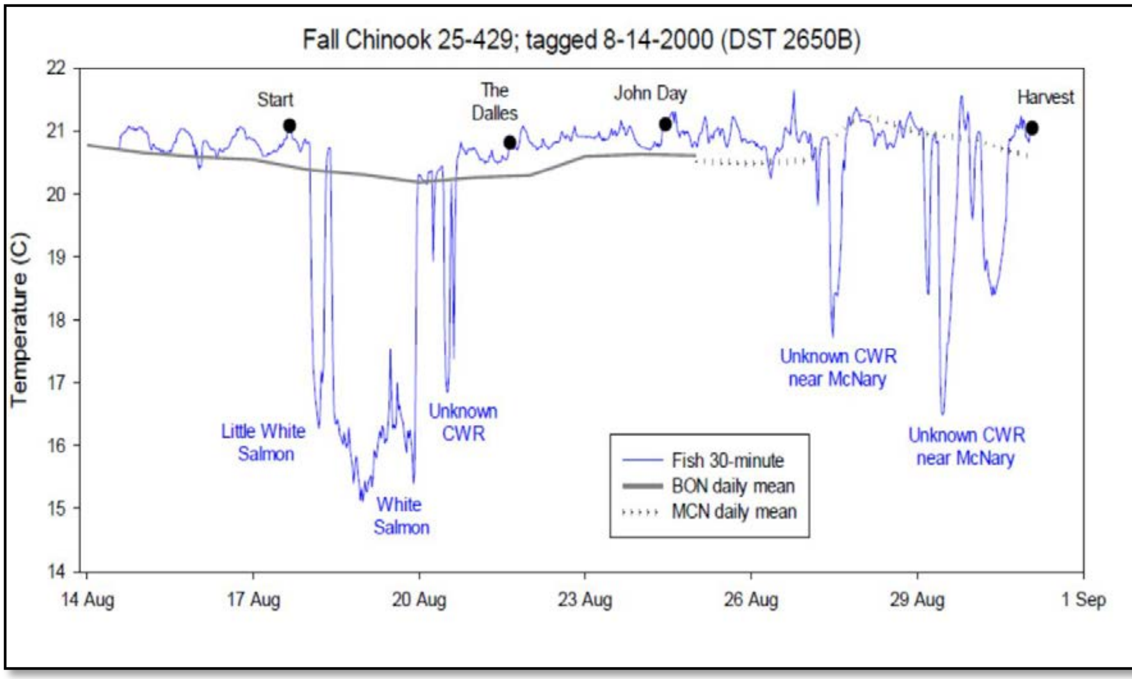


Figure 3-6 Temperature profile of a fall Chinook salmon using cold water refuges (Keefer & Caudill 2017)

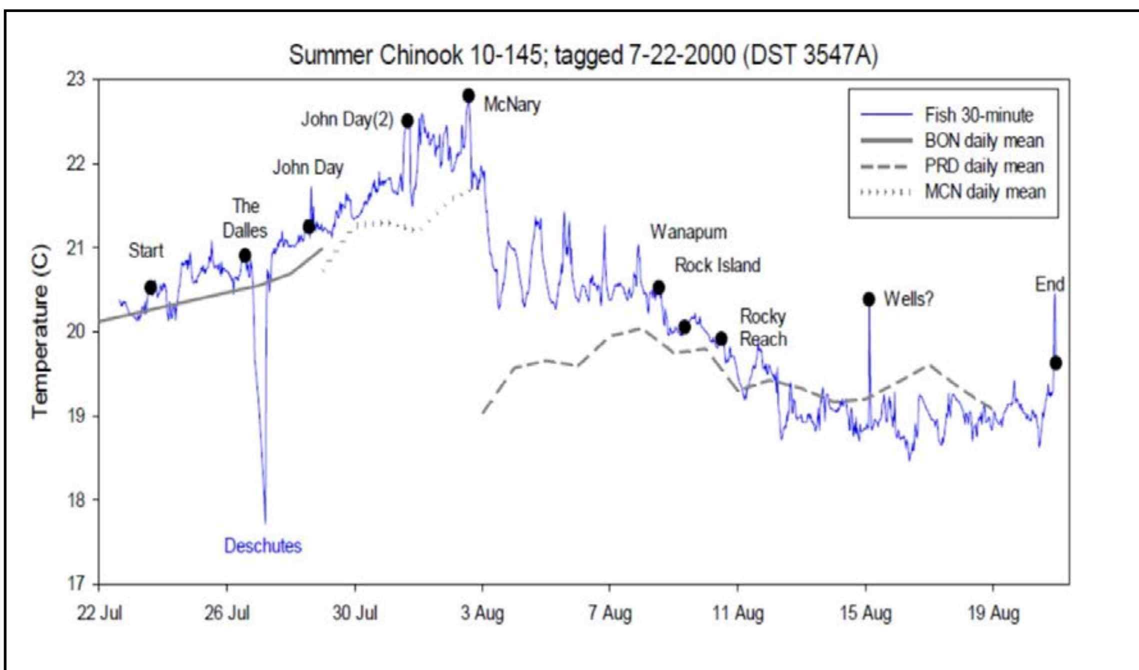


Figure 3-7 Temperature profile of a summer Chinook salmon using cold water refuges (Keefer & Caudill 2017)

3.4 NUMBER OF STEELHEAD IN COLD WATER REFUGES

In order to assess the sufficiency of CWR and to understand their importance to migrating salmon and steelhead, it is important to estimate the number of fish using CWR. The research conducted by the University of Idaho and NMFS demonstrates that salmon and steelhead move in to CWR in the Lower Columbia River to avoid warm Columbia River temperatures. However, there are no research studies estimating the number of salmon and steelhead that are in the respective CWR areas.

EPA developed a method to estimate the number of steelhead in the CWR between Bonneville Dam and The Dalles Dam by using daily passage counts of steelhead at these two dams from DART. ***Figure 3-8*** shows the average steelhead passage counts at each of the two dams and the average Columbia River temperature at Bonneville Dam from 2007 to 2016. This figure shows that as temperatures reach 20°C, many steelhead that pass Bonneville Dam in late July and August (blue line) wait until September to pass The Dalles Dam (green line). Since more steelhead are entering the Bonneville reach than leaving the reach during this time, it results in an accumulation of steelhead within the Bonneville reach, which can be estimated. EPA estimated the number of accumulated steelhead by summing the daily count of steelhead passing Bonneville Dam minus the daily count passing The Dalles Dam and subtracting the percentage of steelhead not expected to pass The Dalles Dam due to fishing harvest, straying, and those returning to spawn in Bonneville reach tributaries. EPA estimated the percentage of accumulated steelhead that is in the reservoir versus in CWR using scientific literature on the relationship of temperature and the percentage of steelhead that enter CWR (Appendix 12.13).

Figure 3-9 shows the results of EPA's estimates of the number of steelhead in CWR within the Bonneville reach in an average year (2007-2016). Up to approximately 80,000 steelhead accumulate in the Bonneville reach in August. Of these, approximately 68,000 (85%) are estimated to be in CWR at the same time during the peak period of use. The peak occurs in the latter half of August since steelhead continue to accumulate within the reach until about the first of September. At this time, temperatures cool to the point that more steelhead are exiting the reach by passing The Dalles Dam than entering the reach by passing the Bonneville Dam as shown in ***Figure 3-8*** (Appendix 12.13).

To corroborate the EPA approach to estimating the number of steelhead in the Bonneville reach CWR, empirical data from the University of Idaho was evaluated (M. Keefer, personal communication, August 31, 2017). ***Figure 3-10*** shows the daily location of 219 recorded steelhead as they migrate through the Bonneville reach. As shown, on a given day when Columbia River temperatures typically exceed 20°C, the vast majority of steelhead (80-90%) are in CWR and only a portion are in the Columbia River. Further, the peak accumulation of steelhead in CWR occurred in the latter half of August/early September. Thus, the EPA estimation approach matches the pattern and percentage of radio-tagged steelhead in Bonneville reach CWR very closely.

The volume of water in the Bonneville reach of the Columbia River is approximately 600,000 acre-feet, and the total volume of CWR in this reach is about 1,453 acre-feet, which means that in late August and early September approximately 80-85% of the steelhead are in 0.2% available water in this reach.

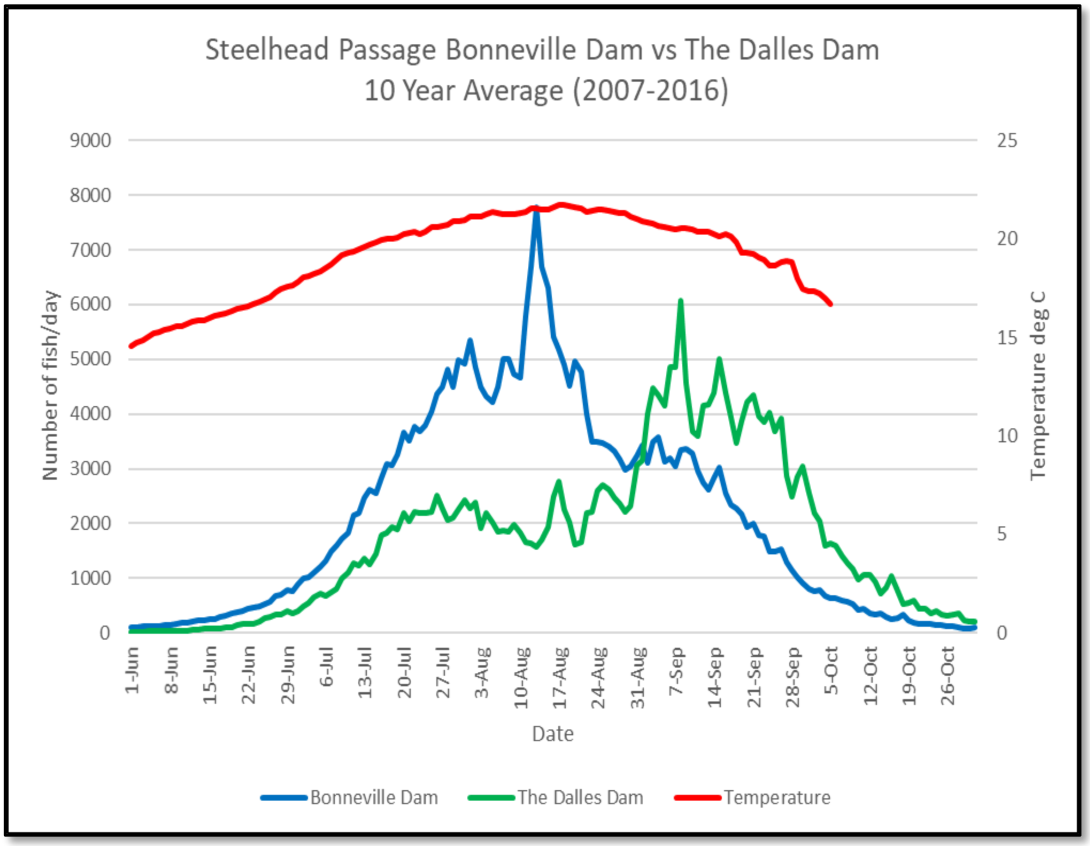


Figure 3-8 Steelhead passage at Bonneville Dam and The Dalles Dam (Appendix 12.13)

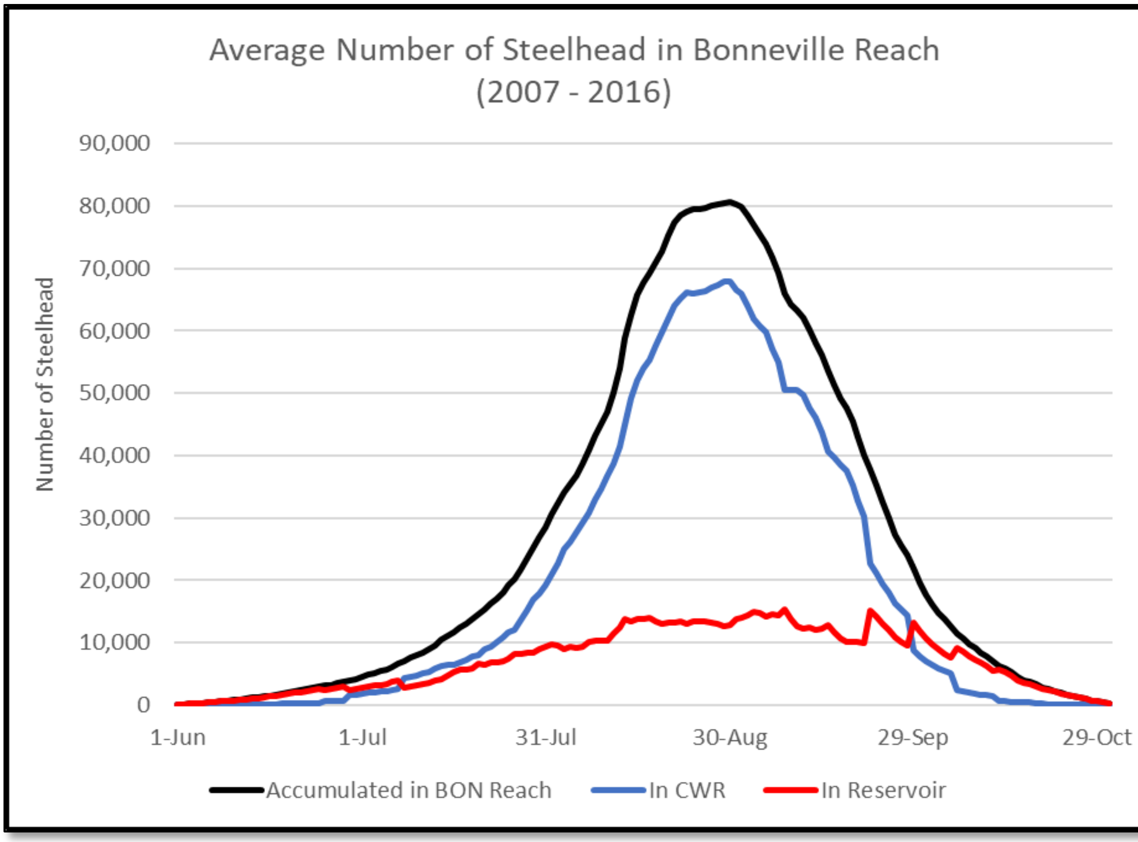


Figure 3-9 Estimated number of steelhead in Bonneville reach cold water refuges (Appendix 12.13)

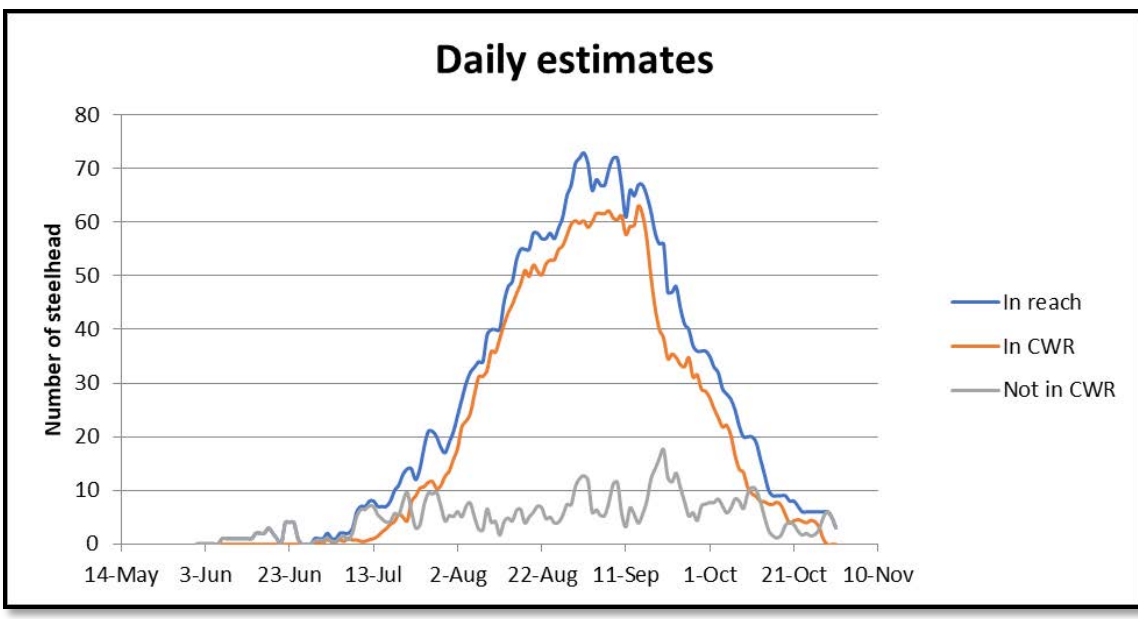


Figure 3-10 Proportion of 219 radio-tagged steelhead in Bonneville cold water refuges (M. Keefer, personal communication, August 31, 2017)

EPA applied a simplified approach to estimate the number of steelhead in the Bonneville reach CWR for individual years from 1999 through 2016, which is shown in ***Table 3-1*** (Appendix 12.13). The simplified approach estimates the peak number of steelhead that accumulate in the Bonneville reach by taking the number of steelhead that would pass The Dalles Dam for the July 15 - August 30 period if steelhead were not using CWR (expected to pass) and subtracting the number of steelhead that actually pass The Dalles Dam during this period. Of the number of accumulated steelhead in the Bonneville reach during the peak accumulation period (late August), 85% were assumed to be in CWR (Appendix 12.13).

As shown in ***Table 3-1***, the number of steelhead in CWR varies year to year and is primarily a function of the size of the steelhead run (number passing Bonneville Dam) and the Columbia River temperature. During a year with a large steelhead run and warm Columbia River temperatures (2009), 155,000 steelhead are estimated to be in the Bonneville reach CWR. During a year with a small steelhead run and cool Columbia River temperatures (2012), only 23,000 steelhead are estimated to be in CWR.

Table 3-1 Estimated number of steelhead in cold water refuges each year (1999-2016) (Appendix 12.13)

Year	Avg Temp July 15 -Aug 31	Passed BON July 15 -Aug 31	Passed Dalles July 15 -Aug 31	Measured % That Passed Dalles June 1-Oct 31	Expected to Passed Dalles July 15 -Aug 31	In BON Reach Peak	In CWR (85%) Peak
2016	21.4	83,919	24,212	80%	66,868	42,656	36,258
2015	21.8	165,138	69,059	84%	137,893	68,834	58,509
2014	21.5	175,686	70,488	80%	140,923	70,435	59,869
2013	21.5	166,926	68,949	83%	138,059	69,110	58,743
2012	20.1	142,032	95,612	86%	122,797	27,185	**23,107**
2011	19.5	252,331	176,573	82%	207,452	30,879	26,248
2010	21.0	231,804	121,974	82%	189,445	67,471	57,350
2009	21.6	451,509	205,163	86%	388,094	182,931	**155,492**
2008	20.0	225,506	117,044	79%	177,048	60,004	51,004
2007	21.1	229,124	83,820	76%	173,420	89,600	76,160
2006	21.1	187,415	53,379	72%	134,561	81,182	69,005
2005	21.4	175,028	55,866	77%	135,090	79,224	67,340
2004	22.0	155,516	42,744	78%	120,905	78,161	66,437
2003	21.7	209,328	58,083	77%	160,904	102,821	87,398
2002	20.4	257,857	131,121	82%	210,238	79,117	67,250
2001	20.7	397,879	169,554	80%	319,544	149,990	127,491
2000	20.6	164,593	75,954	75%	124,114	48,160	40,936
1999	20.0	136,136	76,782	77%	104,458	27,676	23,524
Average	20.9	219,048	98,363		175,585	77,222	65,639

Table 3-2 includes the estimated number of steelhead in each of the eight CWR in the Bonneville reach between Bonneville Dam and The Dalles Dam using the CWR volumes from ***Table 2-2*** and ***Table 2-3*** as an approximate indicator of the distribution of steelhead in the eight CWR. Over half of the steelhead (61%) are expected to be in the Little White Salmon (Drano Lake) CWR with approximately 40,000 steelhead during the peak period for an average year,

with peaks ranging from 14,000 to 95,000 steelhead in low and high years. Other Bonneville reach CWR tributaries with extensive steelhead CWR include Herman Creek, White Salmon River, Wind River, and the Klickitat River.

Table 3-2 Estimated number of steelhead in each Bonneville reach cold water refuge (Appendix 12.13)

Tributary Name	Tributary Temp	Plume CWR Volume (> 2°C Δ)	Stream CWR Volume (> 2°C Δ)	Total CWR Volume (> 2°C Δ)	% of CWR in BON Reach	# Steelhead in Each CWR (1999-2016 Avg)	# Steelhead in Each CWR High Year (2009)	# Steelhead in Each CWR Low Year (2012)
	°C	m3	m3	m3				
Eagle Creek	15.1	2,100	888	2,988	0.2%	109	259	39
Rock Creek	17.4	530	1,178	1,708	0.1%	63	148	22
Herman Creek	12.0	168,000	1,698	169,698	9.5%	6,216	14,726	2,188
Wind River	14.5	60,800	44,420	105,220	5.9%	3,854	9,131	1,357
Little White Salmon River	13.3	1,097,000	11,661	1,108,661	61.9%	40,613	96,208	14,297
White Salmon River	15.7	72,000	81,529	153,529	8.6%	5,624	13,323	1,980
Hood River	15.5	28,000	0	28,000	1.6%	1,026	2,430	361
Klickitat River	16.4	73,000	149,029	222,029	12.4%	8,133	19,267	2,863
Total		1,501,430	290,403	1,791,833	100%	65,639	155,492	23,107

To corroborate the EPA approach to estimate the number of steelhead in each CWR, empirical data from the University of Idaho was evaluated (M. Keefer, personal communication, September 11, 2017). ***Table 3-3*** shows the distribution of 59 radio-tagged steelhead in the Bonneville reach CWR on August 31, which represents the time of peak CWR use. The distribution in ***Table 3-3*** is generally consistent with predicting the number of steelhead in each CWR based on volume shown in ***Table 3-2***, with a large percentage (68%) of the steelhead in the Little White Salmon River (Drano Lake) and a significant percentage (greater than 7%) in Herman Creek, White Salmon River, and the Klickitat River CWR.

Table 3-3 Distribution of radio-tagged steelhead in the Bonneville reach cold water refuges on August 31 (Combined 2000/2001 Data Set) (M. Keefer, personal communication, September 11, 2017)

CWR Location	31-Aug	%	Predicted based on CWR Volume
Herman Creek	6	10%	10%
Wind River	1	2%	6%
Little White Salmon/Drano Lake	40	68%	62%
White Salmon	4	7%	9%
Klickitat River	4	7%	12%
Unknown CWR	4	7%	
Total	59 Steelhead		

Table 3-4 shows the estimated density of steelhead in the Bonneville reach CWR under different run size scenarios (average, high, low) and for two volume metrics of CWR (volume

that is 2°C cooler than the Columbia River and volume that is 18°C or cooler). The density is estimated by dividing the estimated number of steelhead by the CWR volume. The density associated with CWR volume that is 18°C or cooler may be a better indicator of density that fish actually experience, because steelhead residing for an extended period are likely to seek temperatures below 18°C. The maximum estimated density of steelhead is 0.16 steelhead per cubic meter, which is 404 steelhead in an Olympic-sized swimming pool (Appendix 12.13). EPA identified one fish per cubic meter as the maximum potential density from studies on adult Chinook salmon and steelhead held in confined spaces (Berejikian et al. 2001, Hatch et al. 2013). Thus, using this comparison metric, the CWR volume in the Bonneville reach appears sufficient for the number of steelhead using CWR in this portion of the Columbia River. However, this comparison should be viewed with caution due to the different context and small number of fish in the studies noted above and other unknown factors that may affect the carrying capacity of CWR.

Table 3-4 Estimated steelhead density in cold water refuges (Appendix 12.13)

	CWR Volume (> 2°C Δ)			CWR Volume (< 18°C)		
	Average	High	Low	Average	High	Low
	1999-2016	2009	2012	1999 -2016	2009	2012
# fish/m3	0.0366	0.0868	0.0129	0.0683	0.1617	0.0240
# fish/2500 m3	92	217	32	171	404	60

An analysis of PIT-tagged steelhead passing Bonneville and The Dalles Dams conducted by Brian Maschhoff provides an additional corroborating line of evidence on the extent to which steelhead use CWR in the Bonneville reach (see Appendix 12.13). This analysis shows considerable delay and presumed CWR use by most steelhead during warm river temperatures. This analysis also indicates that there is not a difference in the extent of steelhead delay and presumed CWR use between hatchery and wild steelhead and steelhead that were transported as juveniles versus those that were not (Appendix 12.13).

3.5 NUMBER OF FALL CHINOOK IN COLD WATER REFUGES

EPA used the methods described above for steelhead to estimate the number of fall Chinook using CWR in the Bonneville reach. As shown in ***Figure 3-11***, the estimated number of fall Chinook in CWR (blue line) is estimated to be approximately 5,000 during the last week of August and the first two weeks of September for an average year (2008-2017) (Appendix 12.13). This figure shows that, unlike steelhead, the majority of fall Chinook in the Bonneville reach are estimated to be migrating in the reservoir. After mid-September, the number of fall Chinook passing Bonneville Dam begins to decrease and the accumulated number of fall Chinook in the reach begins to decrease as temperatures fall to 20°C and below.

In warmer years such as 2013, when temperatures remain above 21°C into early September during the peak of the fall Chinook run, EPA estimates a higher proportion of fall Chinook will use CWR within the Bonneville reach to avoid mainstem temperatures. As shown in ***Figure 3-12***, 20,000 to 40,000 fall Chinook are estimated to have been in the Bonneville reservoir CWR in 2013 in the latter part of August through mid-September (blue line). This is four to eight times the estimated number of 5,000 fall Chinook in CWR in an average year (see ***Figure 3-11***). Late August and early September temperatures were consistently around 22°C in 2013, which are temperatures at which a significant number of fall Chinook seek CWR. 2013 also represents a relatively high run year with 953,222 adult fall Chinook passing Bonneville Dam, which is about twice the 10-year (2007-2016) annual average of 504,148 (FPC 2014 & 2016 Annual Report). There is more uncertainty in the estimates of the number of fall Chinook in the Bonneville reservoir CWR compared to the estimates of steelhead in CWR because fall Chinook use CWR for a shorter duration (Appendix 12.13).

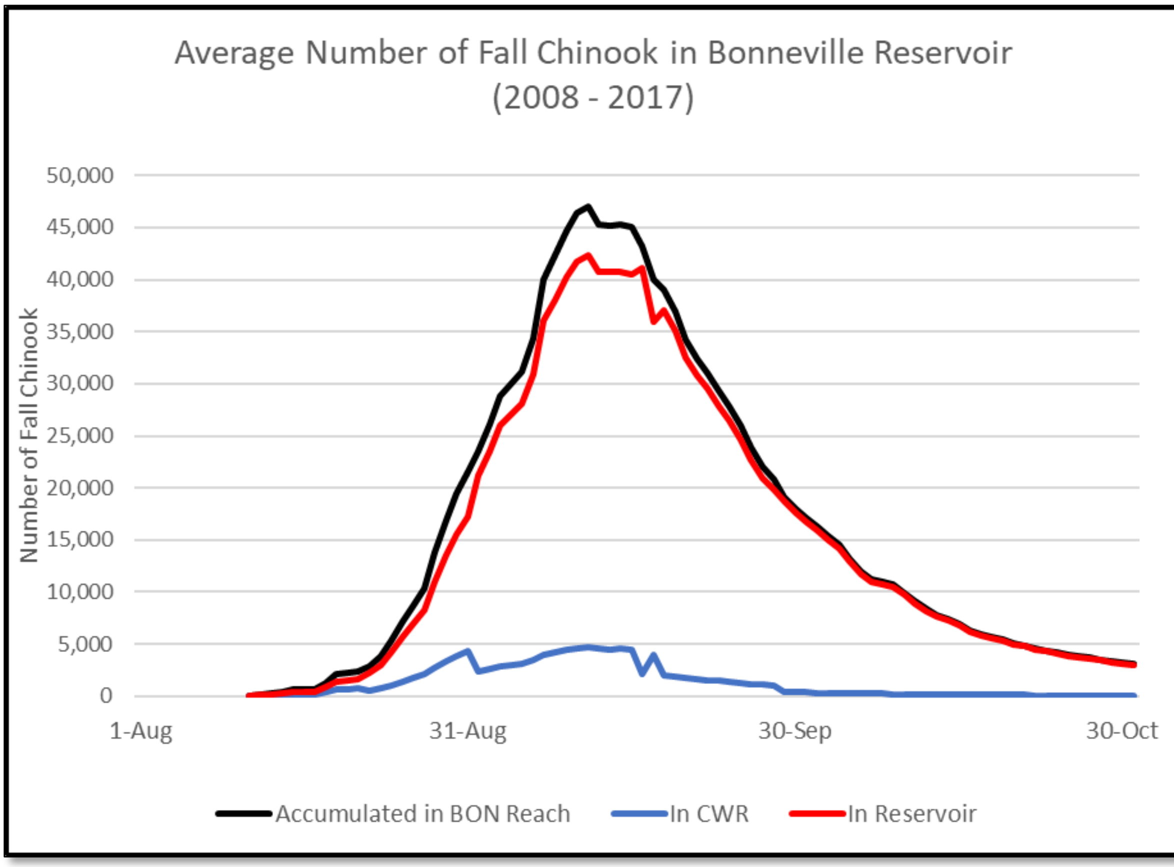


Figure 3-11 Accumulation of fall Chinook in the Bonneville reach and the number of fall Chinook in cold water refuges (2008-2017 average) (Appendix 12.13)

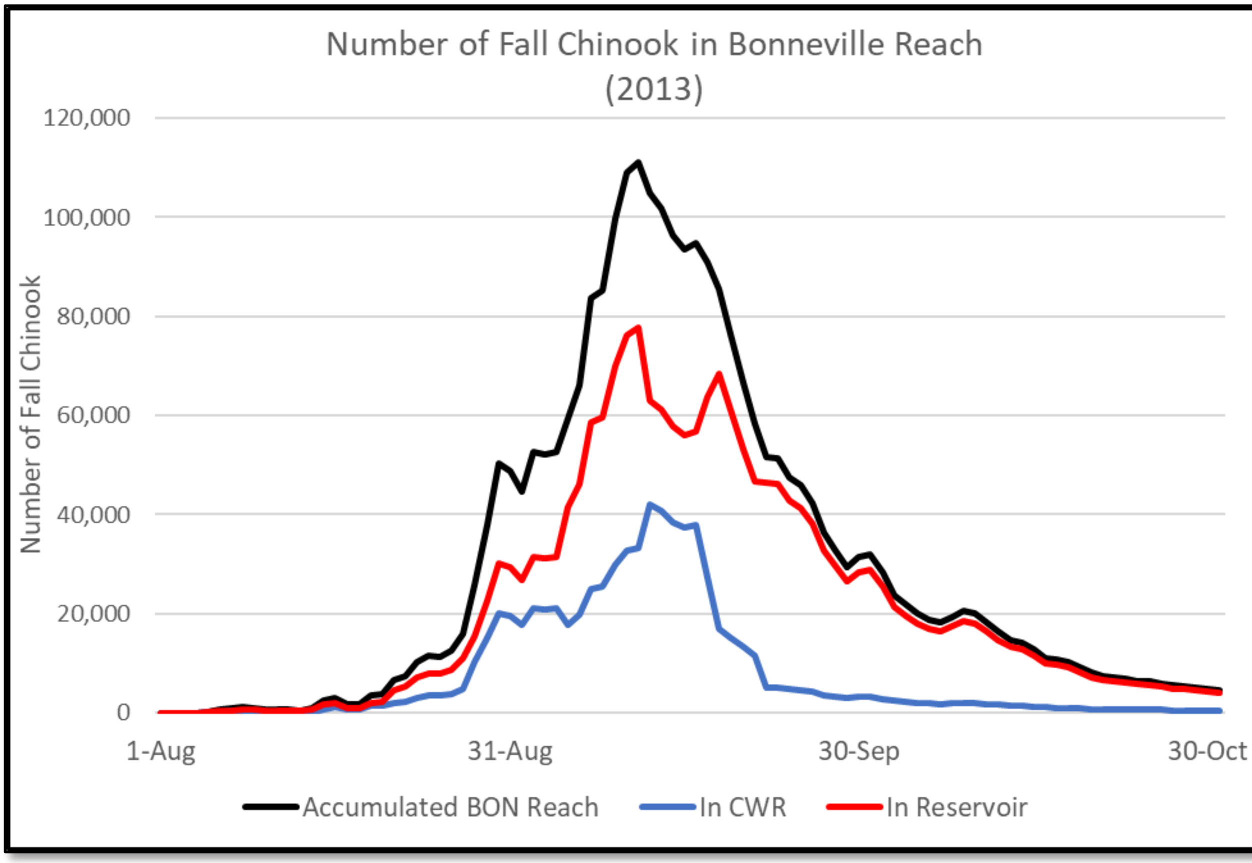


Figure 3-12 Accumulation of fall Chinook in the Bonneville reach and the number of fall Chinook in cold water refuges (2013) (Appendix 12.13)

3.6 SUMMARY OF THE NUMBER OF STEELHEAD AND FALL CHINOOK IN COLD WATER REFUGES

Peak use of Bonneville reservoir CWR by steelhead occurs mid-August through early September, and peak use by fall Chinook occurs in late August through mid-September. During an average year (river temperatures and run size), approximately 65,000 steelhead and 5,000 fall Chinook are estimated to be in the Bonneville reach CWR. During years with warm August-September Columbia River temperatures and high run size, as many as 155,000 steelhead and 40,000 fall Chinook are estimated to be in the Bonneville reach CWR during the period of peak refuge use, although these peak numbers for steelhead and fall Chinook may not occur in the same years. The above estimates should be viewed as rough estimates since they are not based on direct counting of fish in CWR.

3.7 HISTORIC STEELHEAD USE OF COLD WATER REFUGES

Because The Dalles Dam was built in 1957, the comparison of steelhead passage at the Bonneville Dam versus The Dalles Dam is available since 1957. As shown in ***Figure 3-8*** above, passage data from the last decade shows there is a significant delay in steelhead passage over The Dalles Dam and accumulation of steelhead in the Bonneville reach during the period of summer maximum temperatures. Conversely, as shown in ***Figure 3-13***, there is not a significant delay over The Dalles Dam in the decade after The Dalles Dam was built (1957-1966). Limited temperature data collected in the 1950s depicted in ***Figure 3-14*** shows summer peak temperatures were lower compared to current day temperatures. Current daily average temperatures exceed 20°C for about two months and exceed 21°C for one month, but during the 1950s daily average temperatures typically exceeded 20°C only for a short period (a week) and did not exceed 21°C. As described earlier, >20°C temperatures are associated with a high level of CWR use by steelhead. These data suggest steelhead use of CWR in the Bonneville reach was historically less than what we observe currently, and that steelhead are using CWR more today in response to increased summer temperatures of the Lower Columbia River.

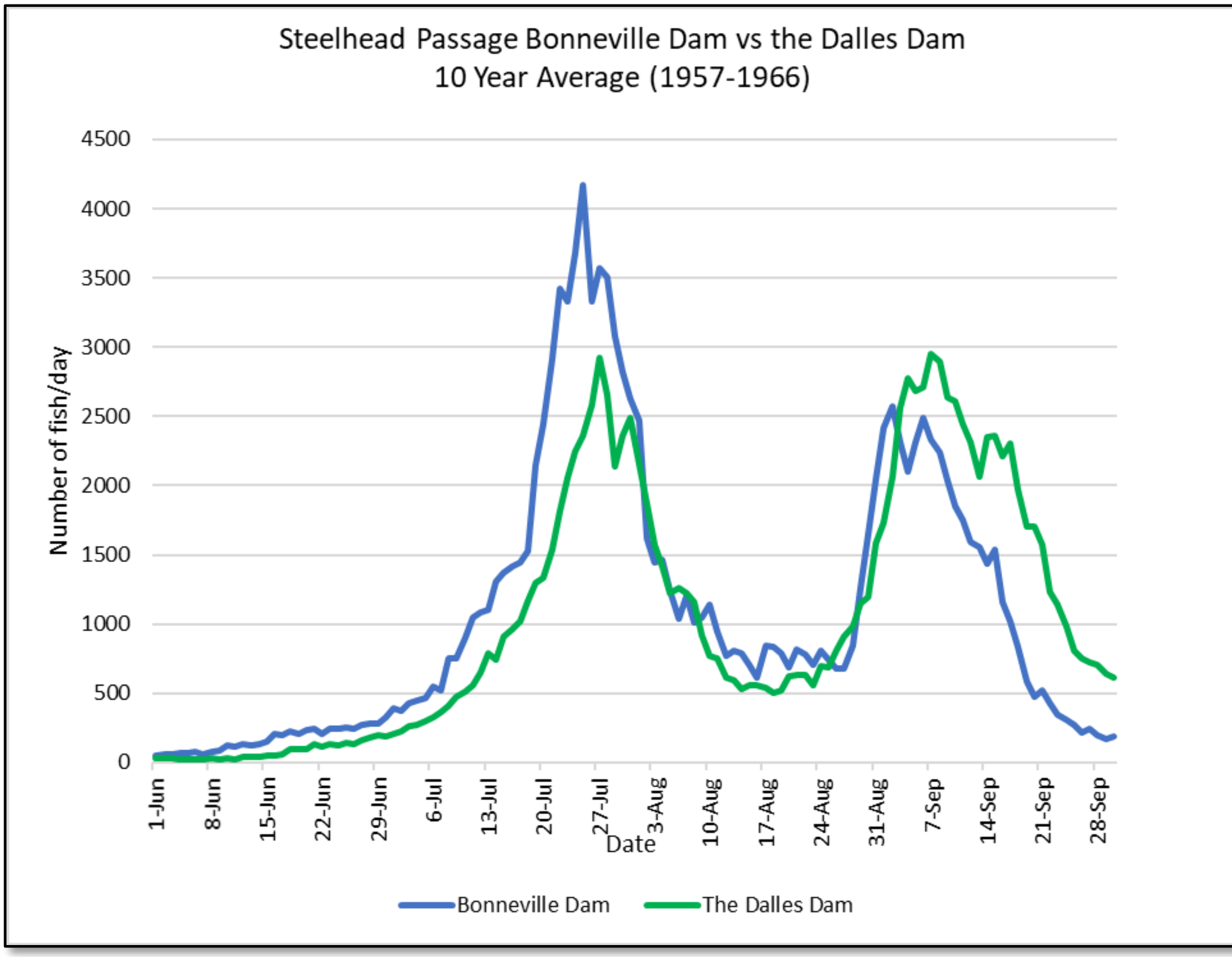


Figure 3-13 Steelhead passage at Bonneville Dam and The Dalles Dam, 1957-1966 (DART)

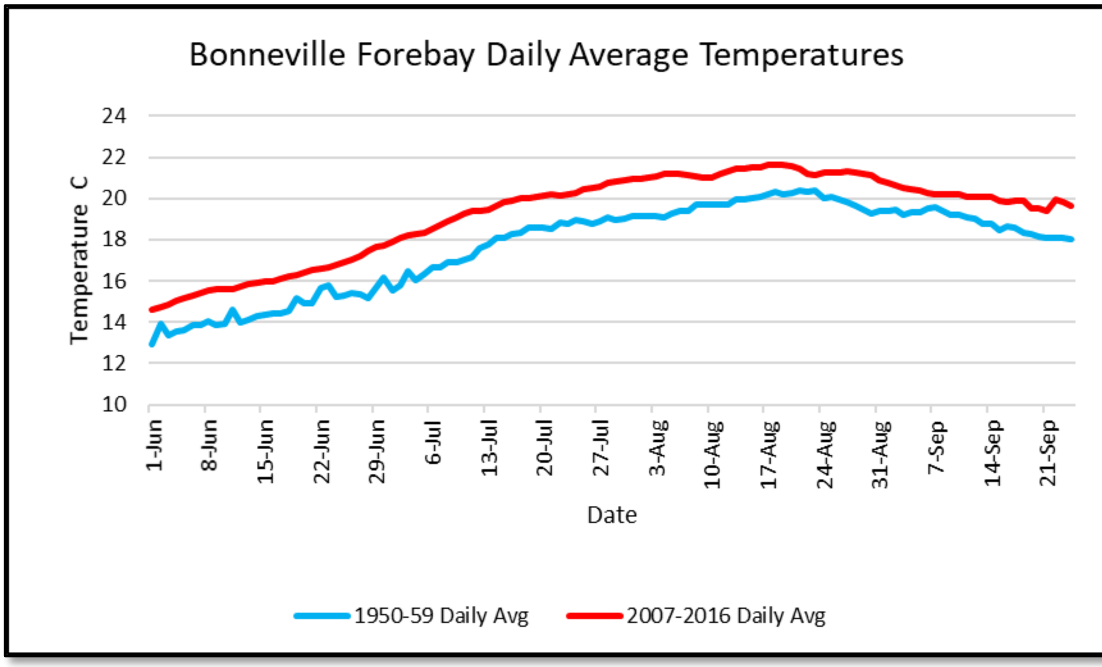


Figure 3-14 Current versus 1950s water temperatures in the Lower Columbia River (DART)

3.8 DESCHUTES RIVER COLD WATER REFUGE USE

The discussion above in Sections 3.4 – 3.7 characterizes the use of CWR by steelhead and fall Chinook in the Bonneville reach between Bonneville Dam and The Dalles Dam. Upstream of The Dalles Dam, the only other significant and primary CWR in the Lower Columbia River is the Deschutes River. The Deschutes River is unique in that it has a PIT-tag detector, installed in 2013 near the mouth, which NMFS has used to analyze the extent that steelhead use the Deschutes River for CWR (NMFS 2017a). ***Table 3-5*** shows that an average of 873 PIT-tagged steelhead were recorded in Deschutes River CWR comprised mostly of Snake River (61%) and Middle Columbia steelhead (30%).

Table 3-5 Deschutes River mouth steelhead PIT-tag detections by calendar year and Distinct Population Segment (DPS) (NMFS 2017a)

DPS	2013	2014	2015	Average	%
Lower Columbia	9	5	31	15	2%
Middle Columbia	174	214	385	258	30%
Snake River	541	506	540	529	61%
Upper Columbia	74	54	86	71	8%
Total	798	779	1042	873	

Table 3-6 shows the number of Snake River PIT-tagged steelhead detected at The Dalles Dam and the percentage of those steelhead detected at the Deschutes River mouth. Approximately

14% (12-18%) of the Snake River steelhead detected at The Dalles Dam were recorded in the Deschutes River mouth. Extrapolating to all Snake River steelhead (including non-Pit-tagged steelhead), ***Table 3-6*** shows that NMFS' estimated total number of Snake River steelhead using Deschutes River CWR in an average year is 27,659 (NMFS 2017a). Assuming 61% of all steelhead in Deschutes River CWR are Snake River steelhead as presented in ***Table 3-5***, the total number of steelhead using the Deschutes River CWR in an average year is 45,343.

Table 3-6 Percent of Snake River (SR) steelhead using Deschutes cold water refuges and number of steelhead using Deschutes cold water refuges (NMFS 2017a)

	SR PIT tagged Steelhead Detected @ Dalles Dam	% of SR PIT tagged Steelhead Detected at Deschutes	Estimated Number of Total SR Steelhead in Deschutes CWR	Estimated Number of All Steelhead in Deschutes CWR
2013	2977	18%	26,162	42,889
2014	4201	12%	30,332	49,725
2015	3279	13%	26,483	43,415
Average	3486	14%	27,659	45,343

Figure 3-15 shows how many Snake River steelhead are estimated to be within Deschutes River CWR for each month. As depicted in ***Figure 3-15***, the peak period of use was September in 2013 and 2014 and in August in 2015. During this peak period of use, approximately 10,000 to 16,000 Snake River steelhead were in the Deschutes River CWR. Assuming 61% of all steelhead in Deschutes River CWR are Snake River steelhead, the total number of steelhead using the Deschutes River CWR during the peak period of use is 16,000 to 26,000. 26,000 steelhead in the Deschutes River CWR would equate to a density of 0.087 steelhead per square meter, which is the same upper range density estimated for Bonneville Reach CWR (based on >2°C delta volume of CWR) reflected in ***Table 3-4***.

As noted above, the overall percentage of Snake River steelhead that use the Deschutes River as CWR is 12-18%. In August, during peak river temperatures, the percentage rises to near 25% (NMFS 2017a). This percentage is less than the percentage of steelhead that use Bonneville Reach CWR, which is up to about 85% during peak temperatures. There are several possible reasons for this lower percentage of use of the Deschutes River: 1) the percent of steelhead using the Deschutes River reported here does not capture use of the Deschutes plume only; 2) the Deschutes River is just one CWR on one side of the river and the Bonneville Reach CWR consists of 7 primary CWR; and 3) steelhead are encountering the Deschutes River after many have already spent time in CWR in the Bonneville Reach and later in the summer as the Lower Columbia River begins to cool. Nonetheless, the Deschutes River is a heavily used CWR and is the only primary CWR between The Dalles Dam and McNary Dam.

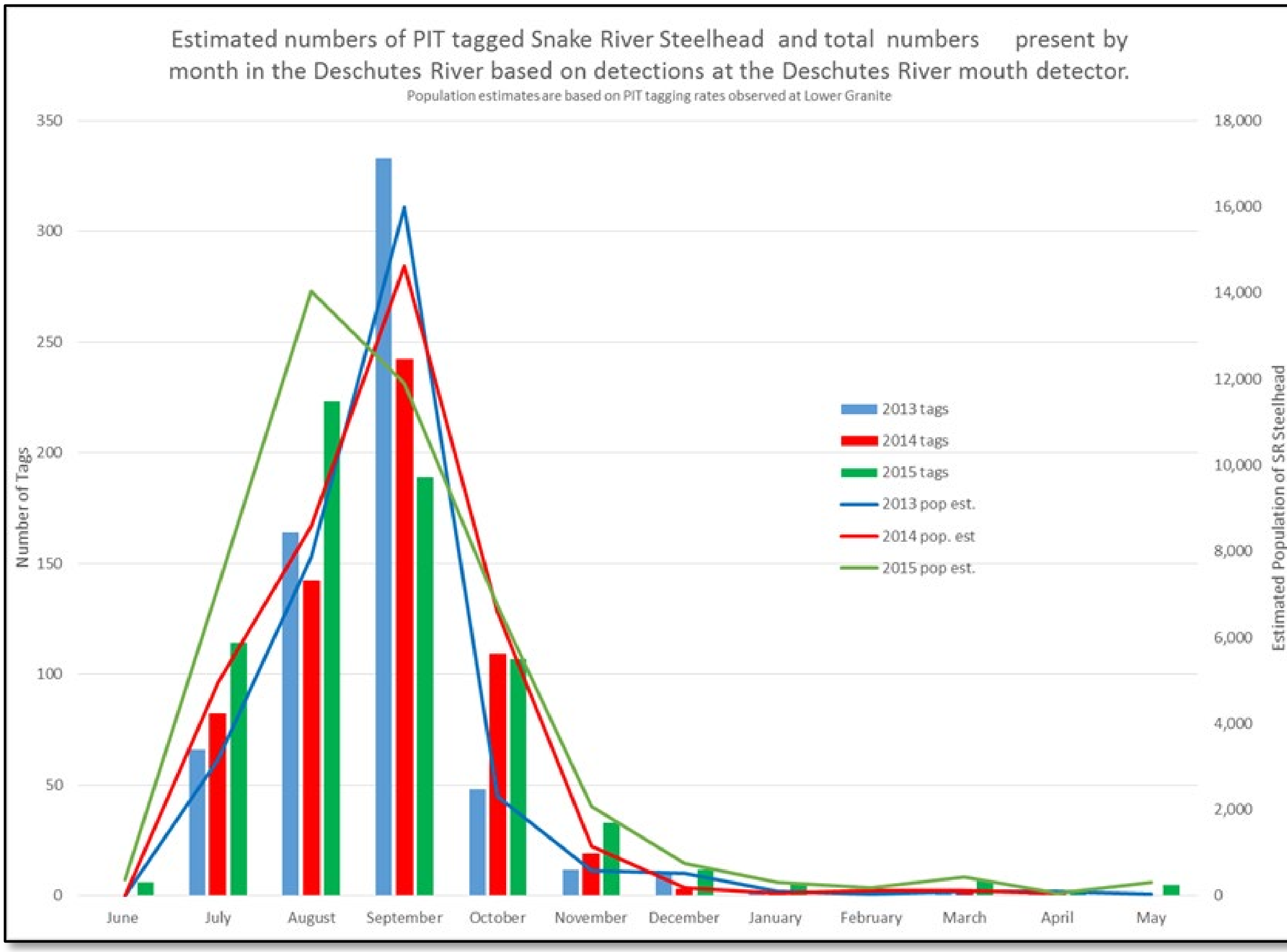


Figure 3-15 Estimated number of PIT-tagged Snake River steelhead and estimated total number of Snake River steelhead (estimated by tag expansion) present in Deschutes River cold water refuges by month 2013-2015 (NMFS 2017a)

3.9 USE OF CWR BY SPECIFIC POPULATIONS OF STEELHEAD AND FALL CHINOOK

The specific populations of steelhead and fall Chinook that use CWR the most are those with run timing that coincides with the warmest Columbia River temperatures. ***Figure 3-16*** shows the percent of specific steelhead populations that use CWR (solid circles and x-axis) and the populations' median passage time (y-axis), which reflect how long individuals from each population spend in CWR. Those steelhead populations in the upper right in ***Figure 3-16*** use CWR extensively while those populations in the lower left use CWR less. ***Figure 3-17*** shows the migration timing for the various steelhead populations, which shows that those steelhead populations with high CWR use are those where a high proportion of the population migrates through the Lower Columbia River when temperatures are warmest (i.e., late July through late August as reflected in the shaded area). Steelhead populations from the John Day, Umatilla, Grande Ronde, Imnaha, Yakima, Snake, Salmon, and Walla Walla Rivers all use CWR to a significant extent. The steelhead populations that use CWR the least are those that mostly migrate through the Lower Columbia River before (Tucannon, Hanford, and Lyons Ferry) or after (Clearwater) the warmest temperatures.

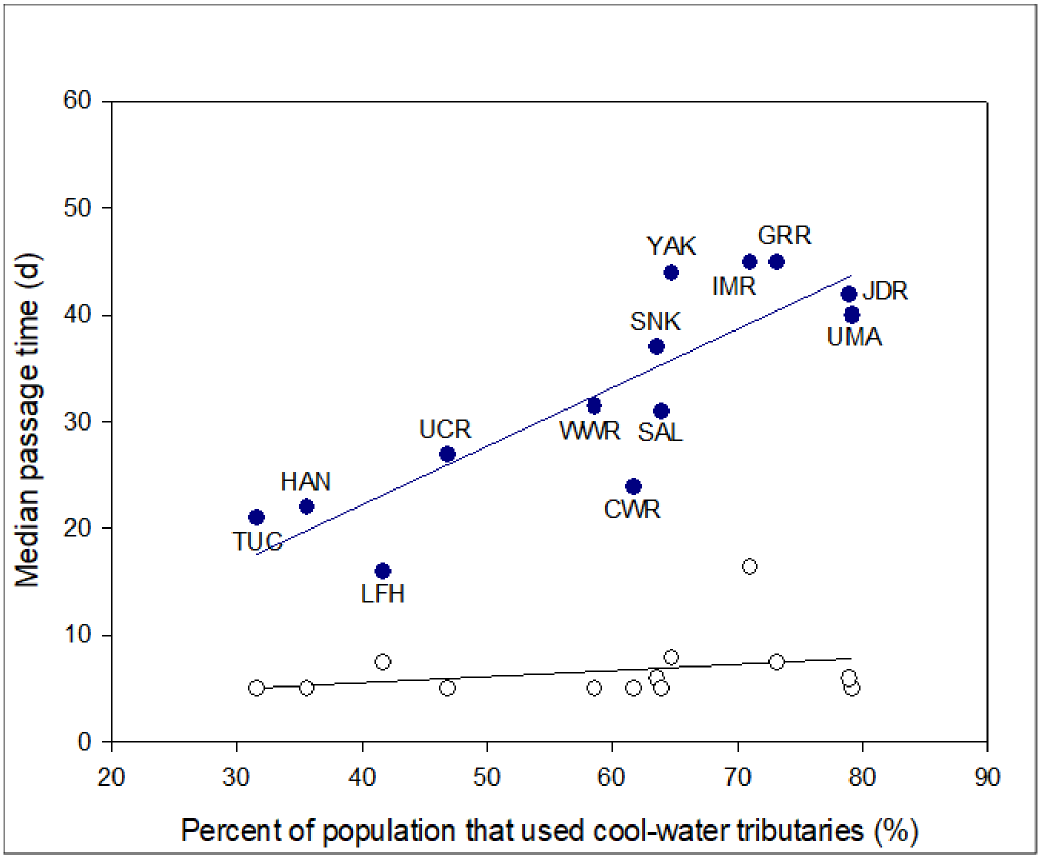


Figure 3-16 Percent of population-specific steelhead that used cold water refuges for >12 hours (solid circles) and associated median passage time from Bonneville Dam to the John Day Dam for those that used and did not use (clear circles) CWR. TUC, Tucannon River; HAN, Hanford Reach; LFH, Lyons Ferry Hatchery; UCR, Upper Columbia River; WWR, Walla Walla River; CWR, Clearwater River; SAL, Salmon River; SNK, Snake River above Lower Granite Dam; YAK, Yakima River; IMR, Imnaha River; GRR, Grande Ronde River; UMA, Umatilla River; JDR, John Day River. (Keefer et al. 2009)

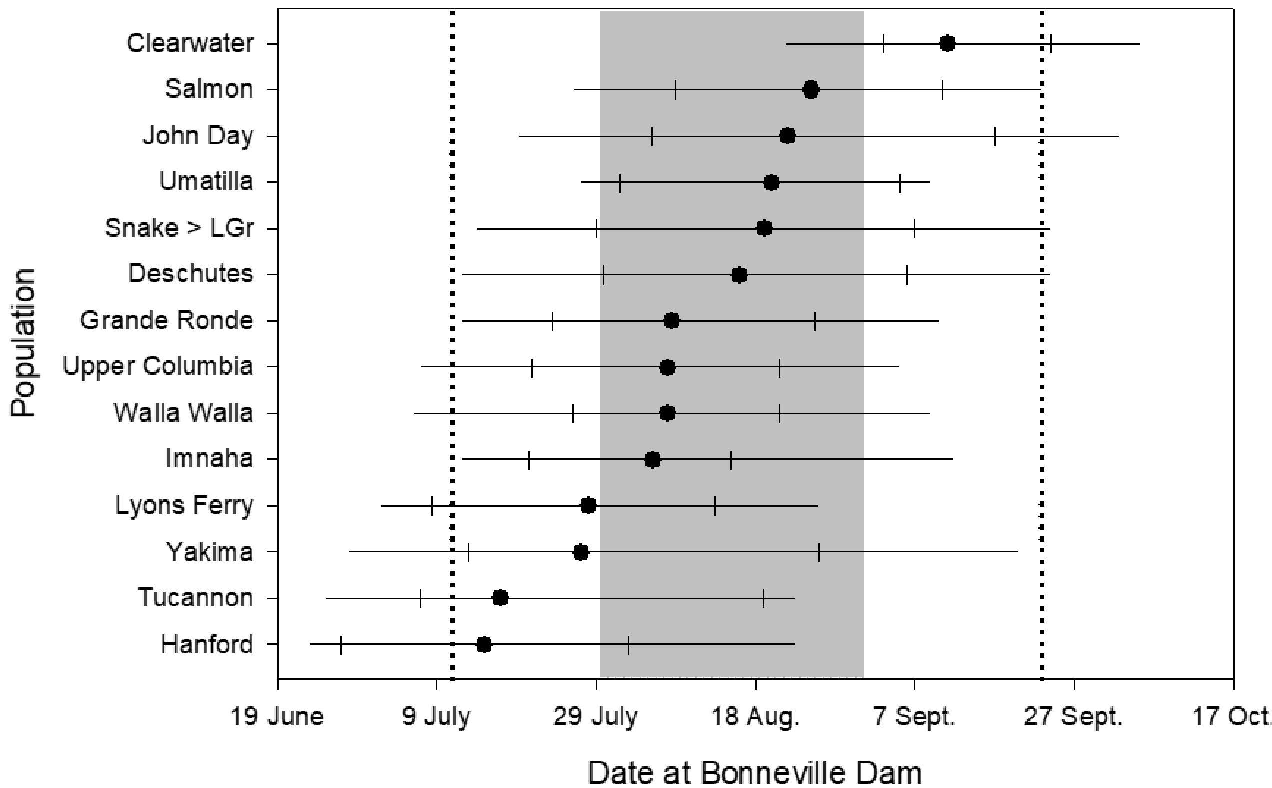


Figure 3-17 Median timing distributions (median, quartiles, and 10th and 90th percentiles) at Bonneville Dam for steelhead that successfully returned to tributaries or hatcheries. Vertical dotted lines show mean first and last dates that Columbia River water temperatures were 19°C; the shaded area shows dates with mean temperatures ≥21°C. (Keefer et al. 2009)

Similarly, those populations of fall Chinook that migrate through the Lower Columbia River in August and early September use CWR the most. ***Figure 3-18*** depicts the composition of the fall Chinook run by date. Fall Chinook are classified as Chinook that pass Bonneville Dam after August 1st. Radio-tag studies of fall Chinook use of CWR mirrors the composition of different fall Chinook populations migrating past Bonneville Dam in August and early September. Hanford reach fall Chinook and fall Chinook populations above Priest Rapids Dam were most predominately in CWR, with lesser numbers of Snake River and Yakima fall Chinook (US Army Corps, 2013). It should be noted, however, that the data in ***Figure 3-18*** is from 1998 and the early 2000s, and the composition of the fall Chinook populations may be different today. In particular, the Snake River fall Chinook population has increased, so today we might expect a higher proportion of Snake River fall Chinook using CWR.

