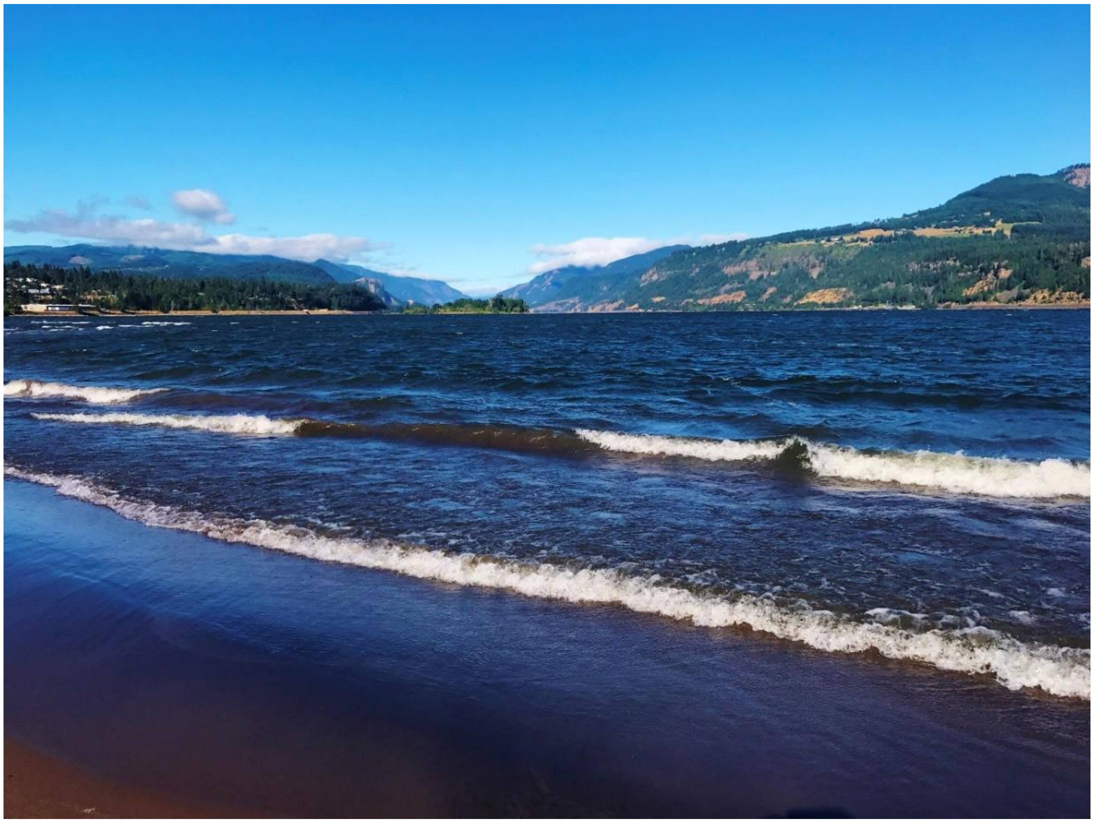
Columbia and Lower Snake Rivers Temperature Total Maximum Daily Load

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue, Suite 155
Seattle, WA 98101-3188



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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
7-DADM	7-day average daily maximum
BMPs	Best management practices
°C	Degrees Celsius
CFR	Code of Federal Regulations
CRSO	Columbia River System Operations
CTCR	Confederated Tribes of the Colville Reservation
CWA	Clean Water Act
CWR	Cold water refuge
DART	(Columbia River) Data Access in Real Time
DM	Daily maximum
Ecology	Washington Department of Ecology
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FCRPS	Federal Columbia River Power System
kcfs	Kilo cubic feet per second
LA	Load allocation
LC	Loading capacity
MOS	Margin of safety
MS4	Municipal Separated Storm Sewer System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
POTW	Publicly owned treatment works
PUD	Public Utility District
RM	River mile
STP	Sewage treatment plan

Acronyms/Abbreviations	Definition
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
WAC	Washington Administrative Code
WLA	Wasteload allocation
WQC	Water quality criteria
WQS	Water quality standards
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

On May 18, 2020, the U.S. Environmental Protection Agency (EPA) established the Columbia and lower Snake River Temperature Total Maximum Daily Loads (TMDLs) with the goals of providing information about the primary sources of temperature impairments in the Columbia River basin and initiating dialogue among federal agencies, state and tribal governments, and the public about reducing temperatures in the Columbia and lower Snake Rivers. Spanning almost 900 river miles, this TMDL examines sources of temperature impairments on the Columbia River, from the Canadian border to the Pacific Ocean, and on the lower Snake River in Washington, from its confluence with the Clearwater River at the Idaho border to its confluence with the Columbia River.

The TMDL is required under the federal Clean Water Act (CWA); significant portions of the Columbia and lower Snake Rivers are identified by the States of Washington and Oregon as impaired due to temperatures that exceed the states' water quality standards (WQS) at various locations and times. The most predominate WQS (in terms of river miles) is the 20 degrees Celsius (°C) summer maximum criterion to protect salmon and steelhead migration, which applies in the lower 397 miles of the Columbia River and the lower 139 miles of the Snake River.

In 2000, EPA agreed in a Memorandum of Agreement with the states of Washington, Oregon and Idaho to develop the Columbia and Snake River Temperature TMDL. EPA completed some work, although the TMDL was never finalized. As a result of litigation initiated in 2017, EPA established the temperature TMDL for the Columbia and lower Snake Rivers on May 18, 2020. EPA solicited public comment on the established TMDL, in accordance with EPA's regulations. After considering public comments and making appropriate revisions, EPA is transmitting this TMDL to the States of Oregon and Washington for incorporation into their current water quality management plans.

EPA examined existing river temperature data and found that temperature water quality criteria (WQC) that protect summer salmonid and steelhead migration are exceeded frequently between June and October, and the temperature criteria that protect the fall salmonid spawning are exceeded in the lower Columbia in the fall. At seven of eleven monitoring locations on the Columbia River and two of four locations on the lower Snake River, the maximum water temperatures typically exceed the WQC during the month of August. The warmest temperatures occur in the lower Columbia River and the lower part of the Snake River, where maximum temperatures reach 22-23°C. The duration and magnitude with which the water quality criteria are exceeded pose a variety of adverse effects to migrating salmon and steelhead, including multiple populations listed as threatened or endangered under the Endangered Species Act.

EPA's TMDL analysis considered all known sources of temperature impairments in the mainstem Columbia and lower Snake Rivers through an examination of existing temperature data, mechanistic models, and available literature. EPA examined the impacts of climate change, 15 dams, 23 major tributaries, 127 individual NPDES point sources, stormwater, upstream boundary temperatures, and withdrawals from the Banks Lake Pump Project and Dworshak Dam. EPA found that climate change and nonpoint source dam impacts are the dominant sources of impairment, with impacts that are an order-of-magnitude higher than point sources, agricultural withdrawals, and tributaries.

EPA determined that the warming trend due to climate change has significantly affected temperatures in the rivers since the 1960s, and these adverse thermal impacts continue to increase. A synthesis of available scientific evidence indicates that climate change has increased summer water temperatures in the Columbia and Snake Rivers by approximately 1.5°C since the 1960s.

Impoundment of the rivers by dams also impacts water temperature in different ways depending on the time of year and locations on the rivers. The impacts of dams on mainstem river temperatures are complex and variable: dam operations can result in cooler or warmer downstream temperatures, depending on time of year and dam operations. Impoundments cause higher, sustained river temperatures in the summer, higher temperatures at the water surface and in fish ladders, and delayed cooling in the fall. Storage reservoirs, like Grand Coulee, on the other hand, may reduce downstream temperatures during the early summer. Deep reservoirs with temperature control structures (e.g., Dworshak Dam) can be used to release cold water and reduce temperatures over substantial distances downstream.

EPA estimates that dams on the Columbia and lower Snake Rivers have a cumulative warming impact on the mainstem rivers in the critical late-summer period, with water temperature increases as high as 2.5°C warming at John Day Dam and 2.2°C warming at Ice Harbor Dam in September. Cold water releases from Dworshak Dam in Idaho near the Washington border provide significant cooling to the upper portion of the lower Snake River in the summer. In August, mean temperatures are estimated to be at least 3.8°C colder in the Snake River at the Clearwater River confluence than they would be without Dworshak Dam releases. EPA recognizes that there are limited additional opportunities to improve river temperatures through operational changes at the federal dams; however, EPA encourages federal agencies and states to work together, with EPA as appropriate, during TMDL implementation to explore feasible opportunities.

Water entering the Columbia and Snake Rivers at the Canadian and Idaho borders exceeds Washington's WQC for temperature during the summer. EPA is unable to quantify the human impacts on temperature at these upstream TMDL boundaries because there are no available temperature models for these areas. If summer temperatures at the Canadian border were cooler, temperature conditions upstream of Grand Coulee would improve; however, EPA's RBM10 model results indicate that these improvements would diminish downstream of Grand Coulee to the lower Columbia, where the temperature increases above the applicable WQS are highest. Similarly, the model shows that the benefits of cooler water at the Idaho border would diminish downstream in the Snake River dam impoundments.

The TMDL includes the following key determinations:

- Temperature impairments are widespread and primarily due to the cumulative impacts of climate change and dam impoundments;
- Temperature reductions of up to 3.1°C are necessary to meet summer WQC within the lower Columbia River, and reductions of up to 2.8°C are necessary to meet summer WQC in the lower Snake River. The reductions necessary to meet standards vary with time and location;
- The allowable thermal loading capacity of the Columbia and lower Snake Rivers is limited, with a total allowable loading capacity of a 0.3°C increase in river temperature, as contemplated in the states' WQS, allocated to all point and nonpoint sources;

- EPA has divided the 0.3°C allowable loading capacity equally among dam impoundments, NPDES point sources, and tributaries. The allowable combined impact of the sources in each category is 0.1°C at any location;
- NPDES point sources are allocated a cumulative temperature increase of 0.1°C, which is consistent with continued discharge of current heat loads;
- A reserve allocation for NPDES point sources is included for each reach of the TMDL study area for future growth, new sources, and WLA adjustments for existing facilities, based on new information;
- The combined impacts of the tributaries are allocated a cumulative temperature increase of 0.1°C in the mainstem Columbia and Snake rivers. This translates to an allowable anthropogenic impact of 0.5°C above natural temperatures at the mouth of each tributary. Although the natural temperature of most tributaries has not been assessed, the mainstem assessment indicates that tributary restoration will lead to modest improvements in water temperatures in the mainstems. For example, attainment of numeric criteria in all 23 major tributaries across the study area would result in a small reduction (0.2°C or less) in temperatures of the mainstem Columbia and Snake Rivers; and
- The TMDL identifies a separate list of 23 tributaries of varying size in the lower Columbia River that provide cold water refuge from high mainstem temperatures for migrating adult salmon and steelhead. The TMDL sets temperature, flow, and cold water volume targets within 13 of these tributaries to maintain and increase available cold water refuge in the lower Columbia River to attain the State of Oregon's cold water refuge WQS.

Even if the temperature reductions identified in this TMDL are fully realized, it is likely that the numeric criteria will not be met at all times and all places. Because this TMDL allocates heat loading to point and non-point sources within the temperature increases authorized by the applicable WQS (not greater than 0.3°C, combined), achieving the TMDL load allocations will significantly reduce the duration and magnitude of WQS exceedances, improving temperatures for migrating salmonids and resident species.

1.0 INTRODUCTION

This document establishes a total maximum daily load (TMDL)[1] for temperature for the Columbia and lower Snake Rivers as required by Section 303(d) of the Clean Water Act (CWA) and its implementing regulations at Title 40 of the Code of Federal Regulations (CFR) Section 130.7. The TMDL is required because the States of Washington and Oregon have identified portions of the Columbia and lower Snake Rivers as impaired because of temperatures that exceed the numeric criteria portion of the States' water quality standards (WQS).

The temperature WQS are designed to protect the beneficial uses in those waters, the most sensitive of which are salmon migration and spawning. Columbia River salmon and steelhead runs were once the largest in the world. Columbia River tribes have depended on native fish

[1] EPA has in the past referred to a "TMDL" in the singular to refer to a single combination of one water quality limited segment and one pollutant. The term "TMDL" in the singular can also refer to a single TMDL *document* that includes multiple TMDLs. This TMDL document is referred to in the singular although it includes multiple TMDLs, i.e., for each of the stream segments addressed in it.

species, including salmon and steelhead, for thousands of years for spiritual, cultural, and nutritional sustenance.

The elevated temperatures are particularly problematic in the lower Columbia River and the lower part of the Snake River, where summer temperatures frequently exceed 20 degrees Celsius (°C), which is the WQC that protects salmon and steelhead migration. River temperatures in excess of 20°C cause adverse effects to migrating juveniles in the form of decreased growth, smoltification impairment, increased disease, and increased predation and impacts to migrating adults in the form of increased stress, increased disease, decreased energy, and impairment to spawning success (EPA, 2003). Increased disease associated with warm river temperatures can often lead to mortality for both juveniles and adults. In 2015, warm temperatures in the lower Columbia and Snake Rivers and associated high levels of disease resulted in significant mortality for migrating adult salmon, particularly for sockeye salmon (NOAA, 2016 and EPA, 2021).

Thirteen species of salmon and steelhead listed as threatened or endangered under the Endangered Species Act use the Columbia River Basin to swim to the Pacific Ocean as juveniles and to return to spawning grounds as adults. A portion of the seasonal migratory runs of most of these 13 species occurs when Columbia and Snake River temperatures exceed 20°C, and these elevated temperatures have been identified by NOAA Fisheries as a limiting factor in the recovery of the listed species (NOAA, 2020).

Adult salmon and steelhead migrating through the lower Columbia River in summertime regularly use cold water refuges, where cool tributaries enter the Columbia River, and thereby avoid areas of the river where temperatures are highest. Some of the best cold water refuges are the largest, coldest tributaries, which EPA identifies in this TMDL (Section 5.0).

Under the Clean Water Act, TMDLs serve as a tool for states and EPA to assess, and provide information needed to address, water quality impairments on a basin-wide scale. Spanning almost 900 river miles, this TMDL examines sources of temperature impairments on the Columbia River from the Canadian border to the Pacific Ocean, and on the lower Snake River in Washington, from its confluence with the Clearwater River at the Idaho border to its confluence with the Columbia River. See ***Figure 2-1***.

In developing this TMDL, EPA evaluated the temperature impacts from the following categories of heat loading: (1) point source discharges of heat subject to National Pollutant Discharge Elimination System (NPDES) permits; (2) nonpoint source heat loading from dams and reservoirs that alter water temperatures within their reservoirs and in downstream river reaches; (3) tributary inflows to the mainstems of the Columbia and lower Snake Rivers that are affected by upstream point and nonpoint sources; (4) increasing air temperatures and other factors associated with climate change; (5) cold water releases from Dworshak Dam in Idaho; (6) agricultural water withdrawals from the Banks Lake project; and (7) water temperatures in the mainstems of the Columbia and lower Snake Rivers where they enter into Washington from Canada and Idaho, respectively.

Given this context, EPA's focus is to provide a comprehensive and informative assembly of data and information on the river temperature regime and estimated impacts from human activities on that temperature regime. The information in this TMDL will assist in prioritizing actions to reduce water temperatures and to mitigate adverse impacts to salmon.

To keep the TMDL document as concise as possible, discussion of the technical analyses and modeling that support the pollutant allocations are summarized, with the more detailed technical support documentation provided in the appendices.

1.1 TOTAL MAXIMUM DAILY LOADS AND CLEAN WATER ACT

Section 303(c) of the CWA requires states to establish water quality standards that identify each waterbody's designated uses and the criteria needed to support those uses. CWA section 303(d) requires states to develop lists of impaired waters that fail to meet the standards set by jurisdictions even after implementing technology-based and other pollution controls. TMDLs are design tools or plans for addressing such impaired waters.

A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet applicable WQS. A mathematical definition of a TMDL is written as the sum of the individual wasteload allocations (WLAs) for point sources, the load allocations (LAs) for nonpoint sources and natural background, and a margin of safety (MOS). [CWA § 303(d)(1)(C); 40 CFR 130.2(i)]:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

where

WLA = wasteload allocation, or the portion of the TMDL allocated to existing and/or future point sources.

LA = load allocation, or the portion of the TMDL attributed to existing and/or future nonpoint sources and natural background.

MOS = margin of safety, or the portion of the TMDL that accounts for any lack of knowledge concerning the relationship between effluent limitations and water quality, such as uncertainty about the relationship between pollutant loads and receiving water quality, which can be provided implicitly by applying conservative analytical assumptions or explicitly by reserving a portion of loading capacity.

This TMDL sets the identified point and non-point source impacts on river water temperatures to the increases that can be allocated under Washington and Oregon WQS, as discussed below.

1.2 TOTAL MAXIMUM DAILY LOAD GEOGRAPHIC SCOPE AND WATER QUALITY IMPAIRMENTS

The geographic scope of this temperature TMDL includes waters within the mainstem of the Columbia River from the Canadian border (River Mile [RM] 745) to the Pacific Ocean; and within the mainstem of the lower Snake River in Washington from its confluence with the Clearwater River at the Idaho border (RM 139) to its confluence with the Columbia River. The stream segments and associated waterbody identification numbers of the Columbia and lower Snake Rivers that are identified as impaired for temperature pursuant to CWA section 303(d) are listed in ***Table 1-1*** and illustrated in ***Figure 1-1***. The Oregon Department of Environmental Quality (DEQ) included the entire Oregon portions of the Columbia River mainstem on its 2012 Section 303(d) list. The Washington Department of Ecology (Ecology) included 49 different segments of the two rivers on its 2012 CWA section 303(d) list.

As detailed in Section 6.0, EPA has completed TMDLs for all 50 segments listed in ***Table 1-1*** by establishing allocations for sources of pollution, including NPDES point sources, tributaries, and dams. EPA also has identified 23 tributaries in the lower Columbia River that provide critical cold water refuge for fish, as explained in Section 5.0.

Table 1-1 Washington and Oregon 303(d) temperature impairments on the Columbia and lower Snake Rivers

Waterbody	Assessment Unit	River Mile (RM)
Washington		
Columbia River	170800030900_01_02	38.6 – 47.5
Columbia River	170800030900_01_04	53.6 – 57.9
Columbia River	170800030900_01_05	57.9 – 68.1
Columbia River	170800030900_01_06	68.1 – 73.1
Columbia River	170800030900_01_07	73.1 – 76.1
Columbia River	170800030200_01_01	86.6 – 101.4
Columbia River	170800030200_01_02	101.4 – 120.5
Columbia River	170800010804_01_01	120.5 – 131.5
Columbia River	170800010802_01_01	136.8 – 142.4
Columbia River	170701051204_01_01	146.1 – 154.7
Columbia River	170701051106_01_01	154.7 – 168.9
Columbia River	170701051105_01_01	168.9 – 180.4
Columbia River	170701050406_01_01	180.4 – 191.8
Columbia River	170701050401_01_01	191.8 – 202.7
Columbia River	170701050103_01_01	202.7 – 215.6
Columbia River	170701011408_01_01	215.6 – 227.7
Columbia River	170701010601_01_01	286.5 – 292.0
Columbia River	170701010207_01_01	292.0 – 294.8
Columbia River	170701010201_01_01	305.2 – 309.3
Columbia River	170701010103_01_01	314.4 – 317.4
Columbia River	170200160604_01_01	324.5 – 338.1
Columbia River	170200160106_01_01	387.9 – 397.2
Columbia River	170200160105_01_01	397.2 – 404.4
Columbia River	170200100507_01_01	410.7 – 415.8
Columbia River	170200100506_01_01	415.8 – 421.7
Columbia River	170200100401_01_01	450.1 – 453.4
Columbia River	170200100313_01_01	453.4 – 464.1
Columbia River	170200100308_01_01	464.1 – 468.4
Columbia River	170200100307_01_01	468.4 – 473.7
Columbia River	170200100306_01_01	473.7 – 483.7
Columbia River	170200050507_01_01	503.4 – 515.6
Columbia River	170200050505_01_01	515.6 – 523.8
Columbia River	170200050405_01_01	533.6 – 545.2
Columbia River	170200050404_01_01	545.2 - 554.8
Columbia River	170200050203_01_01	589.3 – 596.7

Waterbody	Assessment Unit	River Mile (RM)
Columbia River (Roosevelt Lake)	48117J7B8	
Columbia River (Roosevelt Lake)	48117J7C7	
Columbia River (Roosevelt Lake)	47118J6D8	
Columbia River (Roosevelt Lake)	48118F1G1	
Columbia River (Roosevelt Lake)	48118F1J2	
Snake River	170601100404_01_01	0.3 – 9.8
Snake River	170601100403_01_01	9.8 – 21.1
Snake River	170601100106_01_01	29.8 – 41.6
Snake River	170601100103_01_01	41.6 – 51.8
Snake River	170601070807_01_01	67.4 – 70.3
Snake River	170601070804_01_01	77.9 – 91.8
Snake River	170601070802_01_01	91.8 – 107.3
Snake River	170601030307_01_01	139.3 – 150.3
Snake River	170601030303_01_01	157.6 – 168.8
Oregon		
Mid and lower Columbia	1240480000000	0 – 303.9

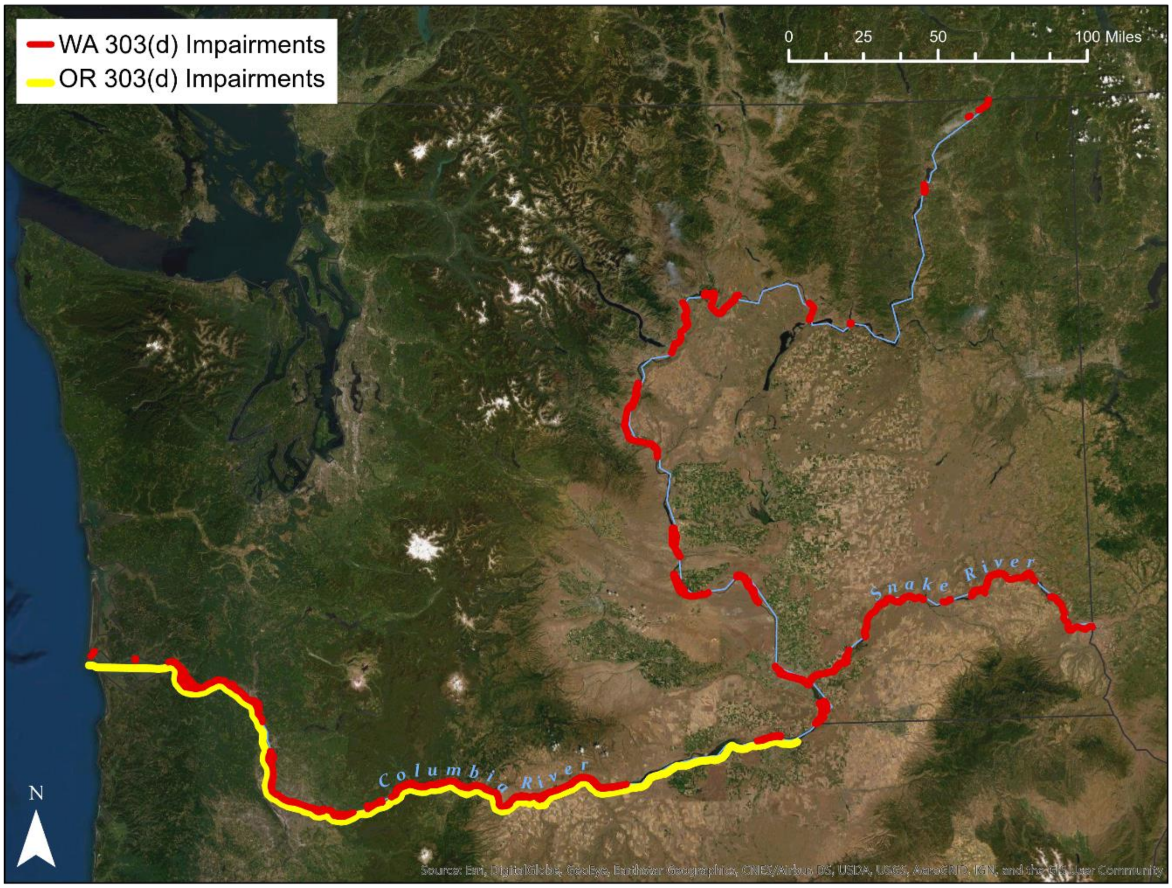

Figure 1-1 Washington and Oregon waterbodies in the Columbia and lower Snake Rivers identified as impaired for temperature pursuant to CWA 303(d)

2.0 WATER QUALITY STANDARDS

This Section identifies the applicable temperature WQS for the mainstems of the Columbia and lower Snake Rivers, including those WQS that have been federally promulgated or adopted by the four governments with jurisdiction over these rivers and approved by EPA: The Confederated Tribes of the Colville Reservation (CTCR), Spokane Tribe of Indians, and the States of Oregon and Washington. These States and Tribes developed the temperature WQS to protect the most sensitive aquatic life uses in the Columbia and lower Snake Rivers, such as salmonid spawning, rearing, and migration.

The CTCR standards were promulgated by EPA in 1989 (40 CFR Part 131.35) and apply within the reservation boundaries along a more than 150-mile section of the upper Columbia River, from RM 534 - 690. The Spokane Tribe of Indians temperature WQS were partially approved and partially disapproved by EPA in 2013. For the temperature standards that were not approved, the previously approved 2003 temperature WQS apply for Clean Water Act purposes. The applicable temperature standards cover a 7-mile stretch of the Columbia River within Lake Roosevelt to protect fish and shellfish, including salmonid migration, rearing, spawning, and harvesting. The applicable CTCR and Spokane Tribe of Indians criteria are summarized in ***Table 2-1***.

EPA has compiled and organized the temperature WQS (which include the designated uses and the numeric water quality criteria (WQC)) into 10 different jurisdictional reaches (Reaches A through J) for the purposes of understanding the geographic areas covered by each of the applicable standards. These reaches are illustrated in ***Figure 2-1*** and summarized in ***Table 2-2***. EPA used the most protective of these criteria to develop the TMDL. A more detailed compilation of the WQS can be found in Appendix A.

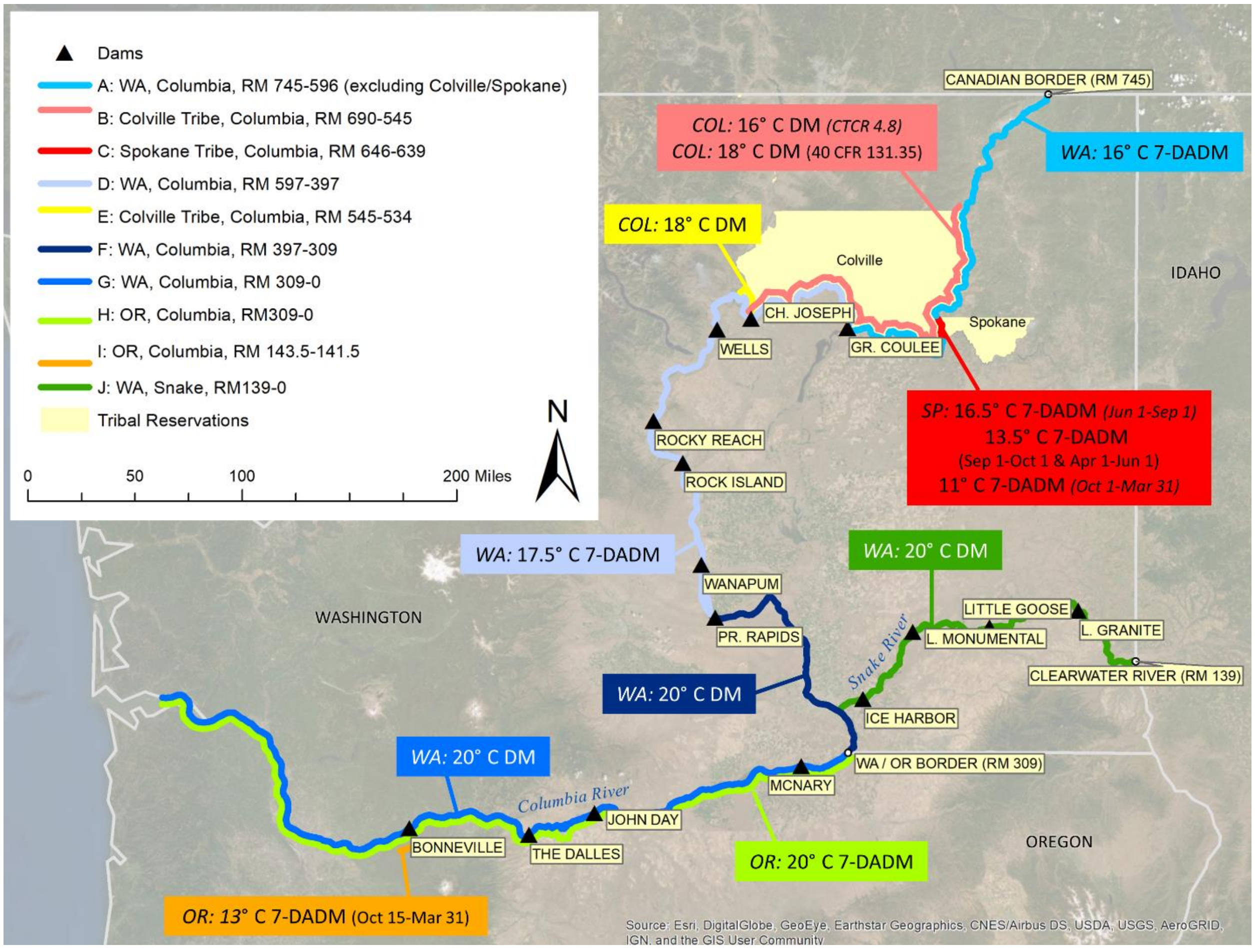

Figure 2-1 Columbia and lower Snake River temperature WQS, jurisdictions, river miles, and numeric criteria

Table 2-1 Summary of temperature criteria and aquatic life uses for the Columbia and lower Snake Rivers

Map	Jurisdiction	RMs	Criterion (°C)	Aquatic Life Use
Columbia River				
A	Washington	Canadian Border (745) to Grand Coulee Dam (596) (excluding RM 646.5-639)	16 7-DADM[2]	Core summer salmonid habitat
B	CTCR	CTCR Reservation Boundary (690) to Chief Joseph Dam (545)	18 DM[3] (40 CFR 131.35)	Salmonid migration, rearing, spawning, and harvesting
C	Spokane Tribe	Reservation Boundary (646.5) to Reservation Boundary (639)	16.5 7-DADM (June 1 - Sept 1) 13.5 7-DADM (Sept 1 – Oct 1 & April 1 – June 1) 11 7-DADM (Oct 1 – March 31)	Fish and shellfish, including salmonid migration, rearing, spawning, and harvesting
D	Washington	Grand Coulee Dam (596) to Priest Rapids Dam (397)	17.5 7-DADM	Salmonid spawning, rearing, and migration
E	CTCR	Chief Joseph Dam (545) to Okanogan River (534)	18 1-DM (40 CFR 131.35 & CTCR 4-8)	Salmonid migration, rearing, spawning, and harvesting
F	Washington	Priest Rapids Dam (397) to WA/OR Border (309)	20 DM	Salmonid spawning, rearing, and migration
G	Washington	WA/OR Border (309) to Pacific Ocean (0)	20 DM	Salmonid spawning, rearing, and migration
H	Oregon	WA/OR Border (309) to Pacific Ocean (0)	20 7-DADM	Salmon and steelhead migration corridors
I	Oregon	Ives Island (143.5) to Beacon Rock (141.5)	13 7-DADM (Oct 15th – Mar 31st)	Salmon and steelhead spawning through fry emergence
Snake River				
J	Washington	Clearwater River (139) to Snake Mouth (0)	20 DM	Salmonid spawning, rearing, and migration

[2] 7-DADM is the 7-day average of the daily maximum temperature.
[3] DM is the daily maximum; averaging period not provided.

2.1 WASHINGTON

Washington's numeric water quality criteria (WQC) are set either as daily maximum temperatures (DM) or as 7-day averages of the daily maximum temperatures (7-DADM) occurring in a waterbody. In developing the temperature standards, Washington recognizes that aquatic species need access to cold water refuges (CWRs), where individual migrating aquatic species sometimes seek refuge to avoid maximum temperatures. The maximum temperature criterion assumes that colder temperatures are available to protect fish at night (Ecology 2002).

In the WQS, aquatic life use categories are described using key species (e.g., salmonid or char versus warm-water species) and life-stage conditions (e.g., spawning versus rearing) (Washington Administrative Code [WAC] 173-201A-200). The temperature criteria established to protect the uses in the Columbia and lower Snake Rivers include 16°C 7-DADM for core summer salmonid habitat and either 17.5°C 7-DADM or 20°C DM for salmonid spawning, rearing, and migration (depending on geographic location), all of which are effective throughout the entire year. Temperatures are not to exceed the criteria at a probability frequency of more than once every ten years on average (WAC 173-201A-200 (1)(c)(iii)).

In addition to the above numeric temperature WQC, the following narrative criteria also apply to the Columbia and lower Snake Rivers in Washington:

- *Upstream actions must be conducted in manners that meet downstream water body criteria [WAC 173-201A-260(3)(b)].*
- *At the boundary between water bodies protected for different uses, the more stringent criteria apply [WAC 173-201A-260(3)(d)].*

Washington WQS define "measurable change" as *a temperature increase of 0.3°C or greater* (WAC 173-201A-320 [3][a]). EPA interprets and implements this definition as establishing an allowable temperature increment for changes in water temperature.

2.2 OREGON

The mainstem Columbia River serves as the border between Washington and Oregon from the Pacific Ocean upstream to RM 309 (***Table 2-2***). Oregon's designated uses for the mainstem include salmon and steelhead migration (20°C 7-DADM) for the entire reach, with one relatively small segment that is also seasonally designated for salmon and steelhead spawning through fry emergence (13°C 7-DADM). The criterion for salmon and steelhead spawning through fry emergence applies from October 15 – March 31 for RM 141 to 143 (Reach I).

In addition to the above numeric temperature WQC, the following narrative criteria also apply to the Columbia River basin in Oregon:

- *The seasonal thermal pattern in Columbia and Snake Rivers must reflect the natural seasonal thermal pattern [Oregon Administrative Rules [OAR] 340-041-0028(4)(d)].*
- *Cold Water Refugia. These waterbodies must have cold water refugia that are sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the waterbody [OAR 340-041-0028(4)(d)].*
    - *Oregon water quality standards define cold water 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 maximum*

temperature of the adjacent well mixed flow of the water body" [OAR 340-041-0002(10)].