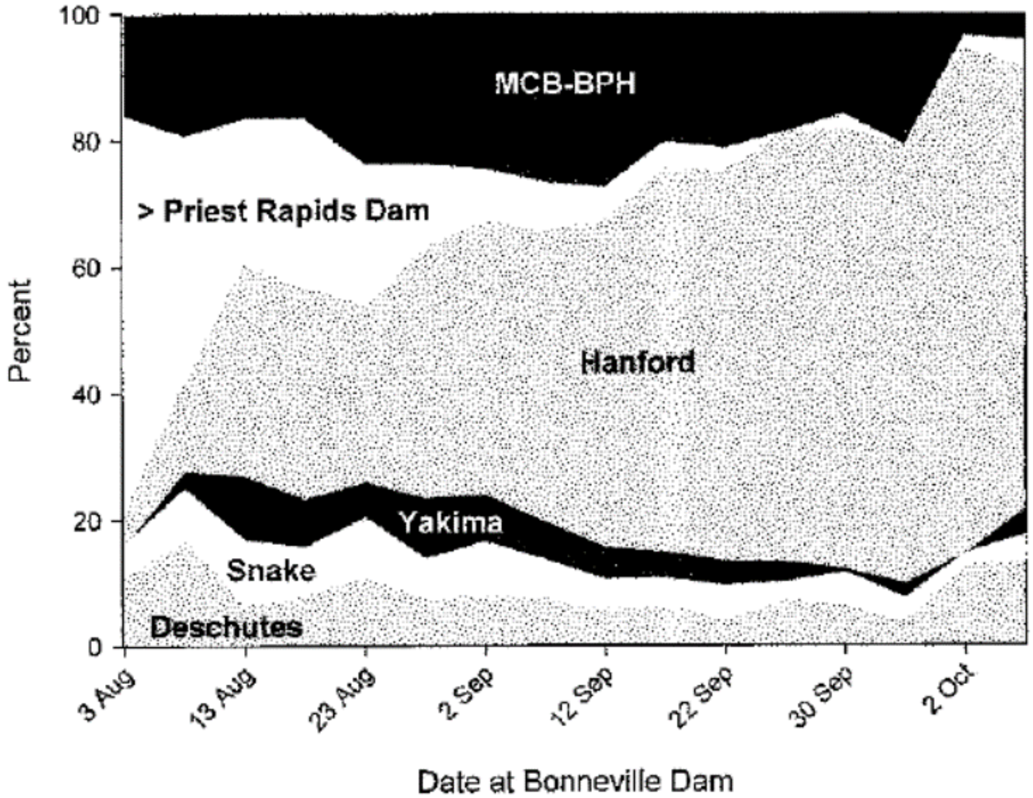


Figure 3-18 Mean composition of upriver bright fall-run Chinook salmon at Bonneville Dam using five-day intervals based on release dates of radio-tagged fish. 1998 and 2000-2004. MCB-BPH = mid-Columbia River bright-Bonneville Pool hatchery stock. (Jepson et al. 2010)

4 TEMPERATURE AND FISH HARVEST IMPACTS ON MIGRATING SALMON AND STEELHEAD

4.1 ADVERSE TEMPERATURE EFFECTS TO MIGRATING ADULT SALMON AND STEELHEAD

Water temperatures significantly affect salmon and steelhead health and survival, since they are ectothermic (cold-blooded) with their internal body temperature closely tracking river temperatures. Salmon and steelhead experience harmful health effects when exposed to warm water temperatures above their optimal range. Optimal temperatures for migrating adult salmon and steelhead are in the 12-16°C range with minimal adverse effects below 18°C (EPA 2003). Both the States of Oregon and Washington have a 20°C maximum water quality criteria for the Lower Columbia River, which is consistent with EPA's recommended numeric criteria for large mainstem rivers that naturally warm to this level and are used by salmon and steelhead for migration (EPA 2003).

Table 4-1 summarizes the adverse effects to migrating adult salmon and steelhead in the Lower Columbia River as temperatures rise above 18°C. The temperature ranges in ***Table 4-1*** represent average river temperatures with multiple day exposure. In general, as temperatures rise, disease risk, stress, energy loss, avoidance behavior, and mortality rates increase. Sockeye are most susceptible to warm temperatures with limited mortality at 19-20°C and significant mortality at 20-21°C. Steelhead are also susceptible to these temperature ranges but exhibit avoidance behavior by seeking cold water refuges (CWR) as is demonstrated in this Plan. Chinook are more tolerant to warm temperatures, with avoidance behavior (seeking CWR) and mortality occurring at higher temperatures (21-22°C and higher).

In other portions of this Plan, documented research on the effects summarized in ***Table 4-1*** is provided, specifically Chapter 2 related to avoidance behavior and CWR use and sections 4.2, 4.5, and 4.6 related to mortality, energy loss, and shifts in migration timing.

Table 4-1 Summary of temperature effects to migrating adult salmon and steelhead in the Lower Columbia River (EPA 2003; McCullough 1999, Richter and Kolmes 2005)

Temperature Range	Effects
Less than 18°C	Minimal effects to salmon and steelhead
18-20°C	Elevated disease risk Low proportion of steelhead seek CWR Slight increase in sockeye mortality
20-21°C	Significant disease risk Increased stress and energy loss Majority of steelhead seek CWR Significant sockeye mortality Low proportion of Chinook seek CWR
21-22°C	High disease risk High stress and energy loss High percentage of steelhead move into CWR High sockeye mortality Moderate proportion of Chinook seek CWR
22-23°C	Very high disease risk Very high stress and energy loss Very high percentage of steelhead move into CWR Very high sockeye mortality Significant proportion of Chinook seek CWR
23-24°C	Very high disease risk Very high stress and energy loss High avoidance behavior for steelhead and all salmon High mortality for steelhead and salmon species

4.2 RELATIONSHIP BETWEEN TEMPERATURE AND MIGRATION SURVIVAL OF ADULT STEELHEAD AND FALL CHINOOK SALMON

The survival rates of migrating adult salmon and steelhead between Bonneville Dam and McNary Dam can be estimated by comparing the passage counts at each of the dams. The Fish Passage Center conducted an analysis of the survival rates between these two dams as a function of Columbia River water temperature. ***Figure 4-1*** shows that the survival rate for steelhead (PIT-tagged 2003-2015) decreases at 18°C temperatures and higher, and that a 10% reduction in survival occurs at 21-22°C temperatures compared to 18°C and below temperatures. ***Figure 4-2*** shows the survival rates for fall Chinook at three different temperature ranges (below 20°C, 20-21°C, and >21°C) with a decline in survival with warmer temperatures. There is approximately a 7-8% decrease in survival for temperature >21°C versus below 20°C. ***Figure 4-2*** also shows that adults that were transported in barges down the Columbia River as juveniles have less survival than those that migrated downstream in the Columbia River.

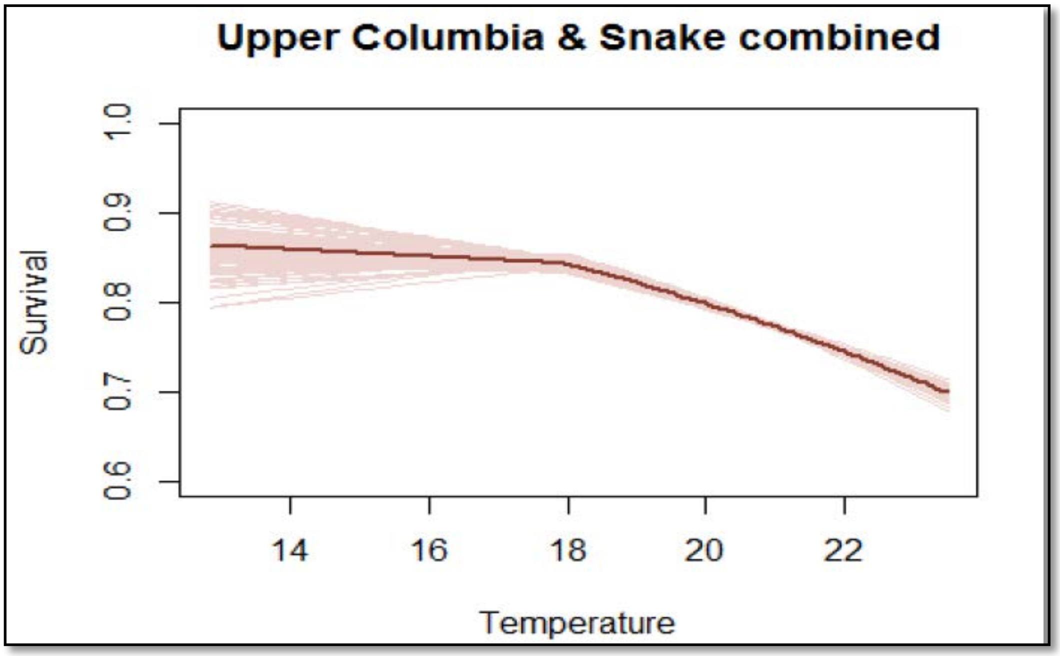


Figure 4-1 Estimated survival rate of adult steelhead between Bonneville Dam and McNary Dam (FPC, October 31, 2016 Memo)

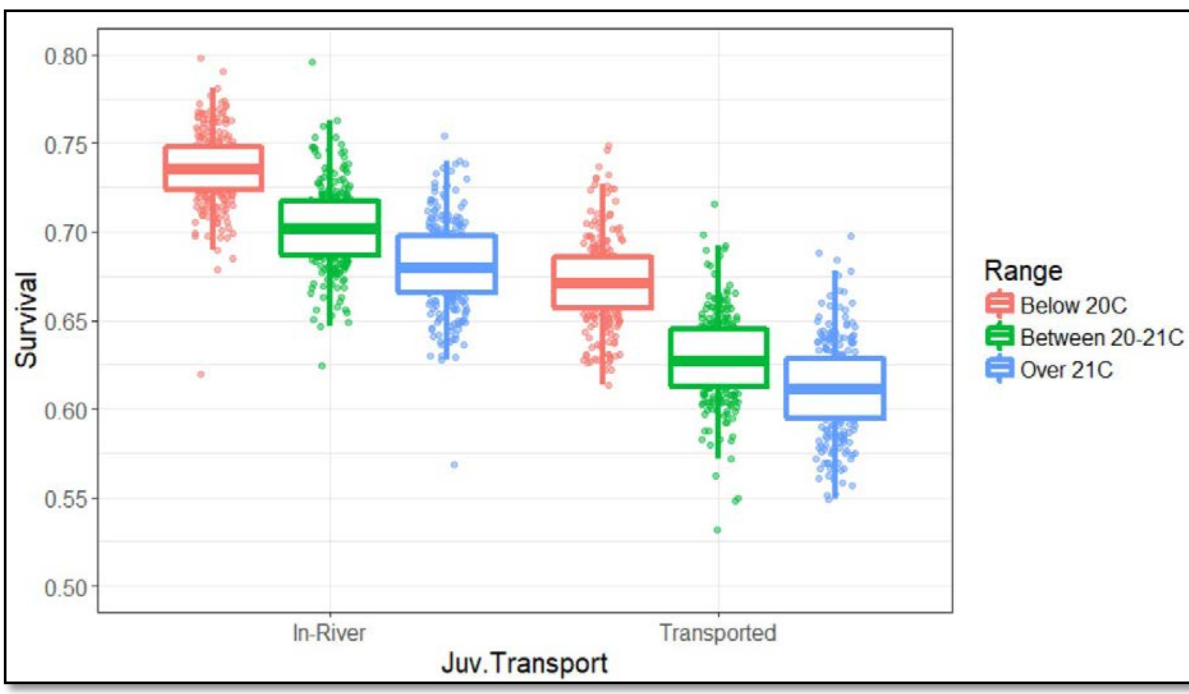


Figure 4-2 Estimated survival rate of adult fall Chinook between Bonneville Dam and McNary Dam (FPC, May 8, 2018 Memo)

The results shown in ***Figure 4-1*** and ***Figure 4-2*** indicate that the migration survival of an individual steelhead or a fall Chinook salmon between Bonneville Dam and McNary Dam decreases by 7-10% as temperatures rise above 21°C. It should be noted that other factors, such as increased harvest of fish that moved into CWR due to the rise in temperature, could be contributing to the decreased survival rates.

4.3 FISHING HARVEST OF SALMON AND STEELHEAD IN COLD WATER REFUGES

As noted above in Section 4.2, the correlation between increased Columbia River temperature and decreased migration survival of adult steelhead and fall Chinook in the Lower Columbia River could also be associated with increased fishing harvest in CWR at warmer Columbia River temperatures. Fishing harvest in CWR also makes it difficult to directly measure the benefits of CWR to migrating adult salmon and steelhead.

Keefer et al. (2009) analyzed the migration success of steelhead that used CWR versus those that did not use CWR. This study found that migration success to the spawning tributaries for those steelhead (wild and hatchery) that used CWR was about 8% less than those steelhead that did not use CWR, which initially suggests CWR use is not beneficial. However, the study also indicated that fishing harvest in CWR likely explained the decreased survival. Wild steelhead using CWR, which are required to be released when caught, experienced a 4.5% decrease in survival during migration to their spawning tributaries compared to wild steelhead that did not use CWR. This increased mortality, however, could be associated with catch and release mortality and illegal catch of wild steelhead in CWR (Keefer et al. 2009).

Another confounding variable is salmon and steelhead that were transported (barged) downstream as juveniles have a higher rate of straying and lower adult survival rates between Bonneville and McNary dams (see ***Figure 4-2***). Some of these strays could be in CWR, thus juvenile transportation could explain some of the lower adult survival rates for fish that use CWR. Further, fish that use CWR may be more susceptible to warm temperatures and may have higher mortality in the mainstem than fish that don't use CWR (Keefer et al. 2009).

NMFS (2017a) also found that the survival rate for steelhead (wild and hatchery) from The Dalles Dam to McNary Dam was about 9% less for those steelhead that used CWR (detected in the Deschutes River) versus those that did not use CWR. NMFS assessment also provided data on fish harvest in the Deschutes River that appears to explain the reduced survival for those steelhead using CWR.

Due to fishing harvest in CWR, it is difficult to directly measure the extent to which steelhead and fall Chinook CWR use may lead to higher migration survival rates due to avoidance and minimization of exposure to warm Lower Columbia River temperatures. Similarly, it is difficult to separate how much of the observed 7-10% decrease in steelhead and fall Chinook survival in the Lower Columbia River when temperatures exceed 21°C is due to temperature effects versus fishing harvest. More sophisticated studies, perhaps during periods with no fishing, would likely be needed to accurately answer these questions quantitatively.

4.4 SNAKE RIVER STEELHEAD AND FALL CHINOOK MIGRATION SURVIVAL RATES IN THE LOWER COLUMBIA AND LOWER SNAKE RIVERS

Section 4.2 assessed the impact that river temperatures have on the survival rate of individual steelhead and fall Chinook. This section looks at the survival rate in the Lower Columbia River for ESA-listed Snake River steelhead and fall Chinook runs to ascertain if elevated temperatures may be contributing to decreased survival rates. NMFS calculates the survival rates of ESA-listed salmon and steelhead in the Lower Columbia River each year for the whole run. As shown in ***Figure 3-17*** and ***Figure 3-18*** above, the Snake River steelhead run passes Bonneville Dam from July through September, and the Snake River fall Chinook run passes Bonneville Dam from August through early October, respectively. Thus, a portion of these runs migrate through the Lower Columbia River when water temperatures exceed 20°C, while a portion of the runs migrate through when temperatures are below 20°C.

Figure 4-3 shows the "adjusted" survival rate for Snake River steelhead between Bonneville Dam and McNary Dam and between Bonneville Dam and Lower Granite Dam on the Snake River for each year (2008-2017). "Adjusted" denotes the survival rate, factoring in the estimated percentage of fish that are harvested or stray. Therefore, adjusted survival highlights the percentage of fish that do not survive for unknown reasons. As shown in ***Figure 4-3***, the ten-year average adjusted survival rate from Bonneville Dam to McNary Dam is 94% (range of 90 to 100%) and from Bonneville Dam to Lower Granite Dam is 87% (range 81 to 94%). These data indicate that there is an average of 6% unexplained mortality of adult Snake River steelhead migrating between the Bonneville and McNary Dams and an additional 7% unexplained mortality between McNary Dam and Lower Granite Dam. Part of this unexplained mortality is likely attributable to mortality associated with prolonged exposure to Columbia River temperatures above 20-21°C during the upstream migration as has been observed to occur (see ***Figure 4-1***). Absent detailed studies, this 6% migration mortality rate appears to be equal for hatchery and wild steelhead. For context, the estimated Snake River steelhead harvest (primarily for hatchery steelhead) between Bonneville Dam and McNary Dam (Zone 6) is approximately 15%, and the estimated stray rate is 5%.

It also should be noted that there is year-to-year variability in unexplained adult steelhead mortality between the Bonneville and McNary Dams, with some years near 10% mortality (e.g., 2009, 2011,2013, and 2017). Also, these data represent an average of all Snake River steelhead populations, and some individual populations could have higher unexplained mortality, especially if the majority of their migration occurs during peak summer temperatures (see ***Figure 4-7***).

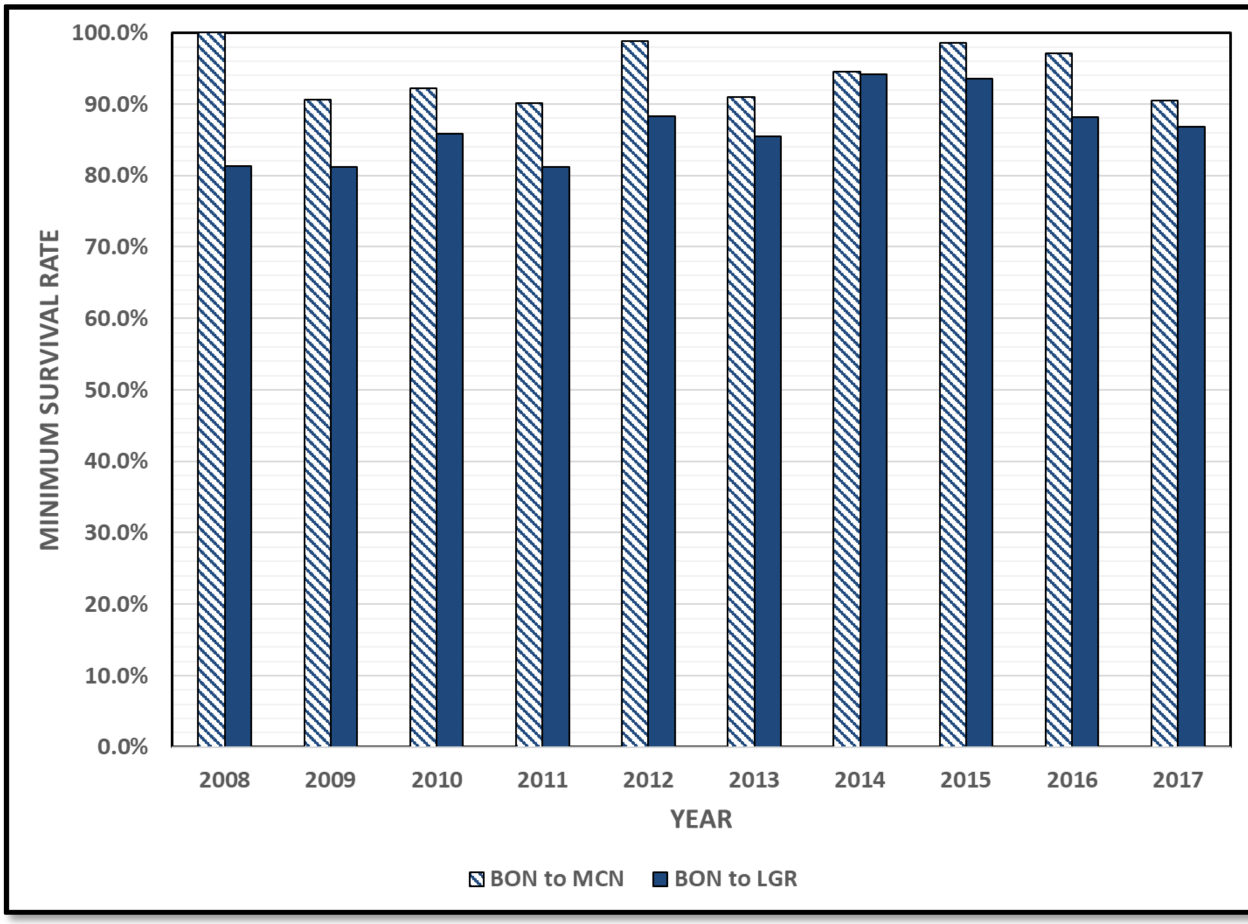


Figure 4-3 Adjusted survival estimates of adult Snake River steelhead between Bonneville Dam (BON) and McNary Dam (MCN) and between Bonneville Dam and Lower Granite Dam (LGR) for the whole run (NMFS, 2019)

Figure 4-4 shows the "adjusted" survival rate for the Snake River fall Chinook run between Bonneville Dam and Lower Granite Dam for each year (2008-2016). The average adjusted survival for Snake River fall Chinook between Bonneville Dam and Lower Granite Dam is 90%, which means there is 10% unexplained mortality of adult Snake River fall Chinook migrating between the two dams. About half (5%) of this mortality occurs between Bonneville Dam and McNary Dam, and half (5%) occurs between McNary Dam and Lower Granite Dam and likely is the same rate for both hatchery and wild Snake River fall Chinook. In some years, the survival rate is 80%, with 20% unexplained mortality (2011, 2013, 2016) between Bonneville Dam and Lower Granite Dam. Part of this unexplained mortality is likely associated with prolonged exposure to Columbia River temperatures above 21°C during the upstream migration as has been observed to occur per ***Figure 4-2*** above. For context, the estimated Snake River fall Chinook harvest rate (primarily for hatchery fall Chinook) between Bonneville Dam and McNary Dam (zone 6) is approximately 23%, and the estimated stray rate is 3%.

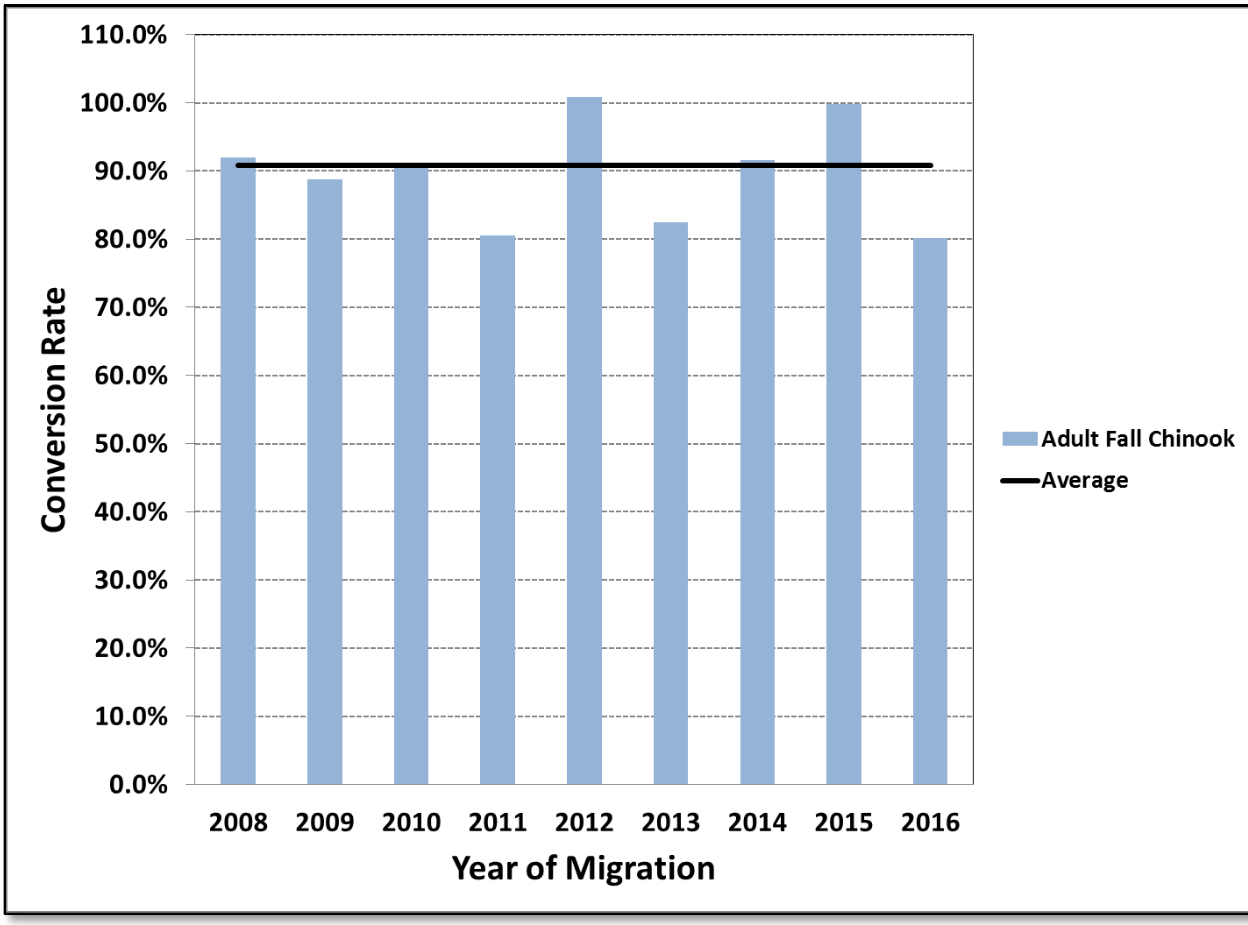


Figure 4-4 Adjusted survival estimates of adult Snake River fall Chinook between Bonneville Dam and Lower Granite Dam for the whole run (NMFS, 2019)

The information summarized above in this section and in Section 4.2 indicates exposure to warm Lower Columbia (and Snake River) temperatures is likely contributing to mortality loss of migrating adult steelhead and fall Chinook salmon. NMFS Biological Opinion (2020) on the Columbia River System Operations (CRSO) recognized these adverse effects to adult steelhead and fall Chinook from warm summer temperatures in the migration corridor. However, NMFS concluded the overall adult survival rates for these species through the Lower Columbia River were “relatively high” and the mortality losses were not at levels that would cause the CRSO to appreciably reduce the survival and recovery of ESA-listed Snake River steelhead and fall Chinook (NMFS 2020). As noted elsewhere, use of CWR by these species may be aiding their migration survival rates through the Lower Columbia River during periods of warm temperatures.

4.5 ENERGY LOSS AND PRE-SPAWNING MORTALITY OF FALL CHINOOK SALMON FROM EXPOSURE TO WARM MIGRATION TEMPERATURES

As described in Section 4.1, prolonged exposure to warm river temperatures can have adverse effects on migrating salmon. The rate of energy expenditure as a fish migrates directly depends on swimming speed (fish speed plus water velocity) and temperature (Connor et al. 2018). For a fish to successfully spawn at the end of its migration, it must have enough energy reserves for gonad formation and to complete the spawning process. A recent study (Plumb 2018) used a bioenergetics model to examine the effects of temperature on migration energy use and spawning success. The study focused on Snake River fall-run Chinook migrating from Bonneville Dam in the Columbia River to the confluence of the Snake and Salmon rivers in Hells Canyon.

Based on previous studies (Bowerman et al. 2017), Plumb defined the energy threshold criterion for successful spawning as 4 kJ/g[3], where fish below this threshold typically die and do not successfully spawn. Migrating salmon have finite energy reserves at the start of their migration, and high river temperatures can hasten the rate at which fish reach this physiological threshold, ultimately limiting spawning success (Plumb 2018).

Increases in time spent and distance traveled during migration lead to increases in pre-spawning mortality, supporting a link between energy expenditure and spawning success (Bowerman et al. 2017). Annual detections of PIT-tagged fish validate that slower travel rates and greater exposure to higher temperatures affect arrival probabilities at spawning grounds. The probability of fall Chinook having sufficient (>4 kJ/g) energy reserves to spawn depends in part on two factors: (1) which day of the year a fish migrates from Bonneville Dam; and (2) whether a fish uses CWR during migration. While early fall Chinook migrants are exposed to warmer temperatures in comparison to later migrants, using CWR as a coping strategy can influence the amount of energy reserves a fish has at time of spawning. Holding in CWR and migrating later when Columbia and Snake River temperatures are lower can reduce thermal exposure and energy loss.

Plumb (2018) modeled the thermal experience of simulated fall Chinook, which was a function of the mainstem river temperatures during migration (Columbia and Snake Rivers), the temperature difference between the mainstem river and a cold water tributary, and the probability of a fish occupying a cold water tributary.

Figure 4-5 demonstrates that simulated fish using CWR experienced lower cumulative temperatures and energy loss, which increased the proportion of early migrants surviving to spawn. For instance, among fall Chinook migrating in August, those that used CWR (light grey line) had a higher proportion with sufficient energy to complete spawning than those that did not (dotted line).

[3] kJ/g = kilojoules per gram of the fish and reflects the amount of energy per unit of mass or in general terms the amount of stored fat relative to the size of the fish.

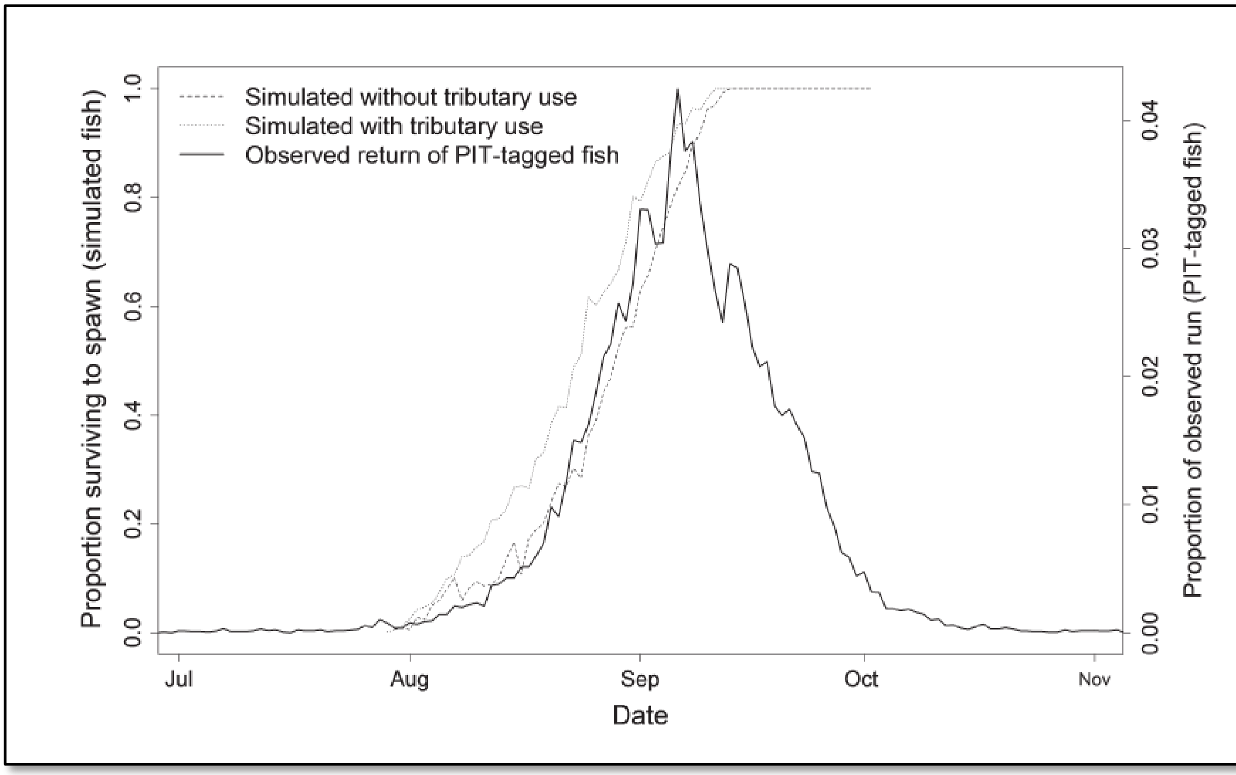


Figure 4-5 The proportion of simulated fish that had energy densities greater than the 4 kJ/g threshold needed for sufficient energy to spawn (Plumb, 2018)

Supporting Plumb's findings, ***Figure 4-6*** (Connor et al. 2018) shows that the early portion of the spawning distribution of fall Chinook is predicted to drop below the energy threshold needed for successful spawning and that these fish may experience pre-spawning or premature mortality.

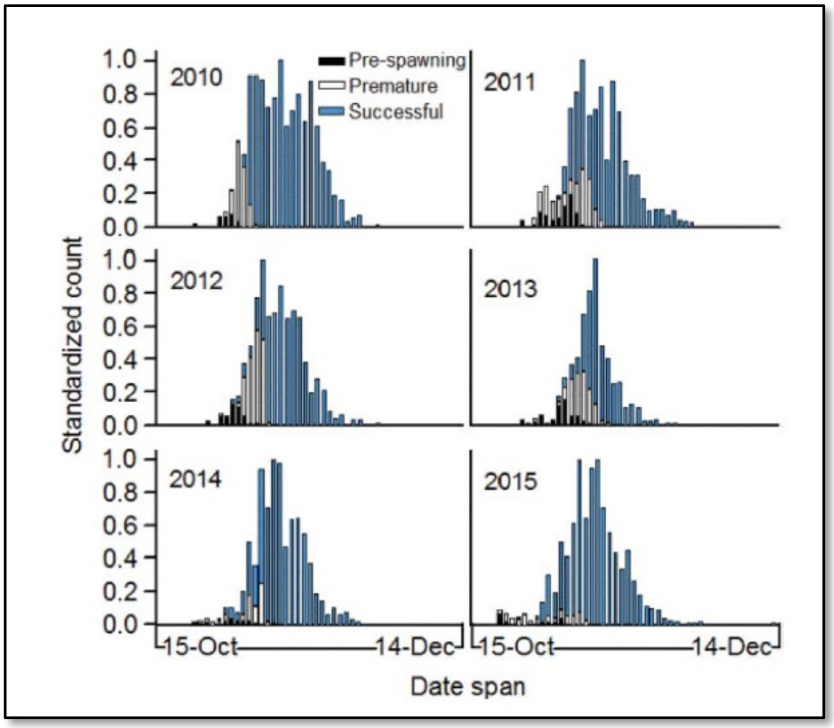


Figure 4-6 Standardized, simulated spawning initiation date distributions for PIT-tagged, hatchery-origin Snake River fall Chinook salmon adults, 2010-2015 (Conner et. al 2018)

Under scenarios to mimic future conditions with climate change, temperature increases of 1, 2, and 3°C from baseline river temperatures showed a linear decline in the median energy remaining at spawning and in the fraction of simulated fish having enough energy reserves to spawn (Plumb 2018). As average temperatures increased, Chinook who did *not* utilize CWR were forced to migrate later in the year from Bonneville Dam to have enough energy reserves left to spawn. However, for Chinook that *did* utilize CWR during migration under increasing river temperatures, passage dates from Bonneville Dam were on average 18-27 days earlier than fish that did not utilize CWR. This finding supports the conclusion that using CWR during upriver migration may provide early migrants with an energetic advantage over fish that do not use them. Further, the proportion of fish that seek and use thermal refuge is likely to increase as temperature increases (Connor et al. 2018).

4.6 INCREASED MORTALITY AND SHIFT IN RUN TIMING OF SOCKEYE AND SUMMER CHINOOK FROM WARM MIGRATION TEMPERATURES

As noted earlier, sockeye salmon do not appear to use CWR to avoid warm Lower Columbia River temperatures, and it does not appear to be advantageous to do so. Sockeye salmon migrate through the Lower Columbia River in June and July prior to the warmest summer river temperatures that typically occur in August. If sockeye salmon were to delay their migration by entering CWR, they would end up encountering warmer Columbia River temperatures during their continued upstream migration.

Warm Lower Columbia River temperatures, however, do have a significant impact on sockeye salmon. The unusually warm June and July Lower Columbia River temperatures that occurred in 2015 illustrate the relationship between warmer river temperatures and increased mortality of sockeye salmon. As shown in ***Figure 4-7***, in 2015 Lower Columbia River temperatures were significantly warmer than average during the June-July sockeye run, reaching 20°C (68°F) at the peak of the run, in late June. Typically, temperatures are about 16°C (61°F) during the peak of the sockeye run in late June.

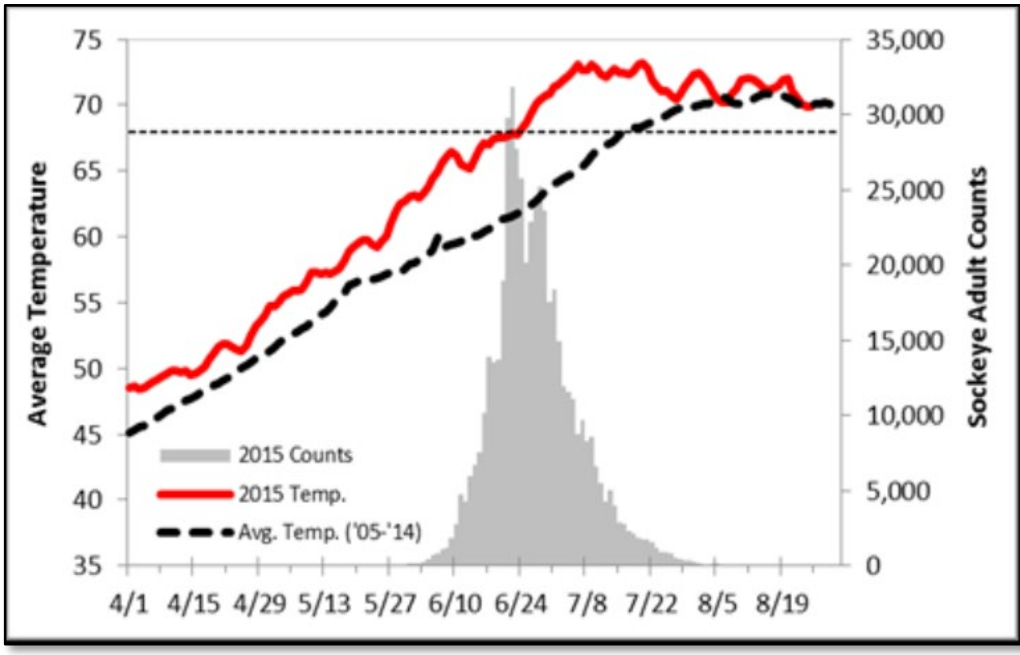


Figure 4-7 Sockeye passage and river temperature at Bonneville Dam (FPC, August 26, 2015 Memo)

Figure 4-8 shows how survival of sockeye from Bonneville Dam to McNary Dam dropped significantly as temperature rose during the sockeye run in 2015. In early June when river temperatures were below 19°C, survival between the two dams was high (90-100%). During week 4 in ***Figure 4-8*** (June 22–28), when river temperature climbed above 20°C, survival dropped to 70% for Columbia River sockeye and 50% for Snake River sockeye (10% for Snake River sockeye transported as juveniles). In weeks 5-8, when river temperatures exceeded 21°C, survival was very low (0-20%). Because most of the Snake River sockeye migrated in late June and July, the overall survival for Snake River sockeye between Bonneville Dam and McNary Dam was only 15% in 2015 (FPC 2015).

Although 2015's unusually warm June-July river temperatures had a dramatic effect on sockeye salmon survival in the Lower Columbia River, warm Lower Columbia River temperatures result in decreased sockeye survival in other years as well. ***Figure 4-9*** shows the sockeye survival rate between Bonneville and McNary dams as a function of river temperature across the sockeye run for six different years (2010-2015). In 2010-2012 when the sockeye migrated through the Lower Columbia River before river temperatures reached 64°F (18°C) survival rates were relatively high (approximately 75%). In 2013 and 2014, for those sockeye migrating through Lower Columbia River when temperatures exceeded 64°F (18°C) survival decreased, most dramatically for Snake River sockeye.

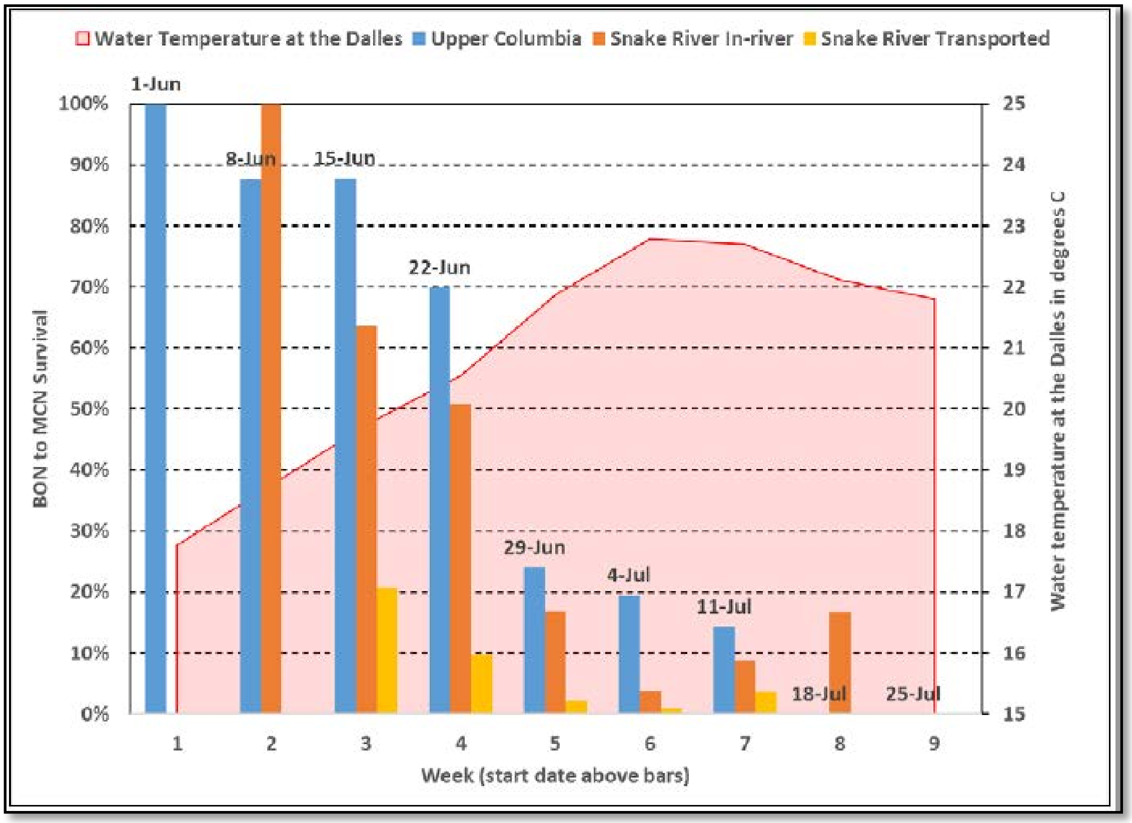


Figure 4-8 Weekly survival estimates from Bonneville Dam to McNary Dam in 2015 for Upper Columbia River Sockeye (blue bars), Snake River sockeye that migrated in-river as juveniles (orange bars), and Snake River sockeye that were transported as juveniles (yellow-orange bars) with water temperatures (red line) at The Dalles Dam (NMFS 2016)

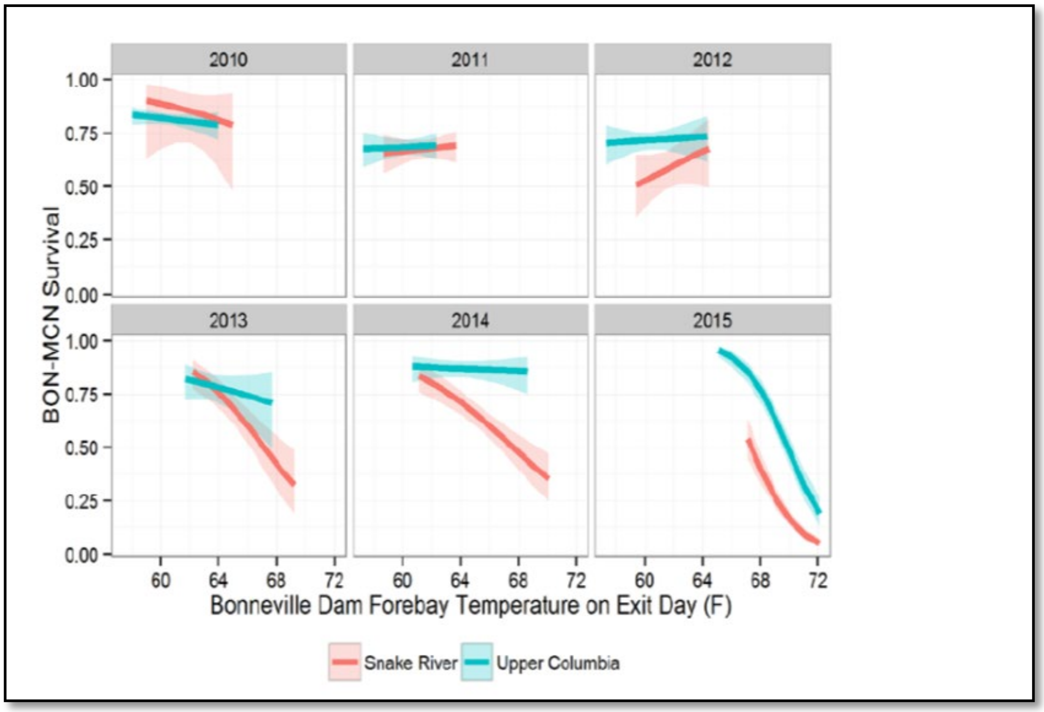


Figure 4-9 Estimated relationship between Bonneville Dam forebay temperature and Bonneville Dam to McNary Dam survival by return year for Snake and Upper Columbia adult sockeye (FPC Memo 2015)

As described in ***Figure 4-8*** and ***Figure 4-9***, July Lower Columbia River temperatures have a pronounced effect on sockeye salmon migration survival. ***Figure 4-10*** shows how increasing July river temperatures at Bonneville Dam (Panel B) over the past 60 years have resulted in earlier migration of Columbia River sockeye salmon. The median passage date, which historically was the first week of July, is now the last week of June (***Figure 4-10***, Panel A). Thus, as July river temperatures have increased, the July sockeye migrant mortality has increased. Over time, because the June sockeye migrants are more successful, the genetic traits of the June migrants increase as a percentage of the population, contributing to the shift in migration timing (Crozier et al. 2011).

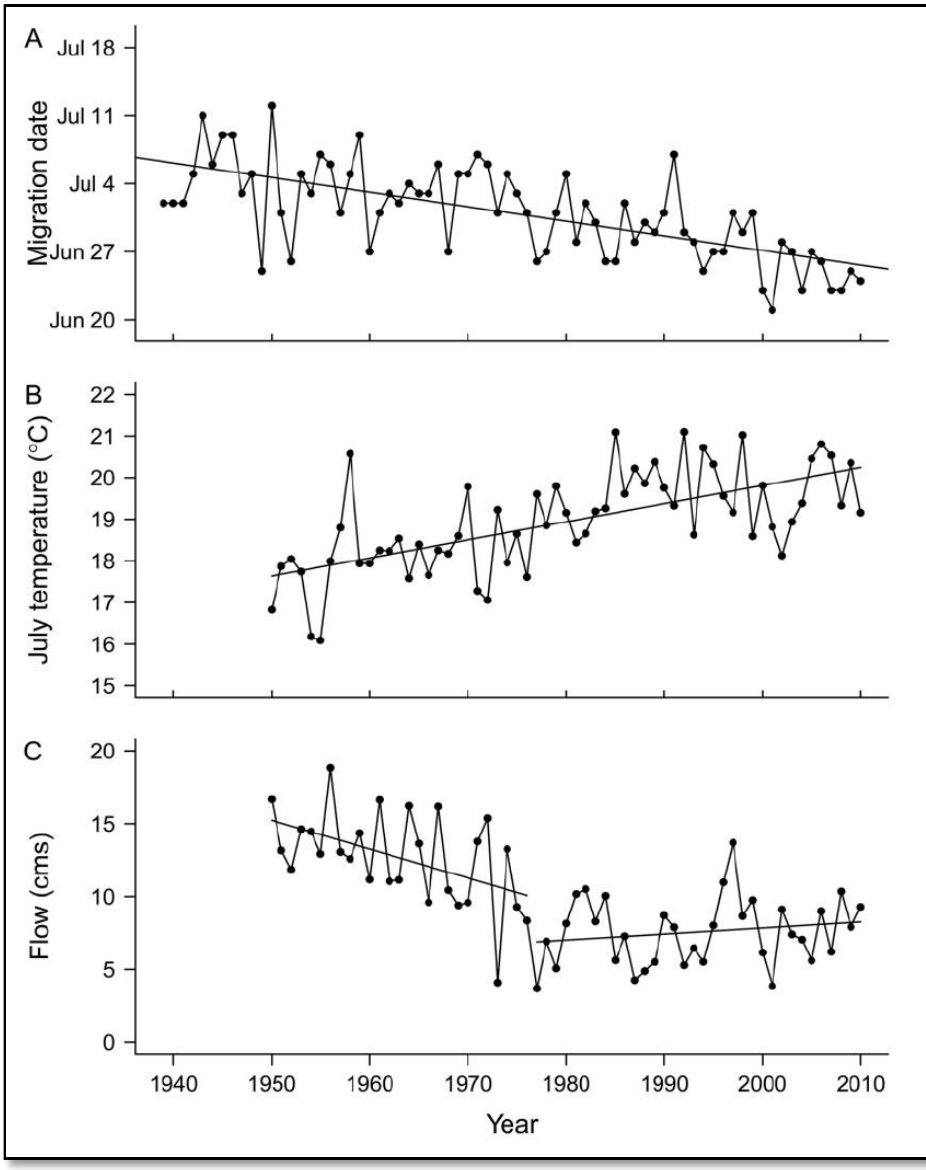


Figure 4-10 Median sockeye salmon migration date (A), July mean temperature (B), and June mean flow (C) at Bonneville Dam (Crozier et al. 2011)

Summer Chinook, like sockeye salmon, migrate through the Lower Columbia River in June and July prior to the warmest summer temperatures (***Figure 3-1***). And, for the reasons described above for sockeye salmon, summer Chinook likely do not use CWR, except for brief periods of respite. Summer Chinook also have increased adult mortality with increased temperatures. ***Figure 4-11*** shows that 2013, 2014, and especially 2015 had above normal river temperatures during the June-July migration period for Snake River summer Chinook passing Bonneville Dam. ***Figure 4-12*** shows the decreased survival rate of Snake River summer Chinook between Bonneville and McNary dams for 2013, 2014, and 2015 relative to the average survival rate (80%). The warmer-than-average temperatures in these years is likely a contributing factor to the decreased survival.

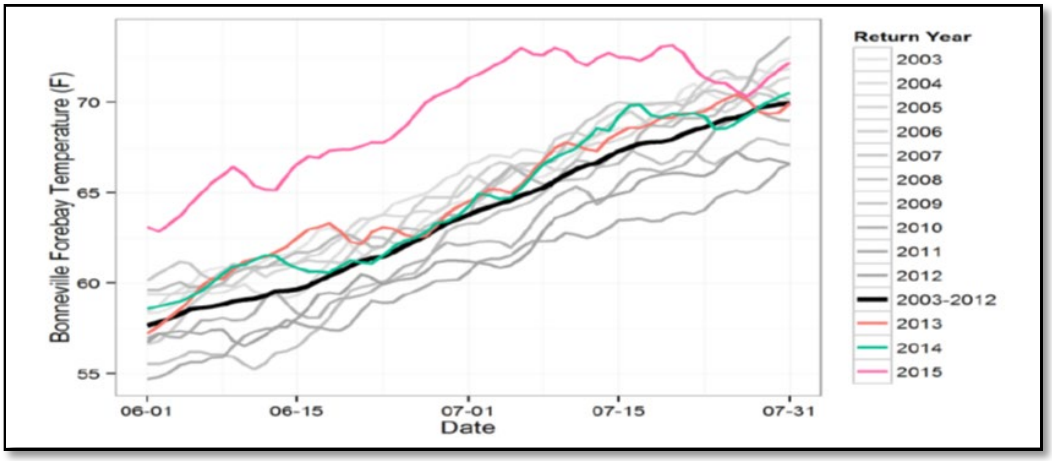


Figure 4-11 Daily average temperature (°F) in the Bonneville Dam forebay from June 1 to July 31 by return year (FPC 2016)

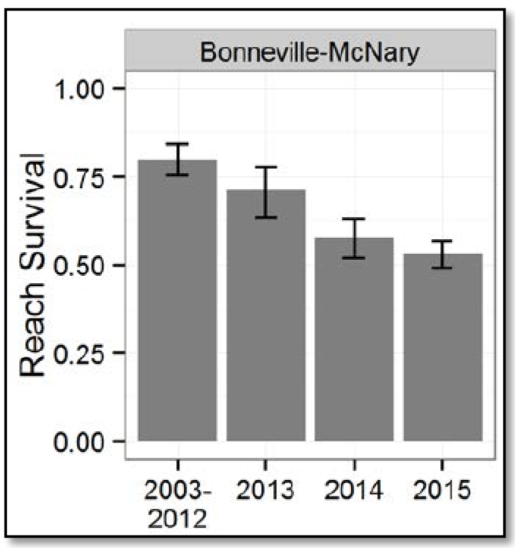


Figure 4-12 Hatchery Snake River summer Chinook adult reach survival with 95% confidence intervals by return year (FPC 2016)

Much like the sockeye salmon run, the summer Chinook run has also shifted to earlier in the year, likely in response to rising July temperatures. ***Figure 4-13*** and ***Figure 4-14*** show the distribution of the summer Chinook run over Bonneville Dam from 1994 to 2018. ***Figure 4-14*** shows that both the 50% passage date (yellow line) and the 90% passage date (blue line) have shifted earlier by about 1 week over the past 25 years. Due to the increase in July temperatures in the Lower Columbia River, only a small portion (10% or less) of the summer Chinook run pass Bonneville Dam in the last two weeks of July.

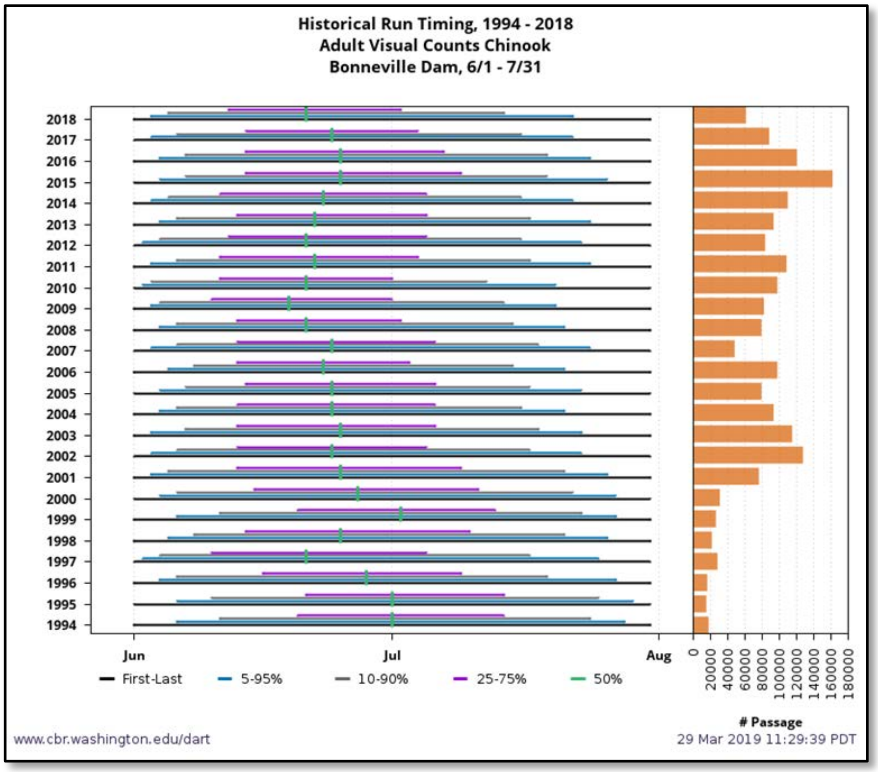


Figure 4-13 Summer Chinook run timing past Bonneville Dam (1994-2018) (DART)

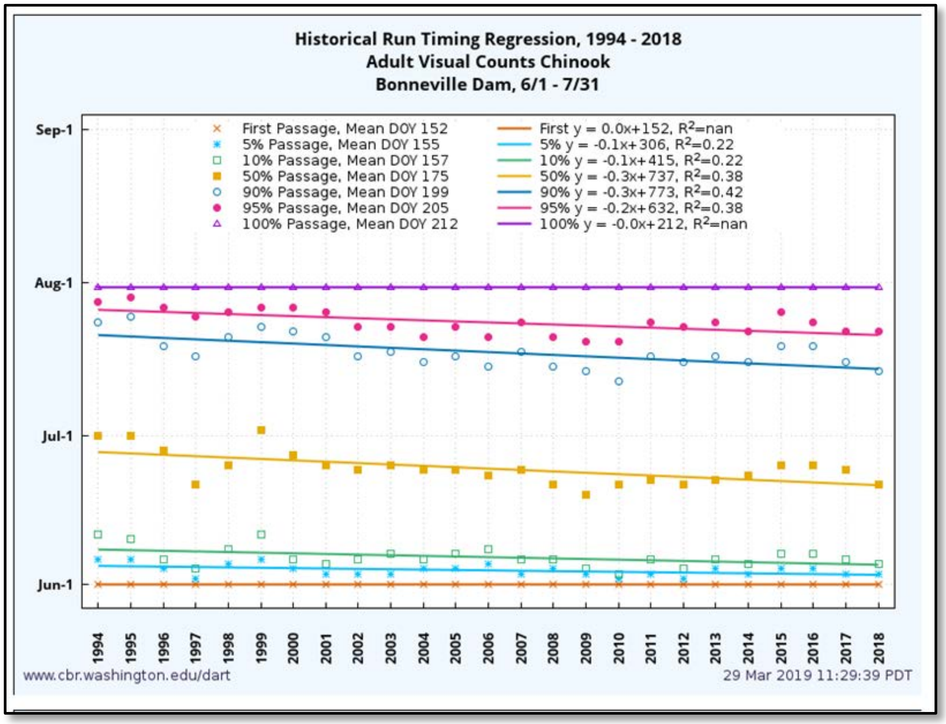


Figure 4-14 Trends in summer Chinook run distribution past Bonneville Dam (1994-2018) (DART)

5 HISTORIC AND FUTURE TRENDS IN COLUMBIA RIVER TEMPERATURES

5.1 HISTORIC TEMPERATURE CONDITIONS OF THE LOWER COLUMBIA RIVER

Based on available literature and EPA analyses (Appendix 12.16), the estimated increase in Columbia River temperatures from climate change since the 1960 baseline ranges from 0.2°C to 0.4°C per decade, for a total temperature increase to date of 1.5°C ± 0.5°C. EPA notes that flow regulation, land use changes, natural variability, and other factors may have also influenced the observed changes. Thus, increased water temperatures since 1960 may not be ascribed solely to anthropogenic climate change influences.

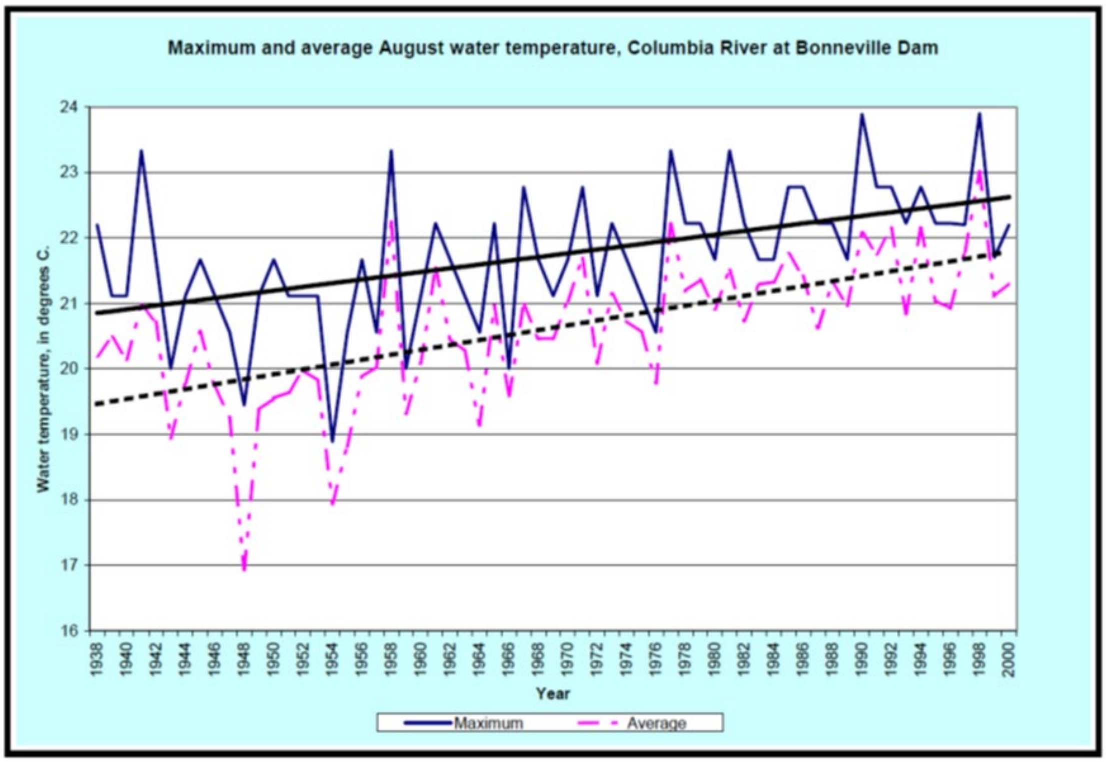


Figure 5-1 Trend in Columbia River August temperatures at Bonneville Dam (National Research Council 2004)

Historic measurement data shown in ***Figure 5-1*** on the Columbia River at Bonneville Dam indicate that the total warming of the river since the late 1930s in August (average) is approximately 2.2°C (dashed line), rising from below 20°C to near 22°C. This increase incorporates all factors in river warming, including dam construction in the middle decades of the century and climate change from 1960 to 2000. It is noted that monitoring data collected at the dams and contained in the DART database prior to 1990 is uncertain due to a lack of data quality procedures. Nevertheless, this is the best available information on historic temperatures, and the increase in August temperatures appears to be generally consistent with current estimates of anthropogenic impacts using EPA's RBM10 model (EPA 2020), combined with the climate-related warming since 1960 noted above.

EPA's RBM10 model can predict past temperatures by using historic air temperatures and river flow, and RBM10 model results were considered in the climate trend analysis in Appendix 12.16. ***Figure 5-2*** is a simulation with the existing Columbia and Lower Snake River dams in place (all dams were built prior to 1970 except Lower Granite, which was built in 1975). ***Figure 5-3*** is a simulation without the U.S. Columbia and Lower Snake River dams (the simulation retained Canadian dams on the Columbia River). A comparison of the two figures indicates that August and September mean Columbia River temperatures at Bonneville Dam would have warmed at a lower rate and to a lesser extent without the dams since 1970. The yellow-dashed line representing the August warming rate in ***Figure 5-2*** shows 0.4°C increase per decade, while the yellow-dashed line in ***Figure 5-3*** shows a 0.26°C increase per decade. For July (red-dashed lines), however, the rate of warming is approximately the same in the two simulations, indicating that the increase in warming since 1970 is primarily attributable to air temperature increases from climate change, and that the dams have not exacerbated the warming trend in July. Therefore, the dams appear to have exacerbated the rate of climate change induced warming in the Columbia River in the late summer (August-September).

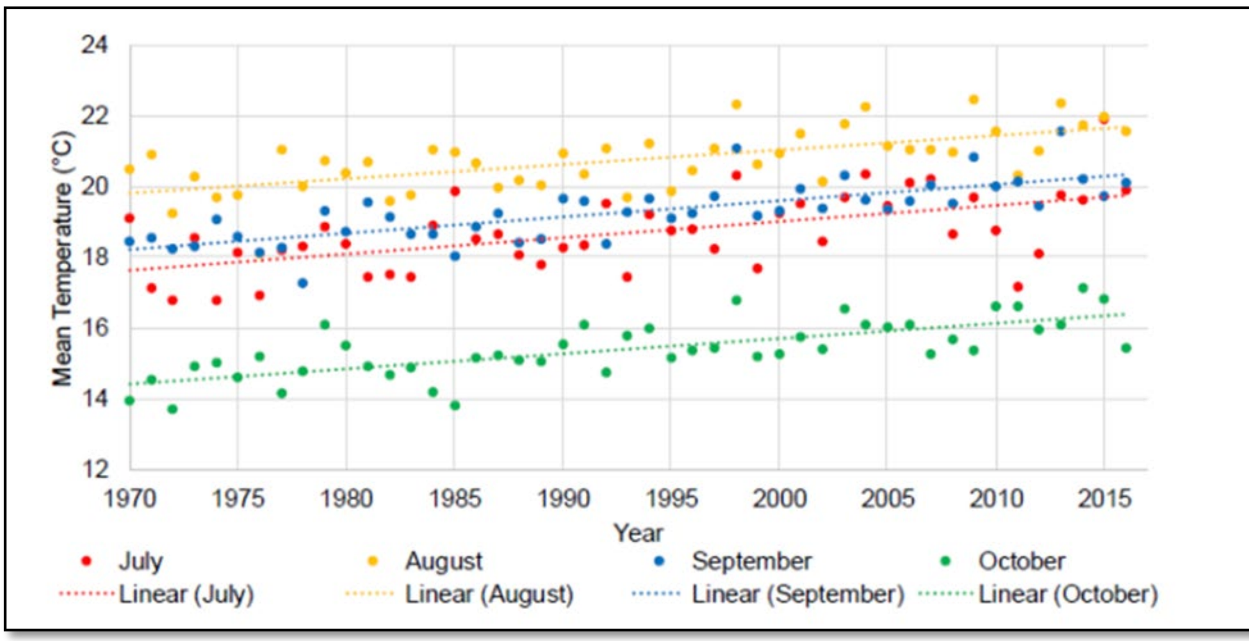


Figure 5-2 Simulated monthly mean temperatures at Bonneville Dam (current) (EPA 2020)

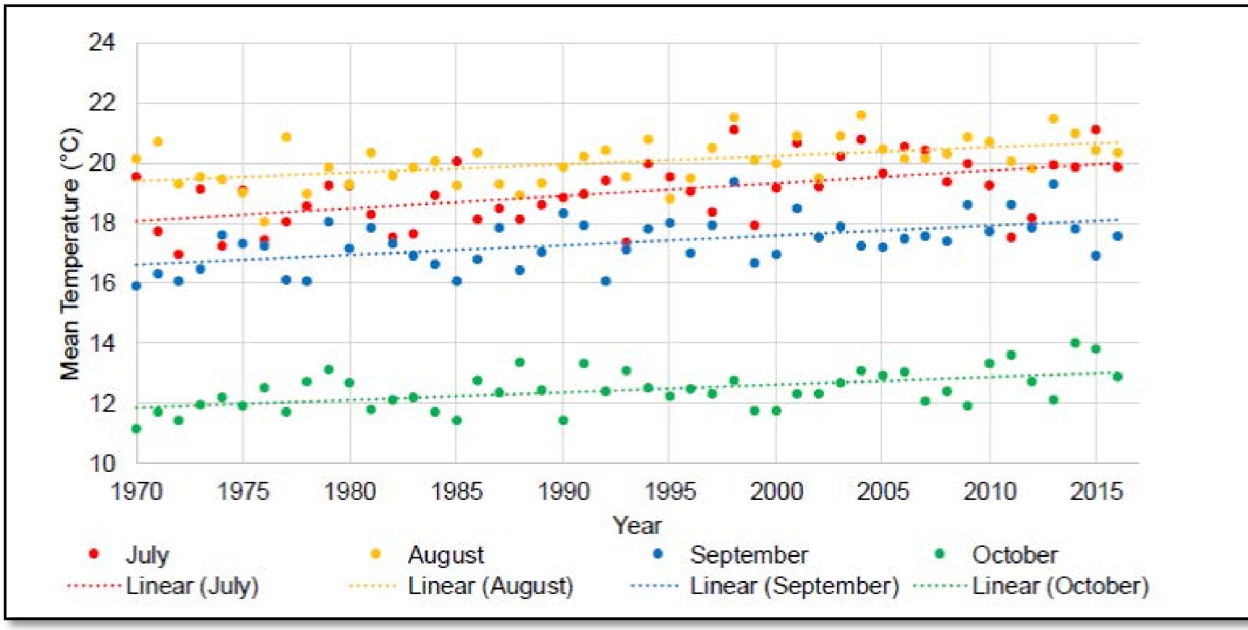


Figure 5-3 Simulated monthly mean temperatures at Bonneville Dam (free flowing) (EPA 2020)

As discussed above in Sections 3.7 and 4.6, the increase in summer river temperature has increased the use of cold water refuges (CWR) by steelhead and fall Chinook in the Lower Columbia River, has contributed to increased mortality of migrating adult sockeye and summer Chinook, and is contributing to earlier sockeye salmon and summer Chinook runs.

5.2 FUTURE TEMPERATURE CONDITIONS OF THE LOWER COLUMBIA RIVER AND ITS TRIBUTARIES

Climate change has already influenced and is projected to continue to influence river temperatures across the Northwest, including the temperatures of the Columbia and Snake Rivers. Climate change will also influence multiple aspects of river hydrographs, including timing and magnitude of river flow. As noted above, climate change is estimated to have increased temperatures in the Columbia and Snake River mainstems by 1.5°C ± 0.5°C since 1960 (0.3°C per decade). From this new baseline, the warming trend is expected to continue in the coming decades.

Figure 5-4, ***Figure 5-5***, and ***Figure 5-6*** display Lower Columbia River August mean temperatures under current conditions, in 2040, and in 2080, respectively, assuming a continuation of the 0.3°C degree per decade warming trend. A continued 0.3°C degree per decade warming trend is very similar to Lower Columbia River reported model predictions using the AB1 scenario of future greenhouse emissions and global warming (Isaak et al. 2018, Yearsley 2009, Appendix 12.19), which represents a mid-range reduction in annual global greenhouse gas emissions over the 21st century.

As shown in ***Figure 5-5*** and ***Figure 5-6***, August mean temperatures in the Lower Columbia River are projected to increase from near 22°C currently to near 23°C in 2040 and near 24°C in 2080. August mean temperatures in the 23-24°C range would likely result in a significant amount of lethality to migrating adult salmon and steelhead (***Table 4-1***). It is therefore likely that fewer salmon and steelhead will migrate in the Lower Columbia River during mid-July through August in the future under these warming trends, resulting in a change in the timing of salmon and steelhead runs. Adult sockeye salmon and summer Chinook will likely continue to migrate earlier as already observed, with very few migrants in July. Adult fall Chinook are likely to migrate later with minimal migrants in August, and those that do migrate then will likely need to use CWR to have sufficient energy to successfully spawn. Steelhead may use CWR for a longer duration to avoid peak temperatures, or they may not be able to use CWR over the mid-summer like they currently do because mainstem temperatures are too warm in late July/early August for steelhead to reach the CWR in the Bonneville reach. If the latter proves true, this may result in a bi-modal migration pattern for steelhead with early summer and late summer runs. However, whether these species can shift their migration timing to adapt to the rate of warming, and whether such shifts can be done successfully without disruption to their full freshwater life cycle, is uncertain (Crozier et al. 2011 and Keefer & Caudill 2017).

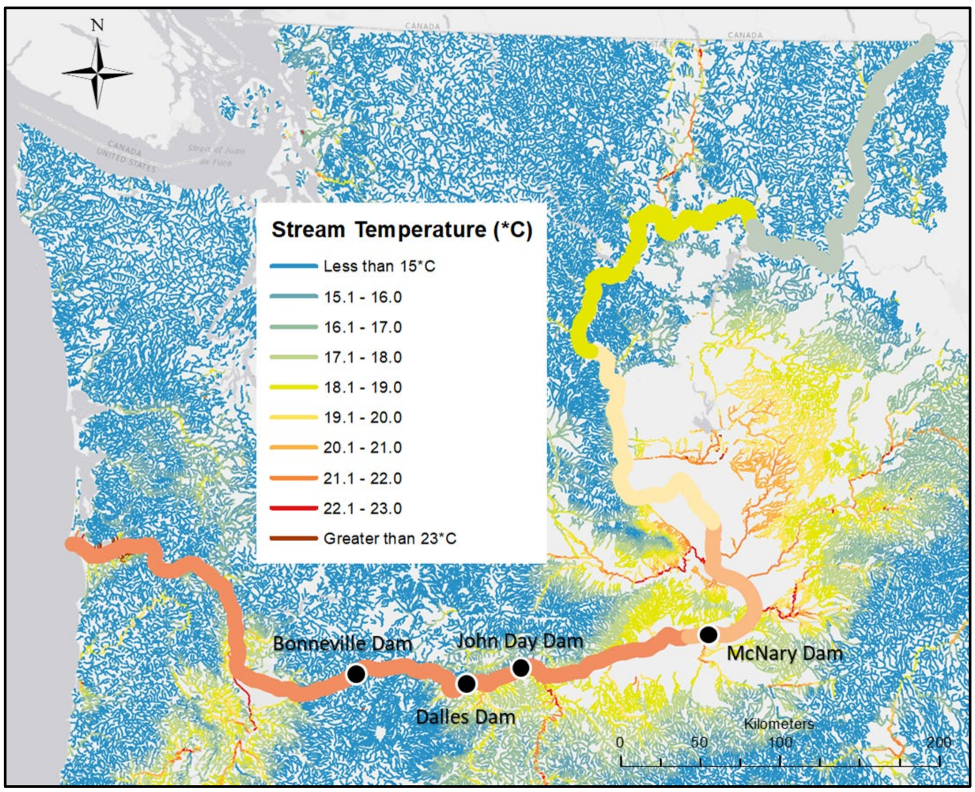


Figure 5-4 Current August mean water temperature in the Columbia River and tributaries (2011-2016) (Appendix 12.14)

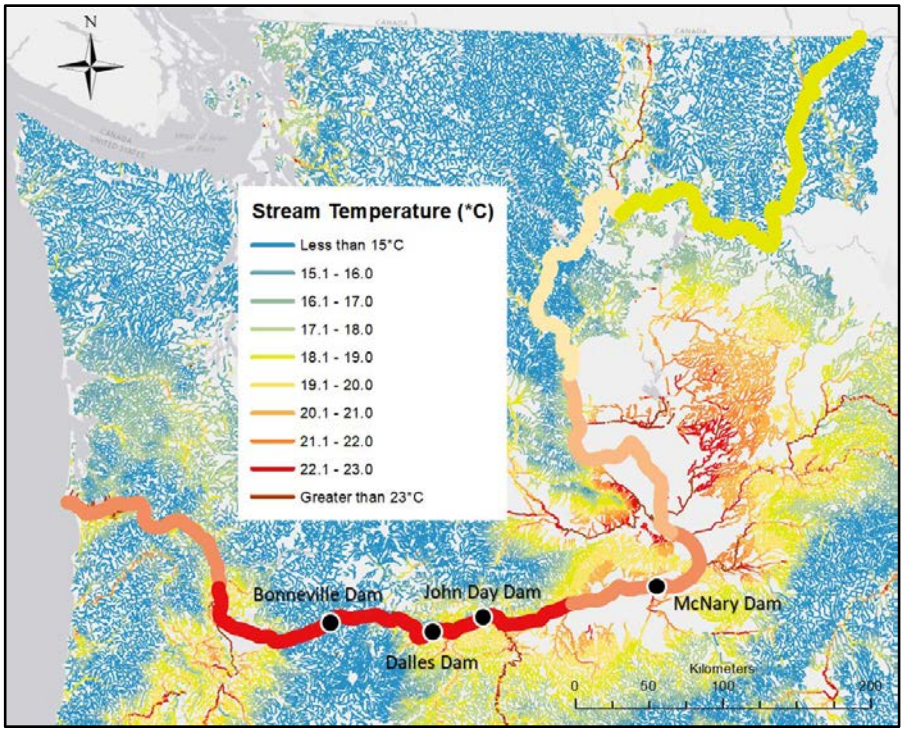


Figure 5-5 Estimated 2040 August mean water temperature in the Columbia River and tributaries (Appendix 12.14)

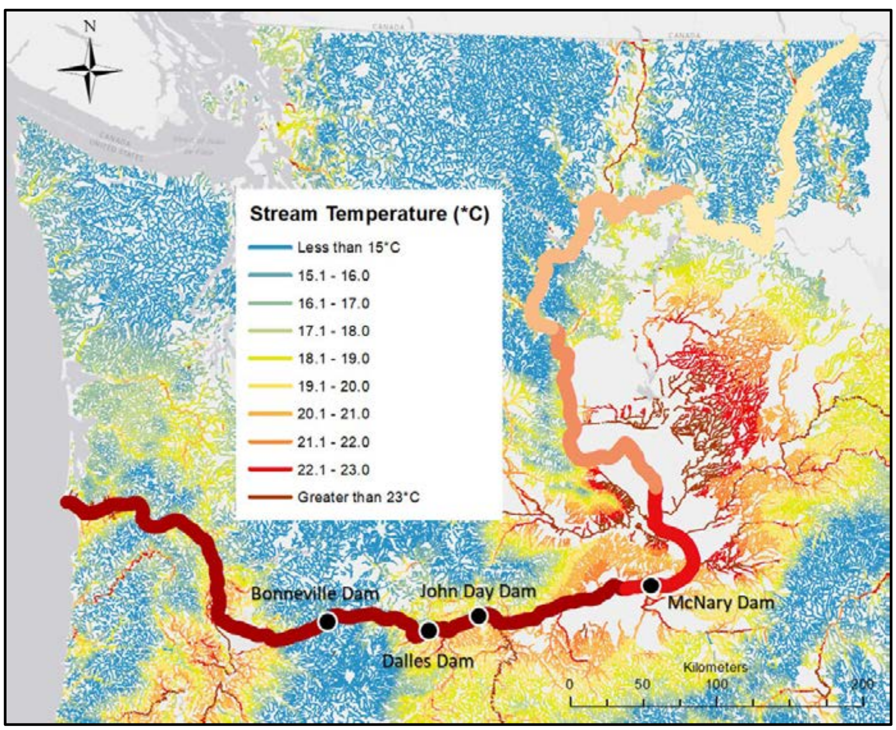


Figure 5-6 Estimated 2080 August mean water temperature in the Columbia River and tributaries (Appendix 12.14)

Temperatures in the tributaries to the Lower Columbia River, including the 23 tributaries that currently provide CWR, are also predicted to increase due to climate change. ***Table 5-1*** displays the predicted increase in August mean temperatures for the 23 CWR tributaries (12 primary CWR highlighted in blue) using the NorWeST SSN model (Appendix 12.17). August mean temperatures for the CWR tributaries are predicted to increase by 1.2–1.5°C by 2040 and by 2.1–2.7°C by 2080 relative to current baseline (1995–2011).

Of significant concern are those primary CWR tributaries that are predicted to have August mean temperatures that exceed 18°C. Tributary temperatures exceeding 18°C, although still serving as CWR if more than 2°C cooler than the Columbia River, are at levels associated with increased risk of disease and energy loss. For instance, by 2040, the Deschutes, Lewis, and Sandy Rivers are predicted to exceed 18°C, temperatures that will diminish their CWR function. By 2080, the Cowlitz, White Salmon, and Klickitat Rivers are predicted to have August mean temperatures exceeding 18°C, diminishing their CWR function.

Table 5-1 Future temperature conditions of the Lower Columbia River tributaries (Appendix 12.17)

Tributary Name	**Current (°C)** (1995-2011)	**2040 (°C)**	**Change between 2040 and current (°C)**	**2080 (°C)**	**Change between 2080 and current (°C)**
Skamokawa Creek	16.2	17.6	1.4	18.6	2.4
Mill Creek	14.5	15.9	1.4	16.8	2.3
Abernethy Creek	15.7	17.1	1.4	18.1	2.4
Germany Creek	15.4	16.8	1.4	17.8	2.4
Cowlitz River	16.0	17.4	1.4	18.4	2.4
Kalama River	16.3	17.7	1.4	18.8	2.5
Lewis River	16.6	18.0	1.4	19.0	2.5
Sandy River	18.8	20.3	1.5	21.4	2.6
Washougal River	19.2	20.7	1.5	21.8	2.7
Bridal Veil Creek	11.7	12.9	1.2	13.8	2.1
Wahkeena Creek	13.6	15.0	1.3	15.9	2.3
Oneonta Creek	13.1	14.4	1.3	15.4	2.2
Tanner Creek	11.7	12.9	1.2	13.8	2.1
Eagle Creek	15.1	16.5	1.4	17.5	2.4
Rock Creek	17.4	18.9	1.5	19.9	2.5
Herman Creek	12.0	13.4	1.4	14.3	2.3
Wind River	14.5	15.9	1.4	16.8	2.4
Little White Salmon River	13.3	14.8	1.4	15.7	2.3
White Salmon River	15.7	17.2	1.5	18.2	2.4
Hood River	15.5	17.0	1.4	17.9	2.4
Klickitat River	16.4	17.8	1.5	18.8	2.4
Deschutes River	19.2	20.7	1.5	21.7	2.5
Umatilla River	20.8	22.4	1.5	23.4	2.6

6 SUFFICIENCY OF COLD WATER REFUGES IN THE LOWER COLUMBIA RIVER

6.1 CWR SUFFICIENCY ASSESSMENT FRAMEWORK

Assessing whether there is a sufficient amount of cold water refuge (CWR) in the Lower Columbia River to attain the Oregon water quality standard is complex. Oregon's CWR narrative standard stipulates the Lower Columbia River must have CWR that is sufficiently distributed to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body (i.e., Columbia River). One of the purposes of this Plan is to provide a framework to make this CWR sufficiency assessment given the current state of information available.

Through the scientific assessment and development of this Plan, EPA identified important context issues for the evaluation of CWR sufficiency. The first issue is the assumption that CWR are beneficial to migrating salmon and steelhead in the Lower Columbia River. There are two exceptions to this assumption in the Lower Columbia River. The first exception is fish mortality from fishing in CWR. As presented in Section 4.3, fish that enter into CWR have a lower adult migration survival rate through the Lower Columbia River compared to fish that do not use CWR. This appears to be explained mostly by fish harvest in CWR and potentially mortality of caught and released fish, although the higher tendency of fish that were barged downstream as juveniles to stray into CWR may also be a causal factor. However, the role of water quality standards under the Clean Water Act (CWA) is to ensure the water is of sufficient quality (in this case, water temperature) to protect designated uses of the water body (in this case, salmon and steelhead). Therefore, EPA did not consider fishing mortality in the assessment of CWR sufficiency, recognizing that the amount of fish mortality in CWR can change through fish management decisions. Thus, EPA evaluated the sufficiency of CWR in the Lower Columbia River as if there was no fishing to focus our assessment on water quality conditions to support migrating salmon and steelhead.

The second exception to the assumption that CWR are beneficial to migrating salmon and steelhead is that using CWR may cause harm due to the delay in their migration. As discussed in this Plan, sockeye salmon and summer Chinook migrate through the Lower Columbia River prior to the onset of the warmest summer temperatures, and extended CWR use would likely be harmful due to exposure to warmer conditions during their continued migration. With these two exceptions explained, the evidence presented in this Plan suggests that CWR use appears to be physiologically beneficial for those species that use CWR the most, which are summer steelhead and fall Chinook.

The second context issue is the temperature of the Columbia River itself. As described in this Plan, the degree to which salmon and steelhead use CWR depends on the Columbia River mainstem temperature. The warmer the river, the more fish use CWR. Thus, assessing CWR sufficiency can be viewed as a function of the Columbia River temperature. However, although CWR can help mitigate adverse effects to migrating salmon and steelhead when Columbia River temperatures exceed 20°C, the CWR narrative standard should not be interpreted to "allow for" or to "fully compensate for" Columbia River water temperatures higher than the 20°C numeric criterion.

EPA assessed whether CWR is sufficient to attain Oregon's CWR narrative criteria based on *current* Columbia River conditions because such water quality data are available, and because water quality standard assessments are generally based on current conditions. However, to address the dynamic of different temperatures in the Lower Columbia River, EPA evaluated sufficiency at three different temperature regimes: August mean temperature of 20°C, which reflects historical conditions; 21.5°C, which reflects current conditions; and 22.5°C, which reflects a predicted 2040 condition. This analytical framework to address sufficiency is helpful to understand the use of CWR in the past, present, and future. Some of the recommendations in this Plan consider predicted future temperature conditions in the Lower Columbia River and the CWR tributaries as practical considerations to improve water quality for migrating salmon and steelhead.

To evaluate sufficiency of CWR at different Lower Columbia River temperatures, EPA considered several factors based on information presented in previous chapters, as well as in the HexSim model discussion below: (1) the extent of CWR use in terms of number of salmon and steelhead in CWR and the proportion of the run using the CWR; (2) a qualitative assessment of the potential for the current volume of CWR to have capacity limitations; (3) the distribution of CWR in the Lower Columbia River; (4) observed and modeled indicators of fish health and risk, including mortality rates, energy loss, and cumulative exposure to stressful temperatures for migrating salmon and steelhead in the Lower Columbia River; and (5) the overall importance of adult migration risk factors in the recovery of salmon and steelhead from review of ESA recovery plans and NMFS' Columbia River Systems Operations Biological Opinion.

6.2 HEXSIM MODEL

To aid in examining sufficiency of CWR in the Lower Columbia River, EPA developed a fish behavior simulation model using the HexSim modeling platform (Schumaker and Brookes, 2018) that simulates behavior, movement, and tracks thermal exposure of individual fish migrating through the Lower Columbia River. The model description and the initial application of the model through the Bonneville reach of the Columbia River between Bonneville Dam and The Dalles Dam is summarized in Snyder et al. 2019. The model has been expanded to include the 178-mile portion of the Columbia River from Bonneville Dam to the Snake River confluence (Snyder et al., 2020).

The HexSim model provides the opportunity to simulate different scenarios and evaluate how they affect CWR use and important indicators related to fish health. For the initial model runs for this Plan, EPA selected the following scenarios: (1) existing CWR; and (2) no CWR. Both scenarios were run under different Columbia River temperatures representing past, current, and predicted future average conditions. These model scenarios help examine how the current amount of CWR affects fish health indicators at different Columbia River temperatures to assess CWR benefits. Health indicators assessed include cumulative energy expenditure, cumulative degree days above warm temperature thresholds (e.g., 21°C and 22°C), and predicted acute mortality between Bonneville Dam and the confluence with the Snake River. EPA evaluated these scenarios and resultant indicators for two populations of summer steelhead, Grande Ronde summer steelhead and Tucannon summer steelhead; and two populations of fall Chinook salmon, Snake River fall Chinook and Hanford reach fall Chinook. An additional model run examined the change in these health indicators if five extra evenly-spaced CWR were theoretically added between the John Day Dam and the Snake River. The size of the extra CWR were 6,000 cubic meters each, which is about twice the size of the Eagle Creek CWR. The extra CWR model run analyzed the Grande Ronde summer steelhead and Snake River fall Chinook population for 2017 temperatures. The results of these model runs are presented in Appendix 12.21.

The following is a summary of the HexSim model assessment. The summary below highlights model results for Grand Ronde summer steelhead because that population represents a steelhead population that uses CWR extensively, as shown in Section 3.9.

Cumulative Number of Hours in CWR as a Function of Columbia River Temperature

The number of hours individuals spend in CWR increases with increased Columbia River temperatures for all four populations evaluated, which is consistent with the CWR use estimates in Chapter 3. For Grande Ronde summer steelhead, the number of hours per fish in CWR is modeled to be 124 hours at past/historical temperatures, 389 hours at current temperatures, and 497 hours at predicted 2040 temperatures (Appendix 12.21).

Energy Loss Under Different Scenarios

The energy loss (fat loss) within the model reach (Bonneville Dam to Snake River confluence) increased for all four populations with increased Columbia River temperatures. ***Figure 6-1*** summarizes the energy loss for Grande Ronde summer steelhead for the different scenarios. If too much energy is lost during migration and pre-spawning, a fish may not have enough energy to complete spawning as discussed in Section 4.5. Because use of CWR increases the amount of time in the model reach, CWR use somewhat increases the population's median amount of energy loss in the model reach relative to no CWR use as shown in ***Figure 6-1***. However, to evaluate the implications of energy use on spawning success, energy loss needs to be evaluated within the context of the entire migration, including holding and spawning. For example, Grande Ronde summer steelhead migrate another 170 miles upstream in the Snake River before traveling up the Grande Ronde River to their spawning grounds. Under scenarios of no CWR use, there is a much earlier average arrival at the end of the modeled reach (Snake River confluence) (***Figure 6-2***), when Snake River temperatures are warmer. The use of CWRs extends the range of arrival dates at the Snake River confluence, which may decrease energy loss for those late arriving individuals who will then migrate through the Snake River when it is cooler. Therefore, while the entire population does not see an energy benefit in the modeled reach of the migration corridor, CWRs potentially increase the diversity of energy conserving migration strategies.

In summary, it is necessary to model the full migration to the spawning grounds to fully assess energy loss and the potential for pre-spawning mortality, as was done in the Plumb (2018) and Conner et al. (2018) papers, which concluded CWR in the Lower Columbia River were beneficial to reduce pre-spawning mortality for early migrating Snake River fall Chinook (Section

4.5). These papers indicate that most of the energy loss for Snake River fall Chinook occurs upstream of the Lower Columbia River. Thus, the river temperature during the latter part of the fall Chinook migration, when the fish are preparing to spawn, is an important factor in spawning success, and CWR in the Lower Columbia River can serve to allow the fish to arrive at the spawning grounds when river temperatures are cooler.

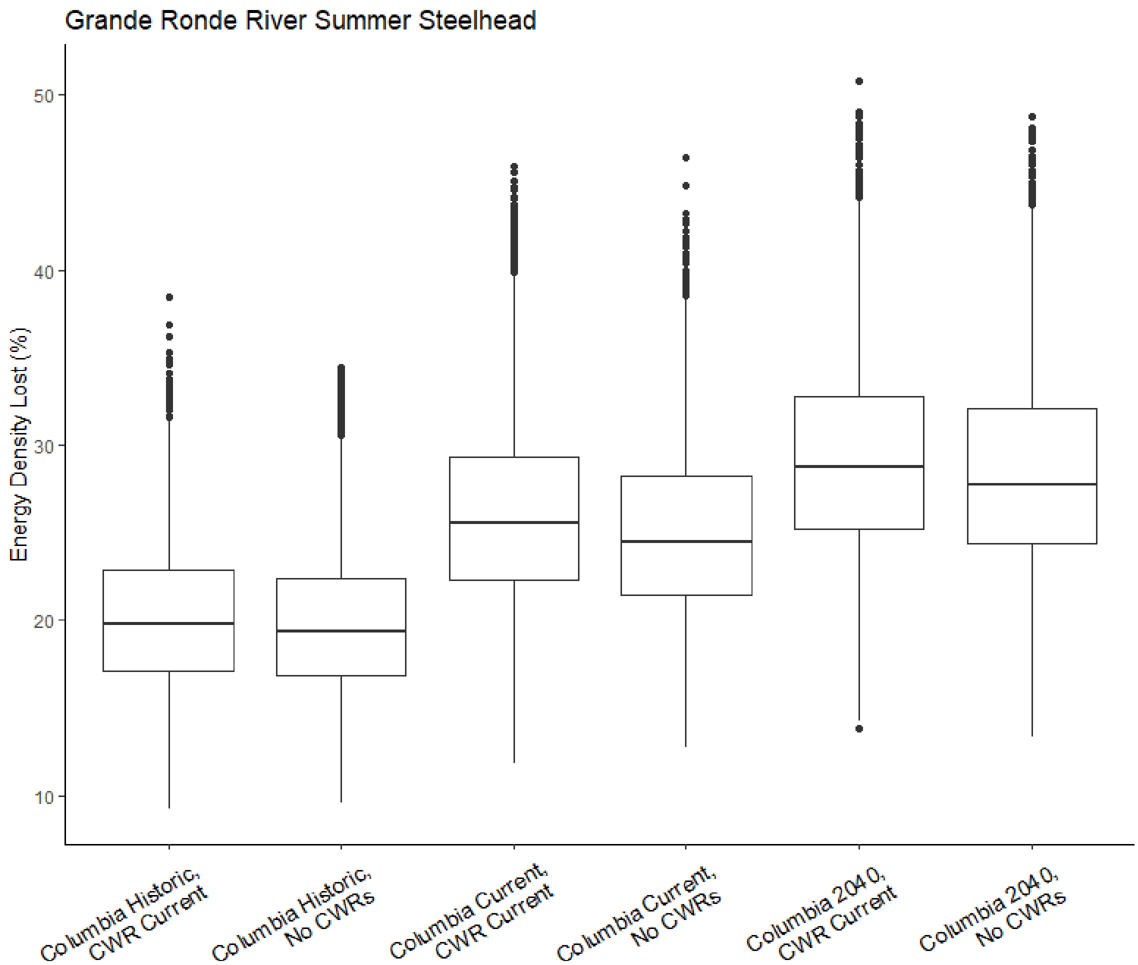


Figure 6-1 Simulated energy loss for Grande Ronde summer steelhead from Bonneville Dam to the Snake River under various scenarios (Appendix 12.21)

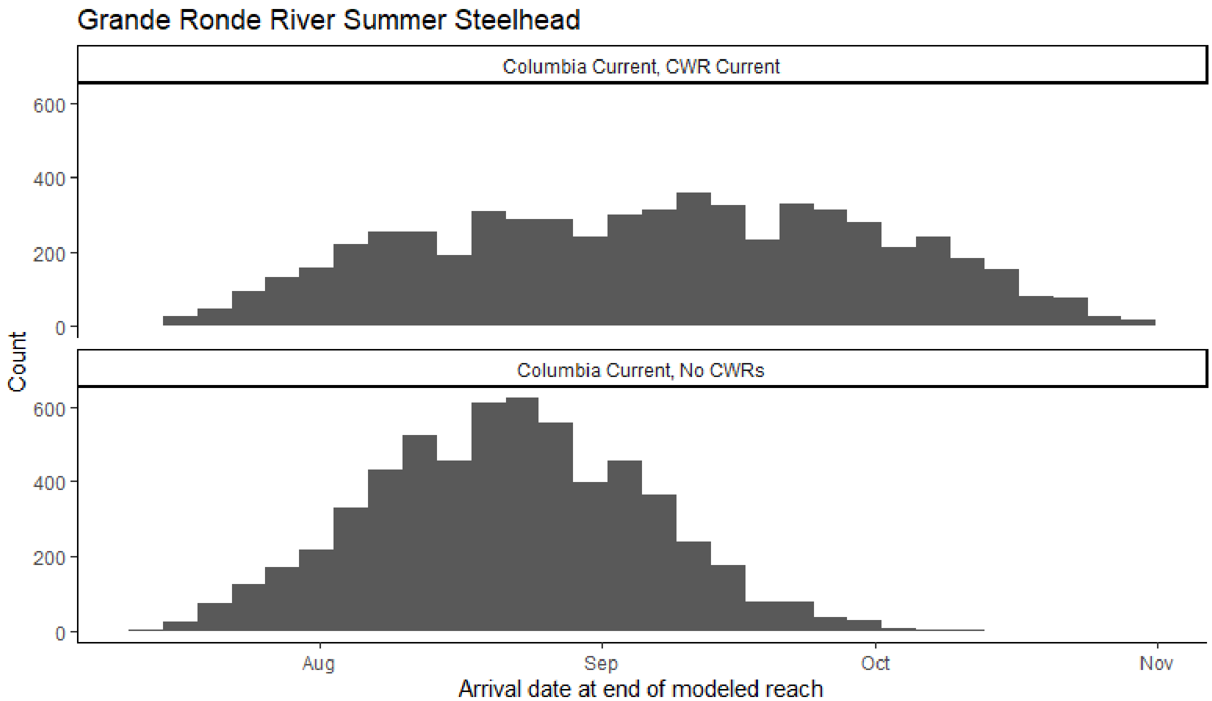


Figure 6-2 Simulated arrival date at the Snake River for Grande Ronde summer steelhead with and without CWR use under current conditions (Appendix 12.21)

Acute Mortality

The model runs with and without CWR at past, current, and future (2040) Columbia River average temperatures did not show any significant acute mortality for the four populations in the model reach (Appendix 12.21). This was not unexpected because acute temperature stress mortality was based on a study that indicates acute stress mortality begins to occur at 24°C (less than 1% chance), climbing to a 10% chance at 27°C with 24-hour exposure (Railsback et al., 2009). Columbia River maximum daily average temperatures currently reach 23°C and are not predicted to reach 24°C until 2040[4] (Appendix 12.1).

Because current and predicted future daily average temperatures are at the threshold of acute temperature stress mortality, an uncertainty analysis was conducted using three different temperature-acute mortality relationships based on multiple studies (Jager 2011, Sullivan et al. 2000, Railsback et al. 2009). Under the more conservative relationship when acute stress mortality starts at 23°C, the HexSim model predicted 18% acute stress mortality in 2040 for Grande Ronde summer steelhead with the current available CWR and 28% acute stress mortality absent CWR (Appendix 12.21). This indicates that use of CWR may serve an

[4] Columbia River temperatures used in the HexSim model, as well as reflected in the figures and tables of this Plan, are from the main channel dam site monitors that are about 30-35 feet deep. As presented in Appendix 12.1, the upper surface layer of the John Day and McNary reservoirs can reach 25-26°C, but exposure to these temperatures was not included in the HexSim model.

important role to reduce acute stress mortality for migrating adult salmon and steelhead in the future when Lower Columbia River temperatures are predicted to reach 24ºC.

Cumulative Degree Days under Different Scenarios

The model runs show large differences in cumulative degree days above warm temperature thresholds of 21°C and 22°C with and without CWR for Grande Ronde steelhead. As shown in ***Figure 6-3***, under current Columbia River temperatures the cumulative number of degree days above 21°C is much higher if there were no CWR compared to the current amount of CWR. The average number of cumulative degree days above 21°C is 139 days for the Grande Ronde summer steelhead population using CWR. If no CWR were available, the population would have 272 degree days above 21°C.

Figure 6-4 shows the cumulative degree days above 22°C for Grande Ronde steelhead. Under current Columbia River temperatures, the 10-year mean of daily average temperatures (reflected in ***Figure 6-4***) rarely exceeds 22°C in the Columbia River, so cumulative degree days above 22°C are near zero with and without CWR. However, under predicted 2040 average conditions, the cumulative degree days above 22°C for the Grande Ronde steelhead population will be higher (286) if no CWR were available compared to the current amount of CWR (118). It is also notable that for current warm years (e.g. 2017 and other recent warm years when Columbia River temperatures were warmer than the 10-year average with numerous days exceeding 22°C), CWR use reduced the cumulative exposure for steelhead above 22°C, similar to what is displayed in ***Figure 6-4*** for 2040 average temperatures (Appendix 12.21).

Figure 6-5 shows the modeled difference in cumulative degree days above 21°C under 2017 Columbia River temperatures for Grande Ronde steelhead with current CWR, with added CWR, and with current CWR if the Columbia River was 1°C cooler than 2017 temperatures. For the added CWR scenario, CWR was theoretically added at five evenly spaced locations between the John Day Dam and the Snake River for a total of 30,000 cubic meters of added CWR. This modest addition of CWR (less than 1% of the total CWR volume in the Lower Columbia River) to this reach with limited current CWR, shows a slight decrease in the cumulative degree days above 21°C for this population. However, if the Columbia River 2017 temperatures were hypothetically 1°C cooler, the reduction in cumulative degree days would be greater, indicating the importance of the river temperature itself and that CWR does not fully offset exposure to warm river temperatures (Appendix 12.21 and Snyder et al., 2020)

The difference in cumulative degree days above the 21°C and 22°C thresholds in the above scenarios illustrate the benefits of CWR use for migrating steelhead by avoiding peak warm temperatures and is consistent with the information and discussion presented in Chapter 3. Prolonged exposure to temperatures greater than these thresholds is stressful for migrating salmon and steelhead and likely increases disease risk associated with mortality as discussed in Chapter 4.

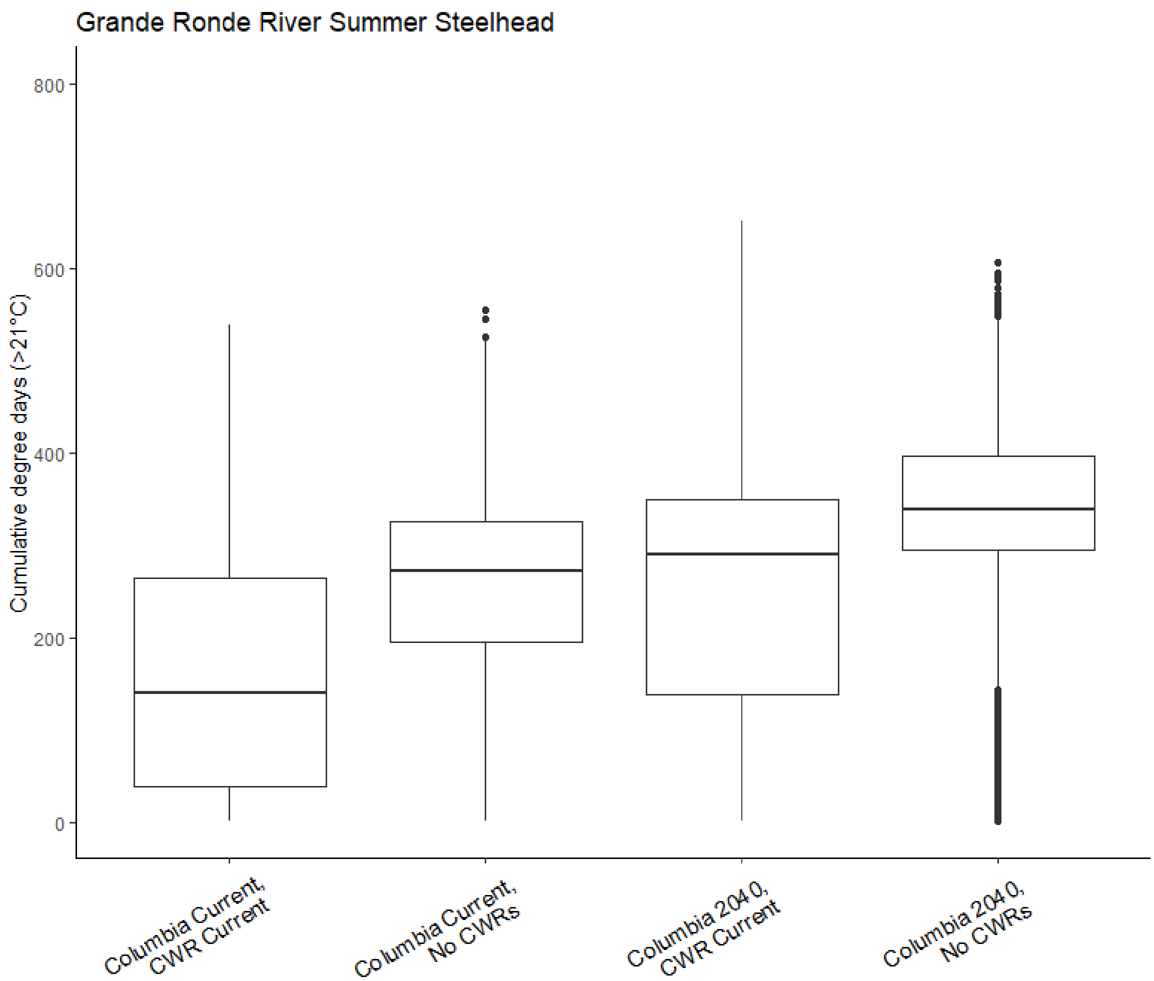


Figure 6-3 Simulated cumulative degree days above 21°C for Grande Ronde summer steelhead between Bonneville Dam and the Snake River under different scenarios (Appendix 12.21)

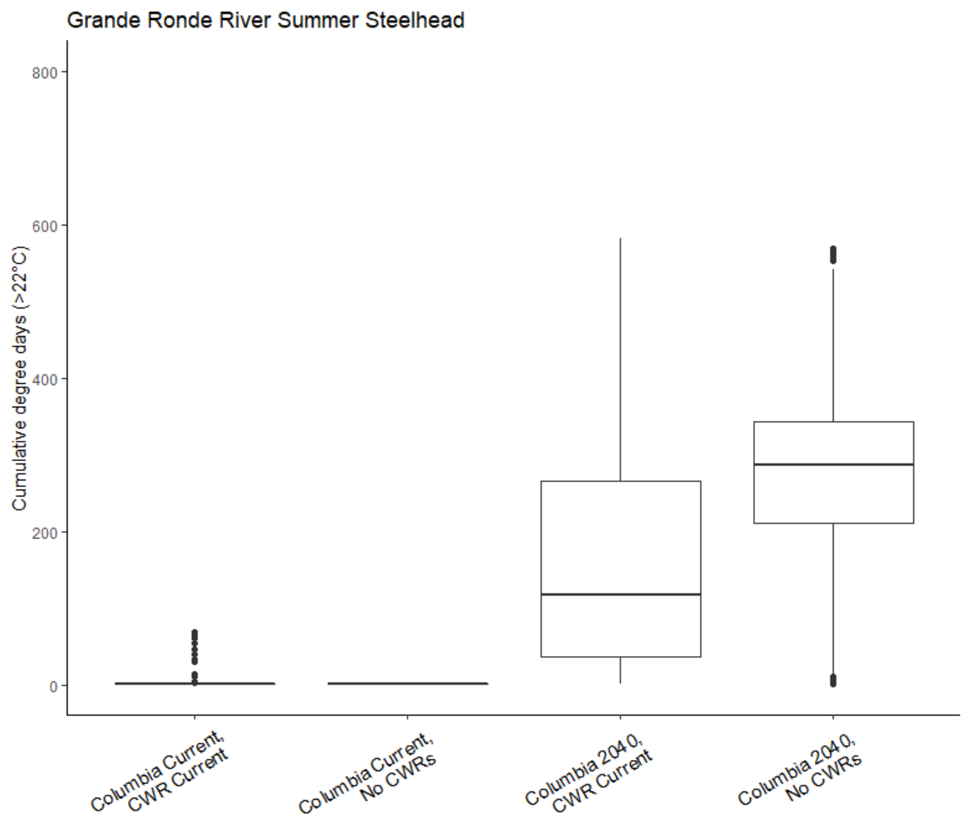


Figure 6-4 Simulated cumulative degree days above 22°C for Grande Ronde summer steelhead between Bonneville Dam and the Snake River under different scenarios (Appendix 12.21)

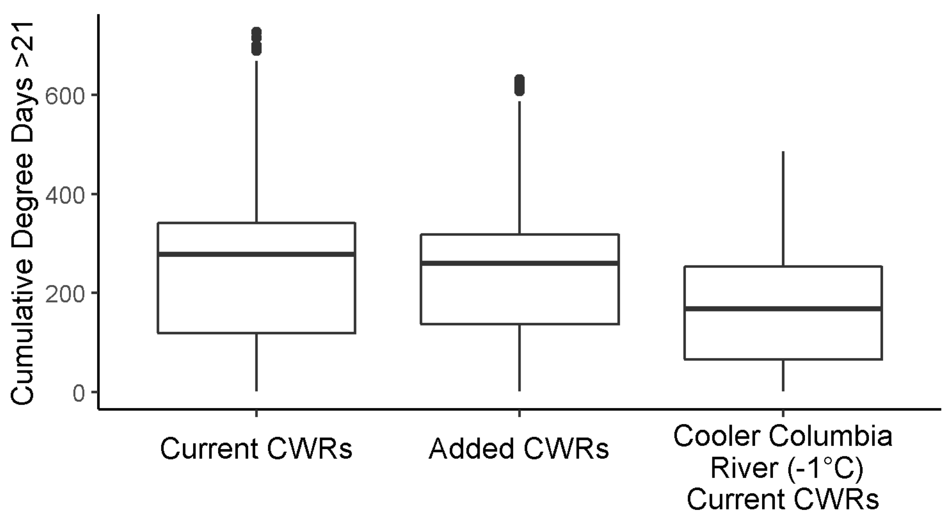


Figure 6-5 Simulated cumulative degree days above 21°C under 2017 Columbia River temperatures for Grande Ronde summer steelhead between Bonneville Dam and the Snake River under different scenarios (Appendix 12.21)

6.3 ASSESSMENT OF SUFFICIENTLY DISTRIBUTED CWR

As noted above, EPA assessed whether CWR is sufficient to attain Oregon's CWR water quality standard under current Lower Columbia River August average temperatures (21.5°C), considering the factors listed in Section 6.1. For context, EPA also evaluated CWR sufficiency under past (20°C) and future (22.5°C) conditions.

Current Conditions: Fish Use and CWR Capacity

As shown in Chapters 2 and 3, current Lower Columbia River temperatures typically exceed 20°C for two months and exceed 21°C for one month, and use of available CWR by steelhead and fall Chinook is well documented and extensive. Based on information in Chapters 3 and 4, and HexSim model results, current steelhead and fall Chinook use of CWR appears to provide some individuals physiological and energetic benefits by allowing them to avoid warm mid-summer Columbia River temperatures and continue migrating upstream when temperatures have cooled. As described in Chapter 3 and displayed in ***Figure 3-1*** and ***Figure 3-17***, the majority of the overall summer steelhead run, as well as most individual summer steelhead populations, migrate though the Lower Columbia River during the peak summer temperatures. This indicates that CWR use in the Lower Columbia River is an important aspect of the contemporary migration strategy for most steelhead populations (Keefer et al. 2009). As described in Chapter 3 and displayed in ***Figure 3-1***, about half the fall Chinook run occurs in August and the first half of September when some fall Chinook salmon seek CWR to avoid warm Columbia River temperatures. Thus, CWR use is an important migration strategy for part, but not all, of the fall Chinook run.

From the density estimates in Chapter 3 and HexSim modeling, it does not appear the capacity in CWR is exceeded, except for Eagle Creek and Rock Creek. The HexSim model showed these small CWR reaching capacity (Snyder et al. 2019). EPA reviewed literature on the density of adult salmon and steelhead held in confined spaces to define a maximum fish density of 1 fish per cubic meter, but it is uncertain whether this is representative of maximum density in CWR (Berejikian et al. 2001, Hatch et al., 2013). Disease risk from high density of fish in CWR is also a concern that could factor into CWR capacity consideration, especially for marginal CWR that are at temperatures (18°C or higher) associated with elevated disease risk. However, EPA is unaware of anecdotal evidence or studies that indicate incidents of disease for adult steelhead or fall Chinook in CWR. Additional research on factors regulating capacities of CWR and disease risk in CWR is needed.

Current Conditions: CWR Distribution

Regarding the distribution of CWR in the Lower Columbia River, migrating salmon and steelhead have several CWR opportunities below Bonneville Dam and extensive CWR opportunities in the Bonneville Dam reservoir reach and the Deschutes River above The Dalles Dam (see ***Figure 2-8***). The cluster of CWR in the Bonneville Dam reservoir reach and the Deschutes River is approximately midway from the ocean to the confluence of the Snake River. It takes approximately one week for salmon and steelhead to travel from the ocean to this cluster of CWR and another week to pass the McNary Dam and get to the Snake River confluence area. Thus, the CWR distribution is advantageous in that the CWR provide the opportunity to escape the warm Columbia River midway through their upstream migration of the

Lower Columbia River and avoid approximately two weeks of continuous exposure to warm temperatures over this 325-mile reach.

However, the lack of CWR in the nearly 100 miles between the Deschutes River and McNary Dam, including the John Day reservoir which has the highest temperatures in the Lower Columbia River, is of concern. This nearly 100-mile reach poses the greatest risk from warm temperatures for migrating salmon and steelhead. Thus, it is difficult to conclude that CWR is sufficiently distributed due to the absence of CWR in this reach. Opportunities to restore CWR in this reach are limited. Under natural conditions there were likely only a few small tributaries (e.g. Willow Creek, Rock Creek) and the Umatilla River that may have provided CWR. As noted in Chapter 2, the Umatilla River is currently warmer than the Columbia River in July and most of August and only provides marginal and intermittent CWR in late August and September after the Umatilla River has cooled relative to the Columbia River. Cooling Lower Umatilla River temperatures in August and September consistent with the Oregon and Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Temperature TMDLs (ODEQ 2001 and EPA 2005) to provide increased CWR volume would make the Umatilla River a more consistent and viable CWR and would help address the overall distribution of CWR in the Lower Columbia River. HexSim model runs indicate small additions of CWR in this reach may be beneficial to reducing cumulative exposure to warm Columbia River temperatures (see ***Figure 6-5***).

Current Conditions: Adult Survival

The strongest line of evidence that the current amount of CWR is sufficient under current Columbia temperatures is the adult survival rates from Bonneville Dam to McNary Dam. As discussed in Section 4.4, the adult survival rate after accounting for harvest and straying for Snake River steelhead and fall Chinook is over 90%. ***Table 2-1*** shows the estimates of adult survival after accounting for harvest and straying for Snake River species from Bonneville Dam to McNary Dam from 2012-2016 (NMFS 2017b). Snake River fall Chinook adult survival is near 96% and Snake River steelhead is 93%. While NMFS recognizes that warm Lower Columbia River temperatures are a concern and cause adverse effects to ESA-listed species, NMFS views the adult migration survival rates for these species as “relatively high” and the losses are not at levels that would cause the Columbia River System Operations to appreciably reduce the survival and recovery of ESA-listed Snake River steelhead and fall Chinook (NMFS 2020). NMFS also noted the importance of CWR to these summer migrating species.