- *Protecting Cold Water. Except as described in subsection (c) of this rule, waters of the State that have summer seven-day average maximum ambient temperatures that are colder than the biologically based criteria in section (4) of this rule, may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the colder water ambient temperature. This provision applies to all sources taken together at the point of maximum impact where salmon, steelhead or bull trout are present [OAR 340-041-0028(11)(a)].*

Finally, Oregon WQS include a supplementary provision for a "human use allowance" that authorizes insignificant additions of heat in water that exceeds the applicable temperature criteria, as follows:

- *Following a temperature TMDL or other cumulative effects analysis, wasteload and load allocations will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact [OAR 340-041-0028(12)(b)(B)].*

2.3 CONFEDERATED TRIBES OF THE COLVILLE RESERVATION

The CTCR WQS, including temperature criteria, were promulgated by EPA in 1989 (40 CFR Part 131.35). The standards apply within the reservation boundaries, from the shoreline to the midpoint of the Columbia River along a more than 150-mile section of the upper Columbia River, from RM 534 - 690. This river reach includes Grand Coulee and Chief Joseph dams. EPA proposed a temperature criterion of 16°C for the mainstem Columbia River in 1988; however, in the final EPA-promulgated standards for the CTCR, there is no classification for the Columbia River. 40 CFR 131.35(g)(8) states that all waters of the reservation not specifically assigned a classification are designated as Class II. This means that the default temperature for streams applies, therefore, an 18°C daily maximum temperature standard protects salmonid migration, rearing, spawning, and harvesting, in addition to other uses (***Table 2-2,*** see Appendix A). The default Class II criterion of 18°C is less stringent than the 16°C standard established for the adjacent Washington state waters from the northern reservation boundary to Grand Coulee Dam, and less stringent than Washington's 17.5°C standard below this point. Therefore, the allocations developed to protect the Washington waters are expected to also protect the Colville Tribes' waters.

2.4 SPOKANE TRIBE OF INDIANS

In 2002, EPA found the Spokane Tribe of Indians eligible for treatment in a similar manner as a state (TAS) for implementing a WQS program. TAS provides tribes with the authority to adopt WQS under the CWA that apply to all waters within the reservation. EPA approved the Spokane Tribe of Indians' first set of WQS, including temperature WQS, in 2003. The Spokane Tribe of Indians later revised its WQS for temperature, and EPA were partially approved and partially disapproved those revisions in 2013. For the temperature standards revisions that EPA disapproved, the previously approved 2003 temperature WQS apply for Clean Water Act purposes. The applicable temperature standards cover a 7-mile stretch of the Columbia River within Lake Roosevelt, upstream of Grand Coulee Dam, to protect fish and shellfish, including salmonid migration, rearing, spawning, and harvesting (***Table 2-2***). The temperature criteria vary throughout the year:

- 16.5°C 7-DADM (June 1 – September 1)
- 13.5°C 7-DADM (September 1 – October 1 and April 1 – June 1)
- 11°C 7-DADM (October 1 – March 31)

The 16.5°C 7-DADM Spokane Tribal WQC (June 1 – September 1) is less stringent than Washington's 16°C 7-DADM standard for state waters upstream and downstream of Spokane Tribal waters. From June 1 –September 1st, EPA used Washington State's more stringent standards to develop the TMDL temperature targets. For September – October, the temperature criterion for Spokane Tribal waters is more stringent than Washington's 16°C 7-DADM criterion for adjacent state waters. Therefore, during these months, the Spokane Tribal standards have been used to develop the TMDL temperature targets in Lake Roosevelt.

2.5 STANDARDS FOR UPSTREAM WATERS

The temperature of water entering the TMDL study area at the Canadian and Idaho borders affects the temperature of the portions of the Columbia and lower Snake Rivers within the TMDL study area (additional information provided in Section 6.34). Guidelines and standards applicable to the waters in these upstream areas protect key aquatic species, although the guidelines and standards are not always met.

The provincial government of British Columbia, Canada has established water quality guidelines for temperature using key species and life stage conditions. Canada has not yet determined the most sensitive species and life stages for the Canadian waters of the Columbia River. Once the fish distribution is determined, the guidelines establish optimal temperature ranges for each species/life stage and restrict temperature deviations outside this range to less than 1°C, as well as an hourly rate of change not to exceed 1°C. For waters with an unknown fish distribution, the province-wide temperature guidelines include a mean weekly maximum temperature of 18°C, a maximum daily temperature of 19°C, and an hourly rate of change not to exceed 1°C, as well as a maximum incubation temperature of 12°C in the spring and the fall (British Columbia Ministry of Environment 2019). Immediately downstream of the Canadian border, the Washington WQS for the Columbia River is 16°C 7-DADM.

Upstream from the lower Snake River TMDL study area, the Idaho WQS established to protect cold water aquatic life are a daily maximum of 22°C and a maximum daily average of 19°C. The Washington WQS for the Snake River is 20°C daily maximum.

2.6 WATER QUALITY STANDARDS USED TO DEVELOP THIS TOTAL MAXIMUM DAILY LOAD

EPA identified the numeric WQC applicable to the waters in the Columbia and lower Snake Rivers in ***Table 2-2***. The table identifies ten reaches in the Columbia River and one reach in the lower Snake River. Because the most protective criterion changes at different times of the year based on the designated uses and the criteria established in each state or tribe for those aquatic uses, the applicable temperature criteria are identified for each month of the year for each reach.

EPA used the most protective criteria in ***Table 2-2*** to evaluate the frequency and time period associated with criteria exceedances, information necessary to TMDL development. At Grand

Coulee Dam and Priest Rapids Dam data collection sites, a change in Washington temperature criteria occurs. The criterion at the tailrace is higher (less stringent) than the criterion upstream of each dam. In this TMDL, at both dam locations, the more protective criterion is used to protect uses and target attainment of the criterion that applies in the reservoirs immediately upstream of these dams. EPA used the more protective criterion to implement the State's narrative WQS at WAC 173-201A-260(3)(d). During those time periods and at those locations where exceedances occur, LAs and WLAs have been developed which, when implemented, will result in water quality improvements, as discussed in detail in Section 6.0.

Although Washington and Oregon have developed numerous temperature TMDLs using the "natural condition" provisions of the States' WQS, those provisions were not used to develop his TMDL. EPA has not attempted to estimate the natural conditions of the mainstems of the Columbia and lower Snake Rivers for two reasons. First, Oregon WQS do not currently include a natural condition provision. Consequently, for the lower Columbia River, where the border between Oregon and Washington divides the River, EPA developed the TMDL using the existing numeric criteria, relying on the more protective aspects of the two States' criteria to determine the total load from bank-to-bank. Secondly, there is no functional basin-wide water quality model for estimating the natural conditions of the Columbia and lower Snake Rivers. An appropriate basin-wide model would incorporate the upper portions of the watershed in Canada and Idaho and would estimate the natural flow and temperature regime that existed prior to construction of dams and irrigation diversions; such a model does not currently exist. For these reasons, EPA relied on the existing numeric criteria to develop this TMDL.

Finally, EPA has applied Oregon's natural seasonal thermal pattern (NSTP) criterion to the lower Columbia River. For the purposes of this TMDL, this narrative criterion applies to the change in the cooling pattern in the fall caused by dam impoundments, because the river cools more slowly in an impounded condition than in a free-flowing condition. EPA determined that numeric targets associated with the numeric criteria used in the TMDL would reduce fall temperatures to attain the NSTP narrative criterion. Specifically, the dam allocations associated with the 16°C criterion at Grand Coulee Dam, the 13°C criterion at Bonneville Dam in October and the 20°C criterion for the lower Columbia Dams in September would result in attainment of the NSTP narrative criterion. See Section 6.5.1 of the TMDL for more information.

Table 2-2 Water quality criteria used to evaluate water quality exceedances in the Columbia and lower Snake River TMDL (June – October)

<table>
<tr><th>RMs</th><th>Jurisdiction</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th><th>WQC Applied[4]</th></tr>
<tr><td colspan="15">Columbia River</td></tr>
<tr><td>745 – 646.5</td><td>WA</td><td colspan="12">16°C 7-DADM (WA)</td><td>16°C 7-DADM</td></tr>
<tr><td>690 -545</td><td>CTCR</td><td colspan="12">18°C DM (CTCR)</td><td>16°C 7-DADM WA State[5]</td></tr>
<tr><td>646.5 - 639</td><td>Spokane Tribe (SP)</td><td colspan="3">11°C 7-DADM (SP)</td><td colspan="2">13.5°C 7-DADM (SP)</td><td colspan="3">16.5°C 7-DADM (SP)</td><td>13.5°C 7-DADM (SP)</td><td colspan="3">11°C 7-DADM (SP)</td><td>16°C 7-DADM WA State (Jun - Aug)[5]
13.5°C 7- DADM SP (Sept)
11°C 7-DADM SP (Oct)</td></tr>
<tr><td>639 – 596</td><td>WA</td><td colspan="12">16°C 7-DADM (WA)</td><td>16°C 7-DADM</td></tr>
<tr><td>596 – 545</td><td>WA</td><td colspan="12">17.5°C 7-DADM (WA)</td><td>16°C 7-DADM[6]</td></tr>
<tr><td>545 – 534</td><td>WA</td><td colspan="12">17.5°C 7-DADM (WA)</td><td>17.5°C 7-DADM</td></tr>
<tr><td>534 – 397</td><td>WA</td><td colspan="12">17.5°C 7-DADM (WA)</td><td>17.5°C 7-DADM</td></tr>
<tr><td>397 – 309</td><td>WA</td><td colspan="12">20°C DM (WA)</td><td>17.5°C[6] DM</td></tr>
<tr><td>309 – 143.5</td><td>WA, OR</td><td colspan="12">20°C DM (WA) – 20°C 7-DADM (OR)</td><td>20°C DM</td></tr>
<tr><td rowspan="3">143.5 – 141.5</td><td rowspan="3">WA, OR</td><td colspan="3">20°C DM (WA)</td><td colspan="6">20°C DM (WA)</td><td colspan="3">20°C DM (WA)</td><td rowspan="3">20°C DM and 13°C 7-DADM</td></tr>
<tr><td colspan="3">13°C 7-DADM (OR)</td><td colspan="6">20°C 7-DADM (OR)</td><td colspan="3">13°C 7-DADM (OR)</td></tr>
<tr><td colspan="3"></td><td colspan="6"></td><td colspan="3">(after Oct 15th)</td></tr>
<tr><td>141.5 – 0</td><td>WA, OR</td><td colspan="12">20°C DM (WA) – 20°C 7-DADM (OR)</td><td>20°C DM</td></tr>
<tr><td colspan="15">Snake River</td></tr>
<tr><td>139 – 0</td><td>WA</td><td colspan="12">20°C DM (WA)</td><td>20°C DM</td></tr>
</table>

[4] These water quality criteria are used to evaluate water quality exceedances during June – October.

[5] For Colville tribal waters (year-round) and Spokane tribal waters (June-August), the temperature criterion of the tribe is higher (less stringent) than the criterion upstream (Washington waters), so the more stringent upstream criterion is used to develop the target temperatures for the TMDL, as discussed further in Section 6.1 and similar to footnote 6, below.

[6] At the tailraces of Grand Coulee Dam (RM 596) and Priest Rapids Dam (RM 397), the temperature criterion is higher (less stringent) than the criterion upstream of the dam. At both of these locations, the more stringent upstream criterion is used to develop the target temperatures, which are discussed further in Section 6.1, in order to protect the state's designated uses and to target attainment of the criterion in the reservoirs immediately upstream of these dams. Washington WQS at WAC 173-201A-260(3)(d) explain that, at the boundary between water bodies protected for different uses, the more stringent criterion applies.

3.0 CURRENT CONDITIONS

In this section, EPA examines current temperature conditions in the Columbia and lower Snake River basins within the geographic scope of the TMDL. EPA used calendar years 2011 to 2016 as the current conditions regime in order to align with the timeframe for the Environmental Impact Statement (EIS) assessment developed by the U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration. This multi-year period includes a range of temperature conditions and provides robust estimates of current conditions. EPA relied on this timeframe for all current condition analyses used to develop this TMDL. All data were accessed through the Columbia Basin Research website administered by the University of Washington's School of Aquatic & Fishery Sciences. The website features the Columbia River Data Access in Real Time (DART) database. River temperatures were evaluated at 18 DART stations on the mainstem Columbia and Snake Rivers and 2 DART stations on the Clearwater River (***Figure 3-1*** and ***Table 3-1***).

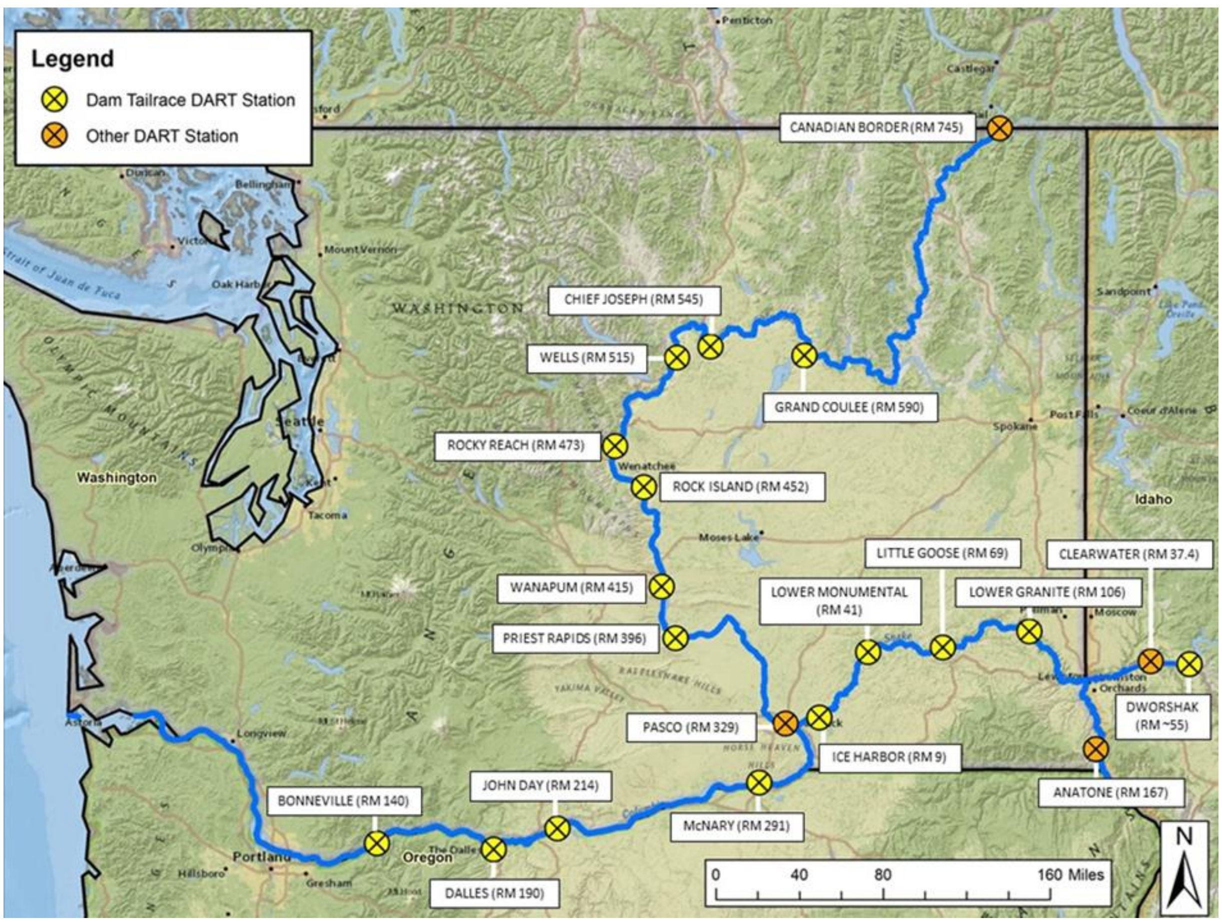

Figure 3-1 DART stations on the Columbia and lower Snake Rivers

Table 3-1 DART data locations

Monitoring Station	DART ID	RM
Columbia River		
Canadian Border	CIBW	745
Grand Coulee Dam tailrace (6 miles downstream)	GCGW	591
Chief Joseph Dam tailrace	CHQW	544
Wells Dam forebay (no tailrace data)	WEL	512
Rocky Reach Dam tailrace	RRDW	472
Rock Island Dam tailrace	RIGW	453
Wanapum Dam tailrace	WANW	413
Priest Rapids Dam tailrace	PRXW	396
Pasco, WA	PAQW	329
McNary Dam tailrace	MCPW	291
John Day Dam tailrace	JHAW	214
The Dalles Dam tailrace	TDDO	190
Bonneville (Warrendale; 6 miles downstream)	WRNO	140
Snake River		
Anatone, WA	ANQW	168
Lower Granite Dam tailrace	LGNW	107
Little Goose Dam tailrace	LGSW	70
Lower Monumental Dam tailrace	LMNW	40
Ice Harbor Dam tailrace	IDSW	6

3.1 COLUMBIA AND LOWER SNAKE TEMPERATURE DATA AND WATER QUALITY EXCEEDANCES

EPA used river temperatures from DART stations located at tailraces of each of the dams on the Columbia and lower Snake Rivers in order to derive monthly (June - October) average and monthly maximum temperatures for each year of the current conditions regime (2011 – 2016). This temperature data is summarized in ***Table 3-2***. The DART stations generate hourly temperature data in well-mixed areas at the tailraces of dams and therefore represent the cross-sectional average river temperature at that location.

EPA conducted an extensive quality assurance review of the temperature data (detailed in Appendix B). Consistent with applicable temperature WQC, the hourly temperature data were translated into the averaging period(s) corresponding to the temperature WQC that apply at that location.[7]

Observed temperatures were compared to applicable temperature criteria to assess whether current conditions exceed the temperature criteria. ***Table 3-3*** through ***Table 3-8*** provide the exceedance statistics at each location for the period between 2011 - 2016.

Between 2011 and 2016, Columbia River water entering the United States at the Canadian Border (RM 745) frequently exceeded Washington's applicable 7-DADM criterion of 16°C in June, July, August, and September. On average, water temperatures at the border exceeded the 7-DADM by 1.8°C, and the maximum exceedance was 4.2°C.

In the portion of the Columbia River above Priest Rapids Dam, the majority of criteria exceedances occur in the months of August and September. In the mid-Columbia, from Wells Dam to Wanapum Dam, water temperatures exceed the criterion more frequently, for a longer average duration and by a higher average magnitude. The lower mainstem Columbia, below McNary Dam, has a higher criterion (20°C) but exhibits only slightly fewer criteria exceedances.

[7] The 7-DADM temperatures were calculated by averaging the daily maximum temperature for a given day with the daily maximum temperature values of the previous three days and the following three days, as specified in the Washington WQS.

Table 3-2 Current conditions regime based on observed average and maximum temperatures (2011-2016, June through October)

RM	Location	River	June		July		August		September		October	
			Mean (°C)	Max (°C)	Mean (°C)	Max (°C)	Mean (°C)	Max (°C)	Mean (°C)	Max (°C)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	13.0	18.2	16.3	19.3	17.8	20.5	16.4	19.7	13.0	16.3
590	Grand Coulee Dam tailrace	Columbia	12.9	16.5	15.7	19.5	18.0	19.9	18.4	20.4	16.9	19.1
545	Chief Joseph Dam tailrace	Columbia	13.2	16.6	15.9	18.9	18.2	20.0	18.5	20.1	17.6	18.9
515	Wells Dam forebay	Columbia	13.6	17.6	16.5	19.3	18.7	20.2	18.8	20.4	16.5	18.7
473	Rocky Reach Dam tailrace	Columbia	13.8	17.9	16.7	19.6	18.9	20.6	18.8	20.5	16.7	18.7
452	Rock Island Dam tailrace	Columbia	13.9	18.0	16.8	20.0	18.9	20.5	18.9	20.9	16.2	18.5
415	Wanapum Dam tailrace	Columbia	14.3	18.6	17.2	19.9	19.4	20.7	18.9	21.1	16.3	18.4
396	Priest Rapids Dam tailrace	Columbia	14.5	19.0	16.8	19.8	19.3	21.0	19.0	21.2	16.2	18.3
329	Pasco, WA	Columbia	15.4	20.1	18.3	21.6	20.3	21.9	N/A	N/A	N/A	N/A
291	McNary Dam tailrace	Columbia	15.8	20.9	19.2	22.4	21.0	22.2	19.7	22.2	16.2	19.0
214	John Day Dam tailrace	Columbia	16.3	21.7	19.7	23.4	21.5	22.8	20.2	22.5	16.8	19.5
190	The Dalles Dam tailrace	Columbia	16.4	21.6	19.8	23.4	21.5	22.9	20.1	22.7	16.6	19.3
140	Bonneville (downstream)	Columbia	16.5	21.9	19.7	23.3	21.3	23.0	19.8	22.9	16.3	19.3
167	Anatone, WA	Snake	16.0	23.8	21.1	24.6	22.4	24.2	N/A	23.4	N/A	N/A
37	Clearwater Station	Clearwater	12.3	16.5	11.3	15.3	10.7	14.0	11.6	15.4	10.2	13.2
0.5	Dworshak Dam tailrace	NF Clearwater	6.3	7.3	7.1	9.2	8.1	10.7	9.3	10.6	9.7	10.8
106	Lower Granite Dam tailrace	Snake	15.0	19.9	18.6	21.4	19.0	20.5	18.3	20.6	15.7	19.3
69	Little Goose Dam tailrace	Snake	15.2	20.7	19.2	22.2	20.0	21.2	18.9	20.8	16.4	19.0
41	L Monumental Dam tailrace	Snake	15.3	21.2	19.5	22.3	20.5	21.4	19.2	21.1	16.5	18.7
6	Ice Harbor Dam tailrace	Snake	15.6	22.2	20.0	23.1	21.4	22.4	19.7	21.8	16.5	18.7

Note: Orange cells indicate incomplete data set. Red cells with a value of N/A indicate substantial missing values for this location, so a regime value was not established.

Table 3-3 Current conditions regime (2011 – 2016) observed annual river temperature exceedances (average number of days, average percent of time, average magnitude, and maximum magnitude)

RM	Location	River	WQC (°C)	Annual			
				Days	Percent (%)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	Washington 16 7-DADM	78	21	1.8	4.2
590	Grand Coulee Dam tailrace	Columbia	Colville Tribe 18 DM	52	14	0.8	2.4
			Washington 17.5 7-DADM	62	17	1.1	2.6
545	Chief Joseph Dam tailrace	Columbia	Colville Tribe 18 DM	50	14	0.7	2.1
			Washington 17.5 7-DADM	64	18	1.0	2.4
515	Wells Dam forebay	Columbia	Washington 17.5 7-DADM	83	23	1.4	2.8
473	Rocky Reach Dam tailrace	Columbia	Washington 17.5 7-DADM	80	22	1.3	2.8
452	Rock Island Dam tailrace	Columbia	Washington 17.5 7-DADM	74	20	1.4	2.9
415	Wanapum Dam tailrace	Columbia	Washington 17.5 7-DADM	80	22	1.4	3.5
396	Priest Rapids Dam tailrace	Columbia	Washington 20 DM	17	5	0.3	1.2
329	Pasco, WA	Columbia	Washington 20 DM	34	9	0.6	2.0
291	McNary Dam tailrace	Columbia	Washington 20 DM	54	15	1.1	2.4
			Oregon 20 7-DADM	49	13	1.1	2.3
214	John Day Dam tailrace	Columbia	Washington 20 DM	62	17	1.4	3.4
			Oregon 20 7-DADM	65	18	1.3	3.2
190	The Dalles Dam tailrace	Columbia	Washington 20 DM	63	17	1.4	3.4
			Oregon 20 7-DADM	65	18	1.3	3.1
140	Bonneville (downstream)	Columbia	Washington 20 DM	61	17	1.3	3.3
			Oregon 20 7-DADM	63	17	1.3	3.0
167	Anatone, WA	Snake	Idaho 22 DM	45	12	1.0	2.6
			Washington 20 DM	70	19	2.3	4.6
37	Clearwater River	Clearwater	Idaho 22 DM	0	0	N/A	N/A
0.5	Dworshak Dam tailrace	NF Clearwater	Idaho 22 DM	0	0	N/A	N/A
106	Lower Granite Dam tailrace	Snake	Washington 20 DM	5	1	0.3	1.4
69	Little Goose Dam tailrace	Snake	Washington 20 DM	42	11	0.5	2.2
41	L Monumental Dam tailrace	Snake	Washington 20 DM	54	15	0.7	2.3
6	Ice Harbor Dam tailrace	Snake	Washington 20 DM	64	17	1.4	3.0

Note: Orange cells indicate incomplete data set. Red cells with a value of N/A indicate substantial missing values for this location, so a regime value was not established.

Table 3-4 Current conditions regime (2011– 2016) observed June river temperature exceedances (average number of days, average percent of time, average magnitude, and maximum magnitude)

RM	Location	River	WQC (°C)	June			
				Days	Percent (%)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	Washington 16 7-DADM	3	11	0.1	1.6
590	Grand Coulee Dam tailrace	Columbia	Colville Tribe 18 DM	0	0	0	0
			Washington 17.5 7-DADM	0	0	0	0
545	Chief Joseph Dam tailrace	Columbia	Colville Tribe 18 DM	0	0	0	0
			Washington 17.5 7-DADM	0	0	0	0
515	Wells Dam forebay	Columbia	Washington 17.5 7-DADM	0	0	0	0
473	Rocky Reach Dam tailrace	Columbia	Washington 17.5 7-DADM	0	1	0.3	0.2
452	Rock Island Dam tailrace	Columbia	Washington 17.5 7-DADM	1	2	0.1	0.6
415	Wanapum Dam tailrace	Columbia	Washington 17.5 7-DADM	1	3	0.1	1.1
396	Priest Rapids Dam tailrace	Columbia	Washington 20 DM	0	0	0	0
329	Pasco, WA	Columbia	Washington 20 DM	0	1	0.1	0.4
291	McNary Dam tailrace	Columbia	Washington 20 DM	1	3	0.1	0.9
			Oregon 20 7-DADM	1	3	0.1	1.0
214	John Day Dam tailrace	Columbia	Washington 20 DM	2	6	0.1	1.7
			Oregon 20 7-DADM	2	5	0.1	1.8
190	The Dalles Dam tailrace	Columbia	Washington 20 DM	2	6	0.1	1.6
			Oregon 20 7-DADM	2	6	0.1	1.8
140	Bonneville (downstream)	Columbia	Washington 20 DM	2	7	0.1	1.9
			Oregon 20 7-DADM	2	6	0.2	2.0
167	Anatone, WA	Snake	Idaho 22 DM	1	3	0.2	1.8
			Washington 20 DM	4	13	0.4	3.8
37	Clearwater River	Clearwater	Idaho 22 DM	0	0	0	0
0.5	Dworshak Dam tailrace	NF Clearwater	Idaho 22 DM	0	0	0	0
106	Lower Granite Dam tailrace	Snake	Washington 20 DM	0	0	0	0
69	Little Goose Dam tailrace	Snake	Washington 20 DM	2	6	0.1	0.7
41	L Monumental Dam tailrace	Snake	Washington 20 DM	1	4	0.2	1.2
6	Ice Harbor Dam tailrace	Snake	Washington 20 DM	2	5	0.2	2.2

Note: Orange cells indicate incomplete data set

Table 3-5 Current conditions regime (2011– 2016) observed July river temperature exceedances (average number of days, average percent of time, average magnitude, and maximum magnitude)

RM	Location	River	WQC (°C)	July			
				Days	Percent (%)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	Washington 16 7-DADM	22	70	1.2	2.8
590	Grand Coulee Dam tailrace	Columbia	Colville Tribe 18 DM	2	8	0.1	1.5
			Washington 17.5 7-DADM	5	16	0.2	1.7
545	Chief Joseph Dam tailrace	Columbia	Colville Tribe 18 DM	2	8	0.1	0.9
			Washington 17.5 7-DADM	6	18	0.3	1.3
515	Wells Dam forebay	Columbia	Washington 17.5 7-DADM	10	33	0.5	1.8
473	Rocky Reach Dam tailrace	Columbia	Washington 17.5 7-DADM	12	38	0.6	2.0
452	Rock Island Dam tailrace	Columbia	Washington 17.5 7-DADM	12	38	0.8	2.2
415	Wanapum Dam tailrace	Columbia	Washington 17.5 7-DADM	16	50	0.7	2.3
396	Priest Rapids Dam tailrace	Columbia	Washington 20 DM	0	0	N/A	N/A
329	Pasco, WA	Columbia	Washington 20 DM	8	25	0.3	1.6
291	McNary Dam tailrace	Columbia	Washington 20 DM	11	36	0.6	2.4
			Oregon 20 7-DADM	11	36	0.6	2.3
214	John Day Dam tailrace	Columbia	Washington 20 DM	16	51	0.9	3.4
			Oregon 20 7-DADM	16	52	0.8	3.2
190	The Dalles Dam tailrace	Columbia	Washington 20 DM	16	52	0.9	3.4
			Oregon 20 7-DADM	16	52	0.9	3.1
140	Bonneville (downstream)	Columbia	Washington 20 DM	16	51	0.9	3.3
			Oregon 20 7-DADM	16	51	0.9	3.0
167	Anatone, WA	Snake	Idaho 22 DM	16	52	0.9	2.6
			Washington 20 DM	23	73	2.4	4.6
37	Clearwater River	Clearwater	Idaho 22 DM	0	0	N/A	N/A
0.5	Dworshak Dam tailrace	NF Clearwater	Idaho 22 DM	0	0	N/A	N/A
106	Lower Granite Dam tailrace	Snake	Washington 20 DM	2	5	0.2	1.4
69	Little Goose Dam tailrace	Snake	Washington 20 DM	16	52	0.4	2.2
41	L Monumental Dam tailrace	Snake	Washington 20 DM	18	57	0.7	2.3
6	Ice Harbor Dam tailrace	Snake	Washington 20 DM	15	47	1.3	3.0

Note: Red cells with a value of N/A indicate substantial missing values for this location, so a regime value was not established.

Table 3-6 Current conditions regime (2011 – 2016) observed August river temperature exceedances (average number of days, average percent of time, average magnitude, and maximum magnitude)

RM	Location	River	WQC (°C)	August			
				Days	Percent (%)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	Washington 16 7-DADM	31	99	2.5	4.2
590	Grand Coulee Dam tailrace	Columbia	Colville Tribe 18 DM	16	53	0.6	1.9
			Washington 17.5 7-DADM	20	66	0.9	2.3
545	Chief Joseph Dam tailrace	Columbia	Colville Tribe 18 DM	20	64	0.7	2.0
			Washington 17.5 7-DADM	27	85	1.0	2.3
515	Wells Dam forebay	Columbia	Washington 17.5 7-DADM	29	93	1.4	2.6
473	Rocky Reach Dam tailrace	Columbia	Washington 17.5 7-DADM	30	96	1.6	3.1
452	Rock Island Dam tailrace	Columbia	Washington 17.5 7-DADM	27	87	1.8	2.9
415	Wanapum Dam tailrace	Columbia	Washington 17.5 7-DADM	30	96	2.0	3.0
396	Priest Rapids Dam tailrace	Columbia	Washington 20 DM	13	42	0.3	1.0
329	Pasco, WA	Columbia	Washington 20 DM	21	67	0.7	1.9
291	McNary Dam tailrace	Columbia	Washington 20 DM	27	86	1.2	2.2
			Oregon 20 7-DADM	27	87	1.2	2.0
214	John Day Dam tailrace	Columbia	Washington 20 DM	30	95	1.7	2.8
			Oregon 20 7-DADM	30	97	1.7	2.5
190	The Dalles Dam tailrace	Columbia	Washington 20 DM	30	96	1.7	2.9
			Oregon 20 7-DADM	30	96	1.7	2.6
140	Bonneville (downstream)	Columbia	Washington 20 DM	29	95	1.6	3.0
			Oregon 20 7-DADM	30	97	1.6	2.7
167	Anatone, WA	Snake	Idaho 22 DM	25	80	1.2	2.2
			Washington 20 DM	28	91	3.0	4.2
37	Clearwater River	Clearwater	Idaho 22 DM	0	0	N/A	N/A
0.5	Dworshak Dam tailrace	NF Clearwater	Idaho 22 DM	0	0	N/A	N/A
106	Lower Granite Dam tailrace	Snake	Washington 20 DM	2	8	0.1	0.5
69	Little Goose Dam tailrace	Snake	Washington 20 DM	20	65	0.4	1.2
41	L Monumental Dam tailrace	Snake	Washington 20 DM	29	94	0.7	1.4
6	Ice Harbor Dam tailrace	Snake	Washington 20 DM	31	100	1.7	2.4

Note: Red cells with a value of N/A indicate substantial missing values for this location, so a regime value was not established.

Table 3-7 Current conditions regime (2011 – 2016) observed September river temperature exceedances (average number of days, average percent of time, average magnitude, and maximum magnitude)

RM	Location	River	WQC (°C)	September			
				Days	Percent (%)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	Washington 16 7-DADM	22	72	1.3	3.4
590	Grand Coulee Dam tailrace	Columbia	Colville Tribe 18 DM	19	63	0.7	2.4
			Washington 17.5 7-DADM	25	82	1.3	2.6
545	Chief Joseph Dam tailrace	Columbia	Colville Tribe 18 DM	25	82	0.7	2.1
			Washington 17.5 7-DADM	29	97	1.1	2.4
515	Wells Dam forebay	Columbia	Washington 17.5 7-DADM	24	81	1.4	2.8
473	Rocky Reach Dam tailrace	Columbia	Washington 17.5 7-DADM	26	86	1.3	2.8
452	Rock Island Dam tailrace	Columbia	Washington 17.5 7-DADM	24	81	1.4	2.9
415	Wanapum Dam tailrace	Columbia	Washington 17.5 7-DADM	28	94	1.4	3.5
396	Priest Rapids Dam tailrace	Columbia	Washington 20 DM	3	8	0.1	1.2
329	Pasco, WA	Columbia	Washington 20 DM	6	21	0.4	2.0
291	McNary Dam tailrace	Columbia	Washington 20 DM	10	33	0.6	2.2
			Oregon 20 7-DADM	10	34	0.6	1.9
214	John Day Dam tailrace	Columbia	Washington 20 DM	16	52	0.9	2.5
			Oregon 20 7-DADM	17	57	0.8	2.3
190	The Dalles Dam tailrace	Columbia	Washington 20 DM	16	52	0.8	2.7
			Oregon 20 7-DADM	17	57	0.8	2.5
140	Bonneville (downstream)	Columbia	Washington 20 DM	14	46	0.8	2.9
			Oregon 20 7-DADM	15	49	0.7	2.6
167	Anatone, WA	Snake	Idaho 22 DM	3	11	0.3	1.4
			Washington 20 DM	13	43	1.5	3.4
37	Clearwater River	Clearwater	Idaho 22 DM	0	0	N/A	N/A
0.5	Dworshak Dam tailrace	NF Clearwater	Idaho 22 DM	0	0	N/A	N/A
106	Lower Granite Dam tailrace	Snake	Washington 20 DM	1	3	0.1	0.6
69	Little Goose Dam tailrace	Snake	Washington 20 DM	4	13	0.1	0.8
41	L Monumental Dam tailrace	Snake	Washington 20 DM	6	21	0.3	1.1
6	Ice Harbor Dam tailrace	Snake	Washington 20 DM	14	45	0.8	1.8

Note: Red cells with a value of N/A indicate substantial missing values at this location, so a regime value was not established.