Table 6-1 Adult salmon and steelhead survival estimates after correction for harvest and straying based on PIT-tag conversion rate analysis from Bonneville (BON) to McNary (MCN) dams, McNary to Lower Granite (LGR) dams, and Bonneville to Lower Granite dams (NMFS 2017b)

Species	Years	BON to MCN	MCN to LGR	BON to LGR
SR Fall Chinook	2012-2016 Avg	95.8%	94.9%	91.0%
SR Spr/Sum Chinook	2012-2016 Avg	93.1%	94.0%	87.3%
SR Sockeye	2012-2016 Avg	59.9%	74.2%	49.7%
SR Steelhead	2012-2016 Avg	93.2%	94.3%	87.9%

The current amount of CWR may be helping to maintain the average survival rates (after adjusting for harvest and straying) above 90% shown in ***Table 6-1*** by minimizing salmon and steelhead exposure to peak summer temperatures in the Lower Columbia River. As illustrated in ***Figure 6-3*** for Grand Ronde summer steelhead, CWR use, relative to no CWR use, reduces the cumulative exposure to temperatures above 21°C, which is associated with increased stress and disease mortality. Moreover, CWR use in the Lower Columbia River also reduces cumulative exposure to warm temperatures for fish migrating up the Snake River due to migrating later in the summer/fall, which likely aids in the survival rates up the Snake River to Lower Granite Dam (LGR). Notably, Snake River sockeye, which do not use CWR due to their early summer run timing, have a much lower adult survival rate due to mortality from warm Columbia River temperatures as discussed in Chapter 4.

Snake River summer steelhead and Snake River fall Chinook adult survival rates (NMFS 2017b) from Bonneville Dam to McNary are generally representative of survival rates of other steelhead species (Upper Columbia River and Middle Columbia River) and other fall Chinook species (Hanford reach) that use CWR. As presented in Section 3.9, Upper Columbia River steelhead migrate earlier in the year compared to Snake River steelhead and therefore have less overall exposure to warm Lower Columbia River temperatures and use CWR less. Likewise, most Hanford reach fall Chinook migrate later than Snake River fall Chinook and therefore have less overall exposure to warm Lower Columbia River temperatures and use CWR less.

However, as discussed in Section 4.4, there is year-to-year variability in unexplained mortality for adult steelhead and Fall Chinook between the Bonneville and McNary Dams. Some years with more than 10% unexplained mortality (i.e., less than 90% adjusted survival) could be associated with exposure to warm migration temperatures. Further, these data for steelhead represent an average of all Snake River steelhead populations, and some individual populations could have higher unexplained mortality, especially if a high percentage of the population's migration occurs during peak summer temperatures. Thus, the variation and uncertainty in the adjusted survival rates are important to recognize.

Current Conditions: Summary

EPA's assessment is that CWR is sufficient under current Columbia River temperatures if the volume of the 12 primary CWR is maintained and the Umatilla River is cooled to provide increased CWR volume in August and September. EPA reached this assessment primarily because there do not appear to be significant capacity limitations on the use of currently available CWR, adult steelhead and fall Chinook migration adjusted survival rates generally exceed 90% between Bonneville Dam and McNary Dam, and increasing CWR in the Umatilla River is important for the overall distribution of CWR in the Lower Columbia River.

Past Conditions

When the Lower Columbia River is 20°C (August mean), which represents historical Columbia River temperatures, EPA's assessment is that the current amount of CWR appears to be sufficient to support migrating salmon and steelhead. Under the scenario of 20°C, CWR use is modest by steelhead and very limited for fall Chinook, as first described in Chapter 3. The level of CWR use when August mean temperature is 20°C is far less than what is observed under current conditions. Because the current CWR volume appears to be sufficient with the exception of the Umatilla CWR under current Columbia River temperatures, as discussed above, the current CWR volume would likely be sufficient when the Columbia River is cooler. Although an August mean temperature of 20°C during migration is above optimal and presents risks in terms of elevated disease occurrence and sub-lethal effects, observed mortality to migrating adults is low under these conditions.

Future Conditions

When the Lower Columbia River is 22.5°C (August mean), which reflects predicted future (2040) conditions, EPA's assessment is that there is significant risk that the current amount of CWR will not be sufficient to minimize the risk to migrating salmon and steelhead. As presented in this Plan, a warmer Lower Columbia River at these temperatures (22.5°C August mean with daily average temperatures frequently reaching 23-24°C) will significantly increase the stress, energy loss, and mortality risk to salmon and steelhead migrating in the Lower Columbia River in the summer. Under these temperatures, the extent of CWR use, as discussed in Chapter 3 and presented in HexSim model results, is expected to be higher. Steelhead may be less apt to leave the CWR at these peak summer temperatures. Further, these temperatures will trigger fall Chinook to use CWR at a higher rate. As a result, the density of fish in CWR will be higher, calling into question the capacity of the currently available CWR. Additionally, the CWR tributaries are predicted to warm. This is of particular concern for marginal CWR (***Table 7-1***). For example, the Deschutes River, which although cooler than the Columbia River, currently has an August mean temperature of 19°C, which is above optimal for migrating salmon. These factors suggest there is significant risk that the Lower Columbia River adult migration survival rates for steelhead and fall Chinook will decrease in the future. However, as noted earlier, CWR cannot be expected to fully compensate for warm Lower Columbia River temperatures. As such, the causal factor to the increased risks for salmon and steelhead noted above is the warm Columbia River temperatures, not the lack of adequate CWR to minimize those risks. That said, increasing CWR may serve to mitigate some of the risks of warmer Columbia River temperatures.

Conclusion

EPA's assessment is that CWR is sufficient to attain Oregon's CWR narrative criteria in the Lower Columbia River if the volume of the 12 primary CWR is maintained and the Umatilla River is cooled to provide increased CWR volume in August and September consistent with the Oregon and CTUIR Temperature TMDLs. Therefore, maintaining the current temperatures and flows of the 12 primary CWR tributaries and cooling the Umatilla River is needed to limit significant adverse effects to migrating adult salmon and steelhead from higher water temperatures in the Columbia River. Further, predicted continual future warming of the Lower Columbia River is expected to increase salmon and steelhead use of CWR and diminish the extent to which the current amount of CWR reduces the risks to migrating adult salmon and steelhead. Therefore, increasing the amount of CWR in the future through restoration and enhancement is recommended to help offset the predicted increased future adverse effects associated with a warmer Lower Columbia River.

It is important to note that EPA's assessment of CWR needed to attain Oregon's CWR narrative criteria does not imply that current Columbia River temperatures are at levels to protect salmon and steelhead migration. Current river temperatures exceed the 20°C numeric criterion and cause adverse effects to salmon and steelhead which are not fully mitigated by CWR.

7 ACTIONS TO PROTECT & RESTORE COLD WATER REFUGES

As summarized in Chapter 6, EPA's assessment is that to provide sufficient cold water refuges (CWR) in the Lower Columbia River for migrating adult salmon and steelhead, it will be necessary to maintain the existing amount of cold water that is provided by the 12 primary CWR tributaries and to provide increased CWR in the Umatilla River. This chapter summarizes actions to protect and restore the 12 primary CWR tributaries to both avoid human actions that could increase temperatures and to cool temperatures to partially or fully counteract predicted warming from climate change (Appendix 12.15). In addition, this chapter summarizes actions to restore CWR in the Umatilla River. EPA also included Fifteenmile Creek to highlight a tributary with potential to be restored into a CWR based on the temperature TMDL suggesting substantial cooling potential and the fact that Fifteenmile Creek has been prioritized for restoration for ESA-listed steelhead recovery. These 14 tributaries are illustrated in ***Figure 7-1***.

*A temperature **TMDL** is a waterbody plan that sets the maximum amount of heat allowed to enter a waterbody so that the waterbody will meet temperature water quality standards.*

The other ten non-primary CWR tributaries identified in Chapter 2 may be able to increase the amount of CWR near their confluence areas, if restored. Due to time limitations, EPA did not address those tributaries (Appendix 12.20).

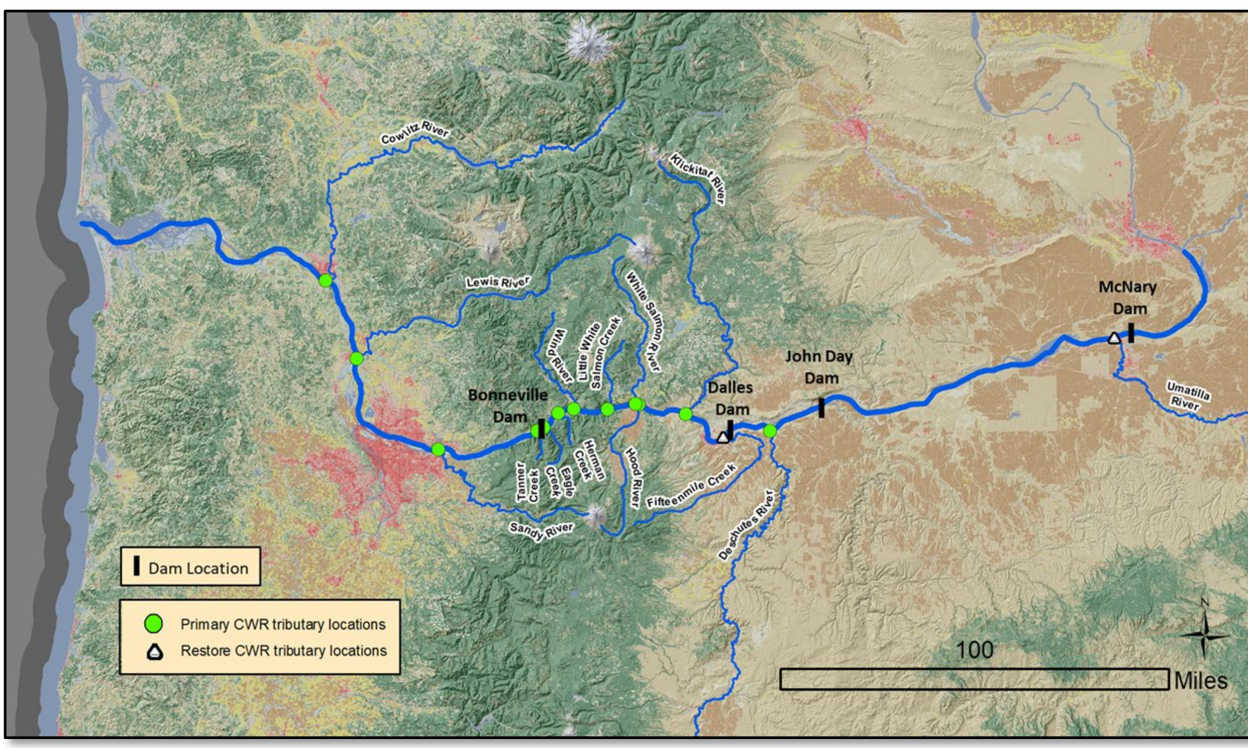


Figure 7-1 12 primary and 2 "restore" cold water refuge tributary locations

7.1 COLD WATER REFUGE WATERSHED SNAPSHOTS

EPA developed "cold water refuge watershed snapshots" of the 12 "primary" CWR tributaries and the two "restore" CWR tributaries to highlight information about the CWR and their respective watersheds. The snapshots describe the quality and characteristics of each refuge, background on the watershed, features of the watershed that can affect CWR quality, and actions in the watershed that can protect and restore the CWR.

One focus of the snapshots is to identify watershed features that help to maintain CWR quality. These are used as the basis for actions to protect those watershed features. A second focus is to identify features that degrade CWR quality. These are used as a basis for restoration actions to reduce temperatures and potentially offset future warming from climate change. These protection and restoration actions are regulatory – related to management actions already established – and voluntary in nature. Whenever possible, an effort is made to identify agencies and organizations that have jurisdictional authority over the actions.

The actions are also intended for local stakeholders and regional planning groups to use in focusing their work and leveraging resources for projects that protect and restore CWR. Most of the restoration actions are actions identified in salmon recovery and watershed restoration plans to benefit species within the watersheds. To this end, the snapshots emphasize ongoing work in the watersheds that provide multiple local benefits in addition to enhancing CWR and put a spotlight on the important regional benefits provided by these restoration actions.

To develop these snapshots, EPA relied on work described in the previous chapters regarding CWR plume volume, upstream extent of fish use, and documented fish use by migrating salmonids. EPA also developed maps for the land cover and land ownership in each CWR tributary and conducted other analyses for riparian cover and water allocation. For background on different activities in each watershed, EPA conducted a literature search relying heavily on subbasin plans, regional salmon recovery plans, and local watershed priority plans. See Appendix 12.20. Chapter 11 includes a bibliography of the sources for each snapshot.

EPA shared drafts of these documents with interested parties in the basin including Tribal Governments, Lower Columbia Estuary Partnership, counties, Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Ecology (Ecology), Oregon Department of Environmental Quality (ODEQ), U.S. Forest Service (USFS), NMFS, watershed councils, and other groups. The snapshots are relatively concise, providing a brief overview of the watersheds, distilling meaningful information for stakeholders, and including actions to protect and restore the CWR.

More detail on the development of the snapshots is included in Appendix 12.20.

7.2 CHARACTERISTICS OF PRIMARY COLD WATER REFUGE TRIBUTARIES

Each of the 12 primary CWR tributaries have characteristics that help to create and maintain cold temperatures during the summer. ***Figure 7-1*** shows that all of the 12 primary CWR tributaries originate from volcanic mountains or forested areas in the Cascade Mountain Range in Washington and Oregon. Many of the tributaries have a large percentage of forest land within their basins, much of which is federal forest land.

The Cowlitz River, Lewis River, and Sandy River share similar features. They are the three most downstream CWR in the Columbia River below Bonneville Dam, whose headwaters include volcanic mountains that provide snowmelt runoff in the summer. Along with forested headwaters, each of these rivers have development (urban, rural, and/or agricultural) in the lower part of their basins and have dams that deliver cool regulated summer flow to the lower section of these rivers.

Tanner Creek, Eagle Creek, and Herman Creek are small, well-forested watersheds that are part of the Columbia River Gorge with cool river temperatures. Wind River, Little White Salmon River, White Salmon River, and Hood River are moderate sized basins, include a significant percentage of forested land, and also drain into the Columbia River Gorge. The White Salmon River and Hood River also have a significant amount of farmland.

The Klickitat River and Deschutes River are located east of the Cascade Mountain range, where the climate is significantly drier and warmer and the percentage of forested land drops significantly. However, both tributaries have volcanic geology which creates opportunity for groundwater infiltration, important for providing a reliably steady source of cold water in the summer which enhances CWR quality. The lower Deschutes River's flow and temperature are influenced by the Pelton-Round Butte Dam 100 miles upstream of the mouth.

Herman Creek and the Little White Salmon River are unique because they drain into artificial cove areas created by infilling (Herman Cove) and by a highway (Drano Lake). These embayments pool inflowing cool tributary flows, creating coves that provide CWR.

Table 7-1 includes a temperature-based classification of CWR quality based on optimal and sub-optimal water temperatures for fish from EPA's Region 10 Temperature Guidance (Appendix 12.20):

- *"Excellent" cold water refuge* – Average August tributary temperatures cooler than 16˚C.
- *"Good" cold water refuge* - Average August tributary temperatures 16-18˚C.
- *"Marginal" cold water refuge* - Average August tributary temperatures greater than 18˚C.

Table 7-1 Location and characteristics of primary cold water refuges

	Watershed Characteristics					
River Name and CWR Quality	Location/ River Mile	Headwaters	Watershed Size (square miles)	River Length (miles)	Percent Forested	Dam Influenced
Cowlitz River (good)	Below Bonneville Dam (RM 65.2)	Mt. Rainier Mt. St. Helens Mt. Adams	2,586	105	62%	X
Lewis River (good)	Below Bonneville Dam (RM 84.4)	Mt. Adams Mt. St. Helens	1,046	95	66%	X
Sandy River (marginal)	Below Bonneville Dam (RM 117.1)	Mt. Hood	508	56	77%	X
Tanner Creek (excellent)	Below Bonneville Dam (RM 140.9)	Mt. Hood National Forest	46	6	87%	
Eagle Creek (excellent)	Bonneville Dam Reservoir (RM 142.7)	Mt. Hood National Forest	90	15	90%	
Herman Creek (excellent)	Bonneville Dam Reservoir (RM 147.5)	Mt. Hood National Forest	50	8	98%	
Wind River (excellent)	Bonneville Dam Reservoir (RM 151.1)	Gifford Pinchot National Forest	225	30	84%	
Little White Salmon River (excellent)	Bonneville Dam Reservoir (RM 158.7)	Gifford Pinchot National Forest	136	19	70%	
White Salmon River (excellent)	Bonneville Dam Reservoir (RM 164.9)	Mt. Adams	400	44	66%	
Hood River (excellent)	Bonneville Dam Reservoir (RM 165.7)	Mt. Hood	279	25	62%	
Klickitat River (good)	Bonneville Dam Reservoir (RM 176.8)	Mt. Adams	1,350	96	48%	
Deschutes River (marginal)	The Dalles Dam Reservoir (RM 200.8)	Mt. Hood Mt. Jefferson Three Sisters	10,500	252	32%	X

7.3 COWLITZ RIVER (RIVER MILE 65) – PROTECT AND ENHANCE

Photo 7-1 Cowlitz River

Refuge Volume: 1,554,230 m^3 (largest)

Average August Temperature: 16˚C

Distance to Downstream Refuge: N/A

Distance to Upstream Refuge: 19 mi. (Lewis River)

Cold Water Refuge Rating: Good (16-18°C)

What features make the Cowlitz River an important cold water refuge to protect and enhance?

The Cowlitz River enters the Columbia River at river mile 65, about 3.5 miles south of Longview, Washington. Cowlitz River temperatures in August average 16°C, almost 5°C cooler than the Columbia River's average August temperature of 20.75°C. This makes the Cowlitz River a good CWR (16-18°C).

Photo 7-2 Aerial view of the Cowlitz River; yellow pin denotes upstream extent of refuge

The lower portion of the Cowlitz River is designated for salmonid spawning, rearing, and migration by the Washington Department of Ecology, which assigns a water quality criterion of 17.5°C for maximum water temperatures. The maximum modeled temperature for the Cowlitz River is 21°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower Cowlitz River is on the 303(d) list for temperature impaired waters. The Cowlitz River is the first major tributary upstream of the mouth of the Columbia where migrating salmonids can seek refuge during their migration, likely using both the mouth and lower portion of the refuge, estimated to be 1.75 miles upstream (yellow pin, ***Photo 7-2***). Of the tributaries along the lower Columbia River, the Cowlitz River has the largest volume of cold water at the confluence in summer months. In August, the Cowlitz River has an average flow of 3,634 cfs, which produces a CWR estimated to be

Photo 7-3 Map of the Cowlitz River Basin

1,554,230 cubic meters, or approximately 622 Olympic-sized swimming pools. The next available cold water refuge for migrating salmonids leaving the Cowlitz River is 19 miles upstream in the Lewis River.

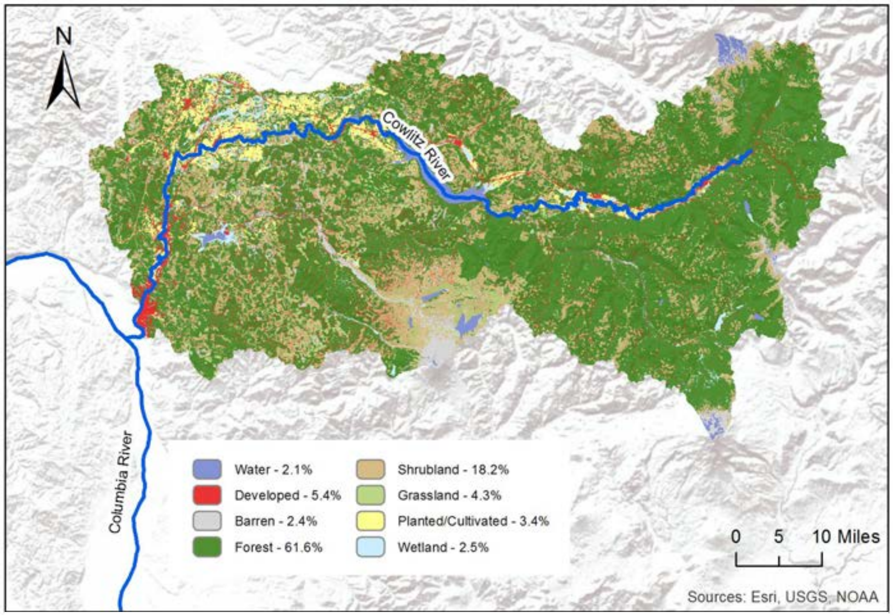


Figure 7-2 Cowlitz River land cover

Introduction to the Cowlitz River Watershed

The Cowlitz watershed drains heavily-timbered mountainous slopes surrounding Mount Rainier, Mount Adams, Mount St. Helens, and the Goat Rocks Wilderness. Flowing for 105 miles in a west-southwest direction, the mainstem Cowlitz passes through the cities of Kelso and Longview near its confluence with the Columbia River. Mayfield Dam at River Mile 42 divides the Cowlitz River watershed into an Upper and Lower Basin.

Figure 7-2 and ***Figure 7-3*** show land cover and ownership in the Cowlitz watershed. A large extent of the upper basin is in the Mount Rainier National Park and the Gifford Pinchot National Forest. Together the U.S. Forest Service and National Park Service own and manage most of the upper basin; in total, public agencies own approximately half of the watershed. Forest covers nearly two-thirds of the watershed – particularly in the upper basin where high levels of riparian canopy cover shade headwater streams, helping to maintain cool water temperatures. Shrubland (18%) grows in fragmented patches throughout the watershed. Nearly the entire Lower Basin is privately owned. Cultivated crops (~3%) and developed areas (~5%) are concentrated along the mainstem and lower tributary valleys below Mayfield Dam and near the river mouth, respectively.

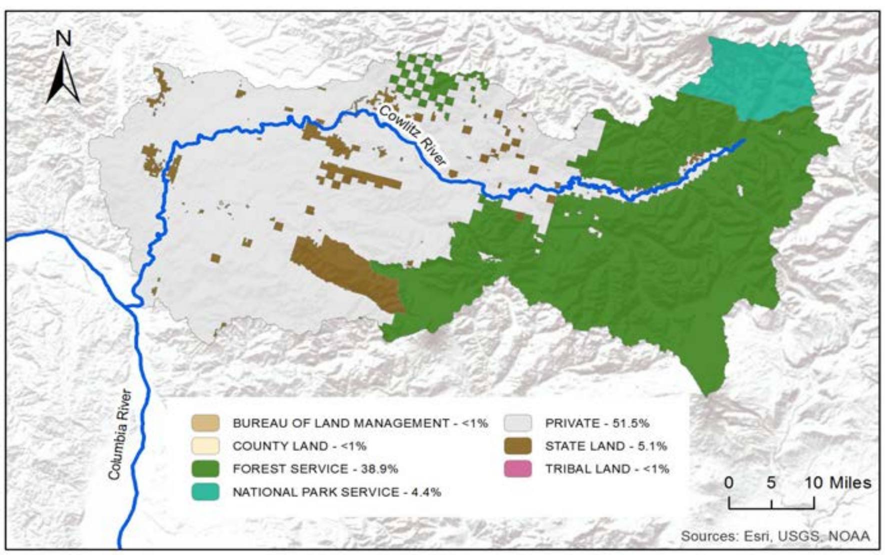


Figure 7-3 Cowlitz River land ownership

The Toutle River, which enters the Cowlitz at river mile 20, is a major tributary that drains Mount St. Helens. In 1980, the volcano's eruption filled the Toutle Valley with billions of tons of erodible debris. Increased sediment loads can lead to the widening and shallowing of rivers and, as a result, can increase water temperature. The U.S. Army Corps of Engineers constructed sediment retaining dams on the Toutle and continuously dredge the channels of both the Toutle and Cowlitz Rivers.

Factors that Influence Temperature in the Cowlitz River Watershed

Riparian Vegetation: The Cowlitz River watershed has well-forested areas in the tributaries of the upper watershed. ***Figure 7-4*** shows the difference between the maximum potential and current shade, demonstrating which areas have the highest restoration potential. The lower mainstem Cowlitz River and associated tributaries are not as well shaded as the upper basin. The riparian forests along the lower 20 miles of the Cowlitz River have been severely degraded through industrial and commercial development, and between river miles 20 and 52 the river lacks mature forests and adequate buffer widths. Riparian shade has been degraded on private commercial forest lands, which cover much of the lower Cowlitz basin, but shade is expected to improve through time and implementation of Washington's State Forest Practice Rules. Loss of riparian shade is likely a primary cause of several tributaries to the Lower Cowlitz River, including Coweeman River, Ostrander Creek, and

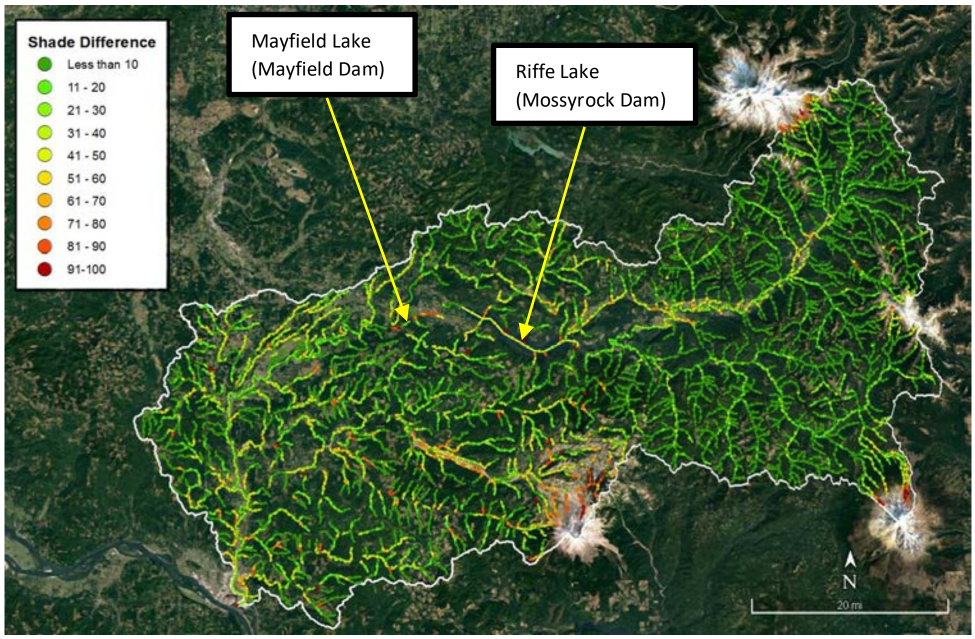


Figure 7-4 Cowlitz River shade difference between potential maximum and current shade

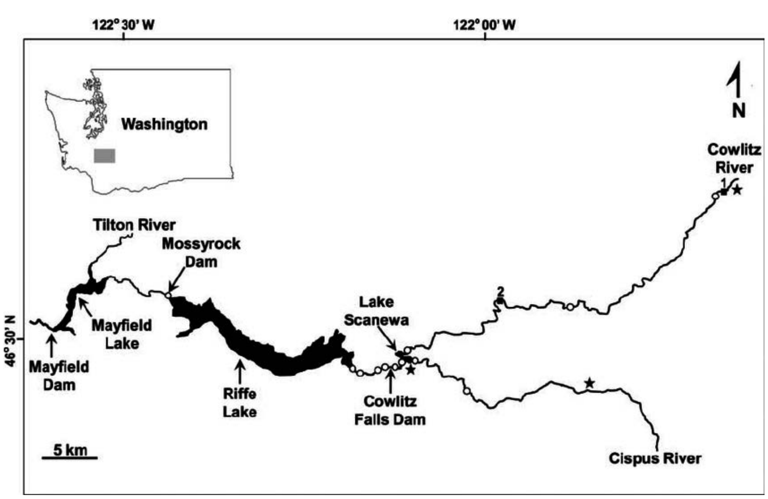


Figure 7-5 Map of Cowlitz River Dams

Arkansas/Monahan/Delameter Creeks, being listed on the state's 303(d) list for temperature impairment. These warm creeks have daily maximum temperatures that exceed 20°C.

Photo 7-4 Cowlitz River as seen from above

Hydromodification: The Cowlitz River is currently modified by three hydroelectric dams in the upper basin (***Figure 7-5***). Tacoma Power operates the Mossyrock and Mayfield Dams; Bonneville Power Administration (BPA) operates the Cowlitz Falls Dam. The Mossyrock Dam is the tallest dam in Washington State and forms 23.5-mile-long Riffe Lake. At river mile 52, Mayfield Dam, built in 1956, blocks natural passage of anadromous fish. Tacoma Power's FERC license for Mayfield Dam requires 2,000 cfs of minimum flow below the dam in August, which approximates August flow prior to the building of the dam. Typically, however, August flows below the dam are higher than this level, which provide most of the flow in the Lower Cowlitz River from the dam to the mouth. The lower 20 miles of the Cowlitz River was channelized to facilitate industrial, agricultural, and urban development, resulting in a significant loss in floodplain function.

Photo 7-5 Sediment retaining structure on the north fork of the Toutle River, which eventually flows to the Cowlitz

Water Use: Tacoma Power has senior water rights in the region for power production for the two dams, but as noted above has minimum flow requirements below Mayfield Dam which provide significant flow to the Lower Cowlitz River that helps maintain cool summer river temperatures. Currently there are no instream flow rules (water rights to protect fish) for the Lower Cowlitz River with current flow viewed as sufficient to meet future anticipated demands. The Cowlitz River watershed is intensely farmed based on Washington Department of Ecology's *Water Availability Summary* (2012). Irrigation withdrawals have contributed to low flows and high water temperatures in several of the tributaries to the Lower Cowlitz River. WDFW has issued surface water source limitations (SWSLs) for minimum instream flow on the Lower Cowlitz River and Salmon Creek and for closure to new water rights for Arkansas Creek, Olequa Creek, and Hazel Dell Creek to protect fish from low flows. SWSLs serve to advise Ecology on the issuance of new water rights. Limiting additional water withdrawals can help maintain cool river temperatures and the CWR volume of the Lower Cowlitz River.

Climate Change: In 2040, average August temperatures in the Cowlitz River are predicted to rise to 17°C compared to 23ºC in the Columbia River. In 2080, August temperatures in the Cowlitz River are expected to rise further to 18°C compared to 24°C in the Columbia River. Therefore, the Cowlitz River could still be considered a marginal CWR by 2080. However, as temperatures rise, mountain glaciers which help the Cowlitz River stay cool, will recede. Studies at the University of Washington have shown that climate change will likely exacerbate low summer flows in the mainstem Cowlitz River, because of lower snowpack melt in the summer.

Ongoing Activities in the Cowlitz River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

In 2010, the *Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan*, which includes the Lower Cowlitz and Coweeman subbasins, was adopted by the Lower Columbia Fish Recovery Board as an integrated plan for salmon recovery, the Northwest Power and Conservation Council (NPCC) fish and wildlife program, and Washington State watershed management. This plan was adopted by NMFS in 2013 as the salmon recovery plan under the ESA. The management plans detail key priorities contributing to recovery and mitigation in the basin, such as managing regulated stream flows through the hydropower system and restoring floodplain and riparian function. Specific restoration projects for the Lower Cowlitz River have been identified in the *Lower Cowlitz River and Floodplain Habitat Restoration Project Siting and Design Report* (2007).

The *Watershed Plan for WRIA 26* (2005) and associated updated *WRIA 26 Water Supply and Streamflow Flow Review* (2014) adopted by Cowlitz and Lewis Counties provide recommendations to Ecology for water resources in the Lower Cowlitz River. The recommendations in the 2014 update include reservations for future use along with closure and instream flow rules for most of the Lower Cowlitz River tributaries, including the Coweeman, Ostrander, Arkansas/Delameter/Monahan, Olequa, Lacamas, Mill, and Salmon Creeks. Although the 2005 plan called for closure of new water rights for the Lower Cowlitz River, the 2014 update recommended it remain open to future appropriations due to adequate flows with reservations for the counties and cities.

Cowlitz County and the U.S. Army Corps of Engineers maintain levees and flood control in the river to regulate legacy sediment contributions caused by the Mount St. Helens eruption. In 2013, USACE initiated a $4.5 million project to construct a sediment retention structure on the Toutle River to prevent further sediment seepage into mainstem Cowlitz River. This action helps reduce sediment deposition into the Cowlitz River CWR.

The Capitol Land Trust manages a 17-acre land parcel along the Lower Cowlitz River, including 1,500 feet of streambank which protects and maintains critical habitat for salmonids and other wildlife species.

As the largest CWR used by migrating salmonids, the Cowlitz River is an important refuge to protect and enhance. Actions to protect and enhance the Cowlitz River CWR include:

- On National Forest Lands, continue to implement the USFS Gifford Pinchot National Forest Land Resource Management Plan (1990) and its amendments, which include aquatic and riparian conservation strategies to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Washington's Forest Practice Rules on private forest lands and the Washington Department of Natural Resources' Habitat Conservation Plan on state lands to protect and restore riparian shade and stream functions to maintain cool river temperatures. (WDNR)

- On private and county lands, continue to implement the riparian protections in the *Cowlitz and Lewis Shoreline Master Programs* (2018; 2017) and critical areas ordinances to regulate development in the Lower Cowlitz River and its tributary shoreline areas to protect and restore riparian shade and stream functions to maintain cool river temperatures. (Cowlitz County and Lewis County)
- Implement actions and projects in the *Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (2010) and the *Lower Cowlitz River and Floodplain Habitat Restoration Project Siting and Design Report* (2007) to restore riparian shade, floodplain functions, and channel complexity that improve salmon habitat and maintain cool temperatures in the Lower Cowlitz River and tributaries. (Multiple parties)
- Address temperature impairments in the Lower Cowlitz River basin by supporting riparian restoration and other projects, many of which are identified in existing plans, and establish a water clean-up plan/TMDL alternative or temperature TMDL, as warranted.(Ecology)
- Continue to provide cool summer flows from Mayfield Dam per the FERC license to maintain the CWR volume and temperatures. (Tacoma Power)
- Consider adopting a watershed management rule with the reservations, closures, and minimum instream flows as recommended in the *WRIA 26 Water Supply and Streamflow Flow Review* (2014) to balance future water uses with maintaining future flow and Cowlitz River CWR volume. Consider a revised SWSL or an instream flow rule for the Lower Cowlitz River to help maintain cool river temperatures and protect CWR volume.(Ecology, WDFW)
- Continue sediment retention on the Toutle River to prevent excess sedimentation at the confluence of the Cowlitz River. (Army Corps)
- Continue to develop state and local partnerships with local land trusts, like the Capitol Land Trust, to obtain and preserve pieces of land to keep riparian areas intact. (Multiple parties)

7.4 LEWIS RIVER (RIVER MILE 84) - PROTECT AND ENHANCE

Photo 7-6 Lewis River looking upstream towards railroad bridge

Refuge Volume: 613,455 m^3 (4^{th} largest)

Average August Temperature: 16.6°C

Distance to Downstream Refuge: 19 mi. (Cowlitz River)

Distance to Upstream Refuge: 33 mi. (Sandy River)

Cold Water Refuge Rating: Good (16-18°C)

What features make Lewis River an important cold water refuge to protect and enhance?

The Lewis River, located at river mile 84.4 of the Columbia River, provides a significant CWR below Bonneville Dam. Average August water temperatures in the Lewis River are estimated to be 16.6°C, approximately 5°C colder than the Columbia River. This classifies the Lewis River as a good CWR (16-18ºC). The Lewis River CWR is 19 miles upstream of the Cowlitz River CWR. The Lewis River CWR includes the confluence area and an estimated 1.7 miles upstream (yellow pin, ***Photo 7-7***).

Photo 7-7 Aerial View of Lewis River at the Confluence with Columbia River; yellow pin denotes upstream extent; Photo: Google Earth

The Washington Department of Ecology designates the lower portion of the Lewis River for salmonid spawning, rearing, and migration and assigns a water quality criterion of 17.5°C for maximum water temperatures. The maximum modeled temperature for the Lewis River is 20.8°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the Lower Lewis River is on the 303(d) list for temperature impaired waters. The Lewis River's relatively high discharge averages 1,291 cfs in August. The Lewis River CWR, including the lower portion of the river and the plume, is estimated to be 613,455 cubic meters, the fourth largest refuge in the Columbia River and the size of approximately 245 Olympic-sized swimming pools. Fall Chinook salmon, and steelhead trout leaving the Lewis River will swim 33 miles before reaching the next refuge in the Sandy River.

Photo 7-8 Lower Lewis River Falls

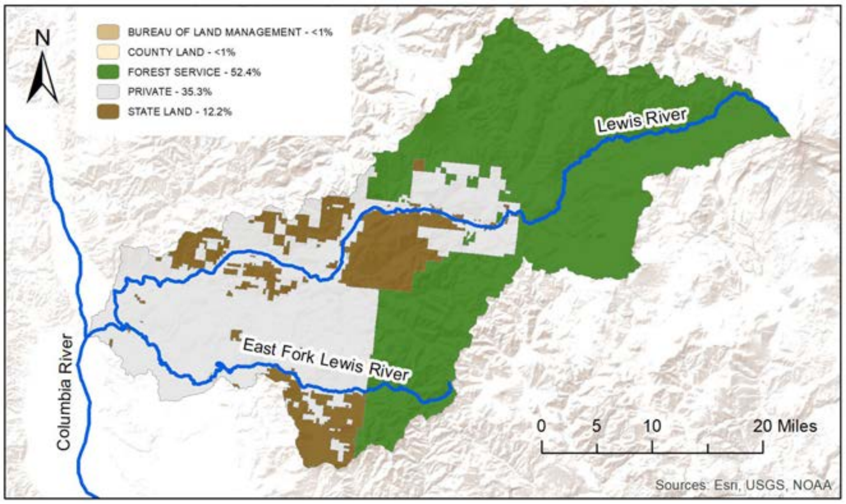


Figure 7-6 Lewis River land ownership

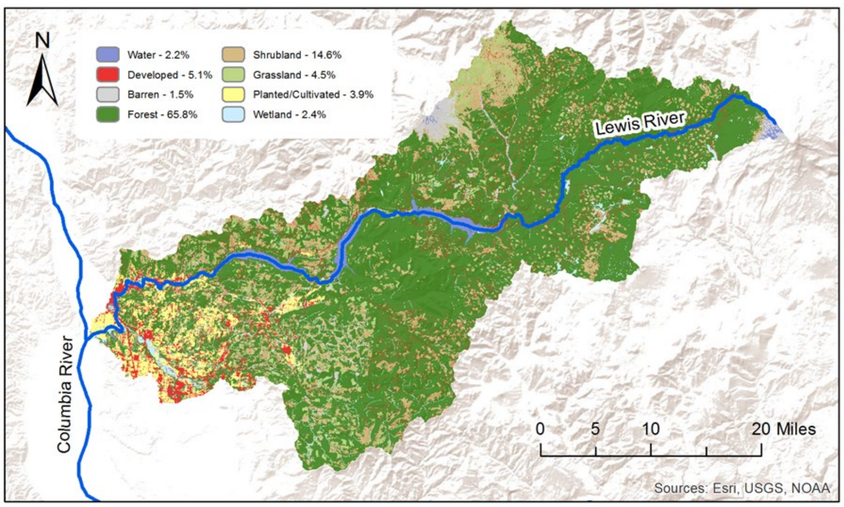


Figure 7-7 Lewis River land cover

Introduction to the Lewis River Watershed

The Lewis River watershed drains the southern slopes of Mount St. Helens and the western flank of Mount Adams. For most of its journey, the Lewis River is synonymous with the North Fork Lewis River. The smaller East Fork joins the North Fork to form the mainstem Lewis River 3.5 miles above the confluence with the Columbia River.

Both forks of the Lewis River have steep, heavily forested headwaters in the Gifford Pinchot National Forest managed by the U.S. Forest Service (***Figure 7-6***). The North Fork begins on the western slope of Mount Adams, while the East Fork Lewis originates near Green Lookout Mountain in the southern portion of the watershed. Approximately two-thirds of the entire watershed is forested. Shrubland (15%) and grassland (5%) are found in fragments throughout the basin. In its last 12 miles, the Lewis River flows through a broad valley predominated by cultivated crops (4%) and urban development, including the City of Woodland and the rapidly growing community of Battle Ground (***Figure 7-7***). The East Fork Lewis River is impaired for temperature with exceedances of maximum water temperatures of 16ºC, the water quality criteria for core salmonid habitat.

A series of dikes along the lower 7 miles of the Lewis River protect farmland and urban development. The dikes and associated channel modifications are estimated to have disconnected the river from more than half of its historic floodplain.

Factors that Influence Temperature in the Lewis River Watershed

Protecting and Enhancing Riparian Vegetation: Shade levels are high on most of the upper tributaries of the North Fork Lewis River, but shade levels are significantly lower in its middle reaches (***Figure 7-8***). The lowest levels of shade are found on the impounded sections of the

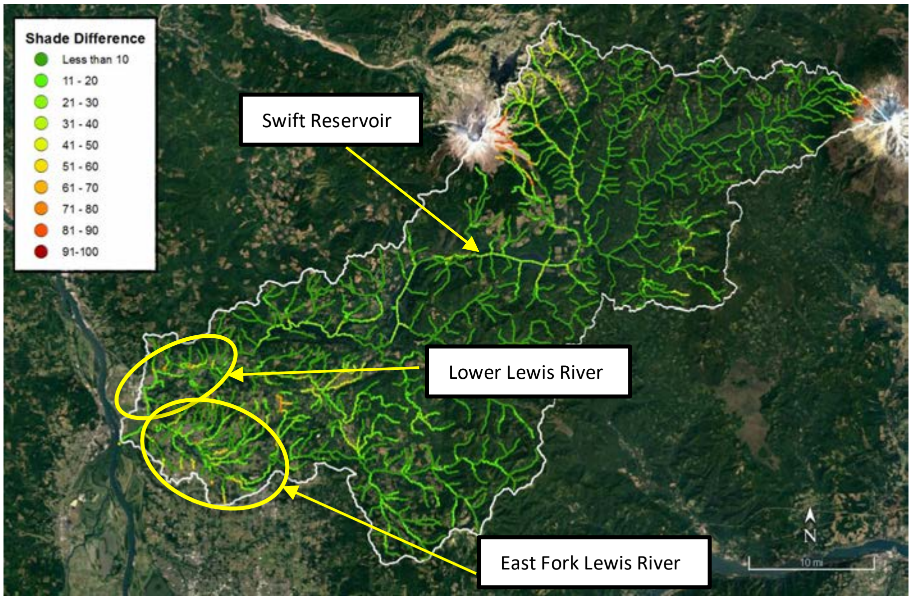


Figure 7-8 Lewis River shade difference between potential maximum and current shade

mainstem Lewis River (Swift Reservoir, see ***Figure 7-8***), where the reservoir is much wider than the stream would be, inhibiting the ability of riparian vegetation to shade the water surface. ***Figure 7-8*** shows that overall stream shade is close to its potential or in reasonable shape, with portions of the lower reaches having the greatest potential for stream shading. The *2010 Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan* noted poor riparian conditions on the mainstem between the mouth and river mile 15. Further, the East Fork Lewis is currently listed as impaired for temperature. Washington Department of Ecology completed the *East Fork Lewis River Watershed Bacteria and Temperature Source Assessment Report* (2018) for the East Fork Lewis in 2018 that specifies reaches lacking riparian shade that contribute to temperature exceedances.

Dams and Hydromodifications: PacifiCorp operates three dams on the North Fork Lewis that have substantial impact on anadromous salmon: Merwin (1931), Yale (1953), and Swift (1958) (***Photo 7-9***). Merwin Dam, the most downstream structure, is at river mile 19.5. The hydropower operations have altered the natural hydrology by decreasing peak flows that historically flooded the lower valley. Decreased peak flows coupled with extensive channelization of the Lower Lewis River through dikes and bank stabilization have reduced floodplain functions that help maintain cool river temperatures. PacifiCorp received a new 50-year FERC license in 2008 that includes minimum flows downstream of Merwin Dam of 2,300 -1,500 cfs from July 1 to July 30 and 1,200 cfs from July 31- October 15, which approximates pre-dam flows. Water releases from Merwin Dam are taken from Merwin Reservoir at a fixed depth of about 178 feet below the surface when the reservoir is at full pool. Because the reservoir is stratified in the summer with cool water at depth, the dam delivers relatively cool, stable flows in August. The cool flows from Merwin Dam are important for cool river temperatures at the mouth that provide the CWR.

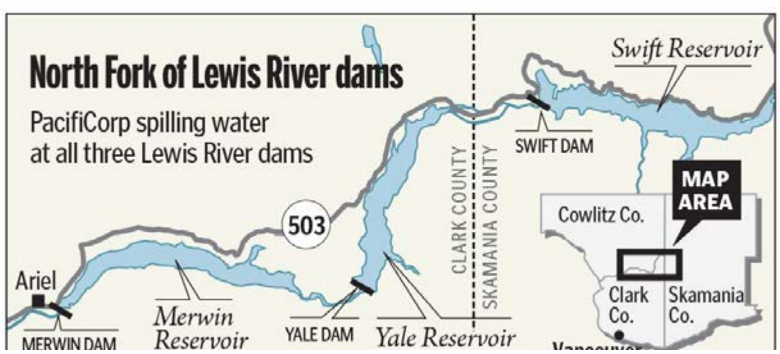


Figure 7-9 Map of Lewis River dams

The lower part of the East Fork Lewis flows through a broad, alluvial valley that historically was an active floodplain with diverse riparian forests. Channel modifications over the years have dramatically altered natural channel migration, floodplain processes, and riparian shading, contributing to warm river temperatures and degraded fish habitat.

Water Use: Senior water rights for PacifiCorp to maintain reservoir levels in Lake Merwin and Yale Lake limit the water available for new sources in the Lewis River upstream of the dams. In addition, farms on the Lower Lewis River hold surface water rights for irrigation. Since snowpack is depleted in the summer, the demands for water are greatest when the supply is lowest, the same time that migrating salmon use the Lewis River mouth as a refuge.

Photo 7-9 North Fork Lewis River at Cedar Creek, looking downstream

Washington Department of Ecology has assigned instream flow rules (water rights to protect fish) at several locations in the basin. Minimum instream flows at river mile 19 of the Lewis River range from 1,200-2,700 cfs between June and August. For the East Fork Lewis River, minimum instream flows at river mile 10.1 in the summer range from 122-420 cfs. There are also areas within each basin where additional flow withdrawals are not allowed, including the Lower Lewis River upstream of river mile 7.1 and the East Fork Lewis River. The *Salmon-Washougal & Lewis Watershed Management Plan, WRIAS 27-28* adopted in 2006 provided the analysis and recommendations for Ecology's 2008 instream flow and closures rules noted above for Lewis River basin.

Photo 7-10 Lewis River looking towards the Columbia River

Climate Change: In 2040, August temperatures in the Lewis River are projected to rise to 18˚C, compared to 23˚C in the Columbia River. In 2080, August temperatures are expected to further rise to 19˚C compared to 24˚C in the Columbia River. Therefore, increases in Lewis River temperatures are expected to shift the refuge from a good quality refuge (16-18˚C) to a marginal quality refuge (>18˚C). Still, the Lewis River is expected to be 5˚C cooler than temperatures in the Columbia River in the summer, even under climate change projections.

Ongoing Activities in the Lewis River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

Groups such as Clark County, Clark County Conservation District, Cowlitz Indian Tribe, non-profit organizations, private citizens, and state and federal agencies have identified and prioritized projects in the Lewis River. Recent plans include the *Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan* (2010), which includes North Fork Lewis and East Fork Lewis subbasin plans, and the *Lower East Fork Lewis River Habitat Restoration Plan* (2009). The 2010 plan, adopted by the Lower Columbia Fish Recovery Board as an integrated plan for salmon recovery, the Northwest Power and Conservation Council Fish and Wildlife Program, and Washington State watershed management was adopted by NMFS in 2013 as the salmon recovery plan. These plans provide a comprehensive assessment of restoration needs and project priorities in the basins. Recommended actions include increasing floodplain function, restoring riparian habitat, and increasing channel complexity, which can help maintain cool river temperatures as well as improve salmon habitat. In addition, the Washington Department of Ecology is currently developing a water clean-up plan/TMDL alternative to address warm temperatures in the East Fork Lewis River based on the 2018 temperature source assessment.

Actions to protect and enhance the Lewis River CWR include:

- On National Forest Lands, continue to implement the USFS Gifford Pinchot National Forest Land Resource Management Plan (1990) and its amendments, which include aquatic and riparian conservation strategies to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Washington's Forest Practice Rules on private forest lands and the Washington Department of Natural Resources' Habitat Conservation Plan on state lands to protect and restore riparian shade and stream functions to maintain cool river temperatures. (WDNR)
- On private and county lands, continue to implement the riparian protections in the Cowlitz and Clark County Shoreline Master Plans (2018; 2012) and critical areas ordinances to regulate development in the Lewis River and East Fork Lewis River shoreline areas to protect and restore riparian shade and stream functions to maintain cool river temperatures. (Cowlitz County and Clark County)
- Continue to provide cool summer flows from Merwin Dam per the FERC license to maintain the CWR volume and temperatures. (PacifiCorp)
- Continue to implement instream flow and new water consumptive use closures per Ecology's water management rule for the Lewis River basin (WRIA 27). (Ecology)
- Continue to implement actions and projects in the *Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (2010) and the *Lower East Fork Lewis River Habitat Restoration Plan* (2009) to restore riparian shade, floodplain functions, and channel complexity that improve salmon habitat and help maintain cool temperatures in the Lower Lewis River and East Fork Lewis River. (Multiple parties)
- Complete the East Fork Lewis River water clean-up plan and implement the plan's actions to reduce river temperatures. (Ecology)

7.5 SANDY RIVER (RIVER MILE 117) – PROTECT AND ENHANCE

Refuge Volume: 31,915 m^3 (11th largest)

Average August Temperature: 18.8˚C

Distance to Downstream Refuge: 33 mi. (Lewis River)

Distance Upstream Refuge: 24 mi. (Tanner Creek)

Cold Water Refuge Rating: Marginal (>18ºC)

Photo 7-12 Upper Sandy River

What features make the Sandy River an important cold water refuge to protect and enhance?

Photo 7-13 Aerial view of Sandy River delta at the confluence with Columbia River; yellow pin denotes upstream extent

The Sandy River is located at river mile 117 of the Columbia River, downstream of the Bonneville Dam. Sandy River temperatures in August are 2.5°C cooler than the Columbia River, averaging 18.8°C. This makes the Sandy River a marginal CWR (>18˚C) for migrating salmonids. The Sandy CWR is 33 miles upstream of the Lewis River CWR. ODEQ assigns a water quality criterion of 18°C for maximum temperatures to protect salmonid rearing and migration in the lower portion of the Sandy River. The maximum modeled temperature for the Sandy River is 23.6°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the Lower Sandy River is on the 303(d) list for temperature impaired waters. Migrating salmon are thought to use the confluence of the rivers and an estimated 1.10 miles up the Sandy River as a CWR (yellow pin, ***Photo 7-13***). Bull Run River, a major tributary to the Sandy River, supplies the drinking water for the City of Portland, and withdrawals from Bull Run River affect the amount of water that reaches the Sandy River. The Sandy River mainstem is currently undammed from the headwaters to the confluence, helping temperatures stay cooler with a more natural flow regime. Historical lahars (fast-moving mudflows) formed a large debris fan with a braided channel in the lower reaches and mouth of the Sandy River, and the glacier that feeds the Sandy River is heavily laden with sediment. Sediment build-up at the mouth can make the refuge shallower and subsequently warmer over time. The Sandy

Photo 7-11 Sandy River at Dodge Park, upstream of confluence

River is the tenth largest CWR in the Lower Columbia River with an estimated volume of 31,915 m^3, the size of approximately 13 Olympic-sized swimming pools, and a mean flow of 469 cfs. The next upstream CWR is 24 miles away in Tanner Creek.

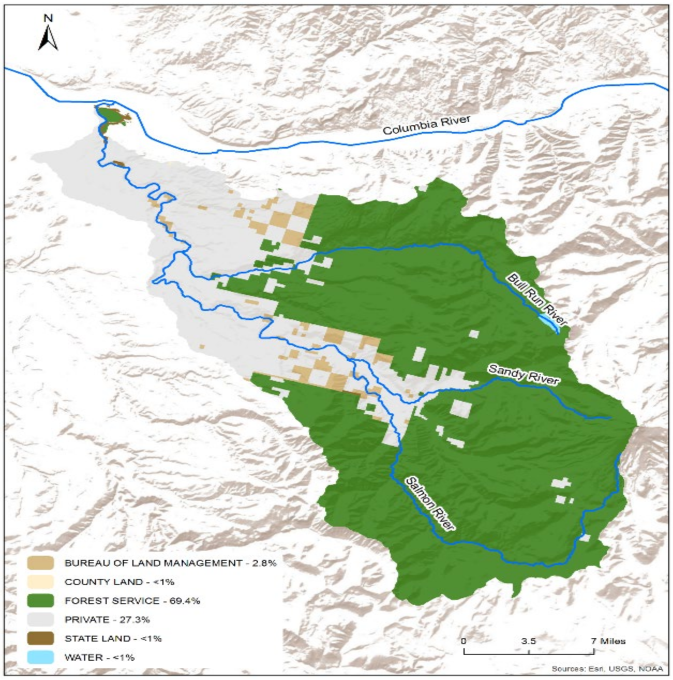


Figure 7-10 Sandy River land ownership

Introduction to the Sandy River Watershed

Glaciers on the western slopes of Mount Hood feed the Sandy River. Much of the upper basin is protected as part of the Mount Hood National Forest and remains heavily forested. The Sandy River watershed includes the Bull Run River subbasin, Portland's drinking water source. Given its proximity to the Portland metropolitan area and its high quality natural areas, the Sandy River watershed is a popular recreation area. Approximately 25 miles of the Upper and Lower Sandy River is designated as a federal Wild and Scenic River and state Scenic Waterway. The Upper Sandy River has a wild designation for 4.5 miles and a recreational designation for 16.6 miles. The Lower Sandy River has a scenic designation from Dodge Park (river mile 18.75) to Dabney Park (river mile 6). The Wild and Scenic designations and the Bull Run River watershed's status as an important drinking water source provide protections by limiting development in the middle and upper watersheds.

Approximately three-quarters of the watershed is forested, predominately in the Mount Hood National Forest which makes up about 2/3 of the watershed (***Figure 7-10*** and ***Figure 7-11***). The lower watershed is mostly privately owned. The lower watershed is also in the Columbia River Gorge National Scenic Area, which includes Forest Service, state, and private lands. The flat topography of the lower watershed supports a mix of cultivated crops (4%) and the cities of Gresham and Troutdale, the only significant areas of developed land other than State Highway 26, which winds through the watershed before passing south of Mount Hood.

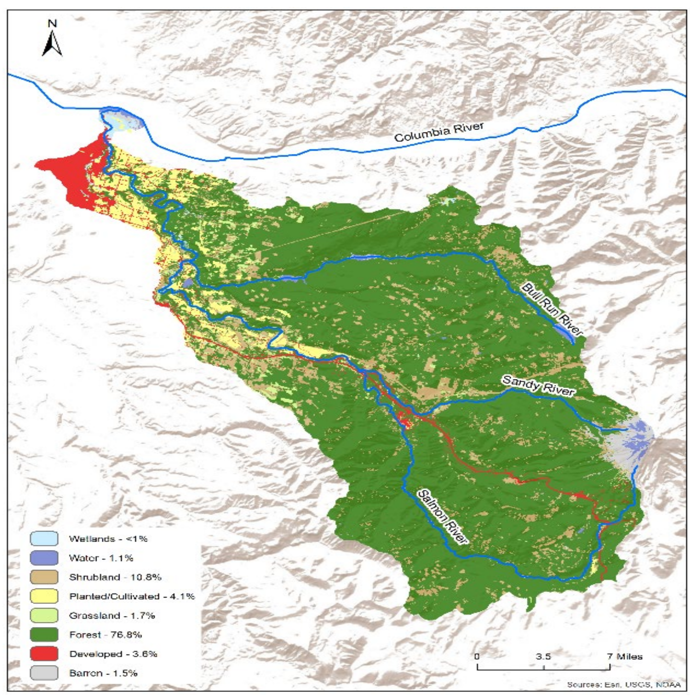


Figure 7-11 Sandy River land cover

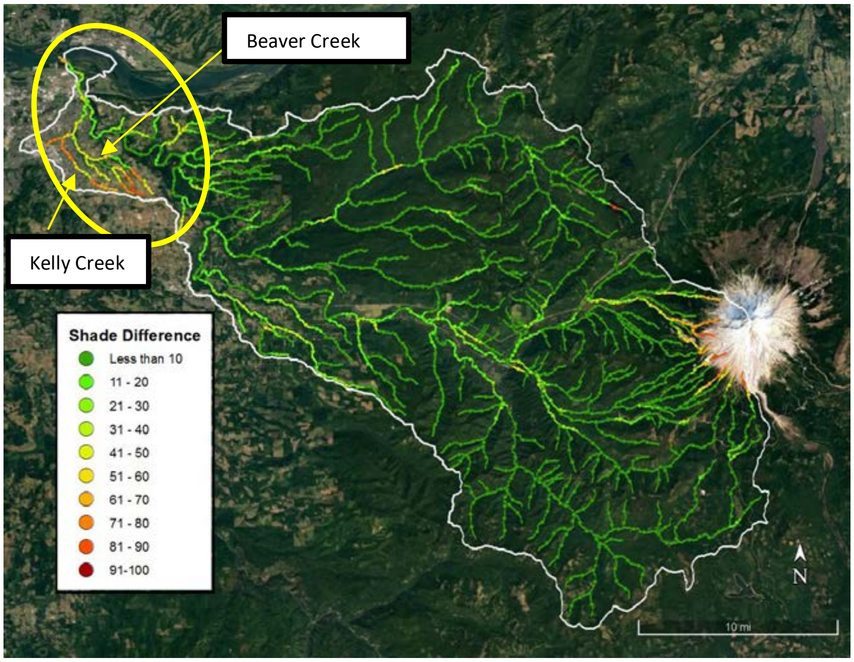


Figure 7-12 Sandy River shade difference between potential maximum and current shade

Factors that Influence Temperature in the Sandy River Watershed

Protecting and Enhancing Riparian Vegetation: The Sandy River watershed has high levels of riparian shade throughout the upper and middle forested tributaries. These are federal, state, and private lands that are governed by the *USFS Mount Hood Forest Land and Resource Management Plan* (1990) and its amendments, which include the *Aquatic Conservation Strategy*, Oregon's State Forest Management Plan, and Oregon's Forest Practices Act. The Upper Sandy River Basin is in designated wilderness and is subject to limited management. This shade serves to block solar radiation and maintain cool stream temperatures. However, there are reaches that have been degraded and have potential for increased shade in the Lower Sandy River. Shade from riparian vegetation reduces solar exposure to the stream channel and helps maintain cool water temperature. ***Figure 7-12*** shows the difference between maximum and current shade levels highlighting the reaches that could benefit the most from riparian revegetation. Beaver and Kelly Creeks, tributaries to the Lower Sandy River, have the greatest potential for more riparian shade.

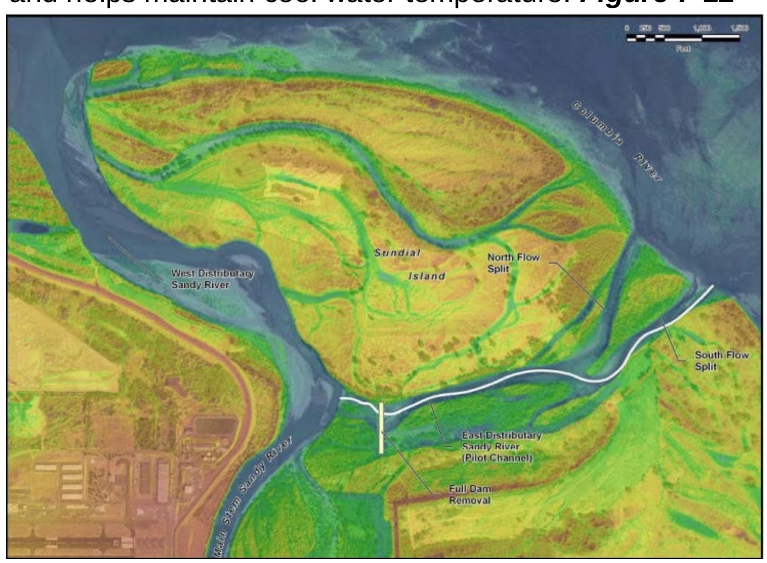


Figure 7-13 Sandy River Delta Dam pre-removal – white line indicates location of former dam (USACE, 2015)

Water quality modeling in ODEQ's *Sandy River Basin TMDL* (2005) predicted a temperature decrease of approximately 0.5°C with maximum potential vegetation under low flow conditions. Increased riparian shade can help to reduce sedimentation and maintain CWR volumes and temperatures.

Dams and Hydromodifications: The mainstem Sandy River is currently undammed for 56 river miles from the headwaters to the confluence. The removal of several dams, including

Marmot Dam (2007), the Little Sandy Diversion Dam (2008), and the Sandy River Delta Dam (2013) has restored a more natural flow regime, increased floodplain connectivity, and added channel complexity. The Sandy River Delta Dam (***Figure 7-13***) had blocked the east channel of the delta, impeding fish passage and access. The U.S. Army Corps of Engineers identified habitat improvements from removal of the Sandy River Delta Dam as including year-round access for salmon to the east channel, cooler waters in the east channel during the summer, and additional shallow water. The State of Oregon owns the land under the East Channel, and the Forest Service owns most of the rest of the Sandy River Delta, all of which is part of the Columbia River Gorge National Scenic area.

Photo 7-12 East Channel post-Sandy Delta Diversion Dam removal (USACE)

The Bull Run River is a significant tributary to the Sandy River, which includes two reservoirs that provide drinking water for the City of Portland. Historically, the unused water from the top of the thermally-stratified Bull Run reservoirs was released to the Bull Run River and warmed temperatures in the Sandy River. In the past few years, however, the Portland Water Bureau has used a selective withdrawal system to release higher volumes of colder water in the summer, which has resulted in colder waters reaching the Sandy River. This along with other measures in the *Bull Run Water Supply Habitat Conservation Plan* (2008) have helped to reduce harmful effects to salmon from the Bull Run River reservoirs.

Table 7-2 Water Availability Analysis, 5/20/20, Sandy River at mouth, Oregon Water Resources Department

SANDY RIVER>COLUMBIA R – AT MOUTH (@ 80% exceedance)			
Month	Monthly Streamflow (cfs)		
	Natural Streamflow	Water Allocated or Reserved	% Allocated*
JUNE	1,190	1,932	162%
JULY	726	1,067	147%
AUGUST	539	583	108%
SEPTEMBER	503	730	145%
Top Users: Municipal (97%), Domestic (2%)			
*% Allocated: [Water Allocated or Reserved]/[Natural Streamflow]. This is the percentage of water either allocated or reserved for in-stream or other uses compared with the natural streamflow. Percentages over 100% indicate the water is overallocated at the mouth of the river.			
Reference: https://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=71480&exlevel=80&scenario_id=1			

The *State of the Sandy* (2017) report by the Sandy River Watershed Council indicates that a dam on Kelly Creek on the Mount Hood Community College campus creates an artificial pond which raises temperatures as much as 4˚C in the summer. The community college is considering removing this dam, which could cool the water temperatures in the lower Sandy watershed. Other dams continue to operate on many tributaries to the Sandy River.

Water Use: Water availability is overallocated in the Sandy River primarily due to Portland's diversion of the Bull Run River for its drinking water.

Table 7-2 shows that the Sandy River is overallocated June through September, and that municipal uses account for 97% of the water use, leaving little water for other uses. As discussed above, the Portland Water Bureau implements the *Bull Run Water Supply Habitat Conservation Plan* to manage water flows. In addition, each year, the City of Portland prepares a seasonal water supply augmentation and contingency plan called the Seasonal Supply Plan (SSP) for water releases. The releases must be consistent with the *Bull Run Water Supply Habitat Conservation Plan* and final *Temperature Management Plan* (2009) requirements.

Oregon Department of Fish and Wildlife applied for and was granted instream water rights (ISWRs) to protect fish at several locations in the basin in 1991 and 1992. ISWRs function like all water rights, and are junior to any earlier water rights. ISWRs provide targets for the flows needed to support fish, wildlife, their habitats and recreation. For the Sandy River, ISWRs at river mile 18.5 (Bull Run River) to the mouth in the summer range from 400 cfs (in August) to 1400 cfs, and from river mile 42.8 (Zigzag River) to river mile 37.5 (Salmon River) from 100-250 cfs. There are 17 ISWRs on tributaries to the Sandy River, including on the Salmon River (summer range: 60-250 cfs) and on the Zigzag River (summer range: 75-150 cfs). These ISWRs serve to help maintain existing flows, although senior water holders primarily for municipal uses can still diminish flows below these levels in low flow years.

Climate Change: In 2040, average August temperatures in the Sandy River are predicted to rise to 20˚C compared to 23˚C in the Columbia River. In 2080, August temperatures in the Sandy River are expected to rise further to 21˚C compared to 24˚C in the Columbia River. Therefore, although the Sandy River will still be cooler than the Columbia River by 3˚C in 2040 and 2080, the absolute temperature of the Sandy River will be higher, which decreases its benefit to salmon.

Ongoing Activities in the Sandy River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

Groups such as the Portland Water Bureau, Sandy River Watershed Council, USFS, Bureau of Land Management, East Multnomah Soil and Water Conservation District, Lower Columbia Estuary Partnership and others have identified, prioritized, and implemented projects in the Sandy River Basin. Oregon adopted the *Sandy River Basin Total Maximum Daily Load and Water Quality Management Plan* (2005) to address warm river temperatures. The Portland Water Bureau's *Temperature Management Plan* (2009), included in the *Bull Run Water Supply Habitat Conservation Plan (HCP)*, set up riparian forest protections, set reservoir flow releases to meet temperature TMDL targets, and called for construction of the selective withdrawal structure in the Bull Run Reservoir currently in use. The Portland Water Bureau is implementing the *Bull Run Water Supply HCP*, a 50-year plan with 49 habitat, temperature, and flow mitigation measures such as conservation easements on 240 acres of private land, engineered logjams, and releases of cold water withdrawals. Implementation includes annual compliance reports to implement the *HCP*.

The lower part of the Sandy River basin is within the Columbia River Gorge National Scenic Area and covered by the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). National Scenic Area land use designations, policies, and guidelines in the Sandy River basin area include buffer requirements and limitations on development to help protect water quality and the Sandy River CWR.

The Lower Sandy River from river miles 6 to 18.5 was designated a State Scenic Waterway in 1972 and a part of the National Wild and Scenic River System in 1988. River miles 16.5 to 18.5 are in Clackamas County, and the remaining portions are in Multnomah County. The *Sandy Wild and Scenic River and State Scenic Waterway Management Plan (1993)* provides limits on development and timber harvest to help protect water quality and the Sandy CWR.

The Sandy River Watershed Council's *State of the Sandy* report highlights restoration work in the basin, including improving and planting riparian vegetation, conducting large wood placement and channel alteration, and improving fish passage. Ongoing and planned activities, particularly increasing riparian vegetation near the confluence and the removal of the Kelly Creek Dam, could benefit the CWR.

Actions to protect and enhance the Sandy River CWR include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Oregon's Forest Practices Act on private forest lands throughout the watershed to protect and restore riparian shade and stream functions to maintain cool river temperatures. (ODF)
- On private and county lands, continue to implement the riparian protections in the Clackamas and Multnomah County land use regulations, and the Multnomah Columbia River Gorge National Scenic Area code to regulate development in the Sandy River watershed to protect riparian shade and stream functions to maintain cool river temperatures. (Clackamas County and Multnomah County)
- Continue to implement higher flows, colder temperatures, riparian restoration, floodplain reconnection, and stream habitat restoration actions in the mainstem Sandy River, Bull Run Reservoir Basin, and other tributaries noted in the *Bull Run Water Supply Habitat Conservation Plan* (2008), *Temperature Management Plan* (2009), and *Sandy River Basin TMDL* (2005). (Portland Water Bureau)
- Continue to implement ongoing protections from the *Sandy Wild and Scenic River and State Scenic Waterway Management Plan* (1993) scenic designation in the Lower Sandy River that limit development and maintain riparian habitat. (BLM, Oregon State Parks and Recreation Department, Multnomah and Clackamas counties)
- Continue to implement instream water rights for fish protection in the Sandy River basin, particularly the Lower Sandy River, to protect existing flow and CWR volume. (OWRD)
- Continue collaboration in the watershed among multiple interested parties for restoration, increased large woody debris, and other watershed restoration activities. (Multiple parties)
- Cool river temperatures by considering the removal of a small dam on Kelly Creek as noted in the *State of the Sandy* (2017). (Mount Hood Community College)

7.6 TANNER CREEK (RIVER MILE 141) – PROTECT AND ENHANCE

Photo 7-13 Tanner Creek drainage from Hamilton Island (2005)

Refuge Volume: 1,713 m^3 (15th largest)

Average August Temperature: 11.7˚C

Distance to Downstream Refuge: 24 mi. (Sandy River)

Distance to Upstream Refuge: 2 mi. (Eagle Creek)

Cold Water Refuge Rating: Excellent (<16˚C)

What features make Tanner Creek an important cold water refuge to protect and enhance?

Tanner Creek provides a small CWR located immediately below Bonneville Dam at river mile 141, 24 miles upstream of the refuge in the Sandy River. With an estimated average temperature of 11.7°C in August, Tanner Creek is approximately 10°C colder than the Columbia River, classifying the creek as an excellent quality refuge (<16°C).

Photo 7-14 Aerial view of Tanner Creek at the confluence with Columbia River; yellow pin denotes upstream extent

ODEQ has designated the lower portion of Tanner Creek for core cold water habitat and salmon and steelhead spawning and has assigned water quality criteria of 16°C and 13°C for maximum water temperatures during spawning (August 15 – May 15), respectively. The maximum modeled temperature for Tanner Creek is 14.5°C (1993-2011) (Appendix 12.18). However, based on measured maximum temperature readings, the lower portion of Tanner Creek is not on the 303(d) list for temperature impaired waters. Migrating salmonids use both the mouth and the stream channel below Tanner Creek Bridge and an estimated 0.08 miles upstream as a refuge (yellow pin, ***Photo 7-14***). While the creek is very cold relative to the Columbia River, the August flow is modest at only 38 cfs. However, the Bonneville Hatchery uses groundwater, which is discharged to Tanner Creek and increases flows below the hatchery. As a result, the CWR is estimated to be 1,713 m^3 in size, or approximately ¾ of an Olympic-sized swimming pool, making it the smallest of the 12 primary refuges on the Lower Columbia River. Returning adults must pass over Bonneville Dam and swim two miles before encountering Eagle Creek, the next primary CWR.

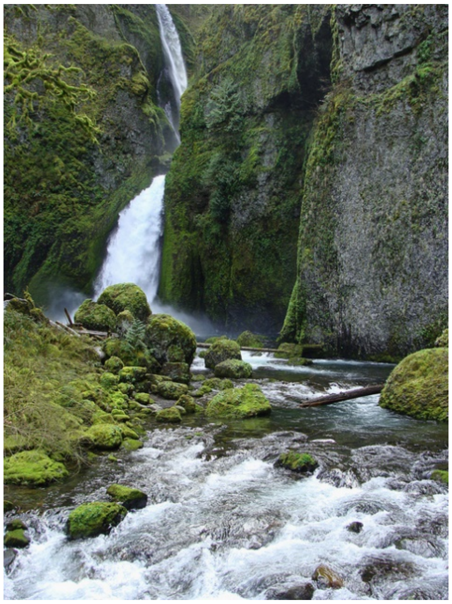


Photo 7-15 Wahclella Falls

Introduction to the Tanner Creek Watershed

The watershed lies in the Mount Hood National Forest and Columbia River Gorge National Scenic Area. Famous for its picturesque Wahclella Falls (***Photo 7-18***), the Gorge attracts many visitors who hike along the creek's lower reaches. The Bull Run watershed, which supplies water to the City of Portland, borders the basin to the southwest; the Eagle Creek watershed abuts Tanner Creek to the east. Tanner Creek is a priority watershed in the *USFS Watershed Condition Framework* (2011) for the Columbia River Gorge National Scenic Area.

Tanner Creek originates from a groundwater spring below Tanner Butte on the southern bank of the Columbia River Gorge. The heavily forested watershed combined with the creek's steep gradient and short length (6.5 miles) produce reliably cold water. Cascading downhill in a nearly due north direction, Tanner Creek collects lateral tributaries from the east and west hillslopes. The upper portion of Tanner Creek is protected as part of the Mark O. Hatfield Wilderness Area, and no urban development or agricultural land exists in the watershed. Forest (87%) predominates in the basin; shrubland (12%) grows on portions of the upper and middle watershed. Bonneville Fish Hatchery, the only developed site, is located north of Highway 84 adjacent to the creek's confluence with the Columbia River (***Figure 7-14***). The USFS owns and manages the entire watershed except for the State of Oregon's Bonneville Fish Hatchery (***Figure 7-15***).

In 2017, the Eagle Creek Fire burned a significant portion of the watershed. Potential post-fire impacts to the refuge include increased water temperatures due to reduced riparian canopy

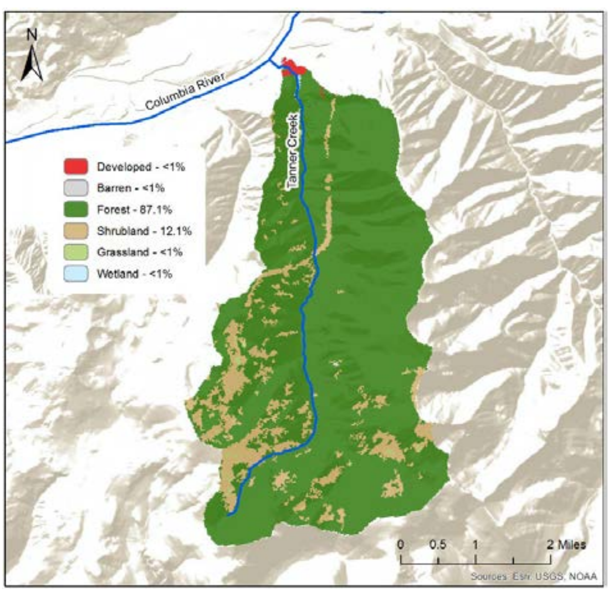


Figure 7-14 Tanner Creek land cover

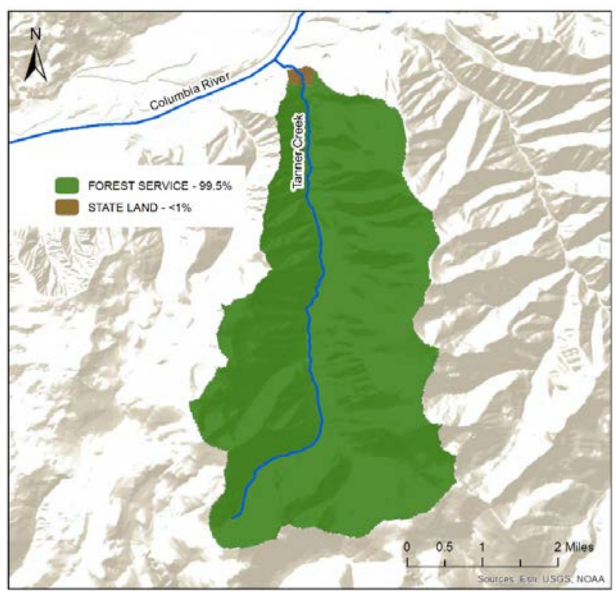


Figure 7-15 Tanner Creek land ownership

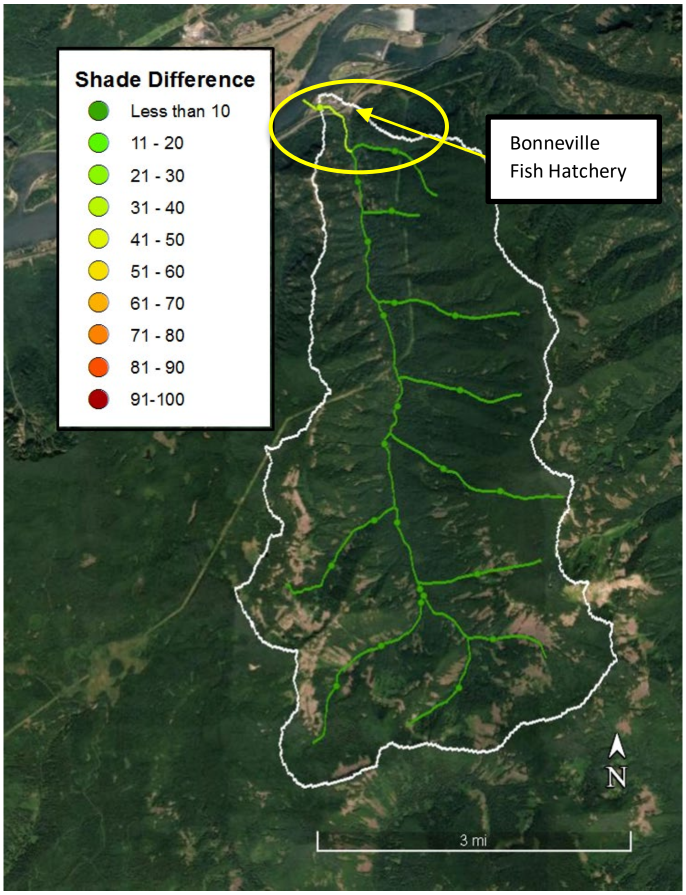


Figure 7-16 Tanner Creek shade difference between potential maximum and current shade

(not shown in ***Figure 7-16***). The USFS has identified National Forest Service Road 8400777 Road, a mid-slope road on the east side of Tanner Creek, as having the largest risk of sediment delivery to Tanner Creek.

Post-fire analysis conducted by the USFS indicated large extents of the mid-basin hillslopes were moderately (yellow) or severely burned (red), meaning the fire consumed at least 80% of the ground cover and surface organic matter (***Figure 7-17***). Fortunately, most of the severe burn areas occurred outside the riparian zone. A GIS analysis of the Burn Severity Assessment data indicated that 14% of the riparian zone suffered low severity fire disturbance, 31% experienced moderate severity disturbance, and 12% experienced high severity cover and sedimentation of the creek mouth resulting from rainfall on bare, steep slopes.

Factors that Influence Temperature in the Tanner Creek Watershed

Protecting and Enhancing Riparian Vegetation*:* Prior to the Eagle Creek Fire, high levels of canopy cover shaded Tanner Creek and its tributaries, except for the lowermost portion of the mainstem channel that has less than 50% cover due to the Bonneville Fish Hatchery and associated development.

Areas in the watershed with the highest potential for canopy cover restoration include the mouth of the creek in and around Bonneville Fish Hatchery and along the riparian areas affected by moderate-to-severe fire severity disturbance levels, predominately along the upper portions of lateral tributaries

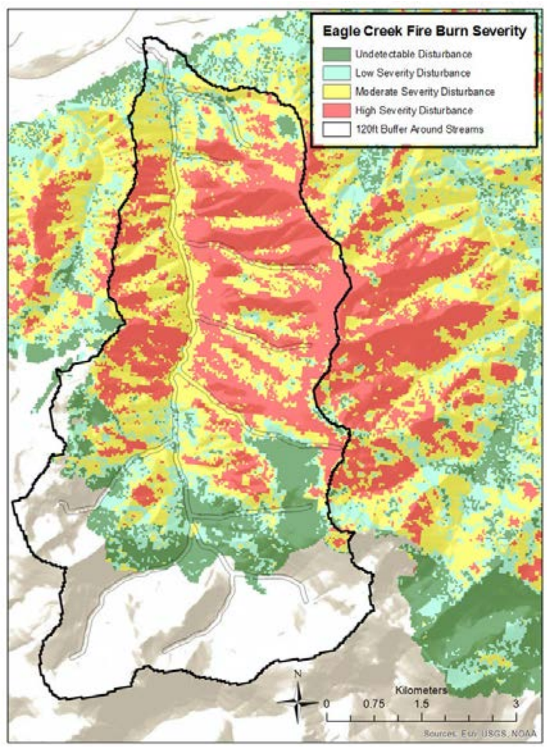


Figure 7-17 Eagle Creek Fire Burn Severity map in the Tanner Creek Watershed. (Peter Leinenbach and USFS)

disturbance. The Middle and Upper Tanner Creek are designated wilderness, which relies on passive rather than active restoration.

Photo 7-19 Tanner Creek

Dams and Hydromodifications: Except for two small dams on the creek's last mile, the basin's landcover and stream channel retain natural characteristics. There is a diversion dam at 0.8 miles above the creek mouth, which withdraws water and blocks fish passage and may cause some stream warming.

Water Use: Water use is not limited in Tanner Creek. Bonneville Fish Hatchery is the only water user in the small watershed. There is no instream water right for fish protection in Tanner Creek. To support fish cultivation, the ODFW owns two year-round water rights: a surface water right that allows for the diversion of up to 50 cfs and a groundwater right that allows for the pumping of an additional 2.2 cfs of water. The diversion and point of use for both water rights is in and around the creek mouth, and the majority of pumped or diverted water returns to the stream after being used in the Hatchery. In addition, up to 39 cfs of cold water is pumped from the aquifer below the Columbia River into the hatchery and is discharged into Lower Tanner Creek resulting in a total flow that exceed 50 cfs at the mouth. Further, the basin's steep topography and designation as a Wilderness Area limit the potential for new water uses in the future.

Photo 7-17 Tanner Creek Drainage post Eagle Creek Fire (USFS)

Climate Change: In 2040, Tanner Creek's average August water temperature is projected to increase to 13°C while the mainstem Columbia River is projected to average 23°C. In 2080, average August water temperature in Tanner Creek is expected to rise by an additional degree to 14°C compared to 24°C in the Columbia River. Therefore, while water temperatures are projected to increase in future decades, Tanner Creek is predicted to provide a small plume of excellent quality refuge (<16°C) for migrating salmonids, even under climate change projections.

It is important to note that temperature modeling of Tanner Creek occurred prior to the Eagle Creek Fire.

Ongoing Activities in the Tanner Creek Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

Tanner Creek's small size and absence of residents make it one of the few watersheds in Oregon without an established watershed council to coordinate restoration and outreach activities. Since almost the entire watershed falls within USFS lands, USFS plans (i.e., the *USFS Water Condition Framework Transition Watershed Action Plan for Tanner Creek and Hamilton Creek – Columbia River* (2011; updated 2016)) provide recommended actions to protect and enhance water quality in the watershed. USFS's highest ranked essential project in the *USFS Water Condition Framework* is to eliminate the road accessing the diversion that confines the stream channel to restore fish passage at the diversion dam and habitat conditions near the mouth.

The lower part of Tanner Creek is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). Most of Tanner Creek is in the Special Management Area of the National Scenic Area under the authority of the USFS, which provides a very high level of protection within the watershed.

Since nearly the entire Tanner Creek watershed is protected as part of the Mark O. Hatfield Wilderness Area and the Columbia River Gorge National Scenic Area, the basin is not at risk of new development and, as a result, is in a good position to maintain cold water temperatures in the future. Actions to protect and enhance the Tanner River CWR include:

- On National Forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. Protect existing riparian vegetation corridors in the watershed in accordance with federal forest protections under the Mark O. Hatfield Wilderness Area.(USFS)
- Apply the protection of cold water quality standard (OAR 430-0410-0028 (11)) to limit new sources and activities to a cumulative warming of no more than 0.3°C above the current ambient summer maximum temperature. (ODEQ)
- Consider revising the designated use in Tanner Creek from 'Salmon and Trout Rearing and Migration Use' to 'Core Cold Water Habitat Use' because current temperatures attain the 16°C criteria associated with Core Cold Water Habitat use (ODEQ).
- Consider applying for instream water rights for fish protection to help maintain existing flows and Tanner Creek CWR volume. (ODFW)
- Implement Tanner Creek Essential Projects in the USFS Watershed Condition Framework Tanner Creek Action Plan (2011) that include eliminating or relocating the surface water diversion from Tanner Creek, eliminating the fish passage barrier on Tanner Creek, removing the access road along 0.6 miles of stream to restore floodplain connectivity, and replanting riparian habitat along the 0.6 miles of stream. (USFS, ODFW)

7.7 EAGLE CREEK (RIVER MILE 143) – PROTECT AND ENHANCE

Photo 7-18 Eagle Creek confluence facing Columbia River (Courtesy photo: Jonnel Deacon)

Refuge Volume: 2,988 m^3 (14th largest)

Average August Temperature: 15.1°C

Distance to Downstream Refuge: 2 mi. (Tanner Creek)

Distance to Upstream Refuge: 4.5 mi. (Herman Creek)

Cold Water Refuge Rating: Excellent (<16°C)

What features make the Eagle Creek an important cold water refuge to protect and enhance?

Photo 7-19 Aerial view of Eagle Creek confluence with Columbia River; yellow pin denotes upstream extent

Located at river mile 143 in Oregon, Eagle Creek is the first CWR tributary salmon encounter upstream of the Bonneville Dam. The confluence of Eagle Creek emerges from a narrow channel, becomes shallow and broad, flows south past Interstate 84, and enters the Columbia River. Eagle Creek temperatures in August are 6°C cooler than the Columbia River, with average temperatures of 15.1°C. This classifies Eagle Creek as an excellent CWR (<16˚C). ODEQ designates the lower portion of Eagle Creek for salmonid rearing and migration and has assigned a water quality criterion of 18°C for maximum water temperatures. The maximum modeled temperature for Eagle Creek is 18.8°C (1993-2011) (Appendix 12.18). The lower portion of Eagle Creek is not on the 303(d) list for temperature impaired waters. However, there have been measured exceedances of 18ºC in Lower Eagle Creek. Eagle Creek is the first among a cluster of eight CWR between Bonneville Dam and The Dalles Dam. Migrating fish use the confluence and an estimated 0.15 miles upstream of the confluence as CWR (yellow pin, ***Photo 7-19***).

Eagle Creek has a mean flow of 72 cfs in August, and the twelfth largest CWR in the Columbia River, estimated at 2,988 m^3, slightly larger than one Olympic-sized swimming pool. Though Eagle Creek provides a smaller CWR compared to others, it presents a reliably colder stream of water on average compared to the Columbia River. The next available CWR is 4.5 miles upstream in Herman Creek.

Photo 7-20 Eagle Creek confluence facing west (Courtesy Photo: Jonnel Deacon)

Introduction to the Eagle Creek Watershed

The Eagle Creek watershed drains north-facing slopes of the Columbia River's southern bank, immediately upstream of Bonneville Dam. Prior to the 2017 Eagle Creek Fire that originated in the watershed, the Eagle Creek Trail was the most popular hiking trail in the Columbia Gorge. Many visitors have hiked to Metlako and Punch Bowl Falls and beyond into the Mark O. Hatfield Wilderness Area within the Mount Hood National Forest, which covers most of the watershed except for a portion of Lower Eagle Creek.

USFS manages nearly the entire watershed except for the State of Oregon's control of the Cascade Hatchery near the creek mouth (***Figure 7-18***). The watershed retains natural vegetation – a mix of forest (89%) and shrubland (9%) cover the steep slopes (***Figure 7-19***). The Eagle Creek Recreation Area and trailhead, fish hatchery, and Eagle Creek Overlook Group campground at the creek mouth are the only developed areas in the basin. Development at the mouth of Eagle Creek impacts floodplain connectivity.

In September 2017, the Eagle Creek Fire spread from the watershed and burned tens of thousands of acres in the Columbia Gorge. In the context of CWR, it is crucial to collect more information on the impacts of the fire on riparian vegetation, channel banks, erosion, and corresponding effects on water temperature and quality.

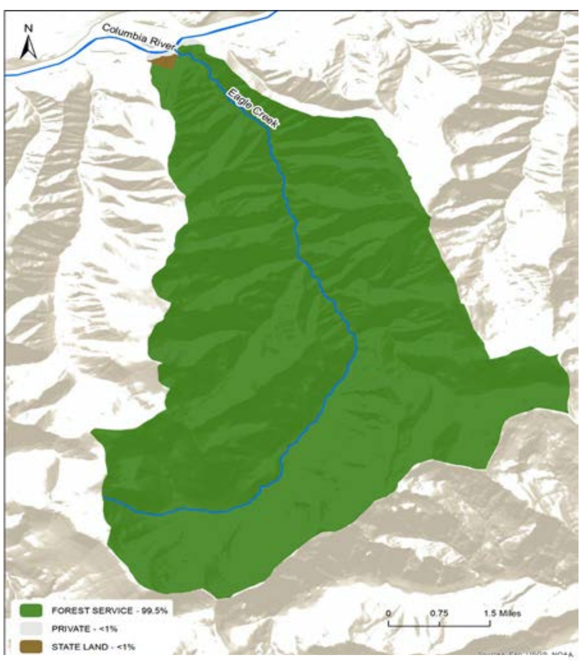


Figure 7-18 Eagle Creek land ownership

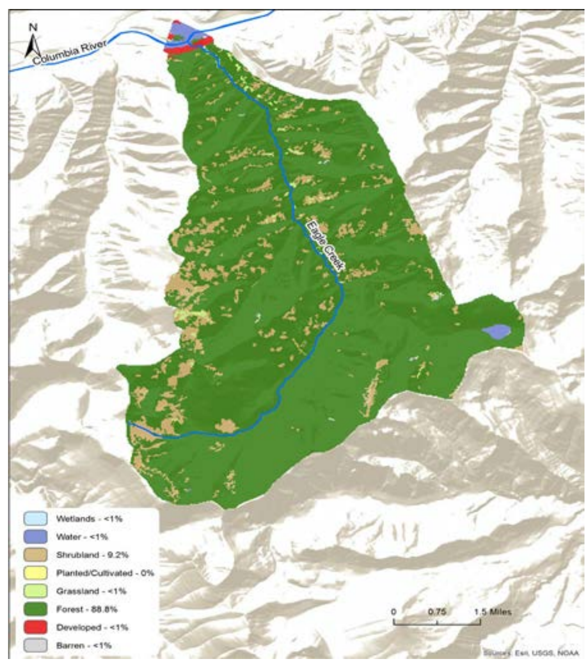


Figure 7-19 Eagle Creek land cover

Factors that Influence Temperature in the Eagle Creek Watershed

Protecting and Enhancing Riparian Vegetation*:* Prior to the Eagle Creek Fire, large amounts of riparian vegetation cover shaded Eagle Creek and its tributaries except for portions of Middle and Lower Eagle Creek. ***Figure 7-19*** compares the shade differences between the potential maximum and shade prior to the 2017 Eagle Creek Fire.

Post-fire analysis conducted by the USFS indicated large extents of Eagle Creek were moderately (yellow) or severely burned (red) in tributaries to Eagle Creek and Middle and Upper Eagle Creek, meaning the fire consumed at least 80% of the ground cover and surface organic matter (***Figure 7-20***). Much of the riparian zone corridor along Lower Eagle Creek, however, experienced

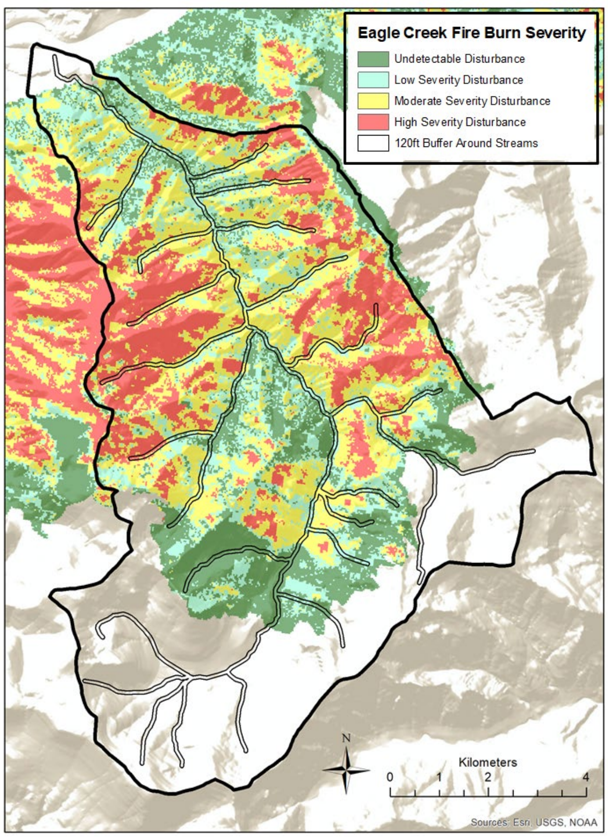


Figure 7-21 Eagle Creek Fire Burn Severity map in the Eagle Creek Watershed (Peter Leinenbach and USFS)

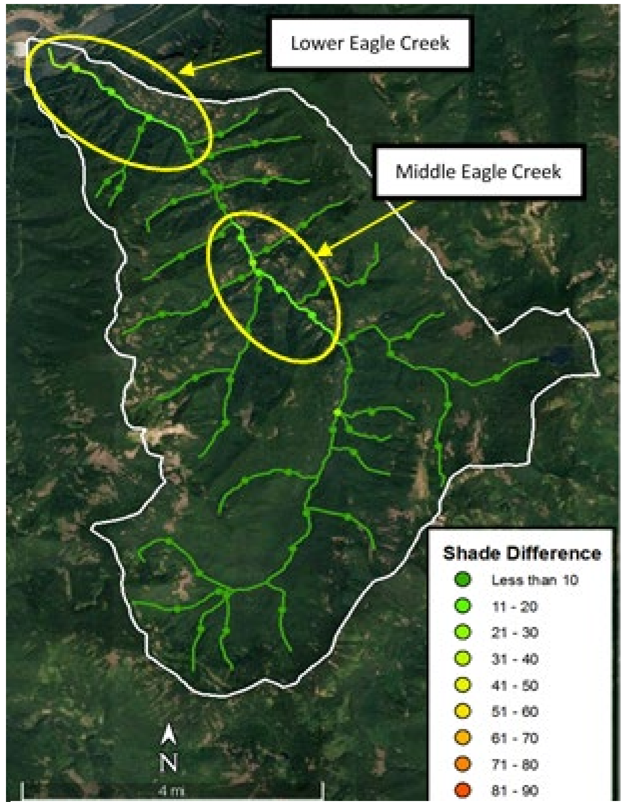


Figure 7-20 Eagle Creek shade difference between potential maximum and pre-2017 fire shade

"undetectable disturbance" in terms of loss of vegetation. A GIS analysis of the Burn Severity Assessment data indicated that 23% of the riparian zone suffered low severity fire disturbance, 24% experienced moderate severity disturbance, and 5% experienced high severity disturbance.

Dams and Hydromodifications. Cascade Hatchery operates a diversion dam at River Mile 2 for approximately 2800 feet that impacts temperatures and flows in that reach. It is also an aquatic organism passage barrier identified by the USFS as a priority for restoration.

EAGLE CR > COLUMBIA R – AT MOUTH (@ 80% exceedance)			
Month	Monthly Streamflow (cfs)		
	Natural Streamflow	Water Allocated or Reserved	% Allocated*
JUNE	93	0	0%
JULY	69	0	0%
AUGUST	42	0	0%
SEPTEMBER	44	0	0%
Top Users: None			
*% Allocated: [Water Allocated or Reserved]/[Natural Streamflow]. This is the percentage of water either allocated or reserved for in-stream or other uses compared with the natural streamflow. Percentages over 100% indicate the water is overallocated at the mouth of the river.			
Reference: https://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=30410510&exlevel=80&scenario_id=1			

Table 7-3 Water Availability Analysis, Eagle Creek at mouth, 5/20/20, Oregon Water Resources Department

Water Use: There are no consumptive or instream uses at the mouth of Eagle Creek. Thus, the net stream availability is the same as the natural streamflow as shown in ***Table 7-3***. The water availability analysis from the Oregon Water Resources Department (OWRD) indicates water is available in Eagle Creek. At river mile 2, the ODFW has a surface water right to divert up to 45 cfs for the Cascade Hatchery and return the water just downstream of the hatchery at the mouth of Eagle Creek. This has resulted in significantly lower flows in this reach during late summer and early fall. There are no instream water rights to protect fish.

Preserving flows in Eagle Creek can help keep temperatures cold. No modeling has been done to determine minimum stream flows that would preserve current cold temperatures.

Climate Change. In 2040, average August temperatures in Eagle Creek are predicted to be 17°C compared to 22°C in the Columbia River. In 2080, August temperatures in Eagle Creek are expected to rise further to 18°C compared to 23°C in the Columbia River. Therefore, Eagle Creek is expected to shift from an excellent CWR (<16°C) to a good CWR (16-18°C), unless restoration actions such as increased riparian vegetation offset increasing water temperatures. Eagle Creek is still expected to be more than 5°C cooler than temperatures in the Columbia River in the summer, even under climate change projections.

Photo 7-21 Eagle Creek looking out to Columbia River, August 2016

Ongoing Activities in the Eagle Creek Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

Eagle Creek is well protected from future development activities. The Mark O. Hatfield Wilderness protects the middle and upper part of the watershed. The lower part of Eagle Creek is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). Most of Eagle Creek is in the

Special Management Area of the National Scenic Area under the authority of the USFS, which provides a very high level of protection within the watershed. The September 2017 fire, however, burned a significant amount of the watershed.

Actions to protect and enhance the Eagle Creek CWR include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. Protect existing riparian vegetation corridors in the watershed in accordance with federal forest protections under the Mark O. Hatfield Wilderness Area.(USFS)
- Review data and consider listing Eagle Creek for temperature impairments on the 303(d) List below the Cascade Hatchery diversion at river mile 2. (ODEQ)
- Consider applying for instream water rights for fish protection to help maintain existing flows and Eagle Creek CWR volume. (ODFW)
- Identify impacts from the 2017 Eagle Creek Fire that have reduced riparian vegetation and hillslope and stream bank stability in the lower watershed. Revegetate or stabilize bare areas to cool water temperatures and reduce sedimentation.
- Evaluate and take appropriate actions to address impacts from the Cascade Hatchery diversion dam flow withdrawal to increase flows in the diversion reach, increase floodplain connectivity, and help maintain cool river temperatures. Evaluate, and if feasible, consider groundwater sources to offset surface withdrawals from Eagle Creek. (ODFW)

7.8 HERMAN CREEK (RIVER MILE 147.5) – PROTECT AND ENHANCE

Photo 7-22 Herman Creek near the confluence with the Columbia River, August 2017

Refuge Volume: 169,698 m^3 (6th largest)

Average August Temperature: 12˚C

Distance to Downstream Refuge: 4.5 mi. (Eagle Creek)

Distance to Upstream Refuge: 3.5 mi (Wind River)

Cold Water Refuge Rating: Excellent (<16˚C)

What features make Herman Creek an important cold water refuge?

Located at river mile 147.5, Herman Creek is one of eight primary CWR between Bonneville Dam and the Dalles Dam that fish use as they migrate upstream. Herman Creek is 4.5 miles upstream of the next closest refuge at Eagle Creek. Herman Creek temperatures in August average 12°C, 9°C cooler than the Columbia River. This temperature makes Herman Creek an excellent quality CWR (<16°C). The lower portion of Herman Creek is designated by ODEQ for salmon and trout rearing and migration, with a water quality criterion of 18°C for maximum water temperatures. The maximum modeled temperature for Herman Creek is 13.7°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower portion of Herman Creek is not on the 303(d) list for temperature impaired waters. Herman Creek and Herman Creek Cove provide 169,698 m^3 of cold water, the size of approximately 68 Olympic-sized swimming pools, and the sixth largest CWR in the Lower Columbia River. In August, the creek has an average flow of 45 cfs.

Photo 7-23 Aerial view of Herman Creek and Herman Cove at confluence with Columbia River; yellow pin denotes upper extent of refuge

Photo 7-24 Herman Creek, August 2017

Constructed levees protect Herman Creek Cove from inflow of warmer Columbia River waters. Thermal stratification of the water in the cove provides a cool layer of water. The CWR is estimated to be primarily limited to the cove, the hatchery discharge channel, and an estimated 0.3 miles upstream on the Herman Creek mainstem. The Port of Cascade Locks has noted high levels of sediment at the mouth of Herman Creek, causing water levels to be shallower. The next available CWR is 3.5 miles upstream in the Wind River.

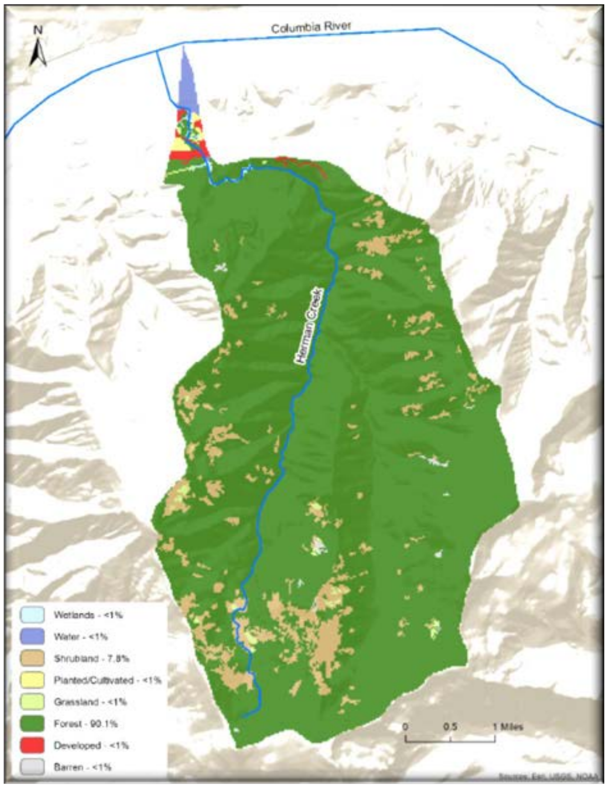


Figure 7-22 Herman Creek land cover

Introduction to the Herman Creek Watershed

The Herman Creek watershed is relatively small, covering 50 square miles. Herman Creek originates at Hicks Lake and flows steeply downhill in a due north direction for 8.5 miles before emptying into the Columbia River. Herman Creek Cove at the mouth of the tributary is an area where fish are known to congregate. Herman Creek Cove is fed by Herman Creek and the hatchery discharge channel. Waterfalls are a natural barrier to fish passage at river mile 2.8 for coho and at river mile 3.5 for steelhead. Oxbow Fish Hatchery also operates a diversion dam at river mile 0.8. The watershed consists almost entirely of protected USFS land (***Figure 7-23***), with most of the watershed protected as part of the Mark O. Hatfield Wilderness Area and lower reaches and mouth in the Columbia River Gorge National Scenic Area. Nearly the entire basin (98.5%) is forested; the small amount of developed and cultivated land is concentrated at the lower reaches of Herman Creek and along Herman Creek Cove. ODFW operates Oxbow Hatchery on Herman Creek. Waterfront property on the eastern side of Herman Cove has been pursued for light commercial and industrial development. Over the last decade, Nestle Corporation proposed a plan to bottle water from Oxbow Springs, reflecting the high quality of water from Oxbow Springs that feeds Little Herman Creek. In August 2017, the Eagle Creek fire affected areas near the Herman Creek watershed, but initial post-fire burn severity analysis conducted by the USFS indicated the watershed experienced only minor impacts from the fire.

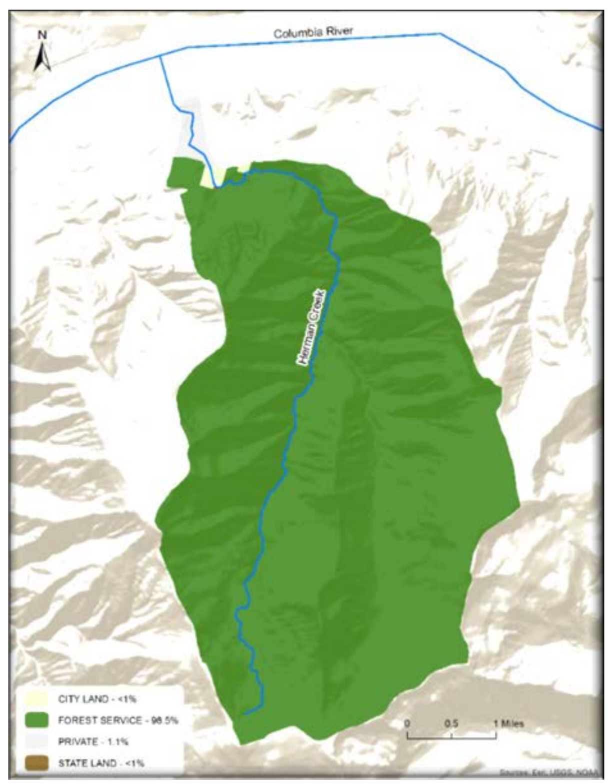


Figure 7-23 Herman Creek land ownership

Factors that Influence Temperature in the Herman Creek Watershed

Protecting and Enhancing Riparian Vegetation: The Herman Creek watershed has high levels of riparian shade throughout the well-forested watershed. This shade serves to block solar radiation and maintain cool temperatures. Riparian shade also maintains channel complexity and groundwater, which keeps water temperatures cold. ***Figure 7-24*** compares the shade difference between the potential maximum and current shade. Lower Herman Creek (from the confluence of two small tributaries with the creek to the mouth of the cove) offers potential for restoration of riparian vegetation to help improve stream cover and contribute to maintaining cool stream temperatures. This is the only area along the creek that has been developed.

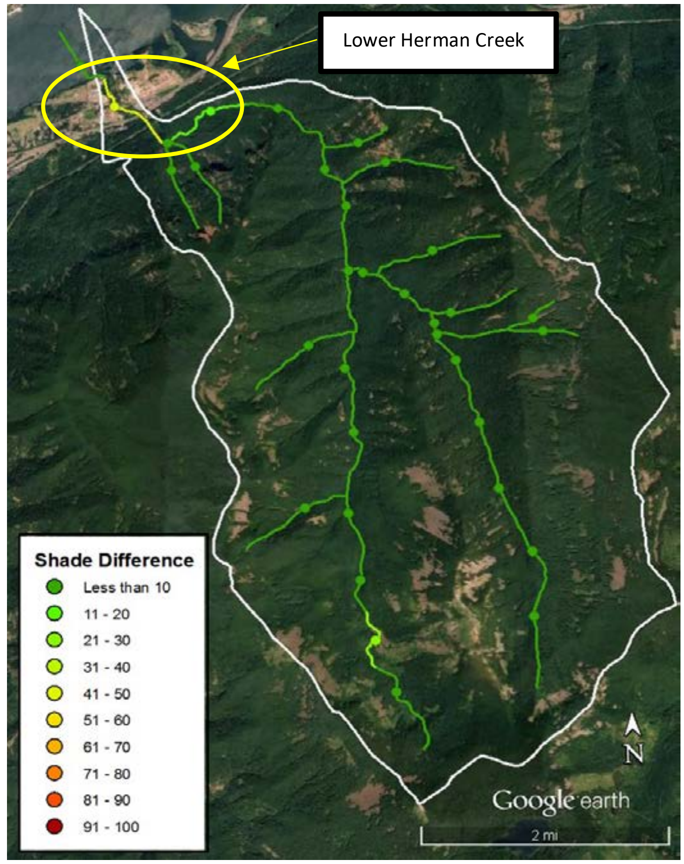


Figure 7-24 Herman Creek shade difference between potential maximum and current shade

Dams and Hydromodifications: Hydromodifications are minimal in the upper parts of the watershed. The Oxbow Hatchery operates two diversion dams that divert water into the hatchery before the water is returned to the creek.

Forest surveys conducted by USFS found little to no large woody debris in the lower and middle reaches due to culverts and channelization. The amount of large woody debris in the watershed did not meet the *Aquatic Conservation Strategy* goals of the Northwest Forest Plan. Placement of large woody debris in Herman Creek could help trap sediment, create pools of cold water, and improve habitat conditions for fish.

Herman Creek Cove itself is the result of levees constructed in the mid-20th century to produce a harbor for milling operations on the shore. The levees now serve to protect the cove from warmer Columbia River waters. The cove is located within the impoundment

Photo 7-25 Oxbow Hatchery on Herman Creek, August 2017

area of the downstream Bonneville Dam, and the water surface level can vary by as much as two feet in response to reservoir operations, potentially affecting fish access to CWR in the impoundment area if certain points become too shallow.

Water Use: ***Table 7-4*** shows the water availability in Herman Creek. There is minimal water use, and water availability in the summer months is close to the natural stream flow. The minimal consumptive uses of Herman Creek consist of domestic water supply by the City of Cascade Locks and for fish cultivation at Oxbow Fish Hatchery. Established in 1913, the hatchery holds water rights to withdraw 19 cfs from Oxbow Springs to the hatchery, which is discharged into Herman Creek. The hatchery has two ponds withdrawing water from Herman Creek. The upper pond withdraws water from Herman Creek and discharges back into the creek. The lower pond withdraws water from Herman Creek as well but discharges into the hatchery discharge channel. The added cold water from Oxbow Springs supplements flows in Herman Creek and Herman Creek Cove. There are no instream water rights for fish protection in Herman Creek.

Table 7-4 Water Availability Analysis, Herman Creek at mouth, 5/20/20, Oregon Water Resources Department

HERMAN CR > COLUMBIA R – AT MOUTH (@ 80% exceedance)			
Month	Monthly Streamflow (cfs)		
	Natural Streamflow	Water Allocated or Reserved	% Allocated*
JUNE	44	0	0%
JULY	28	0	1%
AUGUST	15	0	1%
SEPTEMBER	15	0	1%
Top Users: Domestic (71%), Irrigation (29%)			
*% Allocated: [Water Allocated or Reserved]/[Natural Streamflow]. This is the percentage of water either allocated or reserved for in-stream or other uses compared with the natural streamflow. Percentages over 100% indicate the water is overallocated at the mouth of the river.			
Reference: https://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=30410515&exlevel=80&scenario_id=1			

Climate Change: In 2040, average August temperatures in Herman Creek are expected to be 13°C compared to 22°C in the Columbia River. In 2080, August temperatures in Herman Creek are expected to rise further to 14°C compared to 23°C in the Columbia River. Therefore, Herman Creek will remain an excellent CWR (<16°C), even under future climate change projections. This contrasts with many other CWR in the Lower Columbia River where climate change will warm refuges to sub-optimal temperatures for salmon.

Photo 7-26 Herman Creek side channel, August 2017

Ongoing Activities in the Herman Creek Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

Herman Creek is protected as part of the Mark O. Hatfield Wilderness. In the early 2000s, the Hood River Soil and Water Conservation District worked with USFS, Confederated Tribes of Warm Springs, the Columbia River Inter-Tribal Fish Commission and various state agencies in Oregon to develop the *Hood River Subbasin Plan* (2004). This plan was submitted to the Northwest Power and Conservation Council to meet Endangered Species Act requirements for salmon recovery and adopted by NMFS in 2013. The plan identifies several projects to improve riparian and habitat conditions in Herman Creek that align with the goals for maintaining cold water temperatures and protecting Herman Creek as a CWR. To protect steelhead and rainbow trout, the plan also identifies protecting and restoring Herman Creek from the Hatchery Diversion Dam to the falls between river miles 0.8 and 2.8. It also recommends increasing riparian vegetation and large woody debris to increase stream complexity in the middle and lower reaches.

The lower part of Herman Creek is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area (*2016). Most of Herman Creek is in the Special Management Area of the National Scenic Area under the authority of the USFS, which provides a very high level of protection within the watershed. A small segment of Herman Creek near the mouth is designated urban use.

Actions to protect and enhance Herman Creek and Herman Creek Cove include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. Protect existing riparian vegetation corridors in the watershed in accordance with federal forest protections under the Mark O. Hatfield Wilderness Area.(USFS)
- Apply the protection of cold water quality standard (OAR 430-0410-0028 (11)) to limit new sources and activities to a cumulative warming of no more than 0.3°C above the current ambient summer maximum temperature. (ODEQ)
- Consider revising the designated use in Herman Creek from 'Salmon and Trout Rearing and Migration Use' to 'Core Cold Water Habitat Use' because current temperatures attain the 16°C criteria associated with Core Cold Water Habitat use. (ODEQ)
- Consider applying for instream water rights for fish protection to help maintain existing flows and Herman Creek CWR volume. (ODFW)
- Implement projects in the *Hood River Subbasin Plan* (2004) including increasing large woody debris in Herman Creek to decrease excess sedimentation at the mouth and increase riparian vegetation in Lower Herman Creek from the confluence of two small tributaries of the creek to the mouth of Herman Creek Cove. (Multiple parties)
- Conduct a sediment removal feasibility study in the cove to maintain CWR volumes and fish access.

7.9 WIND RIVER (RIVER MILE 151) – PROTECT AND ENHANCE

Photo 7-27 Wind River looking out to Columbia River, August 2016

Refuge Volume: 105,220 m^3 (8th largest)

Average August Temperature: 14.5°C

Distance to Downstream Refuge: 3.5 mi. (Herman Creek)

Distance to Upstream Refuge: 7.7 mi. (Little White Salmon River)

Cold Water Refuge Rating: Excellent (<16°C)

What features make the Wind River an important cold water refuge to protect and enhance?

Photo 7-28 Aerial view of Wind River confluence with Columbia River; yellow pin denotes upstream extent

Located at river mile 151, the Wind River is one of eight primary CWR between Bonneville Dam and The Dalles Dam that fish use as they migrate upstream. The Wind River is 3.5 miles upstream of the next closest refuge in Herman Creek. Wind River temperatures in August are estimated to be 7˚C cooler than the Columbia River with average temperatures of 14.5°C, making the Wind River an excellent quality CWR (<16°C). Washington Department of Ecology has designated the lower portion of the Wind River as core summer salmonid habitat with a water quality criterion of 16°C for maximum water temperatures. The maximum modeled water temperature for the Wind River is 18.3°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the Lower Wind River is on the 303(d) list for temperature impaired waters.

Photo 7-29 Wind River, August 2016

The confluence of the Wind River has a large amount of sediment which has made the river mouth broader and shallower, increasing water temperatures and reducing the volume and quality of CWR habitat. This is due to a combination of anthropogenic causes, such as historical logging and natural processes. It is estimated that migrating fish use the lower 0.8 miles of the Wind River, below Shipherd Falls, as CWR (yellow pin, ***Photo 7-28***). The Wind River has the eighth largest CWR in the

Columbia River estimated at 105,220 m^3, the size of approximately 42 Olympic-sized swimming pools, with mean flows of 293 cfs. The next available CWR is 7.7 miles upstream in the Little White Salmon River.