Table 3-8 Current conditions regime (2011 – 2016) observed October river temperature exceedances (average number of days, average percent of time, average magnitude, and maximum magnitude)

RM	Location	River	WQC (°C)	October			
				Days	Percent (%)	Mean (°C)	Max (°C)
745	Canadian Border	Columbia	Washington 16 7-DADM	0	1	0.0	0.2
590	Grand Coulee Dam tailrace	Columbia	Colville Tribe 18 DM	8	18	0.4	1.1
545	Chief Joseph Dam tailrace	Columbia	Washington 17.5 7-DADM	12	38	0.5	1.6
			Washington 17.5 7-DADM	3	11	0.4	1.3
515	Wells Dam forebay	Columbia	Washington 17.5 7-DADM	5	15	0.2	1.1
473	Rocky Reach Dam tailrace	Columbia	Washington 17.5 7-DADM	5	16	0.3	1.1
452	Rock Island Dam tailrace	Columbia	Washington 17.5 7-DADM	5	15	0.35	1.4
415	Wanapum Dam tailrace	Columbia	Washington 17.5 7-DADM	5	16	0.3	1.0
396	Priest Rapids Dam tailrace	Columbia	Washington 20 DM	0	0	0	0
329	Pasco, WA	Columbia	Washington 20 DM	0	0	N/A	N/A
291	McNary Dam tailrace	Columbia	Washington 20 DM	0	0	0	0
			Washington 20 DM	0	0	0	0
214	John Day Dam tailrace	Columbia	Washington 20 DM	0	0	0	0
			Oregon 20 7-DADM	0	0	0	0
190	The Dalles Dam tailrace	Columbia	Washington 20 DM	0	0	0	0
			Oregon 20 7-DADM	0	0	0	0
140	Bonneville (downstream)	Columbia	Washington 20 DM	0	0	0	0
			Oregon 13 7-DADM [10/15 – 10/31]	17	100	2.6	5.0
167	Antone, WA	Snake	Idaho 22 DM	0	0	0	0
			Washington 20 DM	0	0	0	0
37	Clearwater River	Clearwater	Idaho 22 DM	0	0	N/A	N/A
0.5	Dworshak Dam tailrace	NF Clearwater	Idaho 22 DM	0	0	N/A	N/A
106	Lower Granite Dam tailrace	Snake	Washington 20 DM	0	0	0	0
69	Little Goose Dam tailrace	Snake	Washington 20 DM	0	0	0	0
41	L Monumental Dam tailrace	Snake	Washington 20 DM	0	0	0	0
6	Ice Harbor Dam tailrace	Snake	Washington 20 DM	0	0	0	0

Note: Red cells with a value of N/A indicate substantial missing values at this location, so a regime value was not established.

Between April and August, average daily maximum temperatures in the lower and mid-reaches of the mainstem Columbia are warmer than the upper Columbia, as measured from below Grand Coulee (RM 590). During this time, river temperatures below Bonneville Dam can be up to 5°C warmer than below Grand Coulee Dam. However, beginning in late September, Grand Coulee's large storage reservoir inverts this relationship. The impounded water, warmed by solar radiation and warm air temperatures in the summer, cools at a slower rate compared to downstream reaches. As a result, between October – December, observed water temperatures in Grand Coulee's tailrace are warmer than temperatures below Priest Rapids, McNary, and Bonneville (***Figure 3-2***).

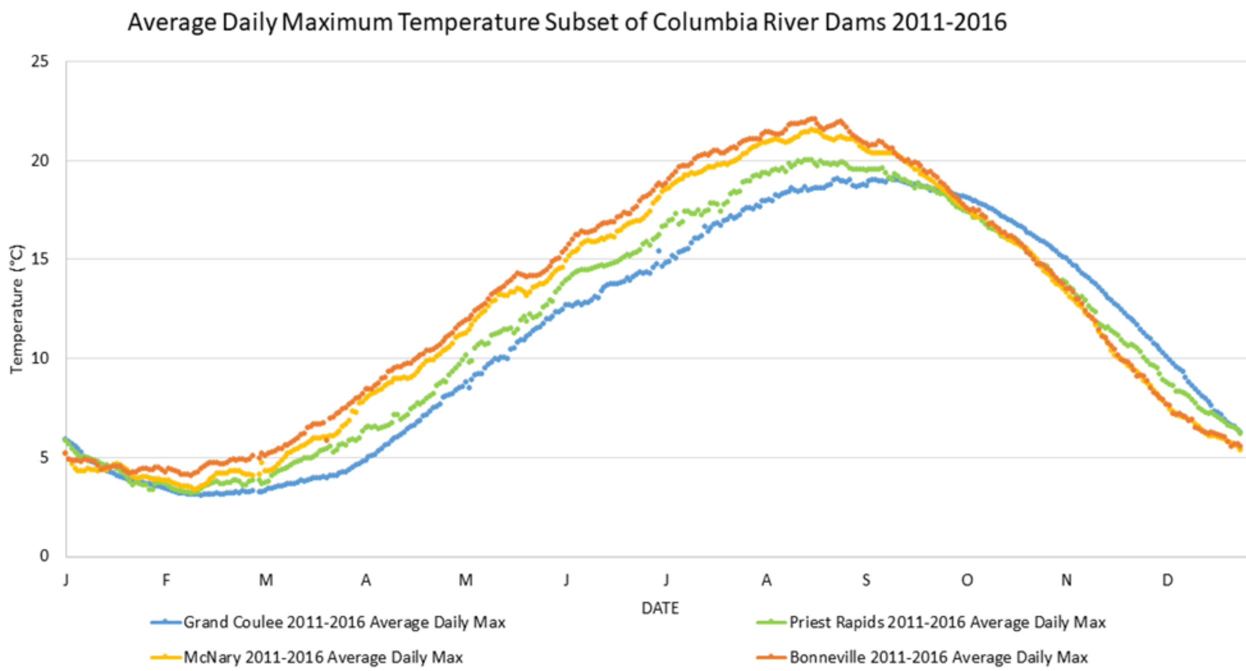

Figure 3-2 Columbia River warming as it flows downstream from Grand Coulee (blue) to Bonneville (orange)

The annual temperature profile of the lower Snake River mirrors that of the mainstem Columbia River. Average annual minima occur in February, and water temperatures steadily rise through the early spring and summer, generally reaching an average maximum temperature of 19°C-22°C in August. Water temperatures decline in the fall and winter, reaching the coldest temperatures in February (***Figure 3-3***).

The lower Snake River enters the TMDL study area at the confluence with the Clearwater River, 139 river miles upstream of its confluence with the Columbia River. Between 2011 and 2016, observed water temperatures upstream of the TMDL boundary in Anatone, Washington, exceed the State of Washington's temperature criterion (20°C DM) for 68 days per year, and by 1.5°C, on average. Managed releases from Dworshak Dam on the Clearwater River, a major tributary to the lower Snake River at the TMDL boundary, deliver cold water to help meet Washington's numeric criterion of 20°C DM at Lower Granite Dam (RM 106), which is the most upstream of the four dams on the lower Snake River. As a result, exceedances at the Lower Granite tailrace occur for only five days per year by 0.3°C, on average. However, the influence of Dworshak Dam's cold water releases decreases steadily as the lower Snake River flows through the three downstream dams: Little Goose Dam (RM 69), Lower Monumental Dam (RM 41), and Ice Harbor Dam (RM 6).

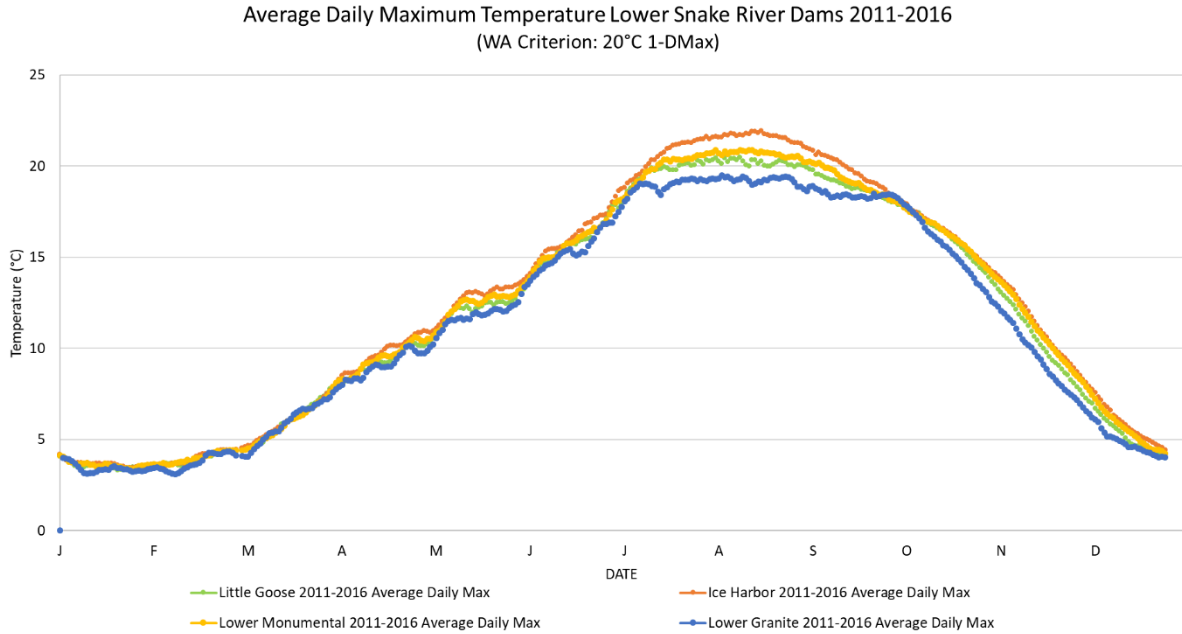

Figure 3-3 Snake River warming as it flows downstream from Lower Granite Dam (blue) to Ice Harbor Dam (orange)

Based on EPA's evaluation of available data from 2011-2016, temperature criterion exceedances at the Little Goose, Lower Monumental, and Ice Harbor Dams generally begin to occur in mid-July, ranging between 15-18 days, on average (***Table 3-5***). In August, water temperatures exceed the WQC for an average of 20 days below Little Goose Dam, 29 days below Lower Monumental Dam, and 31 days below Ice Harbor Dam (***Table 3-6***). In September, exceedances at Little Goose and Lower Monumental Dams drop significantly, averaging 4 and 6 days, respectively. At Ice Harbor Dam, however, water temperatures exceed the criterion for an average of 14 days by an average magnitude of 0.8°C in September (***Table 3-7***).

3.2 TRIBUTARY TEMPERATURE

EPA evaluated the temperatures of Columbia River tributaries by comparing tributary and mainstem temperatures at the confluences. Mainstem Columbia River mean monthly temperatures were obtained from the DART website from 2011 through 2015. Current mean monthly water temperatures for tributaries at their confluences with the Columbia River were obtained from the USFS "NorWeST" Stream Temperature Modeling website, which provides the most comprehensive datasets and statistical estimates of monthly average stream temperatures across the Pacific Northwest. (See ***Figure 3-4***.)

Based on review of available information, EPA found temperature differences between the Columbia River mainstem and tributaries to be highly variable throughout the spring and summer period. Tributary temperatures are generally cooler than the mainstem in the fall (***Table 3-9***, see also Appendix E). In August, most tributaries that were significantly cooler than the mainstem (i.e., the green and purple dots in ***Figure 3-4*** had very low flows proportional to the mainstem flows, and their cold water benefits are generally insignificant compared to the larger and warmer flows associated with the largest tributaries). Large tributary temperatures were often similar to those of the Columbia River mainstem at their confluences. Table 3-8 presents the tributaries relative flow and temperature contributions to the mainstem.

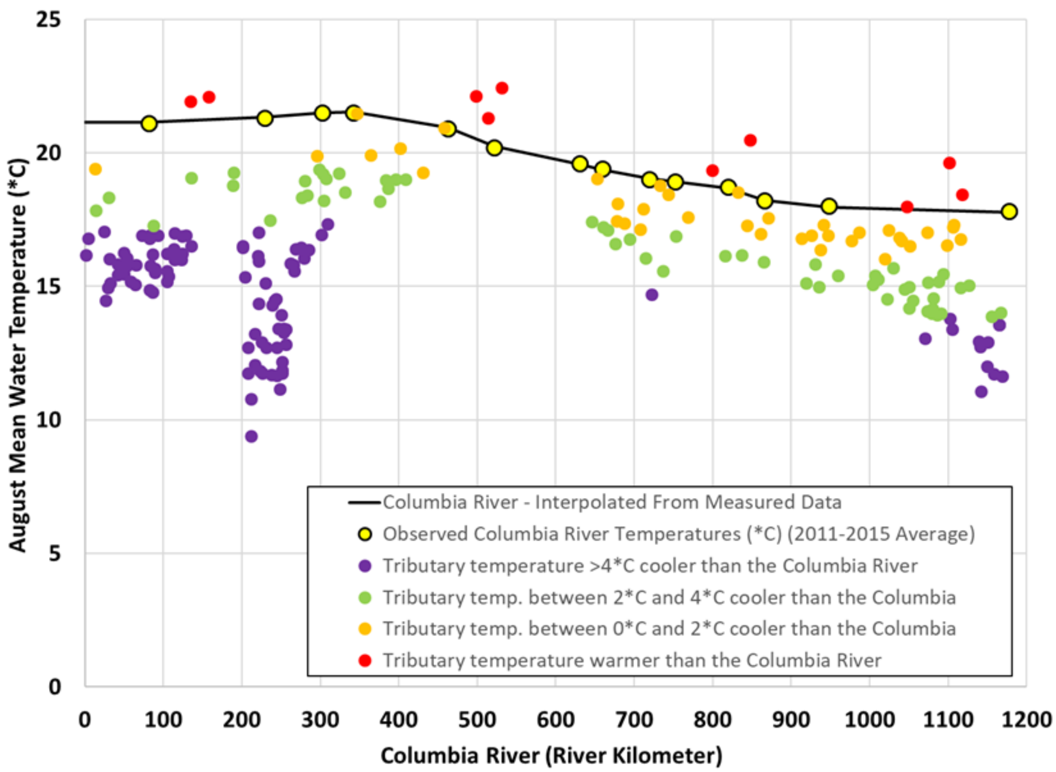

Figure 3-4 Columbia River and tributary monthly mean temperatures – August

Table 3-9 Tributary temperatures relative to mainstem Columbia River temperatures at their confluences from June – September. Negative differences indicate tributary temperatures are colder than the mainstem, positive differences indicate temperatures are warmer than the mainstem.

	Proportion of Total Tributary Flow	Tributary Temperature Difference (°C)
June		
Flow Weighted Average of all Tributaries (N=202)	**100.0%**	**1.2**
Snake River (N=1)	52.6%	2.8
Willamette River (N=1)	8.6%	0.4
Deschutes River (N=1)	4.9%	0.9
Cowlitz River (N=1)	4.7%	-0.9
Okanogan River (N=1)	4.4%	-1.1
Flow Weighted Average of other 197 Tributaries	24.8%	-1.0
July		
Flow Weighted Average of all Tributaries (N=202)	**100.0%**	**1.0**
Snake River (N=1)	47.0%	1.7
Willamette River (N=1)	9.7%	1.3
Deschutes River (N=1)	6.5%	-1.4
Cowlitz River (N=1)	4.7%	0.5
Okanogan River (N=1)	4.7%	0.7
Flow Weighted Average of other 197 Tributaries	27.4%	0.4
August		
Flow Weighted Average of all Tributaries (N=202)	**100.0%**	**-0.3**
Snake River (N=1)	44.7%	0.9
Willamette River (N=1)	14.8%	0.9
Deschutes River (N=1)	7.7%	-2.3
Cowlitz River (N=1)	6.2%	-4.9
Okanogan River (N=1)	3.2%	2.0
Flow Weighted Average of other 197 Tributaries	23.4%	-1.9
September		
Flow Weighted Average of all Tributaries (N=202)	**100.0%**	**-1.6**
Snake River (N=1)	44.2%	-0.4
Willamette River (N=1)	18.8%	-0.2
Deschutes River (N=1)	7.4%	-4.1

Cowlitz River (N=1)	6.2%	-5.4
Okanogan River (N=1)	4.0%	-3.6
Flow Weighted Average of other 197 Tributaries	19.5%	-3.2

As discussed further in Section 6.5.5, EPA used data for 23 major tributaries to the Columbia and lower Snake Rivers to develop this TMDL. ***Table 3-10*** summarizes the estimated current temperatures for these tributaries for the years 2011-2016. These temperatures are calculated from measured temperatures, with measurement gaps filled using interpolation and/or substitution of long-term average temperatures (EPA 2019).

Table 3-10 Estimated mean monthly temperature in 23 major tributaries

Tributary Name	Confluence Location (RM)	Estimated Mean Temperature (2011 - 2016) (°C)				
		June	July	August	September	October
	Columbia River					
Kettle	706	12.8	19.0	20.5	16.0	9.8
Colville	700	16.1	19.5	19.8	15.2	9.9
Spokane	639	16.0	20.4	19.6	17.5	12.1
Okanogan	534	14.3	20.7	21.9	17.4	11.1
Methow	524	10.8	16.0	17.0	14.6	9.3
Chelan	503	16.9	19.9	21.6	18.7	13.7
Entiat	484	9.8	14.2	16.5	13.6	7.9
Wenatchee	468	11.4	16.5	19.0	15.7	10.2
Crab Creek	411	20.3	22.7	21.1	17.8	12.0
Yakima	335	17.7	21.1	21.2	17.9	12.5
Walla Walla	315	18.9	23.1	20.8	17.0	12.1
Umatilla	289	18.2	19.9	20.1	17.0	13.0
John Day	218	18.9	24.3	22.9	19.1	12.4
Deschutes	204	17.4	19.1	18.5	15.9	12.9
Klickitat	180	14.2	16.0	16.8	13.0	8.3
Hood	169	17.5	19.1	18.5	15.9	12.9
Sandy	121	17.5	19.1	18.5	15.9	12.9
Willamette	102	18.0	22.0	22.7	19.1	14.2
Lewis	87	9.9	11.4	12.5	12.9	14.3
Kalama	73	17.4	19.1	18.5	15.9	12.9
Cowlitz	69	13.1	15.7	15.9	13.9	11.1
	Snake River					
Tucannon	62	17.5	21.2	20.2	16.4	11.6
Palouse	60	19.6	23.7	22.0	16.9	11.3

4.0 SOURCE ASSESSMENT

Stream temperature is influenced by natural factors such as climate, geomorphology, hydrology, and vegetation. In developing this TMDL, EPA evaluated the temperature impacts from the following categories of heat loading: (1) point source discharges of heat subject to National Pollutant Discharge Elimination System (NPDES) permits;[8] (2) nonpoint source heat loading from dams and reservoirs that alter water temperatures within their reservoirs and in downstream river reaches;[9] (3) tributary inflows to the mainstems of the Columbia and lower Snake Rivers that are affected by upstream point and nonpoint sources; (4) increasing air temperatures and other factors associated with climate change; (5) cold water releases from Dworshak Dam in Idaho; (6) agricultural water withdrawals from the Banks Lake project; and (7) water temperatures in the mainstems of the Columbia and lower Snake Rivers where they enter into Washington from Canada and Idaho, respectively.