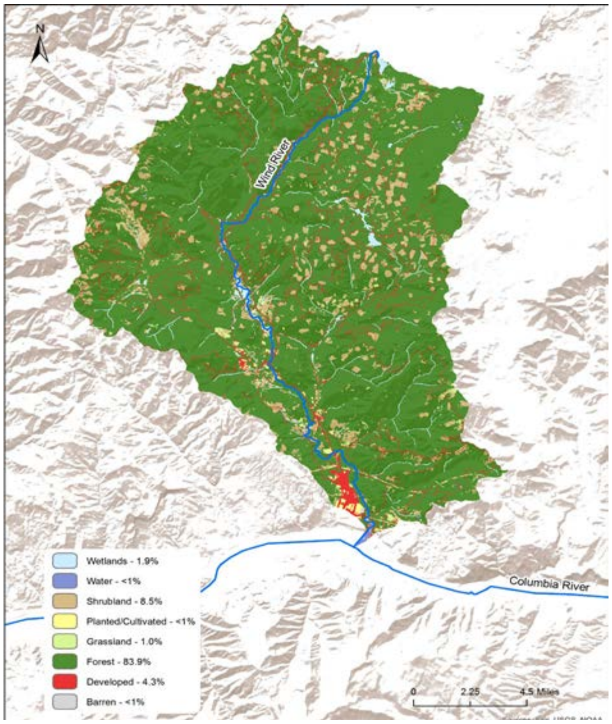


Figure 7-25 Wind River land cover

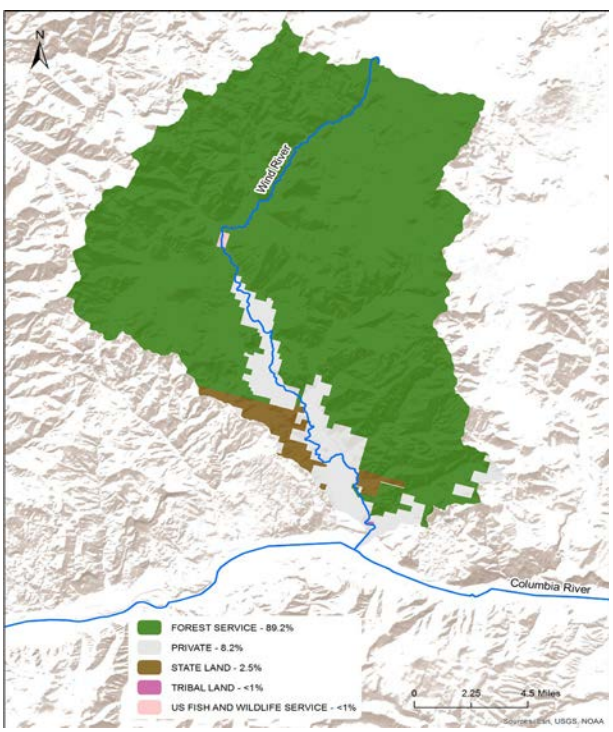


Figure 7-26 Wind River land ownership

Introduction to the Wind River Watershed

The Wind River originates in the Gifford Pinchot National Forest. Snowmelt runoff and high levels of canopy shading produce cold water temperatures. In addition, large groundwater spring inputs in Upper Trout Creek, the mainstem near Carson Hatchery, and Panther Creek contribute to the river's cold temperatures. Panther Creek, the Wind's largest tributary, joins the mainstem at river mile 4.3. Panther Creek is particularly important in keeping the lower portion of the mainstem cool during the summer due to its current cool conditions, flow, and proximity to the mouth of the Wind River. The Wind River meanders and broadens at the mouth, where it passes under State Highway 14 near Home Valley, WA, before entering the Columbia River.

The Wind River watershed is mostly forested with 90% of the land owned by the USFS, with private ownership concentrated from the Middle Wind River to its confluence with the Columbia River (***Figure 7-26***). The land cover near the mouth of the Wind River is primarily developed and de-forested (***Figure 7-25***) and has the greatest impact upon temperature and complexity of the CWR at the mouth of the Wind River.

Factors that Influence Temperature in the Wind River Watershed

Protecting and Enhancing Riparian Vegetation: The Wind River watershed has high levels of riparian shade throughout most of the watershed, especially in the upper well-forested tributaries. These are on federal, state, and private lands that are governed by the *USFS Gifford Pinchot National Forest Land and Resource Management Plan*, the Washington Department of Natural Resource's Habitat Conservation Plan, and Washington's Forest

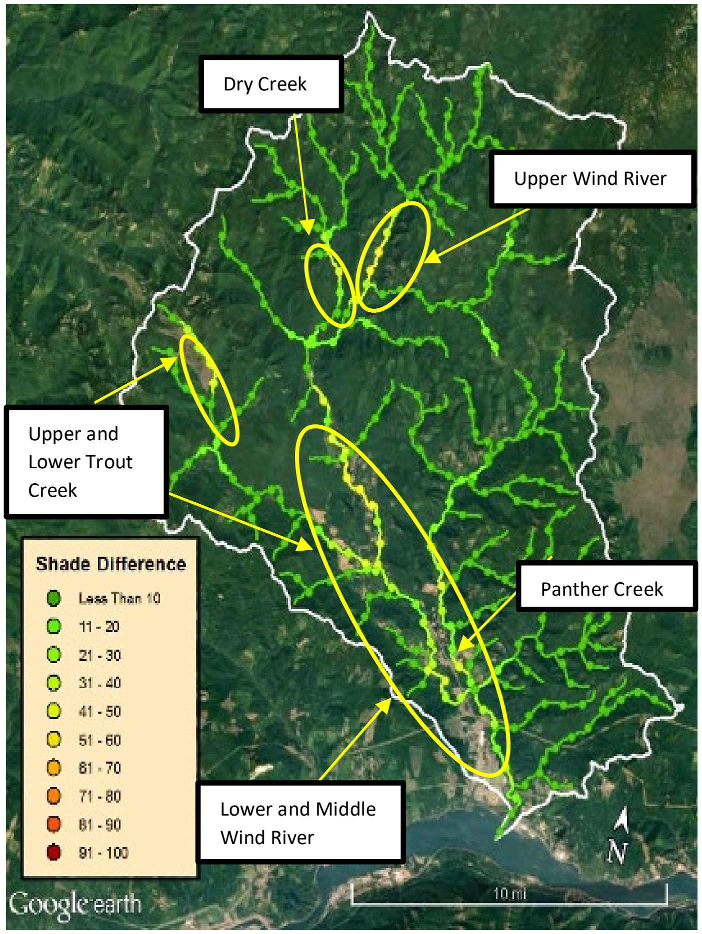


Figure 7-27 Wind River shade difference between potential maximum shade and current shade

Practice Rules, respectively. This shade serves to block solar radiation and maintain cool stream temperatures. However, there are several reaches that have been degraded and have potential for increased shade. ***Figure 7-27*** compares the shade difference between the potential maximum and current shade. Most of the watershed is at or near the maximum vegetation for shading (dark and medium green). The areas with greatest potential to increase riparian shade are the Wind River mainstem, Upper and Lower Trout Creek, and Dry Creek (yellow and light green areas). Increasing riparian vegetation above the confluence is important because cooling water temperatures upstream will transfer downstream.

Water quality modeling in Washington Department of Ecology's *Wind River Watershed Temperature TMDL* (2002) predicted that maximum potential vegetation could decrease water temperatures at the mouth from 18˚C to 14˚C under low flow conditions.

Dams and Hydromodifications: There are no dams in the Wind River watershed. Hemlock Dam on Trout Creek, located two miles upstream from the tributary's confluence with the Wind River, was removed in 2009. Since then, there have been significant improvements in habitat complexity in the former reach. Fish population data to date suggest a trend in increased adult and juvenile steelhead populations in Trout Creek relative to the rest of the watershed.

Water Use: ***Figure 7-28*** shows the water rights and availability in the Wind River watershed (WRIA 29). Water rights are heavily allocated for agricultural uses. Low flows exist in the Upper and Lower Trout Creek

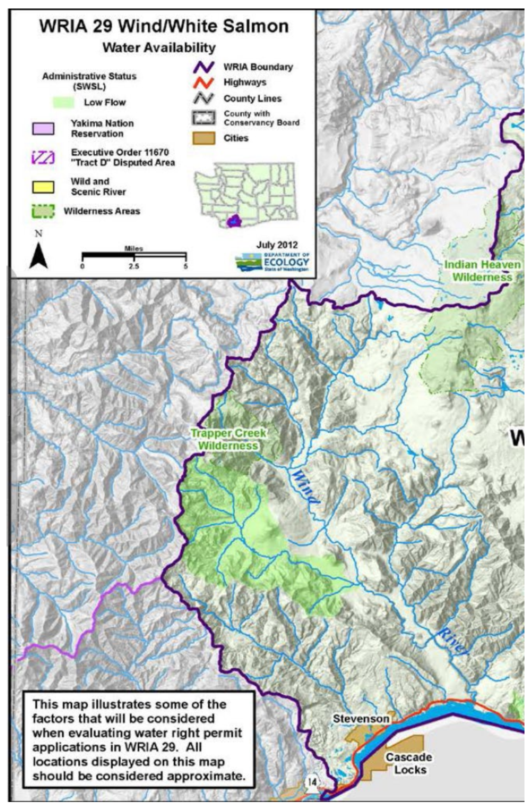


Figure 7-28 Wind River Basin – Water rights and availability, Washington Department of Ecology

and Lower and Middle Wind River. Trout Creek is designated by WDFW as a surface water source limitation area that advises Ecology to protect instream flows and restrict issuance of new water uses. Because water use is high and supply is limited, more water use may reduce the CWR plume volume and increase temperatures in the CWR.

Climate Change: In 2040, average August temperatures in the Wind River are predicted to be 16°C compared to 22°C in the Columbia River. In 2080, August temperatures in the Wind River are expected to rise further to 17°C compared to 23°C in the Columbia River. Therefore, the Wind River will change from being an excellent CWR (<16°C) to a good CWR (16-18°C), unless restoration actions such as increased riparian vegetation offset increasing water temperatures. The Wind River is still expected to be more than 6°C cooler than temperatures in the Columbia River in the summer, even under climate change projections.

Photo 7-30 Wind River looking downstream to confluence, August 2017

Ongoing Activities in the Wind River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

Ecology adopted the *Wind River Watershed Temperature TMDL* and associated implementation plan (2004) to address warm river temperatures, and in 2005 the *Watershed Management Plan for WRIA29* (including the Wind River) was adopted to guide water resource management. The 2004 TMDL implementation plan includes restoration benchmarks to measure progress. In 2010, the *Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan*, which includes the Wind subbasin, was adopted by the Lower Columbia Fish Recovery Board as an integrated plan for salmon recovery, the Northwest Power and Conservation Council fish and wildlife program, and Washington State watershed management. This plan was adopted by NMFS in 2013 as the salmon recovery plan under the ESA. More recently, detailed implementation plans have been developed that have identified and prioritized reach-scale watershed projects and specific water resource actions, which include the *Wind River Habitat Restoration Strategy* (*2017*) and the *WRIA 29a Watershed Planning Detailed Implementation Plan (2015).*

Photo 7-31 Wind River at confluence, August 2017

The lower part of the Wind River basin is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area (*2016). This plan includes "open space" land use designation and associated limits on new development and buffer restrictions for a significant portion of the Lower Wind River, which serves to help protect water quality and the Wind River CWR.

Actions in these plans align directly with actions that would benefit CWR. These include moving the boat ramp and parking area to the southeast corner of the mouth, and converting the current boat ramp and parking area to multi-threaded side channels and vegetated islands to increase complexity. Other projects include bank stabilization projects and revegetation, which would reduce erosion and sediment at the Wind River confluence and cool waters.

Actions to protect and enhance the Wind River CWR include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Washington's Forest Practice Rules on private forest lands and the Washington Department of Natural Resources' Habitat Conservation Plan on state lands to protect and restore riparian shade and stream functions to maintain cool river temperatures. (WDNR)
- On private and county lands, continue to implement the riparian protections in the Skamania County's Shoreline Master Plan, critical areas ordinance, and Columbia River Gorge National Scenic Area ordinance to regulate development in the Wind River shoreline areas to protect riparian shade and stream functions to maintain cool river temperatures. (Skamania County)
- Continue to implement riparian restoration, floodplain reconnection, and stream habitat restoration actions in the mainstem Wind River, Little Wind River, and Upper and Lower Trout Creek noted in the *Wind River Habitat Restoration Strategy (2017), Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan (2010)* and *Wind River Temperature TMDL Implementation Plan (2004)* to cool river temperatures and reduce sedimentation into the Wind River CWR. (Multiple parties)
- Conduct a sediment removal feasibility study at the mouth to enhance CWR volume and fish access.
- Consider establishing surface water source limitation areas and/or adopting instream flow rules for the Lower Wind River and Panther Creek as recommended in the *WRIA 29a Watershed Planning Detailed Implementation Plan* (2015) to help protect stream flows for fish and Wind River CWR volume. (WDFW, Ecology)
- Conduct a temperature TMDL implementation review to assess progress in meeting established restoration benchmarks along with recommendations for further actions. (Ecology)

7.10 LITTLE WHITE SALMON RIVER (RIVER MILE 158.7) – PROTECT AND ENHANCE

Refuge Volume: 1,108,661 m^3 (2nd largest)

Average August Temperature: 13.3°C

Distance to Downstream Refuge: 7.7 mi. (Wind River)

Distance to Upstream Refuge: 6.3 mi. (White Salmon River)

Cold Water Refuge Rating: Excellent (<16°C)

Photo 7-32 Little White Salmon upstream view of lower hatchery intake

Photo 7-33 Aerial view of the Little White Salmon cold water refuge; yellow pin denotes the upper boundary of the refuge

What features make the Little White Salmon River an important cold water refuge to protect and enhance?

The Little White Salmon River is located at river mile 159 and is one of eight primary CWR between Bonneville Dam and The Dalles Dam that fish use to migrate upstream. The Little White Salmon River flows into Drano Lake before entering the Columbia River and is 7.7 miles upstream of the next closest refuge in Wind River. The mean August temperature of the Little White Salmon River where it enters Drano Lake is 13°C, almost 8°C cooler than the mainstem Columbia River in August, making the Little White Salmon River an excellent quality refuge (<16˚C). The lower portion of the Little White Salmon is designated for core summer salmonid habitat by the Washington Department of Ecology with a water quality criterion of 16°C for maximum water temperatures. The maximum modeled temperature for the Little White Salmon is 15.6°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, there are reaches of the Middle and Upper Little White Salmon River upstream of Moss Creek that are on the 303(d) list for temperature impaired waters. Moss Creek near river mile 7, a particularly cold tributary, cools the Little White Salmon River by roughly 4°C in August from 12°C upstream to 8°C downstream (Appendix 20212.22).

Photo 7-34 The confluence of the Little White Salmon River via Drano Lake flowing into the Columbia River

The cooler water in the thermal refuge is primarily near the inlet of the Little White Salmon River into Drano Lake (~10°C–18°C), and at the bottom of Drano Lake (16°C–21°C), and migrating salmon are estimated to use up to 1.3 miles upstream as a refuge. Drano Lake makes the Little White Salmon River confluence the second largest CWR along the Columbia River, with a total volume of 1,108,661 m^3, approximately 443 Olympic-sized swimming pools. The Little White Salmon River has an August mean flow of 248 cfs near its confluence with Drano Lake (Appendix 12.23). Fish leaving the Little White Salmon will travel 6.3 miles upriver before encountering the White Salmon River, the next CWR.

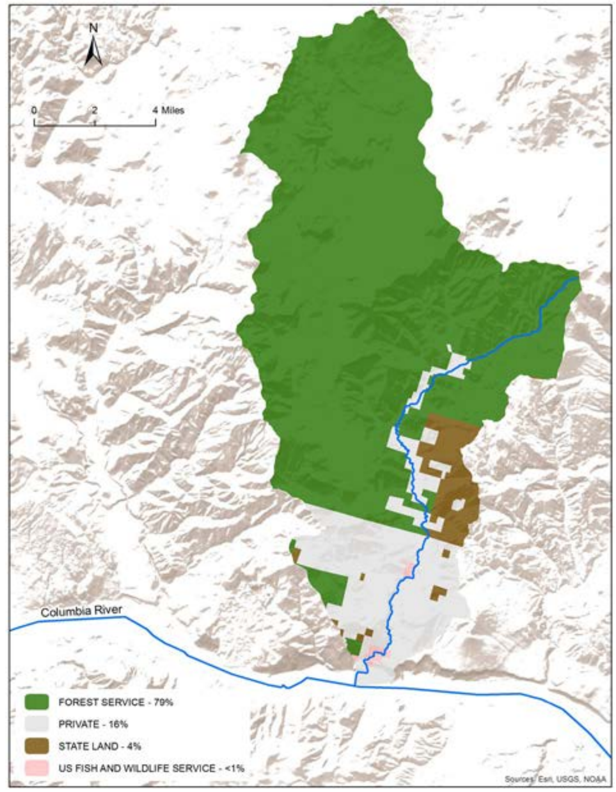


Figure 7-29 Little White Salmon River Basin land ownership

Introduction to the Little White Salmon River Watershed

The Little White Salmon River provides snow-fed water from its headwaters east of the Cascade crest to the confluence. The Gifford Pinchot National Forest makes up roughly 79% of the Little White Salmon River basin (***Figure 7-29***). The National Forest protects the watershed from urban and industrial development. The riparian forest buffers shade the snow- and groundwater-fed streams, keeping them cool as they flow toward the Columbia River. However, a legacy of timber harvesting has left lasting habitat impacts on the subbasin in the form of stream-side clear cuts and roads.

State and private lands in the Little White Salmon River subbasin are generally undeveloped. Less than 1% of the subbasin is used for traditional agriculture (***Figure 7-30***). Only 4% of the subbasin is developed land and is concentrated near the confluence, where most private lands are found. Timber management in Gifford Pinchot National Forest is the dominant land use (***Figure 7-29***, ***Figure 7-30***). The Gifford Pinchot National Forest prevents major urban development from

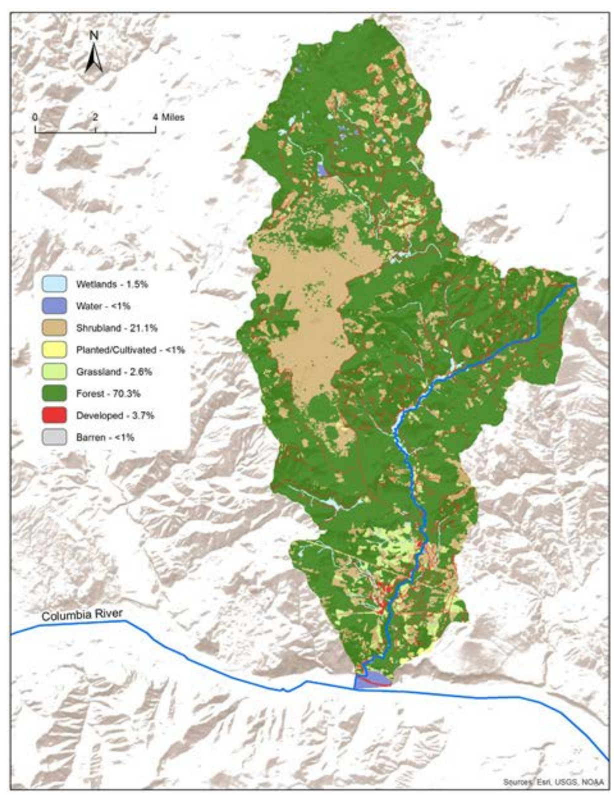


Figure 7-30 Little White Salmon River Basin land cover

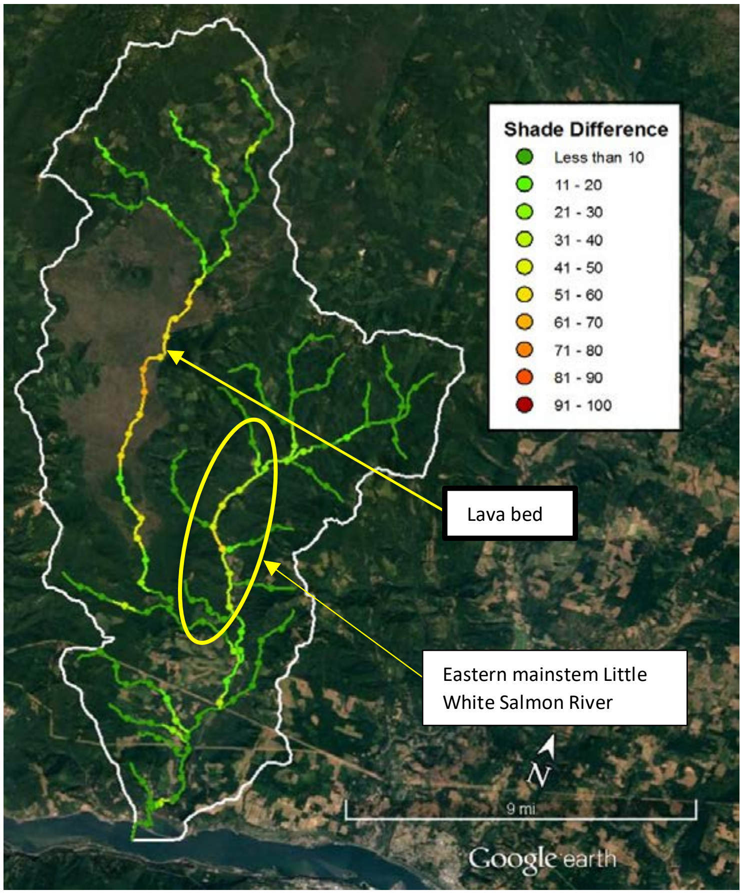


Figure 7-31 Difference between potential stream shade conditions and current stream shade

occurring throughout the subbasin. The lower part of the Little White Salmon River basin is part of the Columbia River Gorge National Scenic Area. Current land uses and associated protections will likely continue in the Little White River subbasin. The quality refuge habitat of Drano Lake makes it a popular fishing destination.

Factors that Influence Temperature in the Little White Salmon River Watershed

Protecting and Enhancing Riparian Vegetation: The Little White Salmon River watershed has high levels of riparian shade to maintain cool river temperatures, except for a few areas. Federal, state, and private lands are governed by the *USFS Gifford Pinchot National Forest Land and Resource Management Plan* (1990), the Washington Department of Natural Resource's Washington Habitat Conservation Plan, and Washington's Forest Practice Rules, respectively. ***Figure 7-31*** compares the shade difference between the potential maximum and current shade. Note the figure displays the greatest potential shade difference is located within a lava bed, where the river is subsurface, so it does not represent actual riparian shading potential. The eastern mainstem of the river has the greatest potential for restoration. Although stream shade potential difference is small, restoring riparian shade in this reach could still have a positive impact on mainstream temperatures. Overall, the Little White Salmon River is well shaded with riparian buffers. The *Gifford Pinchot Forest Land and Resource Management Plan* requires wide buffers which protect water quality from timber harvest practices by reducing the effects of erosion and sedimentation. The *Management Plan for the Columbia River Gorge National Scenic Area* (2016) includes "open space" land use designation and associated limits on new development and buffer restrictions for the Lower Little White Salmon River.

Photo 7-35 Drano Lake

Photo 7-37 Spirit Falls on the Little White Salmon River Source: https://curiousgorgeblog.wordpress.com/44-spirit-falls/

Hydromodifications: The natural hydrology of the Little White Salmon River confluence was altered by the construction of Bonneville Dam. Backwater from Bonneville Dam and the dike that supports Highway 7 spurred the formation of Drano Lake. Drano Lake backwater inundated roughly one mile of spawning habitat at the Lower Little White Salmon River and Columbia River confluence. Historically, the Little White Salmon River provided primary spawning habitat for salmonids up to river mile 3 where Spirit Falls serves as a natural fish barrier. Although inundation led to significant spawning habitat loss, Chinook and steelhead can use the cool water of Drano Lake and the lower reach of the Little White Salmon River as CWR during their migration up the Columbia River.

The Little White Salmon River has a unique geological feature, Big Lava Bed, that covers 16,000 acres in the upper western subbasin. Lava Creek descends into the lava bed, then reappears downstream, cooling the river as the stream flows underground. This geological feature is one of the reasons the Little White Salmon River provides such cold water to the confluence at Drano Lake.

Photo 7-36 View of the Lower Little White Salmon River above Drano Lake

Water Use: The Little White Salmon River is located within the Wind-White Salmon Water Resource Inventory Area 29. The Washington Department of Ecology's Water Resource Explorer indicates that many water diversions exist along the river, although water is considered available for out of stream uses. The largest certified use of water is to the U.S. Fish and Wildlife Service for the Willard and Little White Salmon National Fish Hatchery. Each of these hatcheries withdraw about 55 cfs for use, but the water is returned to the river. Maintaining water flows is important to keeping high CWR volume and cold water temperatures in the summer.

Climate Change: In 2040, average August temperatures in the Little White Salmon River are predicted to be 15°C compared to 22°C in the Columbia River. In 2080, August temperatures in the Little White Salmon River are expected to rise further to 16°C compared to 23°C in the Columbia River. Therefore, the Little White Salmon River will change from being an excellent CWR (<16°C) to a good CWR (16-18°C), unless restoration actions such as increased riparian vegetation offset increasing water temperatures. The Little White Salmon River is still expected to be more than 7°C cooler than temperatures in the Columbia River in the summer, even under climate change projections.

Ongoing Activities in the Little White Salmon River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

In 2010, the *Washington Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan*, which includes the Little White Salmon subbasin, was adopted by the Lower Columbia Fish Recovery Board as an integrated plan for salmon recovery, the Northwest Power and Conservation Council Fish and Wildlife Program, and Washington State watershed management. This plan was adopted by NMFS in 2013 as the salmon recovery plan under the ESA. The subbasin plan was developed in a partnership between the Lower Columbia Fish Recovery Board, NPCC, federal agencies, state agencies, tribal nations, local governments, and others.

Historically, due to natural barriers at Spirit Falls, there was limited use of the Upper Little White Salmon River Basin by salmonids. Therefore, the Little White Salmon River serves a small role in contributing to salmon recovery objectives due to the very limited available spawning habitat in the lower river. However, due to its cold water, the Little White Salmon River is used for anadromous salmon production in the hatcheries.

The subbasin plan provides for broader watershed recovery. The Little White River subbasin plan identified the lower and middle mainstem as priority areas to improve habitat connectivity, forest practices related to sediment, riparian vegetation, and floodplain function. These restoration efforts will benefit habitat in these areas and contribute to maintaining cool river temperatures that provide CWR in the lower river and Drano Lake. However, the current implementation status of the subbasin restoration activities is unknown.

The *Watershed Management Plan for WRIA 29* (2005) and associated *WRIA 29 Watershed Planning Detailed Implementation Plan* (2015) adopted by Skamania County provides recommendations to Ecology for water resources in the Lower Cowlitz River. The recommendations include reservations for future use and adoption of an instream flow rule for the Little White Salmon River for long-term protection of fish uses.

Ongoing protection through current plans and restoring riparian and watershed conditions in the basin will maintain and enhance its importance as refuge habitat for migrating salmonid species. Actions to protect and enhance the Little White Salmon River CWR include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Washington's Forest Practice Rules on private forest lands and the Washington Department of Natural Resources' Habitat Conservation Plan on state lands to protect and restore riparian shade and stream functions to maintain cool river temperatures. (WDNR)
- On private and county lands, continue to implement the riparian protections in the Skamania County's Shoreline Master Plan, critical areas ordinance, and Columbia River George National Scenic Area ordinance to regulate development in the Little White River shoreline areas to protect riparian shade and stream functions to maintain cool river temperatures. (Skamania County)

- In addition to riparian restoration actions in the forest plans noted above, implement riparian restoration on private lands in the middle mainstem of the Little White Salmon River as identified in the *Lower Columbia Salmon Recovery and Fish and Wildlife Plan* (2010) to cool river temperatures. (Multiple parties)
- Consider establishing surface water source limitation areas and/or adopting instream flow rules for the Lower Little White Salmon River near Cook as recommended in the *WRIA 29a Watershed Planning Detailed Implementation Plan* (2015) to help protect stream flows for fish and Little White Salmon River CWR volume. (WDFW, Ecology)
- Apply antidegradation requirements to limit temperature increases associated with any proposed thermal discharges into the Little White Salmon River. (Ecology)

7.11 WHITE SALMON RIVER (RIVER MILE 165) – PROTECT AND ENHANCE

Photo 7-38 Upstream view of the White Salmon River

Refuge Volume: 153,529 m^3 (7^{th} largest)

Average August Temperature: 15.7°C

Distance to Downstream Refuge: 6.3 mi. (Little White Salmon River)

Distance to Upstream Refuge: 1 mi. (Hood River)

Cold Water Refuge Rating: Excellent (<16°C)

What features make the White Salmon River an important Cold Water Refuge to protect and enhance?

Located at river mile 165, the White Salmon River is one of eight primary CWR between Bonneville Dam and The Dalles Dam that fish use to migrate upstream. The White Salmon River is 6.3 miles upstream of the next closest refuge at the Little White Salmon River. Average water temperatures in the White Salmon River in August are roughly 15.7°C, 5.5°C cooler than the Columbia River. This feature makes the White Salmon River an excellent CWR (<16°C). The Washington Department of Ecology designates the lower portion of the White Salmon River for core summer salmonid habitat and has assigned a water quality criterion of 16°C for maximum water temperatures. The maximum modeled temperature for the White Salmon River is 19.6°C (1993-2011) (Appendix 12.18). However, based on measured maximum temperature readings, the lower White Salmon River is not on the 303(d) list for temperature impaired waters except for a segment at the confluence which is currently listed as impaired. This impairment appears to be influenced by the Columbia River.

Photo 7-39 Aerial view of the White Salmon River cold water refuge; yellow pin denotes upstream extent

Photo 7-40 Upstream of the White Salmon River confluence with the Columbia River

Migrating Chinook and steelhead are estimated to use the lower 1.3 miles of the White Salmon River as a CWR (yellow pin, ***Photo 7-39***). The cold water refuge has a volume of roughly 153,529 m^3, the equivalent of 39 Olympic-sized swimming pools, and mean flows of

715 cfs, making the White Salmon River confluence the seventh largest CWR identified on the Lower Columbia River. The next available CWR is one mile upstream in the Hood River.

Introduction to the White Salmon River Watershed

With headwaters in the Gifford Pinchot National Forest, the White Salmon River watershed drains glaciers on the southwest flank of Mount Adams. The mainstem flows south for 44 miles before emptying into the Columbia River directly across from the City of Hood River, Oregon. Portions of the mainstem are designated as Wild and Scenic and managed by the USFS and Klickitat County, and the river is a popular destination for commercial and recreational activities including fishing, kayaking, and rafting. Major tributaries include Trout Lake, Buck Creek, Mill Creek, Dry Creek, Gilmer Creek, and Rattlesnake Creek. The river remains cool throughout the year due to snowmelt runoff and contributions from groundwater. Groundwater recharge provides an estimated 200 cfs or more of baseflow to the river throughout the year, with the largest contribution occurring between June and September when precipitation averages below 2 inches per month.

The Gifford Pinchot National Forest, managed by the USFS, protects the slopes of Mount Adams in the upper watershed and composes nearly half of the basin's land area (48%). The lower portion of the basin is a mix of private and state-owned land (***Figure 7-32***). The White Salmon River basin is largely forested (66%), with developed (5%) and cultivated lands (3%) along riparian areas south of Trout Lake to the Columbia River confluence. The lower three miles of the river are part of the Columbia River Gorge National Scenic Area. Road networks exist throughout the watershed, but the most heavily developed areas surround the

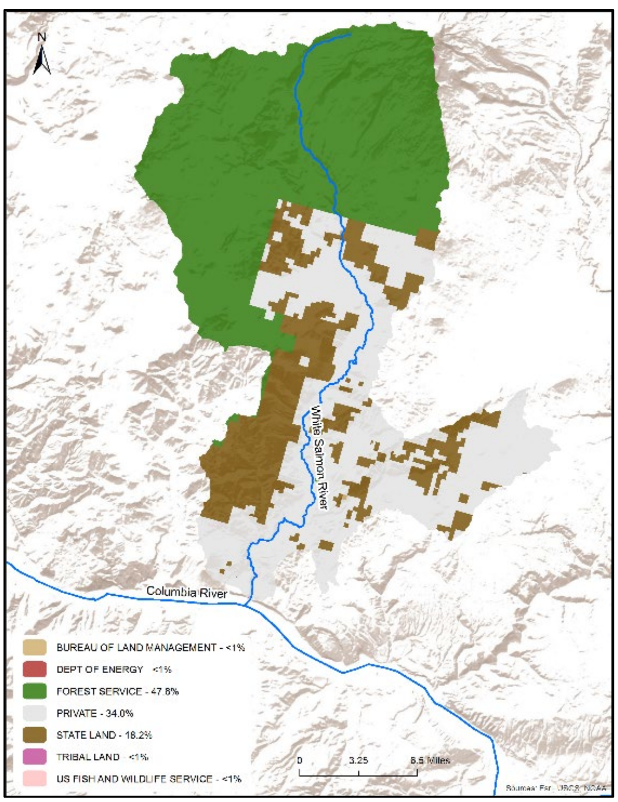


Figure 7-33 White Salmon River Basin land ownership

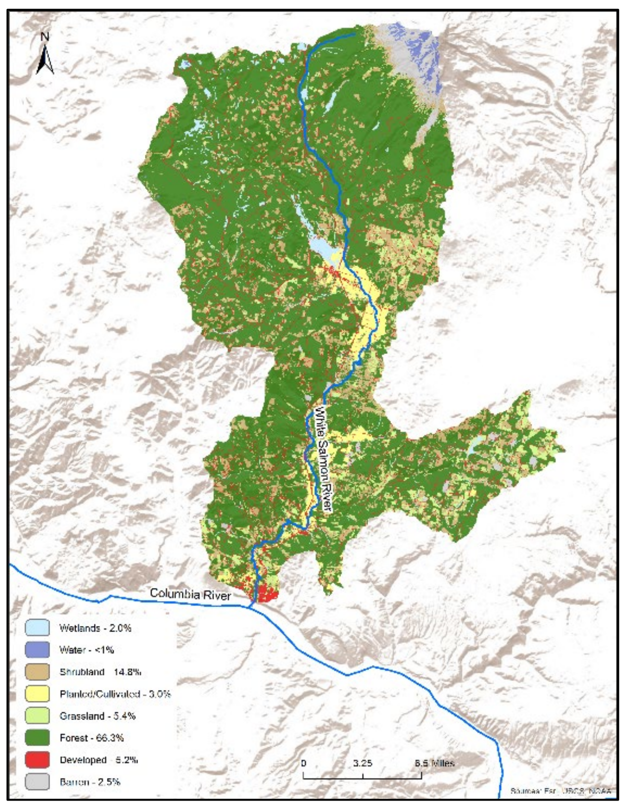


Figure 7-32 White Salmon River Basin land cover

Photo 7-41 White Salmon River confluence before and after the removal of the Condit Dam; USGS, U.S. Department of Interior, 2015

unincorporated community of Underwood near the river's confluence with the mainstem Columbia River.

Factors that Influence Temperature in the White Salmon River Watershed

Protecting and Enhancing Riparian Vegetation: The White Salmon River watershed has high levels of riparian shade throughout most of the watershed, except for some areas mostly on private land. Federal lands are governed by the *USFS Gifford Pinchot National Forest Land and Resource Management Plan* (1990) in the upper watershed. State and private forest lands in the middle and lower watershed are governed by the Washington Department of Natural Resource's Washington Habitat Conservation Plan and the Washington's Forest Practice Rules, respectively. ***Figure 7-34*** highlights the difference between current and potential maximum shade. The yellow, orange, and red river segments reflect the areas with the most potential for enhancing riparian cover (***Figure 7-34***). There is some potential for enhancing riparian vegetation along the mainstem segments and tributaries around and south of the Trout Lake Creek confluence, and in segments of the Rattlesnake Creek tributary in the southeastern area of the subbasin. The largest potential for restoration is in the eastern portion of the mid-basin where there is a high proportion of agricultural or pastureland (circled, ***Figure 7-34***).

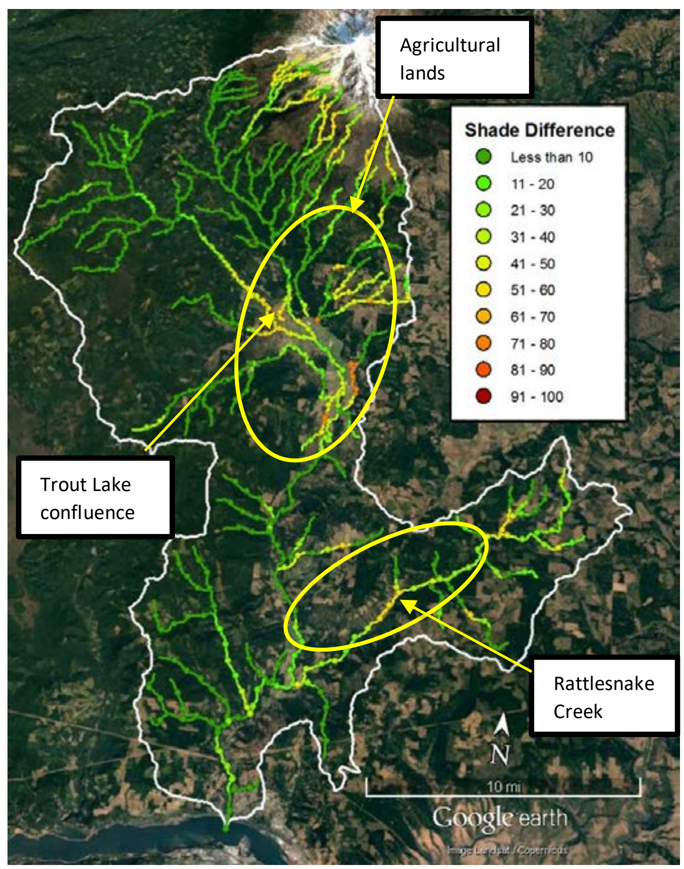


Figure 7-34 White Salmon River shade difference potential maximum and current shade

Hydromodifications: Currently, there are no dams in the White Salmon River. The most significant hydromodifications on the White Salmon River relate to the removal (2012) of Condit Dam at river mile 3.4, which reestablished salmon and steelhead access to historical habitat in the basin. The initial breaching of the dam was rapid, resulting in short-term damage to salmonid and aquatic life, as large amounts of sediment were flushed downstream. Conditions have since settled and improved. Much of the built-up sediment previously trapped behind the dam settled downstream near the

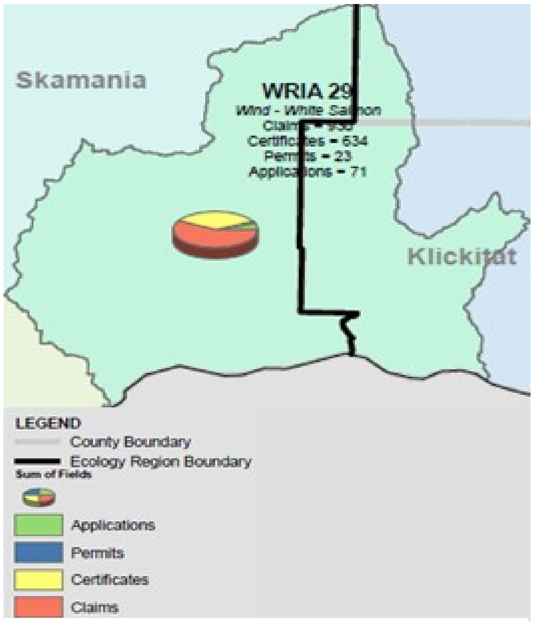


Photo 7-42 Water rights in the Wind-White Salmon, December 2016 (Washington Department of Ecology)

Columbia River confluence. This resulted in the formation of a new beach line at the confluence, reducing the average depth and total volume of the CWR used by salmon at the confluence plume. Confluence conditions are dynamic; gravel banks continue to shift and expand in the lower stem during high flow events.

Water Use: Water rights for the White Salmon River basin are managed under Washington WRIA 29, which includes the Wind River and Little White Salmon River to the west. There are no existing instream flow rules (water rights to protect fish). There is a need for more water use data to determine the risk and protection needs in the subbasin. Maintaining water flows is important to keeping high CWR volume and cold water temperatures in the summer.

Climate Change: In 2040, average August temperatures in the White Salmon River are predicted to be 17°C compared to 23°C in the Columbia River. In 2080, August temperatures in the White Salmon River are expected to rise further to 18°C compared to 24°C in the Columbia River. Therefore, the White Salmon River is expected to be a good CWR (16-18°C), even under climate change projections. The White Salmon River is still expected to be more than 6°C cooler than temperatures in the Columbia River in the summer.

Ongoing Activities in the White Salmon River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

The removal of Condit Dam resulted in an increase in restoration projects and initiatives to protect returning salmonid populations and their spawning and rearing habitats. Along with the Wild and Scenic River land designation protections, these initiatives align with many of the same best practices to protect and enhance the confluence as a CWR. Goals for Wild and Scenic Rivers include keeping rivers "largely primitive and [their] shorelines undisturbed," which aligns with CWR goals of reduced sedimentation and the preservation of riparian vegetation.

Photo 7-43 West side of the confluence with the Columbia River with emerging sediment delta

The Yakama Nation, Klickitat County, and Washington Department of Fish and Wildlife were the lead entities in the development of the *White Salmon Subbasin Plan (2004)* adopted by the Northwest Power and Conservation Council. Building on this effort, NMFS finalized the *ESA Recovery Plan for the White Salmon River Subbasin* (2013). These plans identify Rattlesnake Creek and Indian Creek, which are on the state's 303(d) list as impaired for water temperature, as priority areas to improve riparian conditions and stream complexity to reduce water temperatures and improve habitat. Restoring riparian habitat and shade along the previous reservoir behind Condit Dam (Northwestern Lake) and along the agricultural land near Trout Lake are other opportunities to cool the river.

The site of the Underwood Indian Village was inundated by sediments after the removal of the Condit Dam, limiting fishery access for Columbia River Treaty Tribes. Yakama Nation Fisheries conducted a restoration project in 2018 to manage the sediment delta that formed at the White Salmon/Columbia River confluence. This project included dredging the navigation channel and using the dredge material to build islands to minimize shallow nearshore habitats near the confluence and restore habitat for juvenile salmonids.

The lower part of the White Salmon River basin is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). This plan includes “open space” land use designation and associated limits on new development and buffer restrictions for a significant portion of the lower White Salmon River, which serves to help protect water quality and the White Salmon River CWR.

White Salmon River from River Mile 12.7 at Gilmer Creek to River Mile 5 at the head of the former Northwestern Lake is designated a wild and scenic area. The *Lower White Salmon Wild and Scenic River Management Plan* (1991) calls for many actions including maintaining or enhancing riparian habitat within and outside of a 200-foot buffer, preventing development that would have a serious adverse effect on water quality, and establishing instream flows.

Actions to protect and enhance the White Salmon River CWR include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Washington’s Forest Practice Rules on private forest lands and the Washington Department of Natural Resources’ Habitat Conservation Plan on state lands to protect and restore riparian shade and stream functions to maintain cool river temperatures. (WDNR)
- Continue to implement the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) open space land use designation and riparian protections along the White Salmon River shoreline areas to protect riparian shade and stream functions to maintain cool river temperatures. (Columbia River Gorge Commission and Skamania County)
- On private and county lands, continue to implement the riparian protections in the *Klickitat County Shoreline Master Plan* (1998) to protect riparian shade and stream functions to maintain cool river temperatures, and update the plan to meet state requirements. (Klickitat County)
- Continue to implement actions in the *Lower White Salmon Wild and Scenic River Management Plan* (1991) to protect riparian shade and stream functions and land uses to maintain cool river flows and temperatures. (USFS, Klickitat County, and others)
- Restore riparian vegetation to reduce water temperatures in Rattlesnake Creek and Indian Creek and along the previous Northwest Lake location on the White Salmon River

as identified in the *ESA Recovery Plan for the White Salmon River Subbasin* (2013) to help maintain cool temperatures in the White Salmon CWR. The White Salmon River around Trout Lake may also have potential for riparian restoration for increased shade and cooler river temperatures. (Multiple parties)

- Consider establishing surface water source limitation areas and/or adopting instream flow rules for the White Salmon River as recommended in the *Lower White Salmon Wild and Scenic River Management Plan* (1991) to help protect stream flows for fish, recreation, and White Salmon River CWR volume. (WDFW, Ecology)
- Assess residual sediment impacts to CWR from the 2012 Condit Dam removal and to CWR volume and temperature. Continue conducting excess sediment removal feasibility studies at the mouth of the White Salmon River to preserve CWR volume and temperatures.
- Apply antidegradation requirements to limit temperature increases associated with any proposed thermal discharges into the Little White Salmon River. (Ecology)

7.12 HOOD RIVER (RIVER MILE 166) – PROTECT AND ENHANCE

Refuge Volume: 28,000 m^3 (12th largest)

Average August Temperature: 15.5°C

Distance to Downstream Refuge: 1 mi. (White Salmon River)

Distance to Upstream Refuge: 11 mi. (Klickitat River)

Cold Water Refuge Rating: Excellent (<16°C)

Photo 7-44 Hood River

What features make the Hood River an important cold water refuge to protect and enhance?

Photo 7-45 Aerial view of Hood River at the confluence with Columbia River; yellow pin denotes upstream extent

Located at river mile 166 of the Columbia River, the Hood River is approximately halfway between the Bonneville Dam and Dalles Dam. It is located one mile upstream from the White Salmon River, the next downstream refuge. Hood River temperatures in August average 15.5°C, 6°C cooler than the Columbia River. This classifies the Hood River an excellent CWR (<16°C). However, the large sand bar at the confluence, channelization in the lower Hood River, and relatively low depth (~0.8 meters) in the summer may present barriers to salmon using the Hood River as a refuge. Additionally, a fish monitoring station near the mouth of the Hood River detected few out-of-basin steelhead (10-15 annually) migrating upstream of the station between 2010-2015. For that reason, only the mouth of the Hood River is included as a CWR (***Photo 7-45***).

Photo 7-46 Middle Fork of the Hood River

The lower portion of the Hood River is designated by ODEQ as core cold water habitat with an assigned water quality criterion of 16°C for maximum water temperatures. The maximum modeled temperature for the Hood River is 19.1°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower Hood River is on the 303(d) list for temperature impaired waters. The Hood River is the eleventh largest CWR in the Lower Columbia River with a cold water plume volume of 28,000 m^3, or 11 Olympic-sized swimming pools, and mean flows of 374 cfs. The next available CWR is 11 miles upstream in the Klickitat River.

Introduction to the Hood River Watershed

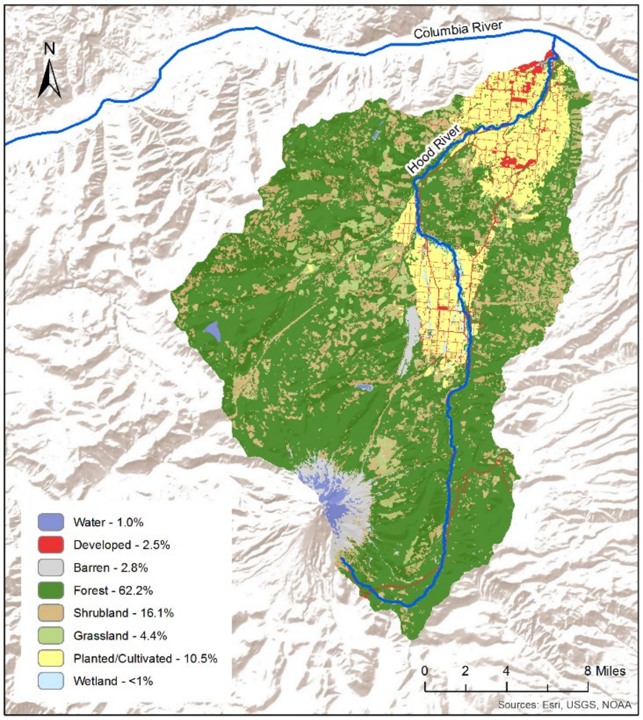


Figure 7-35 Hood River land cover

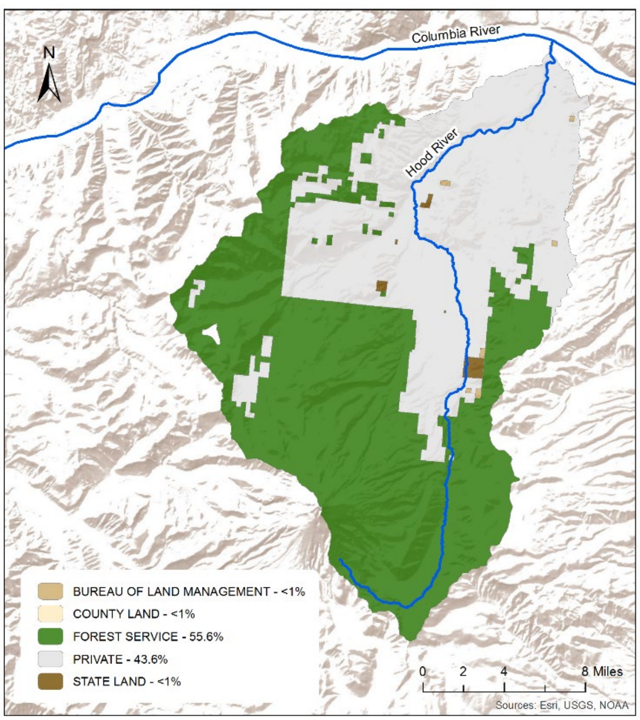


Figure 7-36 Hood River land ownership

The Hood River watershed drains the snow-laden eastern flank of Mount Hood and the land to the north of the volcano. Three major tributaries, the East, West, and Middle Forks, cascade down from the mountainous headwaters. The longest tributary, East Fork, drains Mount Hood Meadows ski and snowboard resort and flows east and then north, collecting Dog River and the Middle Fork before meeting the West Fork near the small unincorporated community of Dee, Oregon, approximately 11 miles south of the City of Hood River, the only significant urban development in the basin. Above this confluence, the East Fork is considered the mainstem Hood River.

Protected as part of the Mount Hood National Forest, much of the upper basin retains natural land cover, contributing to high levels of riparian shading. Approximately 60% of the basin is forested; shrubland (16%) is found in fragments throughout the watershed, and cultivated crops (11%) predominate on flat topography south of Hood River and surrounding Dee. USFS owns and manages 56% of the watershed, with the remaining 44% privately owned (***Figure 7-36***). The City of Hood River, located at the confluence of the Hood and Columbia Rivers, has the largest population in the watershed. In the past, the Hood River delta and lowlands were flooded during the construction of Bonneville Dam. Currently, the mouth of Hood River is channelized. The mouth of the Hood River is in the Hood River Urban Area of the Columbia River Gorge Scenic Area and is managed by the City of Hood River and the Port of Hood River.

Factors that Influence Temperature in the Hood River Watershed

Protecting and Enhancing Riparian Vegetation

Although much of the Hood River watershed is well-shaded to maintain cool river temperatures, there are several developed river reaches that have lost much of their riparian shade. ***Figure 7-37*** displays the difference between potential maximum and current shade conditions, helping to identify reaches in the Middle and Lower Hood River that could be restored to provide more riparian shade where high levels of development and agriculture occur. On average, shading from riparian conditions could be improved by 37% to cool temperatures at the confluence. Areas with the most potential for riparian shade include Indian Creek, Odell Creek, Neal Creek, and the East Fork Hood River Creek. Water quality modeling in ODEQ's *Western Hood Subbasin TMDL* (2001) predicted maximum potential vegetation and a minimum instream flow of 250 cfs from Powerdale Dam could decrease maximum water temperatures at the mouth from 18˚C to 15˚C.

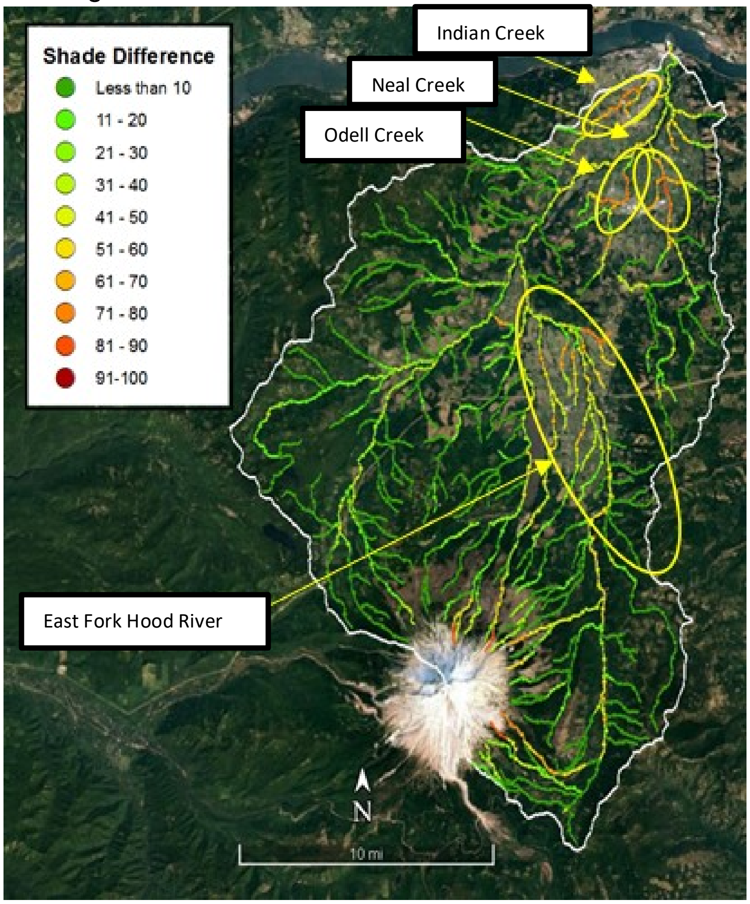


Figure 7-37 Hood River shade difference between potential maximum and current shade

Dams and Hydromodifications: In the past, Powerdale Dam, located on river mile 4.5 of the Hood River, withdrew a significant amount of water that affected the water quality and quantity downstream in a 3-mile bypass reach. In 2010, the Powerdale Dam was decommissioned. Although there are no permanent flow and temperature gauges since Powerdale Dam was removed, the updated *2018 Western Hood Subbasin TMDL* projected that temperatures would decrease with increased flows in the lower 4.5 miles of the Hood River. A small hydroelectric dam on Odell Creek was removed in 2016, which has expanded the time for resident salmonid spawning. The dam on Clear Branch, a tributary to the Middle Fork Hood River, raises temperatures downstream of the reservoir during

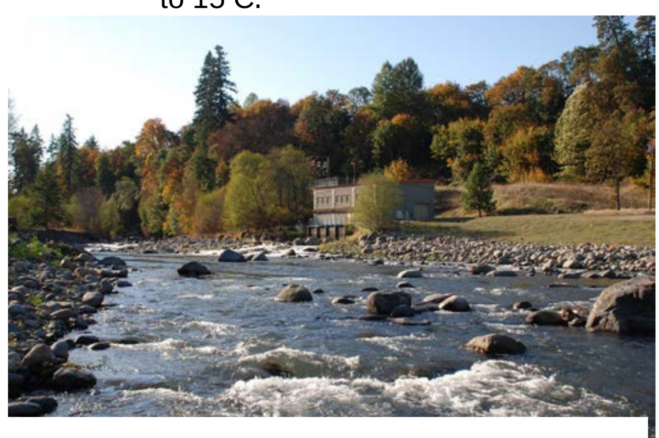


Photo 7-47 Hood River at the site of the former Powerdale Dam

most of the summer. The Confederated Tribes of the Warm Springs Reservation also operates and manages a fish hatchery on the Middle Fork Hood River.

Water Use: Irrigation is the dominant water use, and there are past and ongoing efforts to improve the efficiency of irrigating crops to reduce water demand, decrease agricultural runoff, and increase flow in streams. The three primary irrigation districts are: Farmer's Irrigation District (FID), Middle Fork Irrigation District (MFID), and East Fork Irrigation District (EFID). MFID operates the Clear Branch Dam for irrigation. EFID has the largest water withdrawals for irrigation. ***Figure 7-38***, from the *2006 USFS Mount Hood National Forest Aquatic Habitat Restoration Strategy*, shows the large amount of diversions throughout the basin, especially the lower Hood River. ***Photo 7-47*** Hood River at the site of the former Powerdale Dam***Photo 7-47*** also shows the now-decommissioned Powerdale Dam. In 2016, the

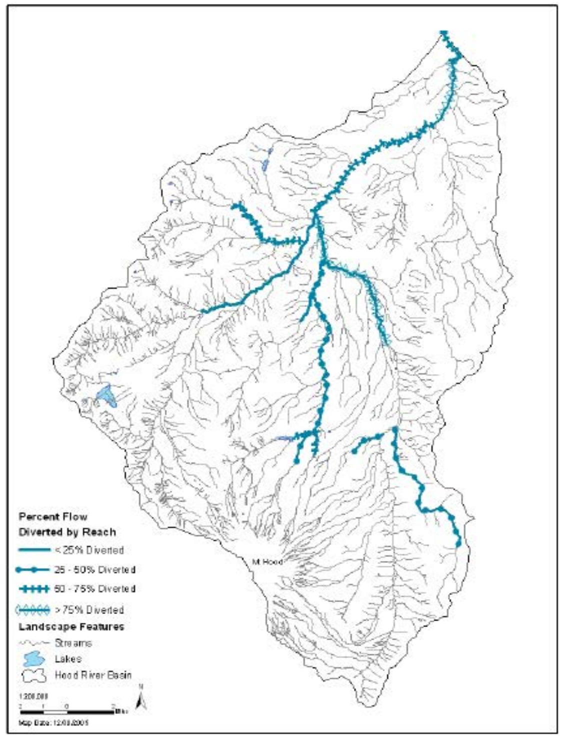


Figure 7-38 Estimated flow diversions in the Hood River Basin in 2006

Hood River Soil and Water Conservation District published the *Hood River Water Conservation Strategy*, a report developed with the agricultural community to evaluate different alternatives to reduce water usage. ***Table 7-5*** shows that the Hood River is overallocated during the summer months at river mile 0.75. ODFW applied for and was granted instream water rights (ISWRs) to protect fish at several locations in the basin in different years. ISWRs function like all water rights, and are junior to any earlier water rights. ISWRs provide targets for the flows needed to support fish, wildlife, their habitats and recreation. In 1966, 1983, and 1998, ODWR approved three ISWRs on Hood River at river mile 4.5 (former Powerdale Dam) to the mouth at 45, 100, and 250 cfs, respectively, in August. There were 18 ISWRs on tributaries to the Hood River granted from 1966 to 2016,

Table 7-5 Water Availability Analysis, 5/20/20 Hood River at river mile 0.75, 5/23/18, Oregon Water Resources Department

HOOD R > COLUMBIA R – AT RM 0.75 (@ 80% exceedance)			
Month	Monthly Streamflow (cfs)		
	Natural Streamflow	Water Allocated or Reserved	% Allocated*
JUNE	745	1,069	144%
JULY	588	1,031	175%
AUGUST	457	989	216%
SEPTEMBER	438	918	210%
Top Users: Other (68%), Irrigation (21%)			
*% Allocated: [Water Allocated or Reserved]/[Natural Streamflow]. This is the percentage of water either allocated or reserved for in-stream or other uses compared with the natural streamflow. Percentages over 100% indicate the water is overallocated at the mouth of the river.			
Reference: https://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=30410575&exlevel=80&scenario_id=1			

including on the West Fork Hood River (summer range: 100-255 cfs), East Fork Hood River (summer range: 75-210 cfs), and Middle Fork Hood River (summer range: 10-233 cfs). These ISWRs serve to help maintain existing flows, although senior water holders primarily for irrigation can still diminish flows below these levels in low flow years. Therefore, improving irrigation water efficiency will increase the water quality and quantity for resident and migratory fish in the tributaries and mouth of the Hood River.