The thermal regime of a river is continually changing over space and time in response to the natural factors and human sources listed above. To identify source impacts, EPA distinguishes the effect of human sources from the effects of natural variation in the system using mathematical models. Mathematical models, such as the RBM10 model of the Columbia and lower Snake Rivers, are commonly used by EPA and state agencies in TMDL analyses. By tracking the time-varying factors influencing river temperatures, the RBM10 model estimates the thermal-loading capacity and source impacts across time and space. EPA evaluated and tested the RBM10 temperature model extensively, ensuring that the model is capable of performing this source assessment. The model development report is provided in Appendix C.

The TMDL source assessment methodology for this TMDL presented unique technical features and challenges. With the TMDL study area spanning almost 900 river miles, the scale of modeling and analysis of the mainstem Columbia and lower Snake Rivers is the largest in any Pacific Northwest TMDL. The assessment addresses the cumulative impacts from NPDES permitted point sources (see Section 6.5.2); 23 major tributaries; and 15 hydroelectric dams (see ***Table 6-4***) and incorporates the impact of cold water releases from Dworshak Dam via the Clearwater River to the Snake River. The full modeling source assessment is provided in Appendix D.

A growing body of research has produced and is continuing to produce evidence that changes to regional climate are contributing to an increase in instream temperatures in the Columbia and Snake Rivers. In addition to the RBM10 modeling assessment, EPA reviewed and synthesized available information and data on climate and projected future trends. This is provided in Appendix G.

4.1 WATER QUALITY MODELING FRAMEWORK

Temperatures in streams naturally fluctuate over the day and year in response to changes in solar energy, air temperature, wind, river flows, groundwater flows, and other factors. This

[8]Industrial discharge facilities are facilities discharging process water, cooling water, and other contaminated waters from industrial or commercial activities.

[9]Although temperature TMDLs typically identify loss of riparian shade as a nonpoint source of heat, they are not a source on the mainstem Columbia and Snake rivers. The width of these large rivers results in the surfaces of the rivers being directly exposed to full solar radiation during daylight hours. The presence or absence of trees on the banks does not create any measurable instream temperature effects. In contrast, shade restoration in tributary watersheds frequently improves tributary temperatures.

natural variability in river temperatures is an important factor in the water quality status of a waterbody.

In order to support TMDL development, EPA used the RBM10 water quality model to replicate and predict the temperature fluctuations in the Columbia and lower Snake Rivers. RBM10 is a one-dimensional mathematical temperature model that simulates the thermal energy budget of the mainstem Columbia and lower Snake Rivers. Appendix C provides detailed documentation for RBM10.

The version of RBM10 used for this TMDL is an updated version of the model code and database that has been used to estimate conditions in the Columbia and Snake rivers since 2001 (Yearsley et al. 2001). A model update report (EPA 2019) that documents all aspects of the updated version of the model is included as Appendix C, which includes a description of the model update process, model structure and limitations, data inputs, model calibration, and evaluation of model performance. A summary of the information in Appendix C is presented below.

Spatial Representation

RBM10 simulates the daily heat budget and resulting instream temperature of the Columbia River from the Canadian border (Columbia RM 745.0) to the mouth at Astoria, Oregon; the Snake River from Anatone, Washington (Snake RM 168) to its confluence with the Columbia River near Pasco, Washington; and the Clearwater River from Orofino, Idaho (Clearwater RM 44.6) to its confluence with the Snake River near Lewiston, Idaho (Snake RM 139.3). The Clearwater River is included in the model domain to represent the cold water releases from Dworshak Dam, which have a cooling effect on the Snake River. All other major tributaries are represented as model boundary inputs, represented by their flow and temperature at their confluences with the mainstem Columbia and lower Snake Rivers (i.e., the tributaries listed in ***Table 3-10***).

Temporal Resolution

RBM10 simulates daily average temperatures in the Columbia and Snake Rivers from 1970 through 2016. The simulation period was constrained by the timeframe of the completion of the hydroelectric system and the availability of publicly available data necessary to set up and run the model. The full simulation period is used for long term trend analysis, and the period 2011—2016 is used to represent current conditions for the TMDL.

The use of daily average temperature simulations for the TMDL presents a challenge when comparing daily average modeling results to the water quality temperature criteria, which are expressed as daily maximum or 7-DADM values. Because the daily average time step does not capture the peak daily temperature, EPA could not compare the model results directly to criteria values. As discussed further in Section 6.5.1, however, EPA relied on the model only for source assessment, where the focus of the methodology was changes in temperature rather than the baseline temperature. Moreover, EPA used actual temperature measurements obtained from the DART site (not modeling estimates) to confirm the States' impairment determinations and to develop the TMDL, and then to calculate the temperature reductions needed to meet the relevant criterion. The use of one-dimensional, daily average simulations carries benefits as well. The modeling approach allows for an efficient, long-term simulation (over a 47-year period) that captures the overall range of variation and long-term trends.

4.2 MODEL SCENARIOS AND RESULTS

EPA's conceptual approach for assessing source impacts begins by using the calibrated model results (current conditions) as the baseline for source scenario comparisons. The individual model inputs are then modified in a prescribed manner to investigate impacts of sources, leaving all other inputs of the model unchanged. The model is run with the modified inputs (e.g., a source or set of sources is removed or altered), and results from the model scenario runs are compared to the modeled baseline condition. Any changes in the simulated temperature output are the result of the change made to the model inputs for the scenario run.

The impacts of dams are complex and variable: dam operations can result in cooler or warmer downstream temperatures, depending on time of year and dam operations. Impoundments cause higher, sustained river temperatures in the summer, higher temperatures at the water surface and in fish ladders, and delayed cooling in the fall. Storage reservoirs, like Grand Coulee, on the other hand, may reduce downstream temperatures during the early summer. Deep reservoirs with temperature control structures (e.g., Dworshak Dam) can be used to release cold water and reduce temperatures over substantial distances downstream.

EPA estimated the temperature impacts of dams by altering (in the model) the river geometry within the TMDL study area to reflect the free-flowing river conditions that could occur in the absence of the existing dams. EPA's evaluation does not consider or reflect free-flowing conditions upstream of the TMDL study area boundaries in Canada or Idaho.

The modeling scenarios and subsequent RBM10 assessment estimated the impacts of dams, Dworshak Dam cold water releases, tributaries, boundary conditions, NPDES point sources (including a reserve allocation, as discussed in Section 6.5.4), and the Banks Lake pump storage project. A summary of the modeling results is presented in ***Table 4-1*** and detailed results are provided in the model scenario report (Appendix D).

Table 4-1 Estimated range of current source impacts on Columbia and lower Snake River mainstems from June to October across RBM10 model domain

River	Point Sources (∆°C)	Tributaries (∆°C)	Dworshak Dam Cooling (∆°C)	Dams (∆°C)	Climate Change (∆°C)
Columbia River	0.0 – 0.1	0.0 – 0.1	(-0.2) – 0.0	(-0.8) – 4.5	1.0 – 2.0
Snake River	0.0 – 0.1	0.0 – 0.1	(-3.8) – 0.0	(-0.2) – 3.2	1.0 – 2.0

4.3 EFFECTS OF CLIMATE CHANGE

EPA conducted a technical review of available research on the impacts of regional climate change, particularly increasing air temperatures, on Columbia and lower Snake River temperatures, with data and information dating back to 1960 (Appendix G). EPA synthesized available information on river warming that is estimated to have occurred to date, as well as warming that is projected to occur in the future. Because this TMDL evaluates current sources of heat, the estimated current impacts to the rivers (i.e., river warming to-date) are most relevant to this TMDL source assessment.

Based on EPA's technical review (Appendix G), predicted trends in river temperatures since the baseline of 1960 vary between sites, as shown by the analysis of historical data, and there is considerable variation at the sites themselves (which is expected, given the influence of the El Niño – Southern Oscillation and the Pacific-North American pattern). Amid this variation there is evidence of a warming trend in Pacific Northwest waters and in the Columbia River mainstem since 1960, as indicated by literature and the analyses conducted by EPA (Appendix G). Based on available information, the estimated increase in river temperatures since 1960 ranges from 0.2°C to 0.4°C per decade, for a total water temperature increase to date of 1.5°C ± 0.5°C.

4.4 ACCOUNTING FOR UNCERTAINTY

Uncertainty is inherent for both model-based and measurement-based assessments. Models and measurements (data) are complementary information sources used to assess the condition of the environment. Models are often developed and used to address gaps and limitations in our measurement systems because measurement at every location at every time across a large-scale watershed is infeasible. At the same time, measurement data are critical inputs for model development, and gaps and/or imprecision in data affect the accuracy of a model.

EPA relies on the RBM10 model (Appendix D) and the climate change assessment (Appendix G) as the best available estimates of the temperature changes in the Columbia and lower Snake Rivers. The analysis is limited and influenced by the following sources of uncertainty:

- Measurement gaps and errors: Monitoring is not seamless, and gaps must be filled. Quality assurance checks cannot identify all measurement and recording errors.
- Model uncertainty: Models are simplifications of the natural system, and predictions do not perfectly match field observations and monitoring data. The model report for RBM10 documents the simplifications and assumptions of the model, as well as the differences between simulated and measured temperatures.
- System variability: Assessments attempt to identify source impacts in a dynamic and variable environment. Methods and considerations are discussed in Section 6.2.
- Synthesis challenges: Climate change estimates are based on a synthesis of available information that may employ different kinds of observations, statistics, models, and assumptions.

As with any scientific endeavor, the results in this assessment may be reviewed and reevaluated over time as new information and analyses about this topic are produced by EPA and others.

5.0 COLD WATER REFUGE

The Oregon WQS include a narrative cold water refuge (CWR) criterion for the lower Columbia River that supplements the numeric criteria by providing additional protection for migrating salmon and steelhead. The CWR criterion stipulates that the lower Columbia River "must have cold water refugia that are sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body" (OAR 340-041-0028(4)(d)).

EPA cooperated with the States of Oregon and Washington, National Oceanic and Atmospheric Administration (NOAA) Fisheries, Tribal governments, local watershed groups, and other experts and interested parties to identify and assess the sufficiency of cold water refuges in the lower Columbia River, from the mouth to its confluence with the Snake River at river mile 325. This work effort concluded with EPA's issuance of the *Columbia River Cold Water Refuges Plan* (EPA 2021), which evaluates the amount of CWR needed to attain Oregon's CWR criterion. The Plan can be downloaded from EPA's website at https://www.epa.gov/columbiariver/columbia-river-cold-water-refuges-plan.

Approximately 700,000 to 2,000,000 adult salmon and steelhead currently return from the ocean and migrate up the Columbia River past Bonneville Dam each year. Roughly 40% of these fish migrate when Columbia River water temperatures reach or exceed 20°C; consequently, they may endure adverse effects in the form of disease, stress, decreased spawning success, and lethality (EPA, 2003). To minimize exposure to warm temperatures in the Columbia River, adult salmon and steelhead temporarily move into CWRs during their upstream migration. In the lower Columbia River, CWRs occur primarily where cooler tributary rivers flow into the Columbia River.

The University of Idaho found that migrating steelhead begin to use CWRs when the Columbia River temperature reaches 19°C (USACE 2013, Keefer et. al. 2009). When temperatures are 20°C or higher, approximately 60 - 80% of the steelhead use CWRs. Fall Chinook start to occupy CWRs at slightly warmer temperatures (20 - 21°C) and about 40% use cold water refuges when temperatures reach 21 - 22°C (Goniea et al. 2006).

As described in EPA's Cold Water Refuges Plan, EPA identified 23 tributaries that provide CWR in the lower Columbia River, including 12 that are identified as primary CWR tributaries based on CWR volume, stream temperature, and documented or presumed use by salmon and steelhead. The CWR tributaries, including the primary CWR tributaries, are illustrated in ***Figure 5-1***. In ***Figure 5-1***, primary CWR tributaries that are >4°C cooler than the Columbia are highlighted in purple, two primary CWR tributaries with temperatures 2-4°C cooler than the Columbia are highlighted in green, and the other "non-primary" CWR tributaries are highlighted with a white triangle. The volume of CWR for each of the CWR tributaries, including the estimated volume accessible in the lower portion of the tributary (stream CWR volume) and the estimated volume protruding into the Columbia River (plume CWR volume), is displayed in **Error! Reference source not found.**. The primary CWRs, highlighted in purple and green in ***Table 5-1*** constitute 98% of available CWR in the lower Columbia River. The availability of these CWRs contribute to attainment of the designated uses, particularly for adult migration. The EPA CWR Plan discusses the geographic extent of these CWR in more detail.

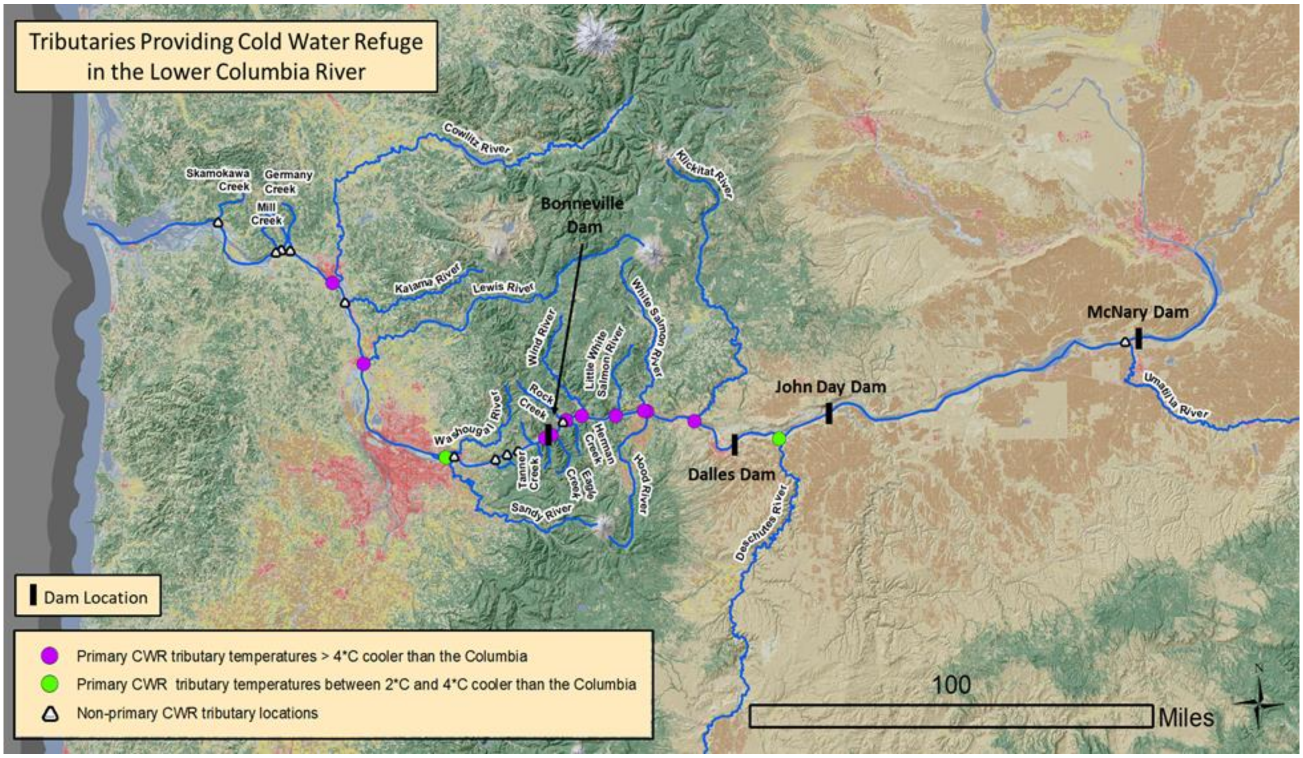

Figure 5-1 Tributaries providing cold water refuge

Table 5-1 Cold Water Refuges in Lower Columbia River

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[10] (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[11] (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[11] (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
Deschutes River (OR)	200.8	21.4	19.2	-2.2	4772*	300,000	580,124	880,124
Umatilla River[11] (OR)	284.7	20.9	20.8	-0.1	87*	0	10,473	10,473

[10] Tidally influenced and may be inaccessible during low tides.

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

6.0 TOTAL MAXIMUM DAILY LOAD ANALYSIS

6.1 TEMPERATURE TARGETS

6.1.1 Target Sites

In this TMDL, EPA assesses and allocates heat loads to almost 900 river miles of study area. As part of this relatively large, basin-scale assessment, EPA selected a reasonable number of target sites that span the study area. Target sites are locations in the river where EPA quantified river temperatures and source impacts based on both measured and simulated temperature data.

The TMDL's target sites are at the tailraces of dams and within Lake Roosevelt. The water temperature monitoring system for the Columbia and Snake rivers has been conducted for several decades by the operators of federal and PUD dams, using monitoring stations located at each dam site. The temperatures are monitored in the forebay (upstream) and tailrace (downstream) of each dam. Because the rivers are relatively well-mixed at the tailraces, these data provide a better estimate of the cross-sectional average river temperature than the forebay, where flow is less well-mixed. Selection of the tailrace as the target location also aligns with EPA's application of the one-dimensional RBM10 model, which assumes complete mixing within the water column and simulates the cross-sectional average temperature of the rivers. The model is also calibrated to the measured tailrace temperature.

To address specific source impacts, EPA has also used model estimates at sites that are not monitored target sites. For example, the source assessment modeling includes simulation results for RM 639 in Lake Roosevelt, just downstream of Spokane tribal waters. EPA does not have water quality data at this location, and therefore has used the model to estimate whether state waters are protecting Spokane tribal water quality. The source assessment modeling also includes simulation results for RM 42. This location is downstream of the Bonneville target site in the vicinity of large point source discharges and is the location of modeled maximum point source impacts. Water quality data are not available at RM 42, but EPA used the model to estimate the cumulative impacts of upstream heat loads (from point sources and tributaries) at this location. EPA also considered model temperature estimates above and below the lower Snake River confluence on the Columbia River. EPA included these sites (labeled Hanford Reach and Snake Confluence) in the dam impact assessment to evaluate the extent to which the lower Snake River dams are contributing to downstream warming of the mainstem Columbia River.

EPA recognizes that there are limitations to any set of temperature data used to characterize an assessment area of this size, including the use of data from sixteen target site locations in a TMDL area that spans nearly 900 river miles. The limitations and advantages in the temperature data analysis are outlined above and in Appendix B.

6.1.2 Target Temperatures

At each target site, EPA used the water quality criteria identified in Section 2.0 to develop target temperatures. Sections 2.1 and 2.2 explain EPA's reasons for applying the additional 0.3°C above criteria temperatures for Washington and Oregon. The additional 0.3°C increment, when combined with other criteria, establish the maximum temperature allowed by the Washington and Oregon water quality standards. The criteria + 0.3°C are therefore the temperature targets for the TMDL. The Spokane Tribal WQS do not include an analogous allowable temperature increment, so during those times when the Spokane Tribal temperature criterion is the most stringent applicable WQC (September – October), the temperature target at Lake Roosevelt RM 639 is equal to the WQC. This is explained further in Section 6.3. Future monitoring programs should compare temperature data to these target temperatures to determine whether target criteria are attained. The numeric criteria and TMDL target temperatures at each target site are included in ***Table 6-1***. As described in detail in Appendix D, EPA compared these target temperatures to water quality data (2011-2016) at each target site to determine the level of exceedance above the target temperatures.

Although the criteria averaging-periods vary (e.g., 7-DADM, DM), EPA evaluated the targets in ***Table 6-1*** as daily maxima. As explained in Appendix H, analysis of the differences between 7-DADM and DM values indicates minor differences in the impact of using either metric. At two locations in the Columbia River — Grand Coulee Dam and Priest Rapids Dam — the applicable Washington temperature criteria changes at the dam. At both of these locations, the TMDL uses the more stringent criteria as the target temperature (***Table 6-1***) in order to protect uses and to target attainment of criteria in the reservoirs upstream of these dams.

Table 6-1 TMDL target temperatures

Location (Tailrace)	RM	Water Quality Criterion (°C) (See Table 2-2)	TMDL Target Temperature (°C) (June – Sept.)	TMDL Target Temperature (°C) (October)
Columbia River				
Lake Roosevelt	639	16.5 7-DADM (June 1-Sept 1), 13.5 7-DADM (Sept 1- Oct 1) 11 7-DADM (Oct 1 -Mar 31)	16.3 DM (June -Aug) 13.5 DM (Sept)	11.0 DM
Grand Coulee	591	16.0 7-DADM /17.5 7-DADM	16.3 DM	16.3 DM
Chief Joseph	544	17.5 7-DADM	17.8 DM	17.8 DM
Wells	512	17.5 7-DADM	17.8 DM	17.8 DM
Rocky Reach	472	17.5 7-DADM	17.8 DM	17.8 DM
Rock Island	453	17.5 7-DADM	17.8 DM	17.8 DM
Wanapum	413	17.5 7-DADM	17.8 DM	17.8 DM
Priest Rapids	396	17.5 DADM / 20.0 DM	17.8 DM	17.8 DM
McNary	291	20.0 DM	20.3 DM	20.3 DM
John Day	215	20.0 DM	20.3 DM	20.3 DM
Dalles	189	20.0 DM	20.3 DM	20.3 DM
Bonneville	140	20.0 DM (June-Sept) 13.0 7-DADM (Oct)	20.3 DM	13.3 DM[12]
Snake River				
Lower Granite	107	20.0 DM	20.3 DM	20.3 DM
Little Goose	70	20.0 DM	20.3 DM	20.3 DM
Lower Monumental	40	20.0 DM	20.3 DM	20.3 DM
Ice Harbor	6	20.0 DM	20.3 DM	20.3 DM

[12] Oregon's 20°C is the applicable WQC until October 15, when the 13°C WQC takes effect.

EPA used available hourly data to identify the maximum monthly temperature at each target site for June – October over a six-year period (2011–2016). EPA used the maximum monthly temperatures to estimate the magnitude of temperature exceedances that occur at each target site during the critical time periods for the TMDL. The exceedance values in ***Table 6-2*** are estimates, based on available data, of the extent to which the maximum monthly temperatures are predicted to exceed the target temperatures at most locations throughout the summer and fall, including the upstream borders of the TMDL study area (at the Canadian border and at Anatone, at the Idaho border).

The TMDL target temperatures apply at all locations within the mainstem Columbia and Snake rivers. This includes not only the target sites (dam tailraces) but also areas such as fish ladders, dam forebays, surface waters in impoundments, and nearshore zones. Although it is not feasible within this TMDL to assess source impacts (e.g., cumulative dam impacts) at these more precise locations, the target temperatures at the nearest target site should be applied when evaluating observed conditions at these locations.

Table 6-2 Summary of maximum monthly temperature and target temperature exceedance

Location	Target (°C)	Measured Maximum Monthly Temperature (°C) 2011 – 2016					Maximum Exceedance (°C)				
	Year Round	**June**	**July**	**August**	**Sept**	**Oct**	**June**	**July**	**August**	**Sept**	**Oct**
Columbia River											
Canada Border	16.3	18.2	19.3	20.5	19.7	16.3	1.9	3.0	4.2	3.4	0
Lake Roosevelt[13]	16.3 / 13.5 / 11.0[14]	17.1	19.2	20.3	21.0	18.4	0.8	2.9	4.0	7.5	7.4
Grand Coulee	16.3	16.5	19.5	20.5	20.4	19.1	0.2	3.2	3.6	4.1	2.8
Chief Joseph	17.8	16.6	18.9	19.9	20.1	18.9	0	1.1	2.2	2.3	1.1
Wells	17.8	17.6	19.3	20.0	20.4	18.7	0	1.5	2.4	2.6	0.9
Rocky Reach	17.8	17.9	19.6	20.2	20.5	18.7	0.1	1.8	2.8	2.7	0.9
Rock Island	17.8	18.0	20.0	20.6	20.9	18.5	0.2	2.2	2.7	3.1	0.7
Wanapum	17.8	18.6	19.9	20.5	21.1	18.4	0.8	2.1	2.9	3.3	0.6
Priest Rapids	17.8	19.0	19.8	20.7	21.2	18.3	1.2	2.0	3.2	3.4	0.5
McNary	20.3	20.9	22.4	22.2	22.2	19	0.6	2.1	1.9	1.9	0
John Day	20.3	21.7	23.4	22.8	22.5	19.5	1.4	3.1	2.5	2.2	0
Dalles	20.3	21.6	23.4	22.9	22.7	19.3	1.3	3.1	2.6	2.4	0
Bonneville	20.3 / 13.3[15]	21.9	23.3	23.0	22.9	17.9[15]	1.6	3.0	2.7	2.6	4.6[15]
Snake River											
Anatone	20.3	23.8	24.6	24.2	23.4	NA	3.5	4.3	3.9	3.1	NA
Lower Granite	20.3	19.9	21.4	20.5	20.6	19.3	0	1.1	0.2	0.3	0
Little Goose	20.3	20.7	22.2	21.2	20.8	19.0	0.4	1.9	0.9	0.5	0
Lower Mon	20.3	21.2	22.3	21.4	21.1	18.7	0.9	2.0	1.1	0.8	0
Ice Harbor	20.3	22.2	23.1	22.4	21.8	18.7	1.9	2.8	2.1	1.5	0

[13] No measurements available. Temperatures are maximum daily averages from RBM10 model (2011-2016)
[14] Targets are June-August (16.3°C), September (13.5°C), and October (11.0°C)
[15] Targets are June – September (20.3°C) and October (13.3°C). October exceedance at this location is calculated for the period October 15-31.

6.2 SEASONAL VARIATION AND CRITICAL CONDITIONS

The critical time periods for this TMDL are June – October for all locations. Available data indicate that temperature criteria exceedances occur during this time period. Seasonal variability is illustrated in ***Figure 3-2*** and ***Figure 3-3***. EPA used RBM10 to incorporate seasonal variation of river temperature into the TMDL evaluation.

EPA's recognition of system variability and inherent model uncertainty (discussed further in Section 4.4) influences how the TMDL is developed, and, in turn, how model scenarios are run and outputs processed to provide information for the TMDL. EPA's goal is to capture central tendencies in the multi-year simulations (e.g., long-term mean conditions), while also considering seasonal variation and critical conditions, in accordance with regulations at 40 CFR 130.7(c)(1). In addition, conservative assumptions are needed to ensure that impacts are not underestimated and to account for uncertainties in the data (see Margin of Safety discussion in Section 6.6). Some of the assumptions include:

- Timeframes and magnitudes of impairment are estimated using measured data (DART site) to ensure that times/locations of impairment are fully identified and to provide a uniform analysis. As discussed in Section 6.1, EPA used DM statistics at all locations, even where criteria are expressed as 7-DADM. For each month, the maximum recorded temperature for the 2011 – 2016 period is used to estimate the exceedance level.
- Model simulations are represented by the aggregated results for 2011 – 2016 to provide robust estimates of temperature conditions.
- Model results are aggregated by month (approximately 30-day periods) to address seasonal variation and provide robust estimates that are not influenced by outlier days/weeks.
- The impacts of point sources are conservatively evaluated at the 90th percentile level.
- Dam impacts are evaluated using daily average temperatures to conservatively estimate the impact of these sources (See Appendix H).
- To ensure that critical temperature locations are identified, model outputs are processed at all dam tailrace sites, major tributary confluences, and a location with substantial point source inputs (Columbia RM 42) to ensure that worst-case locations of impact are identified (See ***Table 6-11***).
- EPA determined that the Banks Lake water withdrawal impacts the temperature of the Columbia River by decreasing river flow in the summer (See Appendix D). EPA has assumed that the current rate of withdrawal of water for agricultural use will continue (2011-2016). This represents the critical low-flow summer condition downstream of Grand Coulee dam. Reducing these water withdrawals would improve instream temperatures in the Columbia River and could be considered as a management measure during TMDL implementation.

6.3 LOADING CAPACITY

EPA defined the loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 CFR 130.2(f)). The regulations governing TMDL development provide for the expression of TMDLs as "either mass per time, toxicity, or other appropriate measure" (40 CFR 130.2(h)). The water quality standards at issue are numeric and narrative temperature criteria. Given the characteristics of the temperature sources in the Columbia and lower Snake Rivers, as discussed below, the loading capacity for this TMDL is most logically and appropriately expressed as a temperature in degrees Celsius (°C).

According to Oregon WQS, when the receiving waters are not attaining standards, the available increase in loading capacity for human-caused sources in the Columbia River is 0.3°C above the criterion. Washington WQS have an analogous 0.3°C allowable temperature increment, resulting in an available increase in loading capacity for anthropogenic sources of 0.3°C above the criteria at the target sites, and at the Canadian and Idaho borders (see ***Table 6-1***, “TMDL Target”).

The Spokane tribal WQS, by contrast, do not provide for an analogous allowable temperature increment when waters do not attain standards, so during the time period when the Spokane tribal standards are the most stringent applicable criteria (September – October), the TMDL target temperatures at Lake Roosevelt RM 639 are established using the Spokane WQC. The TMDL employs an allocation approach across the TMDL study area that implements the states’ allowance of 0.3°C for anthropogenic sources, and the critical location for cumulative source impacts is far downstream of tribal waters in the lower Columbia River.

At the Grand Coulee and Priest Rapids target sites, the criteria differ above and below the target sites. At these locations, the more stringent criterion is used to establish a loading capacity that protects the uses below each target site and in the waters immediately upstream of each target site.

The loading capacities at the TMDL target sites, along with the reductions that would be needed to achieve them, are illustrated in ***Figure 6-1*** through ***Figure 6-5*** for June, July, August, September, and October. Each figure illustrates the criteria used, the States’ allowable temperature increases, and the reduction that needs to be observed at each target site to meet the loading capacity. These figures illustrate the loading capacity increases that occur as the river moves downstream, due in part to changing criteria. The temperature reductions needed at each location to meet the loading capacity are illustrated by the upper, orange-shaded portion of each bar graph based on the measured temperatures provided in ***Table 6-2*** (note that there are no river temperature measurements available at the Lake Roosevelt target site and the blue-shaded reduction is based on RBM10 model estimates for the 2011-2016 period). The temperature reductions needed to achieve the criteria change through the summer (e.g., the most significant reductions are needed in August) and as the river moves downstream.

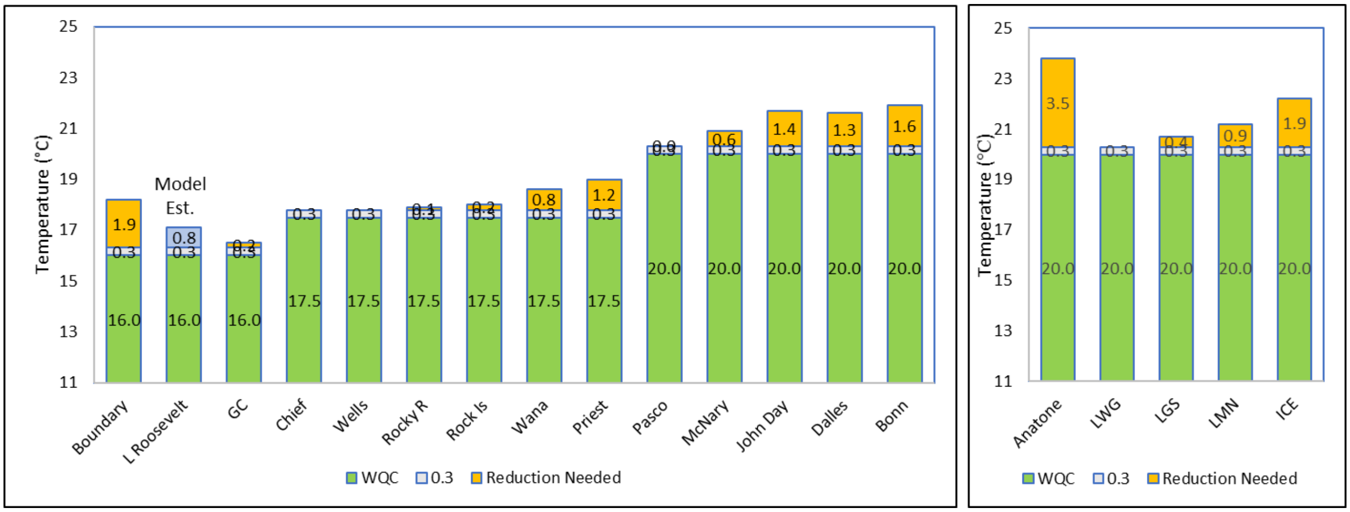

Figure 6-1 Comparing measured maximum monthly temperatures to the target temperatures – June

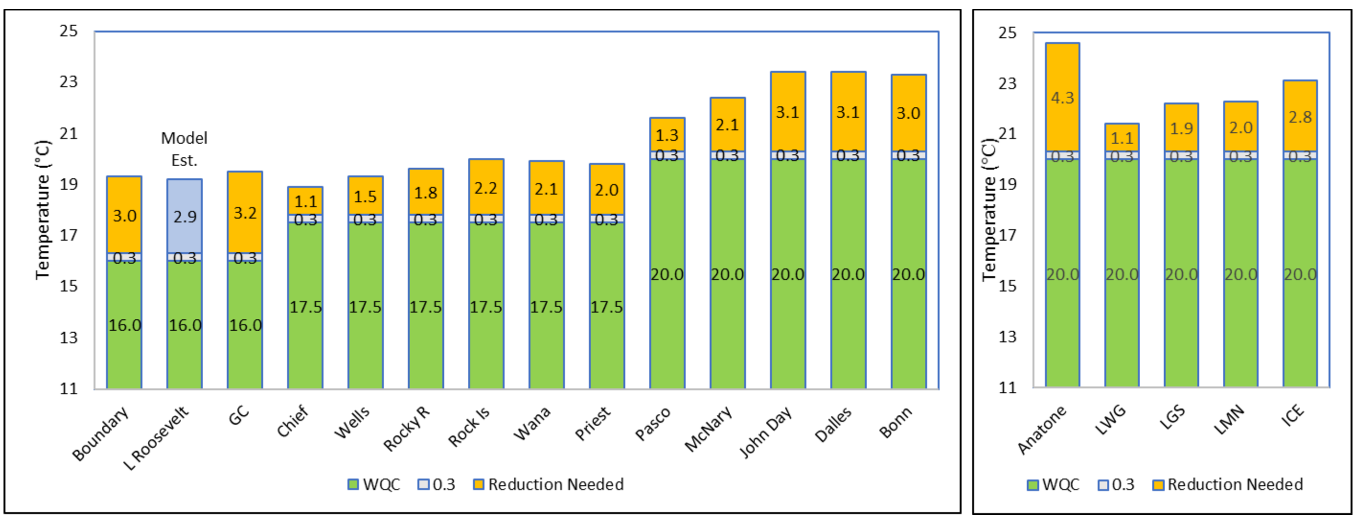

Figure 6-2 Comparing measured maximum monthly temperatures to the target temperatures – July