Climate Change: In 2040, August temperatures in the Hood River are projected to rise to 16°C, compared to 23°C in the Columbia River. In 2080, August temperatures in the Hood River are expected to rise to 17°C compared to 24°C in the Columbia River. Therefore, increases in Hood River temperatures are expected to keep the Hood River as a good CWR (16-18°C). Still, the Hood River is expected to be more than 7°C cooler than temperatures in the Columbia River in the summer, even under climate change projections.

Ongoing Activities in the Hood River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

The existing watershed plans with targeted actions and partnerships provide a solid foundation for protecting and improving conditions in the basin and at the confluence. In 2004, the Hood River Soil and Water Conservation District completed the *Hood River Subbasin Plan*, a comprehensive review of the watershed with prioritized actions identified by many stakeholders in the basin, which was adopted by the Northwest Power and Conservation Council. In 2014, the Hood River Watershed Group updated the subbasin plan and published the *Hood River Watershed Action Plan (2014)*, which provides a list of new projects to be implemented over several years. In 2006, the USFS completed the *Hood River Aquatic Habitat Restoration Strategy,* which targets the lower watershed for greater riparian cover and increased flows. In 2016, the Soil and Water Conservation District released a study on water conservation and efficiency, *Hood River Water Conservation Strategy*. ODEQ updated its *Western Hood Basin TMDL* in 2018, retaining the riparian shade targets from the 2001 TMDL. Numerous other plans have been developed targeting efforts on USFS lands, more efficient water use, reduction of pesticide use and runoff, improvement of fish passage and habitat, among other plans. The Confederated Tribes of Warms Springs has worked extensively in the basin conducting monitoring and restoration projects. Many recommendations in these plans will benefit the downstream CWR area. Increased riparian vegetation on agricultural land will reduce pesticide runoff and shade streams, helping improve water quality.

The lower part of the Hood River basin is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). This plan includes “open space” land use designation and associated limits on new development and buffer restrictions for a significant portion of the lower Hood River, which serves to help protect water quality and the Hood River CWR.

Actions to protect and enhance the Hood River CWR include:

- On national forest lands, continue to implement aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments, and the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)

- Continue to implement Oregon's Forest Practices Act on private forest lands in the watershed to protect and restore riparian shade and stream functions to maintain cool river temperatures. (ODF)
- On private and county lands, continue to implement the riparian protections in the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) through the county Scenic Area ordinance to regulate development in the lower Hood River watershed to protect riparian shade and stream functions to maintain cool river temperatures. (Hood River County)
- Restore riparian vegetation in the Hood River basin including Indian Creek, Neal Creek, Odell Creek, and the area of the decommissioned Powerdale Dam (**Photo 7-47**) as identified in the *Western Hood Basin TMDL* (2001, 2018), *Hood River Aquatic Habitat Restoration Strategy* (2006), and the *Hood River Watershed Action Plan* (2014).
- Continue implementing water efficiency projects to maintain and increase flows in the Hood River basin noted in the *Hood River Basin Water Conservation Strategy* (2016). (Multiple parties)
- Increase the amount of instream large woody debris to create pools of cold water and trap sediment that would otherwise reach the river mouth. (Multiple parties)
- Support education and outreach opportunities for habitat and riparian restoration on privately-owned properties in Hood River watershed plans. (Multiple parties)

7.13 KLICKITAT RIVER (RIVER MILE 177) – PROTECT AND ENHANCE

Photo 7-48 Klickitat River near the confluence with the Columbia River

Refuge Volume: 222,029 m^3 (5th largest)

Average August Temperature: 16.4°C

Distance to Downstream Refuge: 11 mi. (Hood River)

Distance to Upstream Refuge: 24 mi. (Deschutes River)

Cold Water Refuge Rating: Good (16-18°C)

Photo 7-49 Aerial view of Klickitat River confluence with Columbia River; yellow pin denotes upstream extent.

What features make the Klickitat River an important cold water refuge to protect and enhance?

The Klickitat River is located at river mile 177 of the Columbia River. It is one of the first tributaries migrating salmon encounter east of the Cascades. The Klickitat River is eleven miles upstream of the CWR in the Hood River. Average August temperatures in the Klickitat River are estimated to be 16.4°C, approximately 5°C cooler than the Columbia River. This classifies the Klickitat River as a good CWR (16-18°C). With mean flows of 851 cfs and lower temperatures relative to the Columbia River, migrating fish to use the confluence and approximately 1.8 miles of stream in the Klickitat River as a CWR (yellow pin, ***Photo 7-49***).

Photo 7-50 Klickitat River, upstream of confluence

The lower portion of the Klickitat River is designated as core summer salmonid habitat by Washington Department of Ecology, which assigns a water quality criterion of 16°C for maximum water temperatures. The maximum modeled temperature for the Klickitat River is 20.5°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower Klickitat River is on the 303(d) list for temperature impaired waters. The Klickitat River has the fifth largest CWR in the

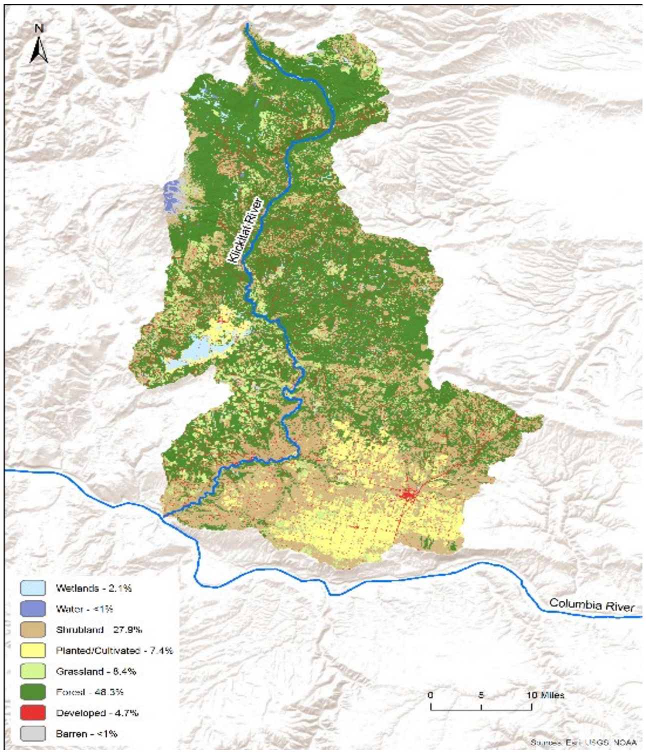


Figure 7-39 Klickitat River land cover

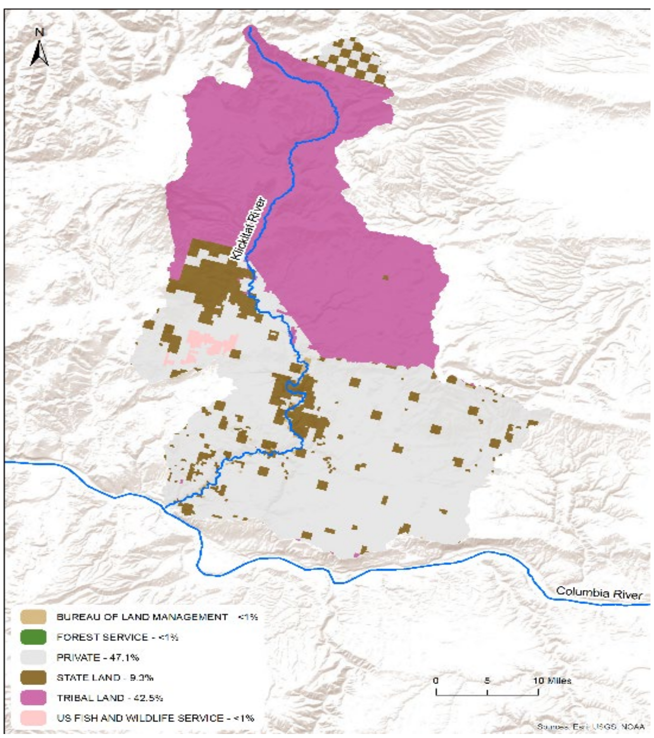


Figure 7-40 Klickitat ownership

Columbia River with a flow of 851 cfs and volume estimated at 222,029 m^3, the size of approximately 89 Olympic-sized swimming pools. The next available CWR is 24 miles upstream in the Deschutes River.

Introduction to the Klickitat River Watershed

The Klickitat River originates from snowmelt off Gilbert Peak on the Yakama Indian Reservation. The river flows south, collecting water from the eastern slopes of Mount Adams and drains the Lincoln Plateau before cutting through steep canyons on its way to the Columbia River near Lyle, WA. Snowmelt runoff and the underlying volcanic basalt rock that create groundwater pools recharge the Klickitat River and provide cool water to the river throughout the summer.

The Klickitat River watershed is semi-arid with a mix of land uses. Forested lands cover nearly half the basin (48%), primarily in the upper watershed (***Figure 7-39***). Shrubland (28%) is found in fragments throughout the basin and along the lower mainstem Klickitat River. Grasslands are interspersed throughout the upper basin (8%), and planted/cultivated lands (7%) surround the small community of Centerville, WA, the patch of developed land (5%) in the southeast of the basin.

The Yakama Nation owns and manages most of the upper watershed (42%), including the largest extent of forested areas. The lower half of the watershed is mostly privately owned (47%) with a mix of forested, shrubland, planted/cultivated land, and developed areas. State lands make up 9% of the watershed; the Bureau of Land Management, USFS, and U.S. Fish and Wildlife Service each manage small (<1%) portions of the basin (***Figure 7-40***). The lower 10 miles of the Klickitat River have federal Wild and Scenic designations. The mouth and lower Klickitat River are located within the Columbia River Gorge National Scenic Area.

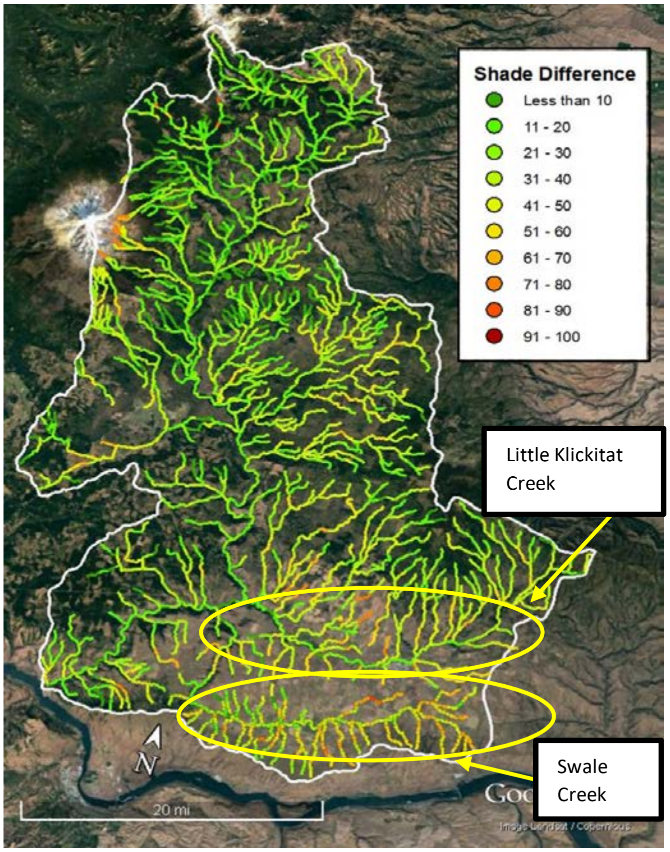


Figure 7-41 Klickitat River shade difference between potential maximum and current shade

Factors that Influence Temperature in the Klickitat River Watershed

Protecting and Enhancing Riparian Vegetation:

Tributaries to the Klickitat River have relatively higher shade levels than the mainstem Klickitat River. The lower and mid-mainstem are shaded because of canyons along the Klickitat River. ***Figure 7-41*** compares the riparian shade differences between the potential maximum and current shade. Swale Creek is impacted by floodplain filling, grading, and bank armoring associated with railroad construction, which has increased erosion and decreased the amount of vegetation. Little Klickitat Creek has the most potential for increased shading in the Klickitat Watershed. Water quality modeling in Washington Department of Ecology's *Little Klickitat River Watershed Temperature TMDL* (2002) concluded that potential maximum vegetation and reduced width-to-depth ratios could decrease temperatures at the mouth from 23°C to 21.5°C under average flow conditions.

Dams and Hydromodifications: There are no dams in the mainstem Klickitat River. Lyle Falls is a series of five cascades at river mile 2.2. The creation of the Bonneville Pool altered the conditions at the mouth. Before the construction of the Bonneville Dam, historic aerial photos of the confluence show a multi-thread channel with expansive cottonwood. Today, the Klickitat River is confined to a straight, simplified channel that lacks the complexity of the natural confluence.

Water Use: Water availability is limited in the watershed, both in the Upper Klickitat River, within the Yakama Nation tribal boundaries, and in the lower portions. WDFW has recommended a surface water source limitation for Swale Creek and in certain areas of the Little Klickitat watershed, where Washington Department of Ecology can condition or deny new water rights permits. ***Figure 7-42*** shows that Little Klickitat, Mill

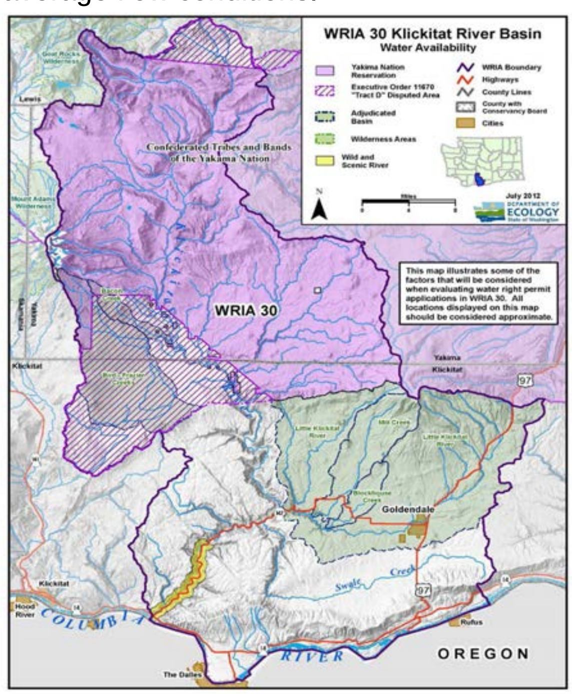


Figure 7-42 Water Availability in WRIA 30 (Washington Department of Ecology, Revised 2012)

Creek, and Blockhouse Creek Basins are "adjudicated basins," which means that water right disputes may be resolved in courts. Basins with past adjudications typically indicate that little water is available for new permits. Because water use is high and supply is limited, more water use may reduce the CWR plume volume and increase temperatures in the CWR.

Photo 7-51 Klickitat River sandbar into Columbia River

Climate Change: In 2040, average August temperatures in the Klickitat River are predicted to be 18°C compared to 23°C in the Columbia River. In 2080, August temperatures in the Klickitat River are expected to rise further to 19°C compared to 24°C in the Columbia River. Therefore, the Klickitat River will change from being a good CWR (16-18°C) to a marginal CWR (>18°C), unless restoration actions such as riparian vegetation and increased water flows offset increasing water temperatures. The Klickitat River is still expected to be more than 5°C cooler than temperatures in the Columbia River in the summer, even under climate change projections.

Photo 7-52 Basalt in Klickitat River

Ongoing Activities in the Klickitat River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

The Klickitat River watershed has been studied by many entities in the watershed. The Yakama Nation, Klickitat County, and Washington Department of Fish and Wildlife were the lead entities in the development of the *Klickitat Subbasin Plan (2004)* adopted by the Northwest Power and Conservation Council. Building from this Plan, NMFS adopted the *Middle Columbia River Steelhead Recovery Plan* (2009), which includes a salmon recovery plan for the Klickitat River. Klickitat County, City of Goldendale, and the Klickitat County Public Utility District completed the *Watershed Management Plan (2005)*, which addresses water quantity, quality, and fish habitat outside Yakama Indian Reservation boundaries. Yakama Nation's *Klickitat Watershed Enhancement Project (KWEP)* includes past and ongoing projects to restore, enhance, and protect aquatic habitats in the Klickitat Basin. The *Klickitat Lead Entity Salmon Recovery Strategy* (2013) is a non-regulatory document describing the vision for salmonid habitat recovery and protection and was led by the Klickitat County Natural Resources Department with involvement from Eastern and Central Klickitat Conservation Districts, Underwood Conservation District, Yakama Nation, environmental, sport fishing, timber interests, USGS, and NMFS. Ecology's *Little Klickitat Watershed Temperature TMDL (2002)*, *Little Klickitat River Watershed Temperature TMDL Detailed Implementation Plan (2005)*, and the *Riparian Vegetation Assessment, Little Klickitat River and Swale Creek* (2009) highlight the need for increased riparian protections to cool river temperatures. The focus of these projects is to restore stream processes and improve habitat conditions and water quality. Completed projects include restoration of fish passage, meadows restoration, forest road management, floodplain reconnection, wood replenishment, and side channel reconnection. These actions in the lower watershed directly align with and benefit CWR. Studies in the Little Klickitat River also identified locations and actions to reduce river temperatures and restore thermal complexity that align with the goal of reducing temperatures in the lower Klickitat River.

The lower part of the Klickitat River basin is part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). This plan includes "open space" land use designation and associated limits on new development and buffer restrictions for a significant portion of the lower Klickitat River, which serves to help protect water quality and the Klickitat River CWR.

The USFS *Lower Klickitat River Wild and Scenic Management Plan Final Environmental Impact Statement* (1991) addresses the lower 10.8 miles of the Klickitat River and calls for many actions including maintaining or enhancing riparian habitat within and outside of a 200-foot buffer, preventing development that would have a serious adverse effect on water quality, and establishing instream flows. The *Klickitat County Shoreline Master Plan* (1998) requires riparian protections from development activities in the basin, and the county is currently amending the plan.

Actions to protect and enhance the Klickitat River CWR include:

- Continue to implement projects on and off Yakama Indian Reservation boundaries in the Klickitat Water Enhancement Project. (Yakama Nation)
- Continue to implement Washington's Forest Practice Rules on private forest lands and the Washington Department of Natural Resources' Habitat Conservation Plan on state lands to protect and restore riparian shade and stream functions to maintain cool river temperatures. (WDNR)
- Continue to implement the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) to regulate development in the Klickitat River shoreline areas to protect riparian shade and stream functions to maintain cool river temperatures. (Columbia River Gorge Commission, USFS)
- On private and county lands, continue to implement the riparian protections in the *Klickitat County Shoreline Master Plan* (1998) to protect riparian shade and stream functions to maintain cool river temperatures, and update the plan to meet state requirements. (Klickitat County)
- Consider adopting an instream flow rule or surface water source limitation the Lower Klickitat River as recommended in the *Lower Klickitat River Wild and Scenic Management Plan (1991)* to help protect stream flows for fish, recreation, and Wind River CWR volume. Consider establishing a surface water source limitation and/or adopt instream flow rules for Swale Creek to help protect stream flows for fish and Klickitat River CWR volume. (Ecology, WDFW)
- Continue to implement projects identified in the *Klickitat Lead Entity Salmon Recovery Strategy* (2018) and through the KWEP that restore stream processes, including increasing large woody debris, channel complexity, and floodplain reconnection on the mainstem Klickitat River, Little Klickitat River, and Swale Creek to maintain riparian shade and stream functions to maintain cool river temperatures. (Multiple parties)

- Continue to implement projects in the *Little Klickitat River Watershed Temperature TMDL Detailed Implementation Plan (2005)* and *Riparian Vegetation Assessment, Little Klickitat River and Swale Creek* (2009), including increasing riparian shade and implementing restoration projects to improve stream functions and floodplain reconnection and to maintain cool water temperatures. (Multiple parties)
- Support education and outreach about grant and tax benefits for habitat and riparian restoration on privately-owned properties to maintain cool water temperatures. (Multiple parties)
- Continue to maintain or increase flows in the Klickitat River through flow conservation, water quantity trading, and minimum instream flows in the summer to maintain CWR volumes. (Multiple parties)

7.14 FIFTEENMILE CREEK (RIVER MILE 188.9) – RESTORE

Photo 7-53 Looking downstream from the confluence with The Dalles Dam in the background

Refuge Volume: N/A

Average August Temperature: 19.15°C

Distance to Downstream Refuge: 11.9 mi. (Klickitat River)

Distance to Upstream Refuge: 12.1 mi (Deschutes River)

Cold Water Refuge Rating: Marginal (>18°C)

What features make Fifteenmile Creek a potential cold water refuge to restore?

Entering the Columbia River at river mile 188.9 immediately downstream of The Dalles dam, Fifteenmile Creek is in the drier, eastern end of the Columbia River Gorge. It is located twelve miles upstream of the CWR in the Klickitat River. Average August water temperatures in Fifteenmile Creek are estimated to be 19°C, approximately 2°C colder than the Columbia River. Currently, an annual August stream flow of 4 cfs and relatively high stream temperatures prevent Fifteenmile Creek from serving as a CWR for migrating salmonids. If restored, Fifteenmile Creek could serve as an additional refuge for migrating salmonids.

Photo 7-54 Flow of Fifteenmile Creek into the Columbia River in August, 2017; the water pooled below is backwater from the Columbia River

The lower portion of Fifteenmile Creek is designated for salmon and trout rearing and migration with an assigned water quality criterion of 18°C for maximum water temperatures. The maximum modeled temperature for Fifteenmile Creek is 26°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower portion of Fifteenmile Creek is on the 303(d) list for temperature impaired waters. Migrating salmonids will need to travel twelve miles upstream before reaching the next CWR in the Deschutes River.

Introduction to the Fifteenmile Creek Watershed

Fifteenmile Creek originates from Senecal Spring in the eastern foothills of Mount Hood. The creek flows in a northeast direction before making a large bend to the west prior to joining the mainstem Columbia River. Its primary tributaries include Eightmile Creek, Dry Creek, Fivemile Creek, Ramsey Creek, and Larch Creek.

The Fifteenmile Creek basin is dominated by private landownership (>85%). A portion of the Mount Hood National Forest managed by the USFS, the only federally-owned land in the watershed, covers the forested slopes of the upper basin, and composes 15% of the basin (***Figure 7-43***). Although USFS land is harvested for timber, land management practices are designed to minimize impacts on streams by conserving headwaters and associated riparian buffers.

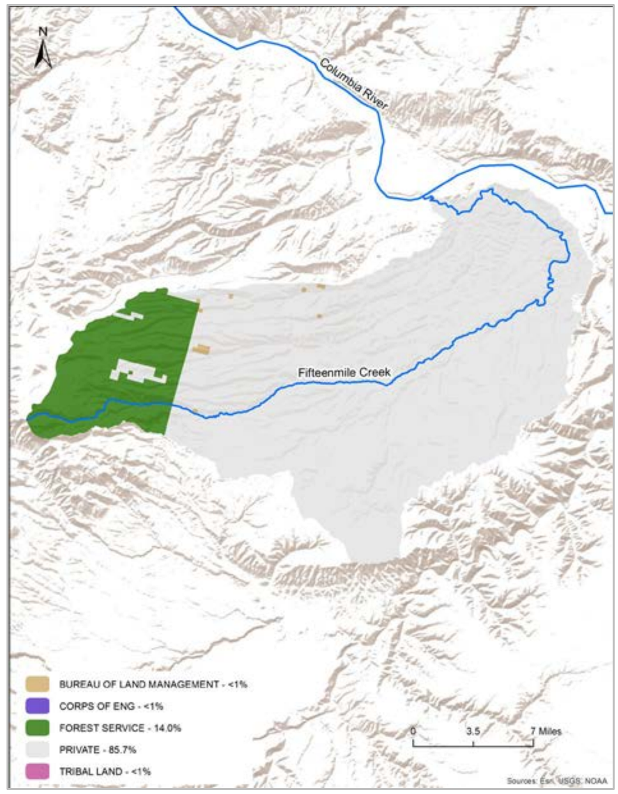


Figure 7-43 Fifteenmile Creek land ownership

Forested lands (18%) are confined to the higher elevation slopes and narrow riparian corridors bordering tributaries in the upper watershed (***Figure 7-44***). Fragmented patches of grasslands (6%) can be found in the upper basin as well. In the lower, flatter, and more arid portions of the basin, shrubland (47%) and cultivated crops (27%) predominate. The watershed's only developed land (3%) is concentrated near the creek mouth in the eastern end of The Dalles, and the small community of Dufur in the middle of the watershed.

Fed by snowmelt runoff and groundwater contributions, Fifteenmile Creek could potentially deliver cold water down to the confluence, providing additional CWR for migrating salmonids with continued water quantity and riparian habitat restoration. However, agriculture is vital to the local economy, valued at roughly $22 million per year. Agricultural land types here include orchards, vineyards, and pasture. Primary agricultural products include wheat, cattle, and cherries.

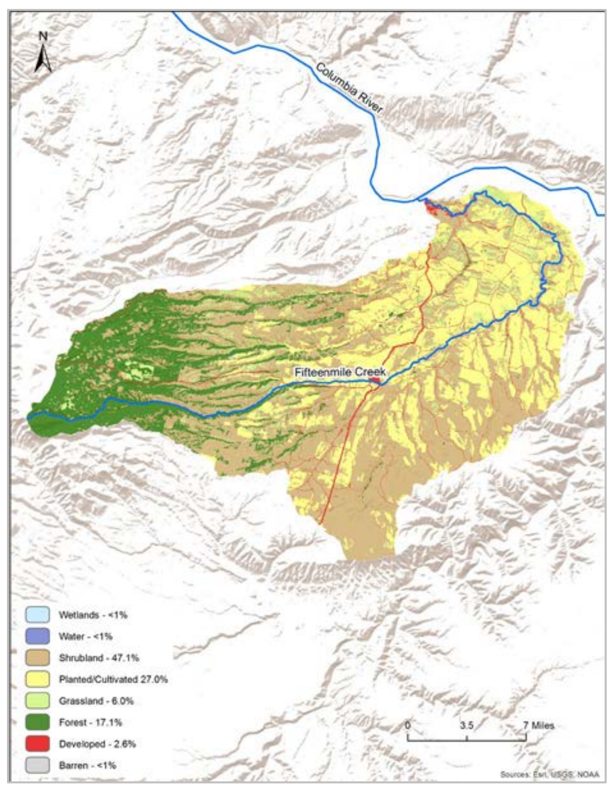


Figure 7-44 Fifteenmile Creek land cover

Factors that Influence Temperature in the Fifteenmile Creek Watershed

Riparian Vegetation: There is a substantial area for additional riparian vegetation restoration in the lower watershed along the tributary streams and creeks on the mainstem (***Figure 7-45***). The lower watershed was widely denuded for use as agricultural land.

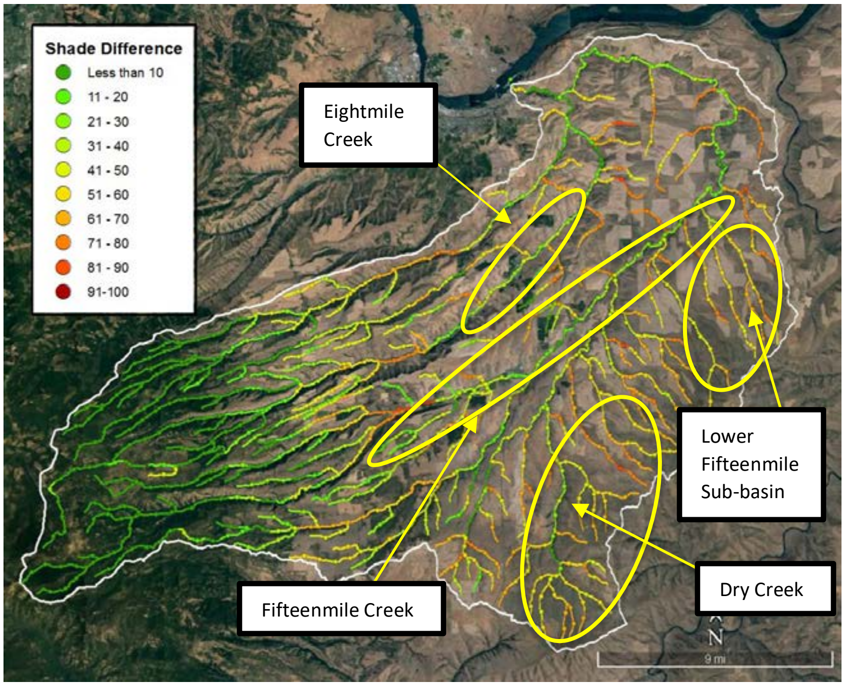


Figure 7-45 Fifteenmile Creek shade difference between potential maximum and current shade

Figure 7-45 highlights areas with potential for substantial restoration on the finger tributaries that contribute to the mainstem. These areas include the Lower Fifteenmile subbasin, Eightmile Creek, and small tributaries of Dry Creek. There is also potential for restoration on the southeast portion of the subbasin. The conversion of riparian areas to agricultural lands has resulted in the removal of tall grasses and small trees. Water quality modeling in ODEQ's *Middle Columbia-Hood (Miles Creek) Subbasin TMDL* (2008) predicted that maximum potential vegetation and increased flows could decrease water temperatures at the mouth from 25˚C to 18˚C under low flow conditions, a significant decrease.

Hydromodifications: Stream channels have been modified via road crossings, diversions, dikes, ditches, etc. to develop farmland, accommodate roads, and protect infrastructure. There are significant surface water alterations to accommodate agricultural irrigation in the subbasin. These modifications alter the hydrologic connectivity to the floodplain and intensify streambank erosion. Historical modeling indicates that flows were likely naturally low in the basin, so additional water withdrawals and diversions during the critical summer period can have an exacerbated effect. There are several aquifers in the Fifteenmile Creek drainage basin. Groundwater levels are declining. Despite the unknowns regarding groundwater-surface water connections, it is clear that these decline rates can be reduced by improving well construction and reducing pumping through cooperative agreements.

Water Use: Consumptive water right use is highest in July. Watermasters are limited in their regulatory authority, as they can only regulate based on priority date of the water right and not on protection of water quality or species. Of the ten 6th order watersheds within the basin, three - Middle Eightmile, Lower Fifteenmile, and Upper Eightmile - have 75% or more of the instream flow diverted. Information to better understand the connective hydrodynamics between authorized underground pumping and Fifteenmile Creek will inform the sustainability of pumping and may impact the Watermaster's decision making.

Climate Change: Like the other cold water tributaries, average August temperatures in Fifteenmile Creek are predicted to increase approximately 1.5°C in 2040 for a temperature of 20.7°C, compared to 23°C in the Columbia River. In 2080, August temperatures in Fifteenmile Creek are expected to rise further to 21.7°C, compared to almost 24°C in the Columbia River.

Ongoing Activities in the Fifteenmile Creek Watershed and Recommended Actions to Restore the Cold Water Refuge

The *2004 Fifteenmile Subbasin Plan* developed for Northwest Power and Conservation Council by the Fifteenmile Coordinating Group (including, but not limited to, Confederated Tribes of Warm Springs, Wasco County Soil and Water Conservation District, NMFS, ODEQ, ODFW, OWRD, and USFS) highlights the need for continued collaboration and the importance of cross-leveraging funds to implement best management practices and priority restoration projects. The plan promotes a restoration philosophy to protect the remaining high quality, productive aquatic habitats in the basin, which is typically the most effective and least costly approach long-term. Other plans include USFS's *Fifteen Mile Creek Basin Aquatic Habitat Restoration Strategy* (2010), *Middle Columbia-Hood (Miles Creek) TMDL,* and Wasco County Soil and Water Conservation District's *Fifteenmile Watershed Assessment* (2003). ODFW's *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment* (2010) as part of NMFS' *Middle Columbia Steelhead ESA Recovery Plan* (2009) identified Fifteenmile Creek as important for steelhead populations. As a result, many agencies have focused restoration actions in Fifteenmile Creek. Because of these efforts and the potential to reduce temperatures, EPA included Fifteenmile Creek as a CWR to be restored.

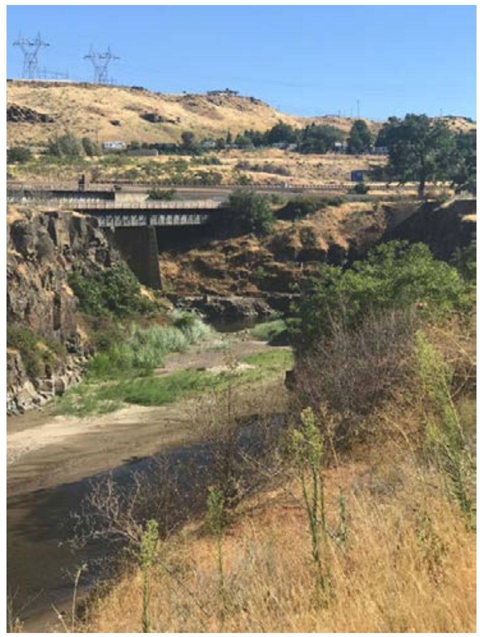


Photo 7-55 Looking upstream from the confluence toward the Fifteenmile Creek flow

Restoring habitat along riparian areas and restoring flow are both important to reestablish Fifteenmile Creek as a CWR. Groundwater decline can be reduced through improved well construction and reduction of pumping through cooperative agreements. The Wasco County Soil and Water Conservation District manages a program, Fifteenmile Action to Stabilize Temperature (FAST), based on predictive modeling that alerts local irrigators to alter their practices when temperatures are lethal for salmon and steelhead at two or more sites for two or more days. It also provides financial compensation to irrigators for their participation in the program. The Fifteenmile Watershed Council spurred work to install new gauges to improve the understanding of flow throughout the basin and increase the ability to regulate water withdrawals.

Actions to further restore Fifteenmile Creek include:

- On national forest lands, continue to implement the aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and its amendments to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)
- Continue to implement Oregon's Forest Practices Act on private forest lands in the watershed to protect and restore riparian shade and stream functions to maintain cool river temperatures. (ODF)

- On private and county lands, continue to implement the riparian protections in the *Management Plan for the Columbia River Gorge National Scenic Area* (2016) through the county Scenic Area ordinance to regulate development in the lower Fifteenmile Creek watershed to protect riparian shade and stream functions to maintain cool river temperatures. (Wasco County)
- Continue partnerships to purchase or lease in-stream water rights during critical periods for salmonids. (Multiple parties)
- Promote and fund irrigation efficiency activities and equipment to adaptively manage practices when temperatures rise. (Multiple parties)
- Improve channel connectivity with floodplains and side-channels as noted in salmon recovery plans and the *Fifteen Mile Creek Basin Aquatic Habitat Restoration Strategy* (2010). (Multiple parties)
- Restore riparian buffers and maintain the riparian restoration work done in previous years as noted in the *Fifteen Mile Creek Basin Aquatic Habitat Restoration Strategy* (2010), *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment* (2010), and *Middle Columbia-Hood (Miles Creek) TMDL* (2008). (Multiple parties)
- Encourage private landowners to enter riparian buffer programs. Fund fencing projects for pasture lands near riparian areas to minimize the impacts of grazing. (Multiple parties)
- Refer to the *Fifteenmile Subbasin Plan* (2004) to focus restoration efforts on priority areas identified by the locally-vetted prioritization method. (Multiple parties)

7.15 DESCHUTES RIVER (RIVER MILE 201) – PROTECT AND ENHANCE

Refuge Volume: 880,124 m^3 (3rd largest)

Average August Temperature: 19.2°C

Distance to Downstream Refuge: 24 mi. (Klickitat River)

Distance to Upstream Refuge: No Upstream Refuge before Snake River

Cold Water Refuge Rating: Marginal (>18°C)

Photo 7-56 Deschutes River, directly upstream of its confluence with the Columbia River

Photo 7-57 Aerial view of the Deschutes River; the upstream boundary of the cold water refuge is demarcated by the yellow pin

What features make the Deschutes River an important cold water refuge to protect and enhance?

The Deschutes River joins the Columbia River at river mile 201, approximately 24 miles upstream of Klickitat River, the closest downstream refuge. In August, the mouth of the Deschutes River averages 19°C, typically about 2°C colder than the Columbia River in August. Because migrating salmon and steelhead are more vulnerable in temperatures above 18°C, the Deschutes confluence is a marginal quality CWR (>18°C) (See ***Figure 2-20***). The lower portion of the Deschutes River is designated for salmon and trout rearing and migration by ODEQ, which assigns a water quality criterion of 18°C for maximum water temperatures. The maximum modeled temperature for the Deschutes River is 26.9°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower Deschutes River, as well as a number of tributaries, is on Oregon's 303(d) list as impaired for temperature.

The average August volume of the CWR at the mouth of the Deschutes River is 880,124 m^3, and the average flow is 4,772 cfs. This makes the Deschutes River one of the largest CWR in the Lower Columbia River system, with a plume approximately the size of 352 Olympic-sized swimming pools. A PIT-tag receiver at the mouth of the Deschutes River and radio-tag studies

Photo 7-58 Lower Deschutes River, viewed from the west bank

have documented extensive use of the lower 3.2 miles of the river for cold water use by salmon and steelhead (yellow pin, ***Photo 7-57***). The Deschutes River is the last significant CWR before the confluence with the Snake River.

Introduction to the Deschutes River Watershed

Photo 7-59 Moody Rapids, approximately 1 km upstream of the confluence

The Deschutes River watershed is the second largest river drainage system in Oregon, flowing through the eastern, more arid, side of the Cascades. The Deschutes River and its tributaries are fed by large amounts of precipitation, mostly snow, coming from the Cascade Mountains. This amounts to more than 100 inches annually, while additional sources of precipitation come from the Ochoco Mountains (40 inches), and lower central areas (10 inches). The Deschutes River's large flow and relatively cooler water results in an observable plume of cold water at the confluence with the Columbia River. The Deschutes River has one major hydroelectric complex, the Pelton Round Butte Hydroelectric Project, which forms Lake Billy Chinook approximately 100 miles upstream of its confluence with the Columbia River. The Upper Deschutes, Crooked, and Metolius Rivers each flow into Lake Billy Chinook. The Metolius River is heavily groundwater fed and provides cool summer flows into Lake Billy Chinook.

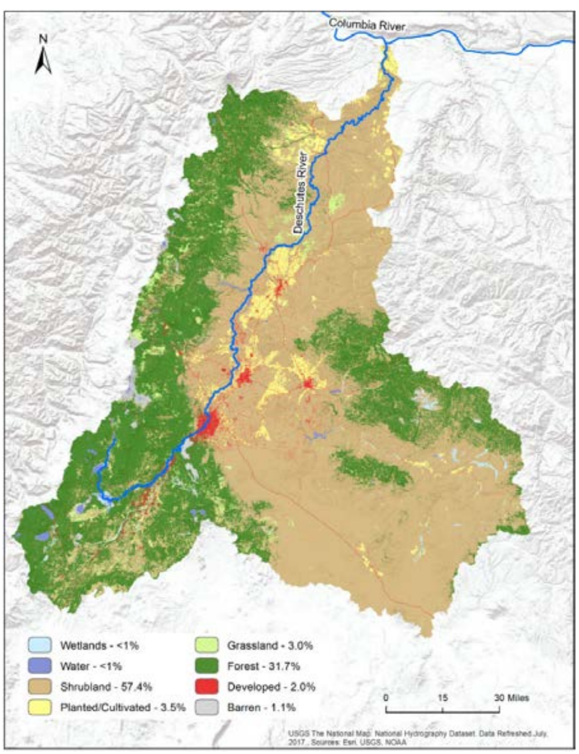


Figure 7-46 Land cover in the Deschutes Basin

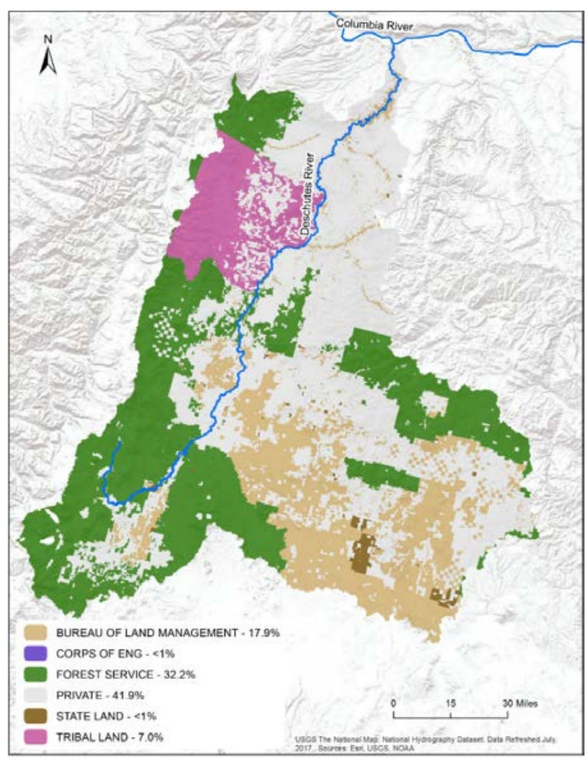


Figure 7-47 Land ownership in the Deschutes Basin

Just over half of the Deschutes River drainage area consists of shrubland (57%), in addition to moderate amounts of forested area located mostly near the headwaters (32%) (***Figure 7-46***). The top two landowners/managers in the Deschutes River drainage area are private landowners (42%) and the USFS (32%). Tribal land comprises 7% of land ownership. The Bureau of Land Management manages about 18% of the land in the watershed, some adjacent to the lower Deschutes River, and the majority of which is in the Crooked River watershed above the Pelton Round Butte Project (***Figure 7-47***). In the Deschutes River watershed, degradation has occurred through livestock use, forestry and agricultural practices, invasion by western juniper, and water storage and diversions. Degradation from urbanization in the Bend, Prineville, Redmond, and Sisters areas has also occurred.

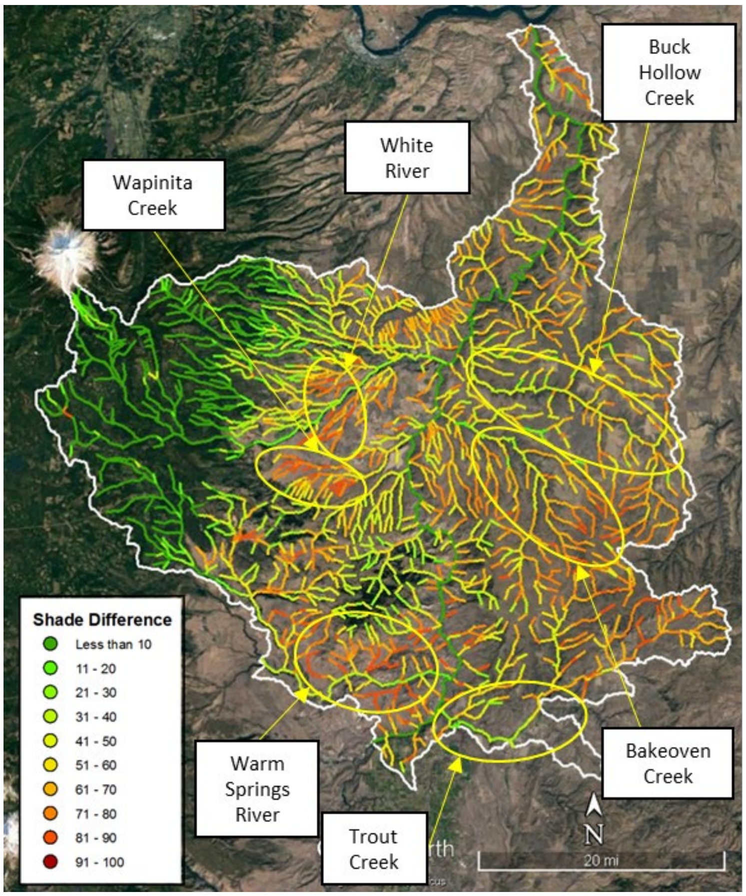


Figure 7-48 Deschutes River shade difference between potential maximum and current shade

In 1970, Oregon designated the lower 100 miles of the Deschutes River as a state scenic waterway, and in 1988 the U.S. Congress designated this same reach as a National Wild and Scenic River. In 1993, the *Lower Deschutes River Management Plan* was adopted by the BLM in collaboration with the State, Confederated Tribes of Warm Springs, and others to implement both the federal and state requirements. Most of the land adjacent to the river in this reach is public land administered by the BLM or the State. There is also tribal land and private land adjacent to the river. The plan helps to protect and enhance the river's outstandingly remarkable and related values, including the riparian conditions.

Near the confluence, lands adjacent to the Deschutes River are also part of the Columbia River Gorge National Scenic Area and covered under the *Management Plan for the Columbia River Gorge National Scenic Area* (2016). These lands are designated as open space under the plan.

Factors that Influence Temperature in the Deschutes River Watershed

Riparian Vegetation*:* The riparian vegetation analysis has focused on the lower part of the watershed below Pelton-Round Butte Project. Although the headwaters in the cascades on forest lands is currently well-shaded, a large portion of the lower basins is not well-shaded. The mainstem of the Deschutes River does not have a high potential for shade, due to its large width. ***Figure 7-48*** compares the shade differences between the system potential and current shade. Efforts to restore riparian vegetation would likely make the largest difference in areas with the largest shade difference. Large portions of the lower Deschutes River watershed have a semi-arid climate, and habitat restoration in these areas is likely to be slow. Most of the land in areas with the highest potential for improvement is located on privately owned or tribal lands. Thus, restoration activities will need cooperation from landowners as well as the Confederated Tribes of Warm Springs. Revegetation in the tributaries will improve their overall health and may also have a cumulative cooling effect on the Deschutes River itself. It should be noted that these maps were developed prior to the summer 2018 fire, which burned much of the riparian vegetation in the lower 38 miles of the Deschutes River.

Dams and Hydromodifications*:* The Deschutes River, particularly the lower portion below Lake Billy Chinook to its confluence with the Columbia River, is influenced by the Pelton Round Butte Hydroelectric Project. Pelton Round Butte is composed of three dams, beginning downstream of Lake Billy Chinook: The Round Butte Dam, the Pelton Dam, and the Re-regulating Dam. Pelton Round Butte is owned jointly by Portland General Electric (PGE) and the Confederated Tribes of Warm Springs/Warm Springs Power Enterprises. A new FERC license was issued in 2005 to operate the Project for 50 years.

In 2010, the building of a Selective Water Withdrawal (SWW) tower at the Round Butte Dam was completed. Prior to the installation of the SWW tower, water was released from the bottom gate of Round Butte Dam. The SWW facilities were built to provide surface withdrawal for downstream juvenile fish passage and to allow the temperature of downstream water releases to be regulated to more closely match temperatures that would occur absent the dams. This is achieved by releasing water downstream of the dam from different depths and targeting temperatures to match the average temperature of the three rivers inflowing Lake Billy Chinook. The SWW operations have increased temperatures in spring and early summer and cooled temperatures in August and September in the lower Deschutes River. Thus, the SWW operations appear to have a somewhat beneficial effect by providing cooler water during the CWR use period. Although the cooler released water attenuates due to the long distance between the dam and the confluence of the Deschutes River, modeling as part of a PGE *Water Quality Study (2019)* by Max Depth Aquatics indicated that in 2017, late August and September temperatures at river mile one of the Deschutes River would have been 1-2°C warmer under the pre-SWW operations.

Table 7-6 Water Availability Analysis, 5/20/20 for the Deschutes River confluence with the Columbia River

DESCHUTES R > COLUMBIA R – AB MOUTH			
(@ 80% exceedance)			
Month	Monthly Streamflow (cfs)		
	Natural Streamflow	Water Allocated or Reserved	% Allocated*
JUNE	5,560	5,670	102%
JULY	4,610	5,407	117%
AUGUST	4,320	4,812	111%
SEPTEMBER	4,410	4,997	113%
Top Users: Irrigation (87%), Municipal (8%)			
*% Allocated: [Water Allocated or Reserved]/[Natural Streamflow]. This is the percentage of water either allocated or reserved for in-stream or other uses compared with the natural streamflow. Percentages over 100% indicate the water is overallocated at the mouth of the river.			

Reference: https://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=70087&exlevel=80&scenario_id=1

Water Use: ***Table 7-6*** displays Oregon Water Resources Department data on water usage in the Deschutes River watershed. Water availability is overallocated in the Deschutes River primarily due to irrigation, municipal use, and storage uses. Oregon Department of Fish and Wildlife applied for instream water rights (ISWRs) to protect fish at several locations in the basin in different years. ISWRs function like all water rights, and are junior to any earlier water rights. ISWRs provide targets for the flows needed to support fish, wildlife, their habitats, and recreation. From 1983 to 1991, for the lower Deschutes River, the OWRD approved several ISWRs at river mile 100 (Pelton Round Butte Dam) to the mouth that range from 3000 and 3500 cfs in August to 4000 cfs in the rest of the summer. There are additional ISWRs in the Upper Deschutes River and 84 ISWRs on tributaries to the Upper and Lower Deschutes River, including on the White River (summer range: 60-341), the Metolius River (summer range: 110-335 cfs) and the Crooked River (summer range: 20-150 cfs). These ISWRs serve to help maintain existing flows, although senior water holders primarily for irrigation can still diminish flows below these levels in low flow years.

Efforts to reduce irrigation diversions and maintain higher flows in the lower Deschutes River and in tributaries to the lower Deschutes River, like Trout Creek, can serve to maintain and potentially enhance the CWR at the confluence.

Climate Change*:* Currently, the Deschutes River averages 19.2°C in August. Modeled stream temperature data from NorWeST shows that by 2040, this is predicted to increase to 20.5°C, and by 2080 to 21.6°C. Comparatively, the mainstem of the Columbia River at river mile 201 where the Deschutes River enters currently averages 21.5°C in August. At this location the Columbia River is predicted to rise to 23.0°C and 24.0°C by 2040 and 2080, respectively. While the Deschutes River is predicted to remain relatively cooler than the Columbia River by about 2.5°C, by 2040, it is likely to be above accepted temperature thresholds for migration. By 2080, it is likely to reach lethal levels for steelhead and salmon.

Ongoing Activities in the Deschutes River Watershed and Recommended Actions to Protect and Enhance the Cold Water Refuge

The *Deschutes Subbasin Plan* (2004) adopted by the Northwest Power and Conservation Council, provides a comprehensive assessment and management plan to protect and restore the basin to support fish and wildlife resources. Building on this work, the State of Oregon, with many partners, developed the *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment (2010),* which is a component of NMFS' *Middle Columbia River Steelhead Recovery Plan (2009)*. In addition to protection programs, these plans identify a variety of habitat restoration actions across the Deschutes basin. Specific implementation actions of the Steelhead Recovery Plan have been developed and are being implemented, which are summarized by ODFW in the *2010-2016 Implementation Progress Report* (2019). In the Lower Deschutes basin, nearly all the major tributaries have degraded habitat and warm summer water temperatures from grazing, agricultural practices, roads, and irrigation withdrawals (e.g., Bakeoven Creek, Buck Hollow Creek, Warm Springs River, Trout Creek, and Shitike Creek). Prioritized actions to restore habitat and reduce temperatures include restoring riparian vegetation, decreasing channel width, increasing channel complexity and floodplain connection, and restoring flows. Portions of the lower Deschutes River also have been identified as needing improved riparian conditions, floodplain connection, and reduced stream width. Implementing these actions may contribute to cooling the Deschutes CWR.

As discussed above, the water temperature of the releases from the Pelton Round Butte Project in accordance with the FERC license conditions influences the water temperature in the lower 100 miles of the Deschutes River. Under current operations, the released water from the dam contains a mix of warmer water near the surface and cooler water at depth, with a maximum of 60% percent cooler water. By mid-August and September, typically 50-60% of the releases are from the cooler water at depth. PGE recently developed a *Water Quality Study* to assess the effects of different mixes of surface and sub-surfaces releases from the dam. There appears to be some potential to consistently provide 60% of cooler water from early August through September to help cool the Deschutes CWR.

Photo 7-60 Confluence of the Deschutes River with the Columbia River

In 2019, a *Draft Deschutes River Habitat Conservation Plan* (HCP) was submitted to the USFWS and NMFS by eight irrigation districts and the City of Prineville and released by the agencies for public comment. The HCP focuses on changes in surface flows and irrigation conservation measures in the upper Deschutes basin to improve habitat conditions for ESA-listed Oregon spotted frog, steelhead, and bull trout as well as non-listed Chinook salmon and sockeye, by restoring more natural river flows, including higher winter flows and in some reaches lower summer flows. It is unclear if these changes will significantly affect the SWW operations and temperature downstream of Pelton Round Butte Project.

The Deschutes River both above and below the Pelton Round Butte Project exceeds temperature water quality standards and is listed on the State of Oregon's 303(d) list of impaired waters along with many tributaries to the Deschutes River. Although ODEQ has initiated work on the temperature TMDL for the upper Deschutes basin and to a lesser extent the lower Deschutes basin, no temperature TMDLs have been completed in the Deschutes Basin.

The Deschutes River has many active watershed groups looking to restore more favorable habitat for cold water fish. One group, the Deschutes River Conservancy, is engaged in restoring stream flow to the river. Most of their work is focused upstream of the Pelton Round Butte Hydroelectric Project where more of the water is diverted for irrigation. Their activities include water rights transfers, water rights leasing, and promotion of water conservation. The Crooked River and Middle and Upper Deschutes Watershed Councils have been actively working on riparian restoration in their respective watersheds. The Lower Deschutes Weed Control Project is an ongoing partnership with several agencies and organizations, focusing on invasive species removal in the lower 40 miles of the Deschutes River. While this may not directly impact temperatures, it is important for improving the overall health of the riparian corridor.

Actions to protect and enhance the Deschutes River CWR include:

- As part of the Pelton Round Butte Project water quality management and monitoring plan, consider the temperature effects of the selective water withdrawal operations on the Deschutes River CWR. Specifically, consider maximum sub-surface cool water blend

(60% percent) in August and September to help maintain temperatures below 18ºC when CWR use is highest. (ODEQ/PGE/Warm Springs Tribes)

- Continue to implement projects to restore riparian vegetation, reduce channel width, increase channel complexity, and restore flow in the White River basin, Bakeoven Creek, Wapinita Creek, Buck Hollow Creek, Warm Springs River, Trout Creek, Shitike Creek, and the Lower Deschutes as identified in the *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment (2010)* and the *Deschutes Subbasin Plan* (2004) to help cool river temperatures in the Deschutes CWR. (Multiple parties)
- Develop temperature TMDLs and associated implementation plans for the upper and lower Deschutes River basin. (ODEQ)
- In the review and/or implementation of the draft *Deschutes Basin Habitat Conservation Plan*, fully consider the effects on summer temperatures downstream of the Pelton Round Butte Project and the Deschutes River CWR to ensure August-September temperatures are not warmed and preferably cooled. (NMFS, USFWS, PGE)
- Protect sources of groundwater from degradation in quality and quantity. Specifically, continue the existing protections and mitigation requirements in place for new groundwater withdrawals above Pelton Round Butte Project. (Multiple parties)
- Support partnerships to purchase or lease in-stream water rights during critical periods to benefit salmonids. (Multiple parties)
- On national forest lands, continue to implement the aquatic strategies and actions in the *USFS Mount Hood National Forest Land and Resource Management Plan* (1990) and *USFS Ochoco National Forest Land and Resource Management Plan* (1989) and associated amendments to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)

7.16 UMATILLA RIVER (RIVER MILE 284.7) - RESTORE

Photo 7-61 Photo of the Umatilla River confluence with the Columbia River

Refuge Volume: 10,473 m^3 (13th largest)

Average August Temperature: 20.8°C

Distance to Downstream Refuge: 83.7 mi. (Deschutes River)

Distance to Upstream Refuge: N/A

Cold Water Refuge Rating: Marginal (>18°C)

Figure 7-49 Aerial view of the confluence of the Umatilla and Columbia Rivers; yellow pin denotes upstream extent of refuge

What features make the Umatilla River a potential cold water refuge to restore?

The Umatilla River confluence with the Columbia River is located at river mile 284.7, just downstream of McNary Dam. The Deschutes River is the nearest downstream refuge, 84 river miles downstream. The Umatilla River is only considered a CWR in late August and September when it is cooler than the Columbia River. The average temperature of the Umatilla River is warmer than the Columbia River in June and July, and the two rivers have the same average temperature of 20.8°C in August. In September, the Umatilla River is on average 1.9°C cooler than the Columbia River but has portions of the day that are more than 2°C cooler than the Columbia River, thereby providing intermittent CWR (***Figure 7-50***). This qualifies the Umatilla River as a marginal CWR (>18°C) for late August and September. ODEQ has designated the lower portion of the Umatilla River for salmon and trout rearing and migration and has assigned a water quality criterion of 18°C for maximum water temperatures. The maximum modeled temperature for the Umatilla River is 27°C (1993-2011) (Appendix 12.18). Based on measured maximum temperature readings, the lower Umatilla River is on the 303(d) list for temperature impaired waters.

With a mean August flow of 87 cfs, the Umatilla River CWR is estimated to have a volume of 10,473 m^3, the size of four Olympic-sized swimming pools during the time the river is 2°C cooler than the Columbia River. The refuge is estimated to consists of cool water within the lower tributary up to one mile upstream (***Figure 7-49***). The confluence is shallow and sandy.

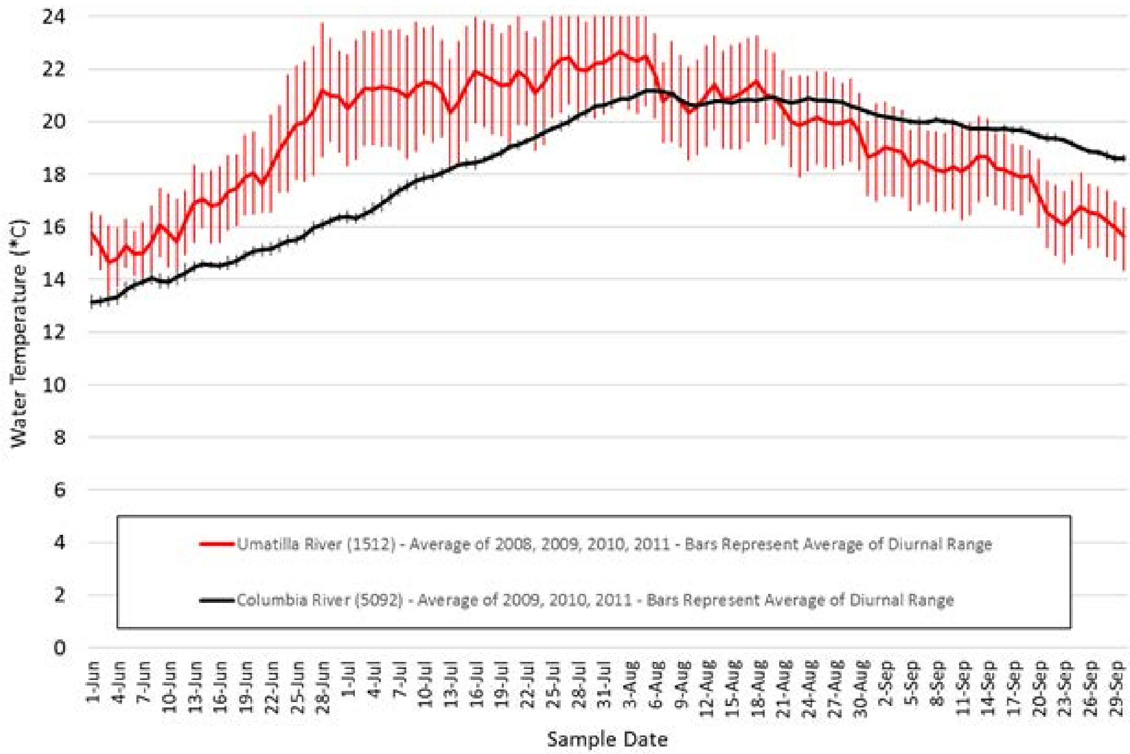


Figure 7-50 Umatilla River and Columbia River water temperatures (Appendix 12.12)

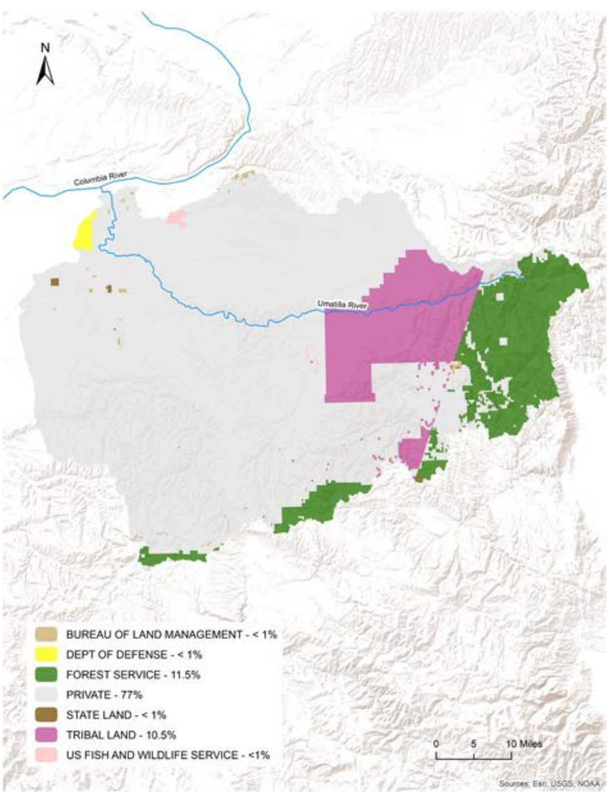


Figure 7-51 Land ownership in the Umatilla Basin

Introduction to the Umatilla River Watershed

The Umatilla River headwaters originate 6,000 feet above sea level in the gently-sloping coniferous forests of the Blue Mountains. The river flows in a northwest direction, winding through an agricultural valley before joining the mainstem Columbia River. The basin characteristics that influence temperature are largely shaped by a long history of agricultural development. For instance, riparian vegetation along the Umatilla River and tributaries has been disturbed to facilitate agricultural land uses, which decreases riparian shading.

The watershed is primarily under private ownership (77%). USFS (11.5%) manages portions of the watershed's forested upper reaches, and the Department of Defense controls a small section (<1%) of the basin near the river mouth. In addition, Confederated Tribes of the Umatilla Indian Reservation (CTUIR) land (10.5%) covers a portion of the basin (***Figure 7-51***).

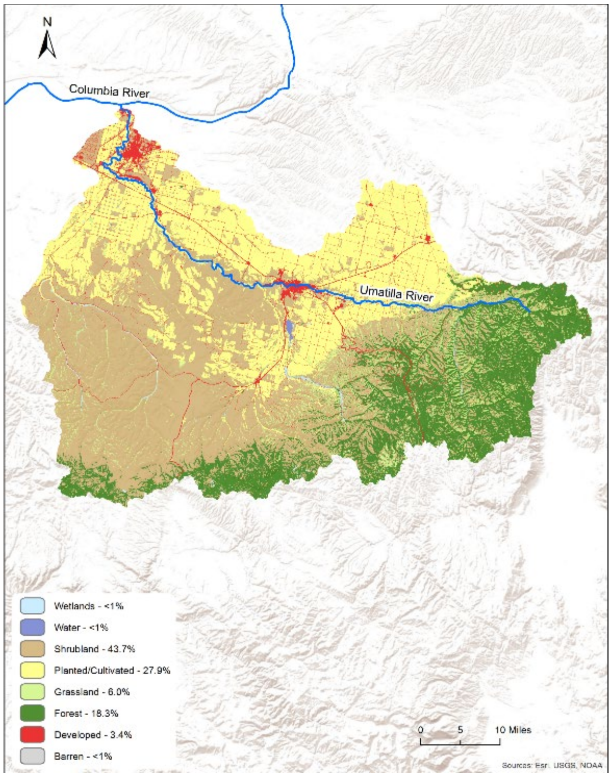


Figure 7-52 Land cover in the Umatilla Basin

Ranching and agriculture predominate in the basin. Forest (18%) covers the higher elevation upper portions of the basin. In the gullies and hills of the southern portion of the watershed, shrubland (43%) grows extensively. Cultivated crops (28%) cover the flat lands north of the mainstem river and south of the Cities of Pendleton, Umatilla, and Hermiston, located on the middle and lower mainstem. Other than the road networks, these cities and small towns throughout the subbasin are the only developed (3%) land in the watershed (***Figure 7-52***).

Extensive water withdrawals in the 20th century to irrigate farmlands resulted in very low flows and occasionally no flow in the Lower Umatilla River. In the 1980s and 1990s, flow restoration and fish passage projects were developed, leading to improved conditions in the confluence for salmonids. The most notable recent restoration projects were the construction of "water exchanges" in the 1990s that pump Columbia River water into the basin for irrigation in exchange for leaving water in the Umatilla river that was previously diverted for agriculture. The preserved Umatilla River water flows back to the Columbia River for an intended no net depletion of Columbia River water.

Factors that Influence Temperature in the Umatilla River Watershed

Riparian Vegetation: The loss of riparian vegetation in the Umatilla Basin – primarily due to agricultural development – has played a role in increasing stream temperatures. ***Figure 7-53*** shows the difference between existing and system potential shade, highlighting the riparian areas that should be targeted for revegetation. The areas with potential to

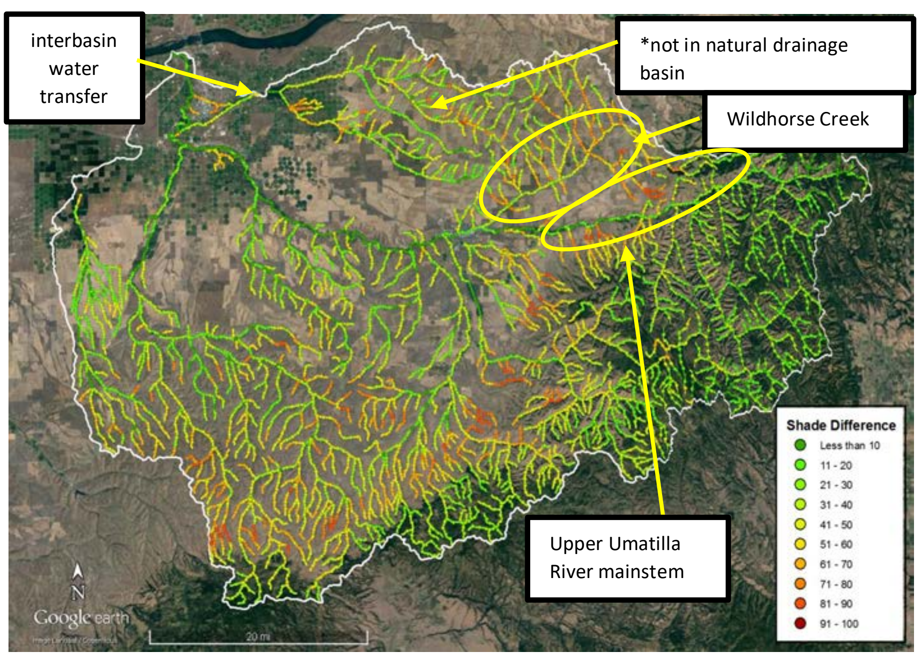


Figure 7-53 Umatilla River shade difference between potential maximum and current shade

Table 7-7 Water Availability Analysis, 5/20/20 for the Umatilla River confluence with the Columbia River

UMATILLA R > COLUMBIA R – AT MOUTH (@ 80% exceedance)			
Month	Monthly Streamflow (cfs)		
	Natural Streamflow	Water Allocated or Reserved	% Allocated*
JUNE	187	1,043	558%
JULY	83	541	654%
AUGUST	48	399	830%
SEPTEMBER	57	488	862%
Top Users: Irrigation (89%), Municipal (11%)			
*% Allocated: [Water Allocated or Reserved]/[Natural Streamflow]. This is the percentage of water either allocated or reserved for in-stream or other uses compared with the natural streamflow. Percentages over 100% indicate the water is overallocated at the mouth of the river.			

Reference: https://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=221&exlevel=80&scenario_id=1

increase riparian shade include Wildhorse Creek and the upper mainstem of the Umatilla River. The restoration of associated riparian wetlands would also contribute to increased water temperature buffering in the mainstem Umatilla River. Land in these sub-watersheds is primarily made up of private agricultural land and private shrubland (***Figure 7-52***), rendering it highly important that there be funding and institutional capacity in the basin to develop revegetation opportunities with private landowners.

Water quality modeling *in ODEQ's Umatilla River Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP) (2001)* predicted that maximum potential vegetation and restored flows could decrease maximum water temperatures at the mouth from 24˚C to 21˚C under low flow conditions. The *CTUIR TMDL for Temperature and Turbidity (2005)* indicates that there is potential for temperature reduction between river miles 56-82 on tribal land.

Hydromodification: There is one main storage reservoir in the Umatilla Basin, McKay Reservoir on McKay Creek, which captures winter flows to be delivered to farms in the summer through an extensive network of irrigation canals. A second storage reservoir, Cold Springs, is not within the natural drainage basin but is diverted into the lower watershed, impacting temperature at the confluence.

In the 1990s, two water exchange projects were built, which collectively pump 380 cfs of water up from the Columbia River into irrigation canals in exchange for an equal amount of Umatilla River water – that otherwise would have been diverted – left instream to benefit fish. These water exchanges were authorized under the Umatilla Basin Project Act of 1988 and implemented by the Bureau of Reclamation. Phase 1 pumped up to 140 cfs of Columbia River water into the West Extension Irrigation District system and helped retain flow in the Umatilla River below the Three Mile Dam diversion. Phase 2 pumped up to 240 cfs into the Stanfield Irrigation District and helped retain flow in the Umatilla River below Stanfield Dam at river mile 32. These exchanges have improved flow in the Lower Umatilla River, but low flow conditions remain. Target flows associated with the project in the Lower Umatilla River to the mouth are 75 cfs (July 15-August 15) and 250 cfs (August 16-September 30), but current flows do not achieve the 250 cfs target.

Water Use: The surface water in the Umatilla Basin – much of which is stored in two main storage reservoirs, McKay and Cold Springs – is over-appropriated, meaning that there are more water rights allocated in the basin than the river can satisfy during normal years. In the peak summer months, over 600% of the natural flow of the river is allocated for out-of-stream uses, over 88% of which is for irrigation and 11% of which is for municipal use (***Table 7-7***). Prior to full implementation of the water exchanges, water withdrawals primarily for irrigation led to very minimal to no Umatilla River flows reaching the Columbia River confluence during the summer irrigation season. Since implementation of the water exchanges and a 2006 agreement to provide for lamprey passage, Umatilla River flows are maintained throughout the summer. However, groundwater aquifers in the basin have been tapped for irrigation, resulting in significant declines in water tables in parts of the basin by more than 500 feet. Because of groundwater decline, the Umatilla Basin has four of Oregon's six Critical Groundwater Areas, leading the OWRD to withhold the groundwater irrigation rights of over 120,000 acres of farmland in the basin, with the goal of steadying the declining groundwater table. The CTUIR have also expressed their concern over unmet claims to tribal reserved water rights, some of which they would likely put towards restoring river flows. Much of the river is diked or flanked by agriculture, which reduces floodplain connection and hyporheic flows. Efforts to conserve and increase water flows will help to cool water temperatures and increase CWR volume.

ODFW applied for and was granted instream water rights (ISWRs) to protect fish at several locations in the basin. ISWRs function like all water rights and are junior to any earlier water rights. ISWRs provide targets for the flows needed to support fish, wildlife, their habitats, and recreation. ISWRs granted in 1983 at river mile 51 (McKay River) range from 85 cfs (in August) to 250 cfs and at river mile 79 (Meacham Creek) range from 60 to 200 cfs in the summer. There were 24 ISWRs granted from 1983 to 1990 on tributaries to the Umatilla River. These ISWRs serve to help maintain existing flows, although senior water holders primarily for irrigation can still diminish flows below these levels in low flow years.

Climate Change: In 2040, average August temperatures in the Umatilla River are predicted to be 21°C compared to 22°C in the Columbia River. In 2080, August temperatures in the Umatilla River are expected to rise further to 22°C compared to 23°C in the Columbia River. If the Umatilla River is restored, there could be a greater difference between Umatilla and Columbia River water temperatures to make the Umatilla River a more consistent CWR.

Ongoing Activities in the Umatilla River Watershed and Recommended Actions to Restore the Cold Water Refuge

Restoration of the Umatilla CWR will involve a multifaceted effort to restore river flows, riparian vegetation, and floodplain function in the basin to balance human and ecological demands. Established plans include: Northwest Power and Conservation Council's *Umatilla/Willow Subbasin Plan* (2004); ODFW's *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment* (2010), which is part of NMFS' *Middle Columbia Steelhead ESA Recovery Plan* (2009); *Umatilla River Basin TMDL and WQMP;* and the *CTUIR TMDL for Temperature and Turbidity* (2005). Implementing actions identified in these plans can contribute to cooler Lower Umatilla River water temperatures and increase CWR volume. Decreasing temperatures by 2°C in late August and early September would result in average temperature near 16-17°C and maximum temperatures near 18°C, which would provide suitable continuous CWR temperatures when salmon and steelhead migrate through this part of the Columbia River when its temperatures commonly exceed 20°C.

Both the *NPCC Umatilla/Willow Subbasin Plan* and the NMFS *ESA Recovery Plan* identify implementation of a Phase 3 Umatilla Basin Project water exchange as a top priority to provide critical increased summer flows in the Lower Umatilla River. The Bureau of Reclamation (USBR) completed the *Umatilla Basin Water Supply Study* in 2012 that examined options for increased flow in the Lower Umatilla River including water exchange options to pump additional Columbia River water that could be used for irrigation in exchange for retaining additional flow in the Lower Umatilla River. Related to this effort, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are currently in negotiations with federal and Oregon state officials and basin stakeholders to settle CTUIR's Umatilla Basin water right claims, which include instream flows to support fisheries. The settlement is predicated on a series of water rights trades whereby Umatilla River Basin water users would trade their water rights to the CTUIR, and the stakeholders would obtain contemporary water rights and supply from the Columbia River. The settlement, which would result in retaining more summer flow in the Lower Umatilla River, requires federal legislation and subsequent funding and agreement among various parties.

Another ongoing effort in eastern Oregon is to find long-term, sustainable solutions to aging flood control levees, which involve the CTUIR and the Governor's Greater Eastern Regional Solutions Team. This initiative provides the opportunity to include enhancing floodplain function into decision making around levees.

Due to the current low summer flow levels, increasing the flow is an important action to cool the Lower Umatilla River as illustrated in the *Oregon Umatilla River Basin Temperature TMDL*. With many projects completed and local champions throughout the basin, there is momentum for ongoing progress to increase summer flow in the Lower Umatilla River through collaboration and partnership as noted above. Actions to further restore the Umatilla Basin include:

- As identified in the NPCC *Umatilla/Willow Subbasin Plan* and the NMFS *ESA Recovery Plan,* seek agreement on and implementation of an additional Umatilla Basin Project water exchange to increase summer flow in the Lower Umatilla River, thereby decreasing summer river temperatures and increasing CWR volume. (USBR, Oregon, CTIUR, irrigation districts, and others)
- Where feasible, set back levees to reduce channelization, restore natural channel complexity, reconnect the river with its floodplain, and restore groundwater interactions., as identified in the *Umatilla River Basin TMDL and WQMP* (2001), *CTUIR Temperature TMDL* (2005), the *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River* (2010). (Multiple parties)
- Restore vegetation of riparian areas across the basin's streams as identified in the *Umatilla River Basin TMDL and WQMP* (2001), *CTUIR TMDL for Temperature and Turbidity* (2005), and the *Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River* (2010).(Multiple parties)
- Continue to implement on-farm efficiency projects to restore flow to the Umatilla River, particularly in August and September, which will help to cool river temperatures and expand CWR volume. (Multiple parties)
- On national forest lands, continue to implement the aquatic strategies and actions in the *USFS Umatilla National Forest Land and Resource Management Plan* (1990) and its amendments to protect and restore riparian shade and stream functions to maintain cool river temperatures. (USFS)

7.17 SUMMARY OF ACTIONS TO PROTECT AND RESTORE COLD WATER REFUGES

The following is a summary of the actions in the 12 primary CWR and two “restore” tributaries highlighted in this chapter to protect and restore CWR in the Lower Columbia River. Additionally, a brief discussion of other opportunities to expand CWR, including the non-primary CWR tributaries identified in ***Table 2-1***, is presented.

Regulatory Protection Programs[5][6]

All 14 tributary watersheds include existing regulatory programs and land use provisions that serve to protect watershed conditions and help keep waters cool. Since the 14 tributary watersheds include forest lands for significant portions of their watersheds, important protective actions include continued implementation of: 1) USFS plans on federal forest land (e.g., aquatic strategies in the *USFS Gifford Pinchot National Forest Land and Resource Management Plan* (1990) and the *USFS Mount Hood National Forest Land and Resource Management Plan(1990))*, 2) the state of Oregon and Washington’s forest management plans on state forest land, and 3) the states’ forest practice regulations on private forest lands.

Protecting existing riparian buffer areas of the CWR tributaries from development activities on non-forest lands (e.g., agricultural, rural, and urban lands) is critical to maintain cool river temperatures. The *Management Plan for the Columbia River Gorge National Scenic Area* (2016) applies to the lower portion of 10 of the 12 primary CWR in the Columbia Gorge National Scenic Area and helps provide this protection on federal, state, county, and private lands. Four tributaries have Wild and Scenic River designations and associated management plans (Sandy River, White Salmon River, Klickitat River, and Deschutes River), which help protect the riparian areas in the designated reaches. County land use regulations also serve an important role in protecting the existing riparian buffers (e.g., Cowlitz, Lewis, Clark, Skamania, and Klickitat Shoreline Master Plans).

Since additional water withdrawal during the summer can diminish the size and function of the CWR tributaries, minimizing additional water withdrawals will help maintain CWR quality and function. The Cowlitz, Lewis, and Deschutes Rivers have upstream dams with FERC license conditions. The Sandy River has an upstream dam on the Bull Run River with an HCP for minimum summer flows. State instream flow rules for Lewis, Sandy, Hood, and Deschutes Rivers help serve to maintain existing summer flows in the lower portion of these tributaries. Existing plans for other CWR tributaries include recommendations to establish minimum instream flows to help maintain current flows (Wind, Little White Salmon, White Salmon, and Klickitat Rivers). Hood River, Fifteenmile Creek, Deschutes River, and the Umatilla River are

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[5] Many of the programs and plans noted in this section are intended to meet various state or federal requirements, and some are updated on occasion based on new information. By citing a program or plan in this CWR Plan as important to prevent degradation of water quality and maintain cool river temperatures, EPA is not stating the program or plan meets applicable state or federal requirements. EPA recognizes some of these plans will be updated as warranted.

[6] EPA recommends use of WDFW’s Management Recommendations for Washington’s Priority Habitats (Riparian Ecosystems) for riparian buffer protection programs and regulations on non-federal lands in cold water refuge watersheds identified in this Plan (see https://wdfw.wa.gov/species-habitats/at-risk/phs/recommendations).

overallocated, so there are limits on additional surface water withdrawals, and efforts in these basins focus on irrigation conservation measures to increase depleted summer stream flows.

Tanner Creek, Herman Creek, Little White Salmon River, and the White Salmon River have river temperatures below the temperature water quality standards, and it is important to maintain these cool temperatures to protect the CWR associated with these rivers. The states' antidegradation water quality standard provisions, and Oregon's protecting cold water standard (OAR 430-0410-0028 (11)), serve to help protect these cool conditions from proposed actions and discharges that may warm these rivers. Additionally, revised use designations in Tanner Creek and Herman Creek based on the existing cool river temperatures to establish colder temperature standards could provide added protection.

Restoration Actions Identified in Existing Plans

Restoring degraded portions of the 12 primary CWR watersheds would enhance the quality of the CWR and help counteract future increases in tributary river temperature from climate change. In addition, restoration of the two "restore" watersheds, consistent with current plans, would improve habitat and thermal conditions within the watershed, as well as increase the availability of CWR in the Lower Columbia River. All but three (Tanner, Eagle, Herman Creeks) of the 14 watersheds have subbasin plans adopted by the Northwest Power and Conservation Council in 2004 as part of the NPCC's Columbia River Basin Fish and Wildlife Program. These subbasin plans help prioritize BPA funding for projects that protect, mitigate, and enhance fish and wildlife that have been adversely impacted by the development and operation of the Columbia River hydropower system.

All of the 14 watersheds are covered under NMFS approved salmon recovery plans that identify actions to recover ESA-listed species. Six of the watersheds (Sandy River, Wind River, Hood River, Klickitat River, Fifteenmile Creek, and the Umatilla River) have temperature TMDLs with associated implementation plans.

These plans, along with other habitat restoration project plans and water use plans noted in the watershed 'snapshots' in this chapter, provide a thorough list of actions to improve habitat and water quality conditions in the 14 watersheds. Many of these actions can serve to reduce river temperatures and increase river flows to provide cooler and expanded volumes of CWR at the river confluences with the Columbia River. These actions include: 1) restoring riparian vegetation to provide river shading; 2) restoring stream morphology and floodplain connectivity to reduce channel widths and create pools and groundwater connectivity; and 3) restoring summer river flows that are more resistant to warming and increase CWR volume.

Each of the 14 watershed 'snapshots' in this chapter identify priority actions in existing plans that can serve to cool river temperatures and maintain or increase the volume of CWR. These actions target restoration for river reaches and tributaries that improve salmon habitat, which also serve to improve CWR at the tributary's confluence with the Columbia River. Examples include riparian and habitat restoration in Coweeman River (Cowlitz), East Fork of the Lewis (Lewis), Middle Wind River (Wind), Rattlesnake Creek (White Salmon), and Trout Creek (Deschutes). Implementing many of these projects typically involves grant funds available from a variety of sources (e.g., BPA fish and wildlife funds, salmon recovery funds, Clean Water Act funds, agricultural conservation funds) and local partnerships.

Existing plans prioritize the water conservation, irrigation efficiency, and water trading/exchanges in the Hood River, Fifteenmile Creek, Little Klickitat River, Deschutes River, and Umatilla River to address overallocation and low summer flows. The Umatilla River has very low summer flows at the confluence, resulting in warm temperatures and limited CWR. Water exchanges that pump water from the Columbia River to serve irrigation districts in exchange for reduced irrigation withdrawals from the Umatilla River as part of the Umatilla Basin Project have helped restore flows to the Lower Umatilla River to some extent. An additional water exchange (Phase 3) is identified as a high priority in existing plans to provide additional summer flow to the Lower Umatilla River. Additional summer flow could improve fish passage in the Lower Umatilla River, and help cool and increase the volume of CWR at the confluence with the Columbia River.

To supplement existing plans in the Deschutes River, completing a temperature TMDL(s) for the Deschutes River basin is highlighted to aid in the implementation of actions to help cool the lower Deschutes River and its CWR. The Deschutes CWR is heavily used by salmon and steelhead, is a relatively warm CWR, and is vulnerable to future warming.

Cool Water Releases from Dams

Upstream dams on the Cowlitz, Lewis, Sandy, and Deschutes Rivers currently serve important roles in providing cool river flows in the lower segments of these rivers that provide CWR. Mayfield Dam on the Cowlitz River and Merwin Dam on the Lewis River release cool water from deep within their respective reservoirs. Both the Bull Run Reservoir Dam in the Sandy River Basin and the Pelton Round Butte Dam on the Deschutes River have the selective ability to release water from different depths, which helps provide cool summer flows. Due to the Deschutes River's high CWR use by migrating salmonids, marginally cool current temperatures, and predicted temperature increases due to climate change, the potential to release cooler water from the Pelton Round Butte Dam in August to provide cooler water at the mouth should be assessed as part of the hydroelectric project's water quality management plan. Under current operations, the maximum amount of cool deeper water is generally released by mid-to-late August, but there may be potential to release more cool water starting at the beginning of August that may influence temperatures at the mouth.

Sediment Management in CWR

Sediment deposition may be a concern for fish access to CWR at the mouth of several CWR tributaries, including Herman Creek Cove, Wind River, White Salmon River, and the Klickitat River. Feasibility studies for habitat restoration and sediment removal at the confluence areas is recommended to assess the potential for increased fish access, increased depth, and reduced warming.

Opportunities for Additional CWR

The protection measures discussed above also generally apply to the other 10 non-primary CWR tributary watersheds, and implementing restoration actions in these watersheds could potentially increase the availability of CWR. As discussed in Chapter 2, most of these tributaries are relatively small with limited availability of CWR.

The Lower Columbia Estuary Partnership is analyzing the feasibility of augmenting CWR for fish by building a log structure at the mouth of Oneonta Creek to deflect mainstem flow and create a pool of cold water at the mouth. Building this structure will help create a larger volume of CWR at the mouth at Oneonta Creek and potentially serve as a model to expand CWR at other small cold streams in the Lower Columbia River.

It may be possible to augment the existing CWR with pumped groundwater to provide increased cool flows in the lower reaches of the tributaries. Both Tanner Creek and Herman Creek are supplemented with cold groundwater that supplies fish hatcheries, which is then discharged into the creeks. If the hatchery on Eagle Creek supplemented its water supply with groundwater and decreased its reliance on surface flows, it could cool the river and increase the CWR volume.

Due to the limited availability of CWR in the John Day Reservoir, opportunities to add CWR in this reach could be explored if fish use of CWR continues to increase in the future as predicted due to warmer Columbia River temperatures.

7.18 ACTION TO ADDRESS FISHING IN COLD WATER REFUGES

As discussed in Chapter 4, fishing in CWR appears to reduce the survival of steelhead that use CWR compared to those that do not, offsetting the benefits to fish using CWR. This plan may inform future updates to fishing regulations in the primary CWR, especially for the CWR with the highest amount of CWR use during periods of warm Columbia River temperatures (e.g., Cowlitz River, Lewis River, Herman Creek Cove, Wind River, White Salmon River, Little White Salmon River (Drano Lake), Klickitat River, and Deschutes River).

8 UNCERTAINTIES AND ADDITIONAL RESEARCH NEEDS

This Plan relies upon the most recent scientific studies, field observations, expert input, and analyses to characterize the amount of cold water refuges (CWR) in the Lower Columbia River and salmonid use of the CWR. However, the study of CWR use is an area with a large degree of uncertainty because of the complex behaviors exhibited by salmonids. This section highlights some of the main uncertainties in this plan and recommends future studies to address them.

Adult Salmon and Steelhead Use of Cold Water Refuges below Bonneville Dam

There have not been any scientific studies characterizing fish use of CWR below Bonneville Dam. The extent different species of salmon and steelhead use the CWR areas below Bonneville Dam is unknown. In this plan, EPA relied on fishing boat presence in the confluence area of tributaries cooler than the Columbia River as the primary basis for determining use as a CWR in tributaries downstream of Bonneville Dam. EPA did, however, visually (from shore and snorkel) document presence of likely out-of-basin salmon and steelhead in the Tanner Creek CWR.

Study Recommendations: Fund a radio-tagging study to characterize salmon and steelhead use of CWR below Bonneville Dam. Install PIT-tag detectors near the mouth of the Cowlitz and Lewis Rivers.

Adult Salmon and Steelhead Use of Cold Water Refuges above Bonneville Dam

Extensive studies characterizing CWR use above Bonneville Dam have been conducted by the University of Idaho. EPA relied upon those studies in this Plan. However, those studies were conducted in the late 1990s and early 2000s. Since then, there have been changes that may have altered CWR use. Those changes include an increased number of returning adult fall Chinook and steelhead, decreased percentage of returning adults that were transported as juveniles, increased sedimentation at the entrance of some CWR areas (e.g., White Salmon River), changes in thermal regimes of CWR (e.g., Deschutes River), and increased mainstem Columbia River temperatures. Additionally, there has been very limited study of CWR use by sockeye and summer Chinook. This Plan concludes CWR use by sockeye and summer Chinook is very limited, but studies would be beneficial to confirm the extent these species use CWR.

The installation of a PIT-tag detector at the mouth of the Deschutes River in 2013 is an investment that has provided valuable information on CWR use in the Deschutes River CWR. Installation of PIT-tag detectors at the mouths of other CWR would benefit future analysis.

Study Recommendations: Fund a radio-tagging study to provide updated characterization of CWR use above Bonneville Dam under current conditions for Chinook, steelhead, and sockeye. Install PIT-tag detectors at the entrance to Drano Lake, Herman Creek Cove, White Salmon River, Klickitat River, Wind River, and Eagle Creek. Conduct a radio-tagging study after PIT-tag detectors are installed to calculate the detection efficiency of the detectors.

Benefits of Cold Water Refuge Use for Migrating Adult Salmon and Steelhead

As discussed in this Plan, measuring the extent to which CWR use provides physiological benefits to migrating adult salmon and steelhead in terms of decreased mortality and other end points is confounded by fish harvest within CWR. Comparing survival rates of fish that use CWR to those that do not shows higher survival rates for fish that do not, but the reduced survival appears to be explained by increased harvest levels in CWR. As noted in this plan, modeling predicts that CWR use can reduce energy loss and increase spawning success. CWR use is also predicted to provide reduced exposure to warm Columbia River mainstem temperatures that is likely to reduce disease risk and stress responses and decrease adult migration mortality, but this has not been documented.

Study Recommendations: Design and fund research studies to document and evaluate the benefits of CWR use to migrating adult salmon and steelhead.

Effects to Migrating Adult Salmon and Steelhead from Exposure to Elevated Columbia River Temperatures

This Plan highlights analysis that shows a correlation between increased mainstem Columbia River temperatures and decreased adult migration survival through the Lower Columbia River. It also notes that some of the decreased survival could be attributed to fish moving into CWR as temperatures rise and being harvested. There are numerous studies documenting various adverse effects (mortality, disease, increased energy loss, decreased swimming speed, avoidance behavior) at temperature in excess of 18-20°C, but there are more studies on juveniles than adults due to challenges of conducting temperature effect studies on adult fish. Better quantification of mortality and adverse effects is needed for adult salmon and steelhead exposed to temperature increments in the 20-25°C range for different durations in the Lower Columbia River.

Study Recommendations: Design and fund research studies to isolate the temperature-mortality relationship for migrating salmon and steelhead in the Lower Columbia River. Studies should also include assessment of the cumulative effects of elevated temperature for the entire return migration to spawning grounds.

Volumes of Cold Water Refuges and Tracking Temperature and Flow Trends

EPA relied upon modeling and, in some cases, measurement techniques to estimate the volume of CWR (steam and plume portion) in each of 23 CWR areas identified in this plan as described in the technical memoranda listed in this plan's appendices. There is significant variability around EPA's CWR volume estimates that EPA did not attempt to quantify. In addition to the uncertainty with the modeling and volume measurements, the actual amount of CWR varies throughout the day and season, depending on variable tributary and Columbia River temperatures, flow, and Columbia River water levels. EPA generalized CWR volume based on August mean tributary and Columbia River temperatures and flows. Further, EPA relied on modeled August mean stream temperatures (NorWeST) and flow (USGS) for some tributaries.

USGS continuous flow gauges currently operate near the mouth of the Cowlitz, Lewis, Sandy, White Salmon, Hood, Klickitat, Deschutes, and Umatilla Rivers. USGS gauges near the mouth of the Wind and Little White Salmon River have operated in the past but do not currently (Appendix 12.23).

Of the eight currently operating USGS flow gauges noted above, only the Deschutes River gauge includes a continuous temperature gauge. State agencies and other organizations have operated continuous temperature gauges during the summer near the mouth of most the CWR tributaries in the past, but these gauges are not currently operational on an annual basis. (Appendix 12.22)

Study Recommendations: All of the 12 primary CWR tributaries and the Umatilla River should have monitors in the lower portion of the tributaries to track both temperatures and flow over time and to provide input data for more detailed and variable estimates of CWR volume for future analysis. EPA recommends continued use of the currently operating USGS flow gauges noted above, USGS flow gauges be re-installed near the mouth of the Wind and the Little White Salmon Rivers, and long-term continuous flow gauges be installed near the mouth of Tanner, Eagle, and Herman Creeks below the hatchery discharges. EPA recommends continued use of the USGS Deschutes temperature gauge noted above and that long-term temperature gauges be established and operated on the Umatilla River and the rest of the primary CWR tributaries at or near USGS flow gauge sites.

In addition, monitoring and research is needed to better understand and estimate CWR volumes available to fish and how those vary through time and in response to management actions (Columbia River pool levels, dredging, flow management in tributaries, etc.).

Upstream Extent of Tributary Cold Water Refuge Use

Most of the 12 primary CWR do not have a barrier limiting how far upstream out-of-basin salmon and steelhead may travel. As described in Appendix 12.4, EPA relied on a variety of scientific lines of evidence to estimate the upstream extent of salmon and steelhead use of a tributary as a CWR, which included a radio-tagging study on the Deschutes River documenting that approximately 85% of out-of-basin steelhead used the lower five kilometers as CWR.

Study Recommendations: Install PIT-tag receivers approximately 3-5 kilometers upstream on the White Salmon, Klickitat, and Deschutes Rivers, or devise other research and monitoring approaches to document and track the extent out-of-basin salmon and steelhead use these tributaries as CWR.

Density Effects and Carrying Capacity of Cold Water Refuges

There is no research on the carrying capacity of CWR for adult salmon or steelhead. The closest research EPA could draw upon was adult fish held in confinement. It is fairly speculative as to what densities cause fish to avoid or leave CWR. Additionally, research is needed to understand how CWR characteristics (e.g., bathymetry, dissolved oxygen levels, submersed aquatic vegetation, presence of other fish species, human disturbance including angling, etc.) may influence CWR use and capacity. Also, high densities of adult fish are known to contribute to the spread of disease. This could be a concern for CWR that are colder than the Columbia River but are in the 18-20°C range, which are temperatures at which disease risk is elevated (e.g., Deschutes River). The extent to which CWR use at varying densities contributes to increased disease (and associated mortality) is unknown.

Study Recommendations: Design and fund a study to define the carrying capacity of CWR for salmon and steelhead, with particular focus on Drano Lake and Herman Creek which have fixed amounts of CWR that is available for use due to upstream barriers.

Effects of Sediment Deposition on Cold Water Refuge Use

As discussed in this Plan, sediment has deposited near the confluence areas of most the 12 primary CWR. This may affect the extent to which salmon and steelhead use the CWR. As noted in Chapter 7, EPA recommends feasibility studies and implementation of projects to remove sediment in several CWR.

Study Recommendations: As part of any project to remove sediment from the CWR, a study should be designed to estimate the amount of CWR use before and after the sediment removal.

9 SUMMARY AND RECOMMENDATIONS

The following is a summary of EPA's Columbia River Cold Water Refuge Plan. These findings and recommendations are grounded in the technical and planning information presented in previous chapters, the plan's technical appendices, and referenced scientific studies.

Lower Columbia River Temperatures

1. The numeric temperature water quality standard for the Lower Columbia River is 20°C, which is intended to minimize the risk of adverse effects to migrating salmon and steelhead from exposure to river temperatures warmer than 20°C.
2. Current daily average water temperatures in the Lower Columbia River (mouth to McNary Dam) exceed 20°C for approximately two months, from mid-July to mid-September, and exceed 21°C for approximately one month. River temperatures are typically the warmest in August with peak daily temperatures in the 22-23°C range.
3. Historically, pre-1940 Lower Columbia River summer temperatures were cooler, with August mean temperatures approximately 2–2.5°C cooler than the current August mean temperature of near 22°C. Both regional anthropogenic sources (e.g., dams/reservoirs) and global climate change have contributed to this warming.
4. Lower Columbia River summer temperatures are predicted to continue to rise. August mean temperatures are predicted to be near 23°C by 2040 and approximately 24°C by 2080.

Cold Water Refuges in the Lower Columbia River

5. There are 12 primary CWR tributaries in the Lower Columbia River. The CWR for each tributary are in and/or near the confluence with the Columbia River. These 12 CWR are known or presumed to be used by steelhead and fall Chinook and constitute 98% of CWR volume in the Lower Columbia River. In addition, there are 11 other tributaries that collectively provide a limited amount of CWR, are smaller in scale, and have limited information on fish use.
6. Four primary CWR are below Bonneville Dam (Cowlitz River, Lewis River, Sandy River, and Tanner Creek); seven primary CWR are between Bonneville Dam and The Dalles Dam (Eagle Creek, Wind River, Herman Creek, White Salmon River, Little White Salmon River, Hood River, and Klickitat River); and one primary CWR (Deschutes River) is between The Dalles Dam and the John Day Dam. There are no primary CWR between John Day Dam and McNary Dam.
7. The Cowlitz River, Lewis River, Little White Salmon River (Drano Lake), and the Deschutes River are the largest CWR.

Salmon and Steelhead Use of Cold Water Refuges

8. Summer steelhead and fall Chinook are the primary species that use CWR in the Lower Columbia River. Summer steelhead use CWR for extended periods (multiple weeks),

while fall Chinook use CWR for shorter periods (days to a week). Use of CWR is generally considered to be a successful migration strategy for these fish that allows them to both escape peak Columbia River temperatures and delay migration until temperatures are cooler.

9. Duration of CWR use is very limited (hours) for summer Chinook, which may provide a brief respite from warm temperatures. Sockeye salmon do not appear to use CWR as a migration strategy, although tracking studies of sockeye CWR use has not been done. Extended use of CWR in the Lower Columbia River is generally considered to be an ineffective and ultimately unsuccessful migration strategy for these fish due to their run timing; extended CWR use would likely expose them to warmer Columbia and Snake River temperatures during the remaining part of their migration later in the summer.
10. Steelhead begin to use CWR when mainstem temperatures reach 19°C. Fall Chinook begin to use CWR when mainstem temperatures reach 21°C. Both species use CWR extensively when temperatures exceed 21°C.
11. CWR use by summer steelhead and fall Chinook likely provides physiological benefits by reducing the adverse effects associated with prolonged exposure to warm Columbia River temperatures. Prolonged exposure to warm temperatures increases disease risk, stress, loss of energy reserves, and mortality risk, and ultimately decreases the probability to successfully spawn.
12. Simulation modeling (HexSim) indicates that existing CWR allows steelhead populations to reduce the cumulative exposure to warm Columbia River temperatures above 21°C and 22°C thereby reducing risk of disease and stress-related mortality.
13. Peak use of Bonneville reservoir CWR by steelhead occurs mid-August through early September, and peak use by fall Chinook occurs in late August through mid-September. During an average year (river temperatures and run size), approximately 65,000 steelhead and 5,000 fall Chinook are in Bonneville reservoir CWR. During years with warm August-September Columbia River temperatures and high run size, as many as 155,000 steelhead and 40,000 fall Chinook are estimated to be in Bonneville reservoir CWR during the period of peak refuge use, although these peak numbers for steelhead and fall Chinook may not occur in the same years.
14. The number of salmon and steelhead in CWR each year is a function of summer Columbia River temperatures and run size – the larger the run size, the greater number of fish in CWR; and the warmer the Columbia River temperature, the greater proportion of the run using CWR.
15. CWR use appears to be a behavioral adaptation in response to increased summer Lower Columbia River temperatures. Under colder historical Columbia River temperatures, which exceeded 20°C for only a short period (a few days) and rarely exceeded 21°C, CWR use was likely to be significantly less than what occurs today. This hypothesis is supported by observations in recent years that show significantly less CWR use during years when Columbia River water temperatures were relatively cool.

Adverse Effects to Migrating Adult Salmon and Steelhead from Warm Columbia River Temperatures

16. Optimal Columbia River temperatures for migrating adult salmon and steelhead is below 18°C. Increased stress, disease, mortality, and stored (fat) energy loss that can ultimately reduce spawning success occur with increasing severity as river temperatures rise above 20°C. At average river temperatures of 22-23°C, all adverse effects become significant.
17. Increased river temperature is correlated with decreased survival for migrating adult summer steelhead and fall Chinook between Bonneville Dam and McNary Dam. Survival rates decrease by about 7-10% at >21°C temperatures relative to temperatures below 20°C. Current CWR use by steelhead and fall Chinook may be minimizing survival loss by reducing exposure to >21°C temperatures. However, CWR use may also be contributing to survival loss from harvest in CWR.
18. River temperatures above 18°C reduce adult sockeye survival between Bonneville Dam and McNary Dam. Sockeye mortality rates are moderate at river temperatures of 18-20°C and are significant at 20-22°C.
19. The migration timing of sockeye and summer Chinook has shifted to earlier in the year by approximately a week due to warming of the Lower Columbia River in July. Peak migration past Bonneville Dam for these fish is now in late June, with very few migrants in mid- to late July.
20. Absent use of CWR, a portion of the early fall Chinook exposed to warm Lower Columbia River temperatures in August are predicted to experience total cumulative migration energy loss such that they cannot successfully spawn in the fall in the Snake River.

Sufficiency of Cold Water Refuges to Support Migrating Adult Salmon and Steelhead

21. EPA's assessment is that CWR is sufficient to attain Oregon's CWR narrative criteria in the Lower Columbia River if the volume of the 12 primary CWR is maintained and the Umatilla River is cooled to provide increased CWR volume in August and September consistent with the Oregon and CTUIR Temperatures TMDLs. Therefore, maintaining the current temperatures and flows of the 12 primary CWR tributaries and cooling the Umatilla River is needed to limit significant adverse effects to migrating adult salmon and steelhead from higher water temperatures in the Columbia River[7].

22. Predicted continual future warming of the Lower Columbia River is expected to increase salmon and steelhead use of CWR and diminish the extent to which the current amount of CWR minimizes the risks to migrating adult salmon and steelhead. Therefore, increasing the amount of CWR in the future through restoration and enhancement is recommended to help offset the predicted increased future adverse effects associated with a warmer Lower Columbia River

[7] EPA's assessment of CWR needed to attain Oregon's CWR narrative criteria does not imply that current Columbia River temperatures are at levels to protect salmon and steelhead migration. Current river temperatures exceed the 20°C numeric criterion and cause adverse effects to salmon and steelhead which are not fully mitigated by CWR.

Watershed Characteristics of 12 Primary Cold Water Refuges

23. The 12 primary CWR tributaries are in watersheds with important characteristics and geographic features that serve to keep the tributaries relatively cool during the summer period. Some drain from the glaciers of Mount Rainier, Mount Adams, or Mount Hood, providing cold headwater source water (Cowlitz, Lewis, Sandy, Hood, White Salmon, Little White Salmon, Klickitat, Deschutes). Some have significant groundwater inflows that serve to keep the tributary cool (Tanner, Eagle, White Salmon, Little White Salmon, Klickitat, Deschutes). Ten of the tributary watersheds are in the central or western Cascades with high percentages of forested areas that minimize solar heating and help keep waters cool.
24. Four of the primary tributaries (Cowlitz, Lewis, Sandy, Deschutes Rivers) have upstream storage dams that play an important role in providing cool summer river flows by releasing cool water that exists deep within the storage reservoir.
25. Although the 12 primary CWR tributaries are relatively cool, there are impacts within the watershed that can warm the tributary, including floodplain degradation, water withdrawals and reduced summer flow, sedimentation, and loss of riparian shade. Climate change has already warmed all tributaries to some extent and is predicted to continue to warm these tributaries in the future. Restoration activities to address the anthropogenic impacts within the watershed can help offset predicted warming.
26. Most of the 12 primary tributaries have sediment build-up at the confluence with the Columbia River that may impede salmon and steelhead access to the CWR, fill deep pools preferred by fish, and create shallow areas more susceptible to solar warming.

Recommended Actions to Protect and Restore Cold Water Refuges

27. Protect existing CWR tributaries through the implementation of existing programs and regulatory actions[8] that help keep waters cool.
    a. Since extensive portions of the priority CWR tributaries include forest lands, important protective programs include continued implementation of USFS plans and aquatic strategies on national forest land, State of Oregon and Washington management plans on state forest land, and the states' forest practice regulations on private forest land.
    b. Protect existing riparian buffers along the CWR tributaries on non-forest lands through ongoing implementation of the *Columbia River Gorge National Scenic Area Management Plan* in the Columbia River Gorge National Scenic area, Wild and Scenic River managements plans for the Sandy, White Salmon, Klickitat,

[8] Many of the programs and plans referenced in this recommendation are intended to meet various state or federal requirements, and some are updated on occasion based on new information. By citing a program or plan in this CWR Plan as important to prevent degradation of water quality and maintain cool river temperatures, EPA is not stating the program or plan meets applicable state or federal requirements. EPA recognizes some of these plans will be updated as warranted.

and Deschutes rivers, and county land use regulations and plans to protect shoreline areas.

c. Maintain existing stream flows, which are important for the size and function of the primary CWR tributaries, by continued implementation of the minimum instream flow requirements below Mayfield (Cowlitz), Merwin (Lewis), Bull Run (Sandy), and Pelton Round Butte (Deschutes) dams and the state minimum instream flow rules for the Lewis, Sandy, Hood, and Deschutes Rivers. In accordance with recommendations in existing plans, consider establishing minimum instream flows for the Wind, Little White Salmon, White Salmon, and Klickitat Rivers.

d. Apply state water quality antidegradation requirements and Oregon's protecting cold water standard (OAR 430-0410-0028 (11)) to help maintain the current summer river temperatures in Tanner Creek, Herman Creek, Little White Salmon River, and the White Salmon River, which are currently colder than the temperature standards. Consider use designation revisions for Tanner Creek and Herman Creek to reflect the current cold water habitat use.

28. Implement projects identified in existing plans (e.g., NPCC subbasin plans, Salmon Recovery Plans, TMDL implementation plans) to restore degraded portions of the 12 primary CWR and the Umatilla River watersheds to enhance the quality of the CWR and to counteract predicted future increases in tributary river temperature. Projects include: 1) restoring riparian vegetation to provide river shading; 2) restoring stream morphology and floodplain connectivity to reduce channel widths and create pools and groundwater connectivity; and 3) restoring summer river flows that are more resistant to warming and increase CWR volume.

29. Develop a temperature TMDL(s) and associated implementation plan(s) for the Deschutes River basin to aid in restoration actions to cool the lower Deschutes River temperatures. Due to the Deschutes River's high CWR use by migrating salmonids, marginally cool current temperatures, and predicted temperature increases due to climate change, efforts to target 18°C temperatures or less during the August-September high CWR use period is a high priority.

30. To increase the CWR in the Umatilla River and help attain Oregon's CWR narrative standard, implement actions in existing plans (e.g., NPCC Umatilla subbasin plan, Mid-Columbia River Steelhead Recovery Plan, and the Umatilla River TMDL implementation plan) that help increase shade, increase floodplain connectivity, and restore rivers flows. A priority project is agreement on and implementation of an additional Umatilla Basin Project water exchange or alternative measure to increase summer flows in the Lower Umatilla River, thereby decreasing summer river temperatures and increasing CWR volume.

31. Maintain or enhance cool water releases during late July through mid-September from upstream dams on the Cowlitz, Lewis, Sandy, and Deschutes Rivers to maintain or increase CWR. Due to the importance and vulnerability of the Deschutes River CWR, assess the potential to release cooler water from Pelton Round Butte Dam in August to potentially cool the river at the mouth.

32. Consider feasibility studies for restoration and sediment removal at the confluence areas of the following watersheds to increase fish access to CWR and increase depth: Herman Creek Cove, Wind River, White Salmon River, and Klickitat River.

33. In addition to protecting and restoring 12 primary CWR tributaries and the Umatilla River, restoring the other non-primary CWR tributaries, Fifteenmile Creek, and potentially other tributaries to the Lower Columbia River is recommended to provide additional CWR in the future to help address the expected increased use of CWR due to a warmer Columbia River. Construct the proposed log structure at the mouth of Oneonta Creek as a demonstration project for CWR augmentation at small stream confluences. Examine the feasibility of groundwater supply supplementation at the Cascade Hatchery to cool and augment the Eagle Creek CWR.

Fishing in Cold Water Refuges

34. Fishing in CWR appears to reduce the survival of steelhead that use CWR compared to those that do not, offsetting the benefits to fish using CWR. This Plan may inform future updates to fishing regulations in the primary CWR, especially related to periods of warm Columbia River temperatures for the CWR with the highest use (Cowlitz River, Lewis River, Herman Creek Cove, Wind River, White Salmon River, Little White Salmon River (Drano Lake), Klickitat River, and Deschutes River).

Recommended Studies and Monitoring to Address Uncertainties and Trends

35. In Chapter 8, several scientific uncertainties associated with this Plan were highlighted with recommended future studies to address them, which include: radio-tag studies to track fish use of CWR below Bonneville Dam, repeated radio-tag studies to track fish use of CWR above Bonneville Dam under current conditions, installation of PIT-tag detectors at the mouth of CWR tributaries, installation of temperature and flow gages near the mouth of CWR tributaries where there are none currently, and studies designed to better characterize the adverse effects to fish from exposure to elevated temperatures in the Lower Columbia River and the associated benefits of CWR use to reduce the adverse effects.

36. Immediate monitoring priorities include: install PIT-tag detectors in Little White Salmon River/Drano Lake and Herman Creek Cove; re-establish USGS flow gauges, including temperature gauges, near the mouth of Little White Salmon River and Wind River; and install and operate long-term annual summer temperature monitors at the USGS flow gauge sites near the mouth of the Cowlitz, Lewis, Sandy, White Salmon, Hood, Klickitat, and Umatilla Rivers.

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12 APPENDICES

12.1 LOWER COLUMBIA RIVER TEMPERATURE VARIATION

12.2 EVALUATION OF THE POTENTIAL COLD WATER REFUGIA CREATED BY TRIBUTARIES WITHIN THE LOWER/MIDDLE COLUMBIA RIVER BASED ON NORWEST TEMPERATURE MODEL

12.3 SCREENING APPROACH TO IDENTIFY THE 23 TRIBUTARIES THAT CURRENTLY PROVIDE CWR IN THE LOWER COLUMBIA RIVER

12.4 LOCATION OF UPSTREAM EXTENT OF 23 CWR AREAS USED BY MIGRATING SALMON AND STEELHEAD

12.5 VOLUME OF COLD WATER REFUGE ASSOCIATED WITH THE 23 TRIBUTARIES PROVIDING CWR IN THE LOWER COLUMBIA RIVER AND SELECTION OF THE 12 PRIMARY CWR

12.6 COLUMBIA RIVER COLD WATER REFUGE ASSESSMENT PLUME MODELING REPORT

12.7 ESTIMATING THE POTENTIAL COLD WATER REFUGIA VOLUME WITHIN TRIBUTARIES THAT DISCHARGE INTO THE COLUMBIA RIVER

12.8 ESTIMATES OF PLUME VOLUME FOR FIVE TRIBUTARY/COLUMBIA RIVER CONFLUENCE SITES USING USEPA FIELD DATA COLLECTED IN 2016

12.9 ESTIMATED CWR VOLUME FOR THE WIND RIVER AND LITTLE WHITE SALMON RIVER/DRANO LAKE

12.10 ESTIMATED CWR VOLUME IN HERMAN CREEK COVE

12.11 SUPPLEMENT TO ESTIMATED CWR VOLUME IN HERMAN CREEK COVE

12.12 TRIBUTARY AND COLUMBIA RIVER MEASURED TEMPERATURE DATA SUMMARY

12.13 ESTIMATED NUMBER OF STEELHEAD AND FALL CHINOOK USING CWR IN THE BONNEVILLE RESERVOIR REACH

12.14 WATER TEMPERATURE ESTIMATES OF THE COLUMBIA RIVER AND TRIBUTARIES IN 2040 AND 2080

12.15 STREAM TEMPERATURE PREDICTIONS UNDER VARYING SHADE AND CLIMATE SCENARIOS IN THE COLUMBIA RIVER BASIN

12.16 ASSESSMENT OF CLIMATE CHANGE IMPACTS ON TEMPERATURES OF THE COLUMBIA AND SNAKE RIVERS

12.17 WATER TEMPERATURE ESTIMATES OF THE LOWER/MIDDLE COLUMBIA RIVER AND TRIBUTARIES IN 2040 AND 2080 BASED ON THE NORWEST MODEL

12.18 PREDICTED MAXIMUM TEMPERATURES USING THE NORWEST MODEL IN 12 PRIMARY COLD WATER TRIBUTARIES AND 2 "RESTORE" TRIBUTARIES

12.19 COMPARISON OF NORWEST FUTURE TEMPERATURE ESTIMATES TO A CONTINUATION OF HISTORICAL WARMING TRENDS IN THE LOWER COLUMBIA RIVER

12.20 WATERSHED SNAPSHOT ASSUMPTIONS AND APPROACHES

12.21 HEXSIM MIGRATION CORRIDOR SIMULATION MODEL PRELIMINARY RESULTS

12.22 COMPARISON OF NORWEST TEMPERATURE ESTIMATES TO MONITORING DATA IN THE TWELVE PRIMARY CWR

12.23 COMPARISON BETWEEN NHDPLUS MODELED AUGUST MEAN FLOW CONDITIONS AND AVAILABLE FLOW DATA COLLECTED AT THE PRIMARY COLD WATER REFUGIA (CWR) STREAMS

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1200 Sixth Avenue, Suite 155
Seattle, Washington 98101