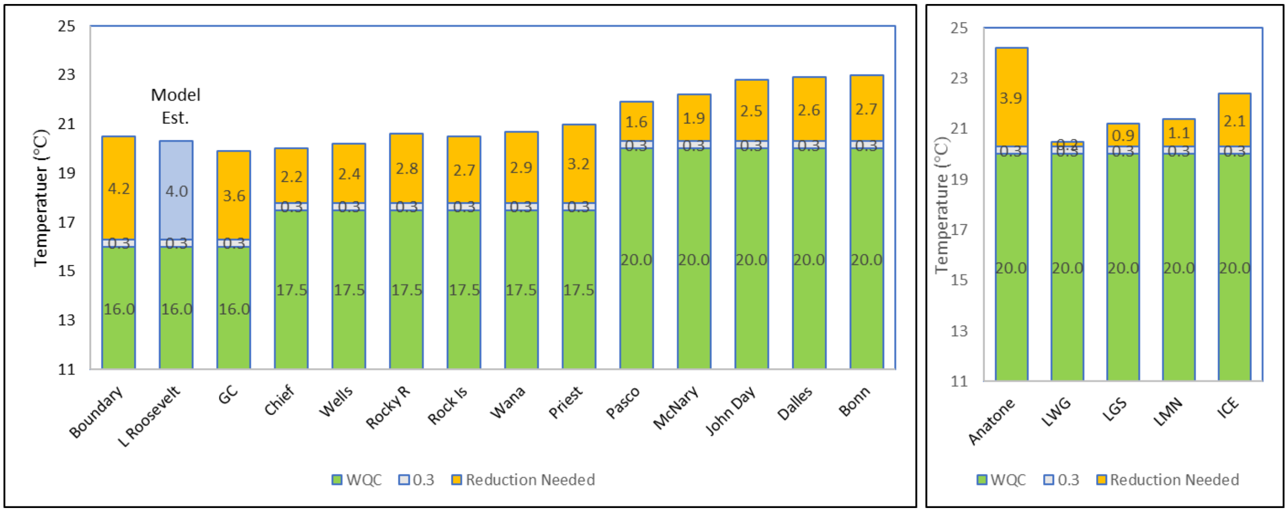

Figure 6-3 Comparing measured maximum monthly temperatures to the target temperatures – August

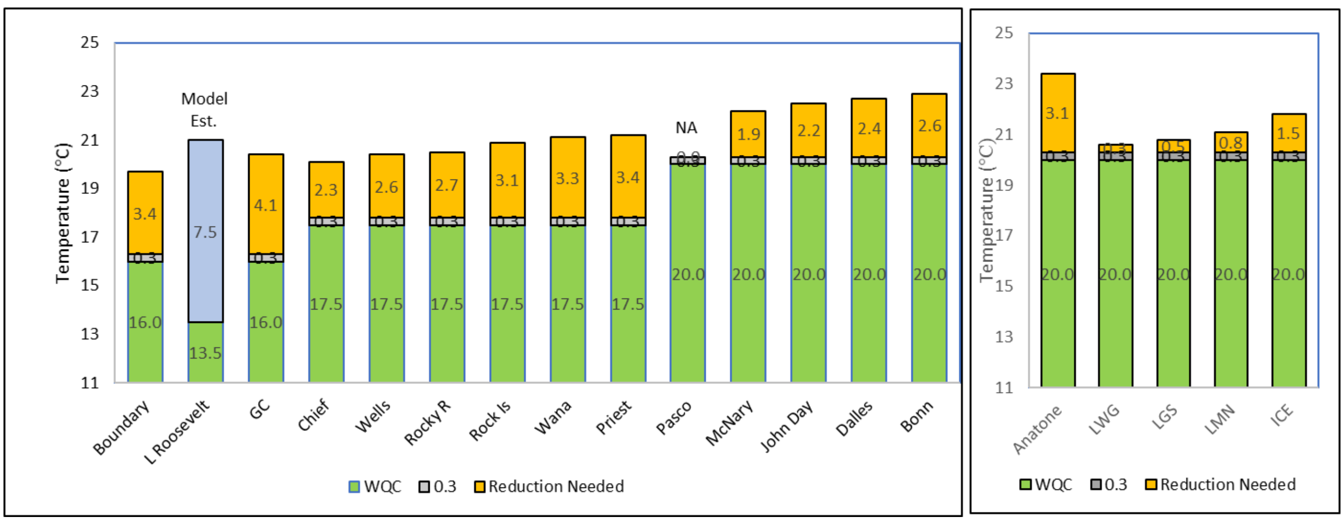

Figure 6-4 Comparing measured maximum monthly temperatures to the target temperatures – September

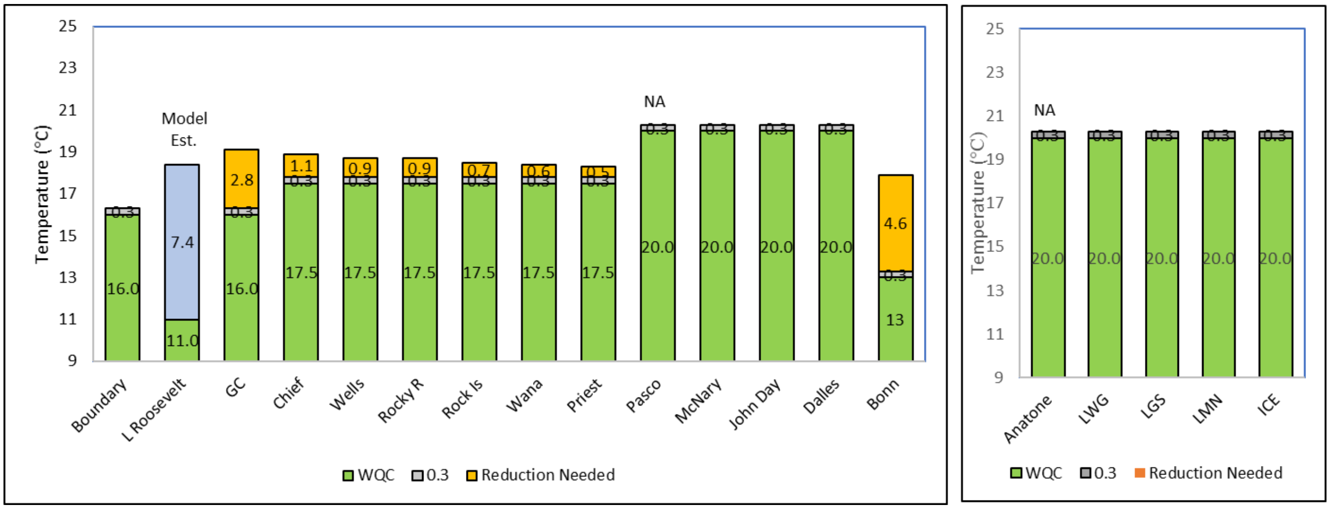

Figure 6-5 Comparing measured maximum monthly temperatures to the target temperatures – October

Temperature is the metric by which loading capacity and TMDL allocations are expressed. In addition, heat loads are provided across the observed range of river flows during the critical period of June – October. These heat loads are calculated as the product of temperature, river flow, and a conversion factor and are expressed in kilocalories per day (kcal/day). The calculated monthly heat loads at target sites are provided in Appendix I. Similarly, heat loads are also provided in Appendix I for the nonpoint source allocations. For individual point sources, wasteload allocations are expressed in the TMDL as heat loads, rather than temperature, because many facilities can manage effluent flow to reduce the impact of their discharge on the receiving water. In expressing the wasteload allocation as heat loads, point sources have the flexibility to manage temperature and/or effluent flow to achieve their wasteload allocations.

6.4 BOUNDARY CONDITIONS

As illustrated in ***Figure 6-2*** through ***Figure 6-4***, where the rivers cross the upstream boundaries of the TMDL study area (Canadian border and the Washington/Idaho border) the water temperatures exceed the Washington water quality criteria by a substantial margin from June through September. The current water quality conditions present a significant challenge to achieving downstream water quality standards in Washington and Oregon. Although EPA used the water quality model RBM10 to examine the potential impacts of colder water temperature inputs at the two boundaries (see Appendix D), this TMDL is established using the *existing* temperature data at both borders because there is inadequate information (e.g., data, water quality models) to evaluate potential future actions that may be taken near these locations and therefore inadequate information to estimate any resulting temperature changes that may occur in the future. A model simulation of source impacts based on an unwarranted assumption of the achievement of the Washington criteria at the borders would show artificial increases in source impacts downstream of the border. Instead, EPA has used an approach grounded in robust estimates of current conditions and impacts. If boundary conditions change substantially in the future, EPA or the states can reexamine the assumptions and resulting allocations of this TMDL.

6.5 ALLOCATIONS

As discussed in Section 6.3, the loading capacity, and therefore the portion available for allocation during the critical period (June – October), is defined by the numeric temperature criteria plus the 0.3°C allowable increase above the numeric temperature criteria provided in the Washington and Oregon standards. EPA's allocation of heat to all point and nonpoint sources is limited to a cumulative increase of no greater than 0.3°C above the numeric temperature criteria. Climate change trends and heat sources in Canada and Idaho are not allocated a portion of the 0.3°C. See Section 6.8 for a discussion of excess temperature.

The allocation of the loading capacity to sources in this TMDL reflect EPA policy decisions based on a number of considerations such as the magnitude of the impacts from different source types, relative level of reduction required by sources, and equity in the allocation approach. In establishing this TMDL for the Columbia and lower Snake mainstems, EPA has divided the 0.3°C portion of the loading capacity equally among three types of sources: tributaries; current and future NPDES sources; and nonpoint source impacts from dam impoundments (***Table 6-3***).

Table 6-3 Aggregate allocation: allowable 0.3°C

	WLA and LA (°C)	Source Group		
		Dams (Nonpoint source) (°C)	NPDES Point Sources and Reserve (°C)	Major Tributaries (°C)
Aggregate Allocations	0.3	0.1	0.1	0.1

An equal division of the 0.3°C allowable temperature increment is a simple approach providing equity and assigning reasonable responsibilities to source categories based on their current impact. For point sources, EPA's analysis of NPDES sources discharging to the Columbia and lower Snake Rivers indicates that the cumulative loading of heat from these point sources is slightly less than 0.1°C. The allocation of 0.1°C to the point sources is therefore achievable by the point sources without imposing a disproportionate burden on other source categories. At the same time, the allocation for point sources will ensure proper management of future new or expanded point source discharges.

For tributaries, a 0.1°C allocation provides an allowance for impacts from human activities within the tributary watersheds, including point sources, riparian shade, dams, and other non-point sources. A complete assessment of tributary impacts is not available, but RBM10 modeling indicates that the 0.1°C load allocation will be attained when tributaries are within 0.5°C of their natural condition (see Section 6.5.5 and Appendix D). For those tributaries identified as impaired for temperature on the 303(d) list (see ***Table 6-23***), sources of anthropogenic heat will be identified by the States during TMDL development and addressed during implementation.

EPA's analysis of the cumulative nonpoint source heat loading from dam impoundments shows that the dam impoundments have a substantially greater temperature impact than point sources and tributaries. In many areas, the dam impact exceeds the full loading capacity (0.3°C) by a substantial margin. EPA is allocating the remaining portion of the loading capacity (0.1°C) to dam impoundments while recognizing that substantial reductions in current impacts will be needed to achieve the allocation. Given the substantially greater impacts from dam impoundments, EPA believes it is equitable to call for greater reductions from these sources.

6.5.1 Dams

As discussed in Section 4.2 and Appendix D, dams can have a cooling effect or a warming effect on the river, depending on the season and the size of the reservoir. The 15 dams within the TMDL area (***Table 6-4***) have a cumulative warming effect during the summer and early fall. In this TMDL, heat contributed by impounding the river in reservoirs behind the dams is considered a nonpoint source of pollution and is given a load allocation. Discharges from cooling water structures, transformers, and sump pumps are considered point sources and are given wasteload allocations. Wasteload allocations are incorporated into NPDES permits during implementation, as discussed in Section 6.5.2.[16]

[16] *National Wildlife Federation v. Consumers Power Company*, 862 F.2d 580 (6th Cir. 1988); *National Wildlife Federation v. Gorsuch*, 693 F.2d 156 (D.C. Cir. 1982).

Table 6-4 Mainstem Columbia and lower Snake River dams

Name	RM	Operator	Type	Year(s) Completed[17]	Generating Capacity (megawatts)
Columbia River					
Grand Coulee Dam	596.6	Bureau of Reclamation	Storage	1973	6,494
Chief Joseph Dam	545.1	U.S. Army Corps of Engineers (USACE)	Run of River	1961/1973	2,069
Wells Dam	515.8	Douglas County Public Utility District (PUD) No. 1	Run of River	1967	774
Rocky Reach Dam	473.7	Chelan County PUD No. 1	Run of river	1961/1971	1,280
Rock Island Dam	453.4	Chelan County PUD No. 1	Run of River	1932/1953/ 1979	624
Wanapum Dam	415.8	Grant County PUD No. 2	Run of River	1964	1,038
Priest Rapids Dam	397.1	Grant County PUD No. 2	Run of River	1961	955
McNary Dam	292.0	USACE	Run of River	1957	980
John Day Dam	215.6	USACE	Run of River	1971	2,160
The Dalles Dam	191.5	USACE	Run of River	1960/1973	1,780
Bonneville Dam	146.1	USACE	Run of River	1938/1982	1,050
Snake River					
Lower Granite Dam	107.5	USACE	Run of River	1975/1978	810
Little Goose Dam	70.3	USACE	Run of River	1970/1978	810
Lower Monumental Dam	41.6	USACE	Run of River	1970/1978	810
Ice Harbor Dam	9.7	USACE	Run of River	1962/1976	603

As explained in Section 6.5, dam impoundments are allocated a cumulative temperature increase to the mainstem Columbia and lower Snake Rivers of 0.1°C, or one third of the 0.3°C allowable temperature increment available for all sources. This allocation is applied at all target locations except the Lake Roosevelt target site, upstream of Grand Coulee Dam. During

[17] Multiple years indicate initial completion year and subsequent installation of additional hydroelectric turbine year(s).

September and October, the Lake Roosevelt temperature targets were developed using the more stringent Spokane Tribal standards, so the dam allocation at this location is zero impact.

EPA used the RBM10 temperature model to estimate the dams' impacts on river temperature by comparing daily average river temperatures with and without the presence of dams. The target temperatures are daily maxima. Since the diel variation is typically greater in a free-flowing river than when dams are present, the impact of the dams on the daily average temperature is greater than the impact on the daily maximum temperature (Appendix H). The daily average temperature is therefore a more conservative indicator of dam impact. This component of the analysis is considered as a margin of safety (Section 6.6).

EPA used a step-by-step process to estimate the contributions to impairment from dam impoundments. This analysis estimates the cumulative temperature impact in each reach caused by all upstream dam impoundments and estimates when and where this impact exceeds the 0.1°C cumulative dam load allocation (the exception is Lake Roosevelt where all temperature impacts are identified for reduction). EPA used both RBM10 simulations and monitoring data from 2011 – 2016 for this analysis, starting at the upstream target sites on the Columbia and lower Snake Rivers, and moving downstream. The results of EPA's analyses are included in ***Table 6-6*** through ***Table 6-10***. These tables contain a month-by-month analysis of the temperature contributions of the dams to address seasonal variation in impacts.

Step 1. Use RBM10 to estimate the river temperature with and without dams for each month, at each of the target locations. See columns C (RBM Current) and column D (RBM free-flowing) in ***Table 6-6*** through ***Table 6-10***.

Step 2. Identify the estimated temperature change in each reach. As an example: at the John Day tailrace in August (***Table 6-8***), the model predicts a temperature increase of (21.54 - 20.86 =) 0.68°C between the McNary dam tailrace and John Day under current conditions; and a temperature increase of (20.28 - 19.88 =) 0.40° under free-flowing conditions. The estimated temperature impact in the John Day reach is the difference between these two (0.68 - 0.40 = 0.3) and is identified as the "Reach Impact" (column E). In some months, a dam cools rather than warms the reach that it impounds.

Step 3. Estimate the cumulative temperature impact at each target site. The current temperature (Column C) minus the estimated free-flowing temperature (Column D) equals the cumulative impact (Column F).

Step 4. For locations with a measured target exceedance (Column G), assess whether the estimated cumulative impact of upstream dam(s) exceeds the 0.1°C LA at that location. If this impact (Column F) is greater than 0.1, then the dams upstream of this location are cumulatively contributing to impairment and the analysis proceeds to Step 5. If no contribution to impairment is identified, the analysis moves to the next target site downstream.

Step 5. Identify the magnitude of the contribution to impairment. If the 0.1°C LA is exceeded, the contribution from dams is calculated one of two ways depending on the level of target exceedance and dam impact. If the measured target exceedance is greater than the cumulative dam impact, the contribution is calculated by subtracting the 0.1°C LA from the cumulative impact of the upstream dams (Column F). If the measured target exceedance is less than the cumulative dam impact, the contribution is equal to the exceedance. The contribution is listed as the "Allocation Exceedance" (Column H).

When dams are estimated as contributing to an exceedance (through Steps 4 and 5 above), the cumulative contribution is identified in Column H ("Allocation Exceedance") of ***Table 6-6*** through ***Table 6-10***. In most cases, multiple upstream dams are contributing to downstream impairments. The dams contributing to downstream impairments are those dams in column E with a reach impact greater than zero. The "notes" column (Column I) in each of these five tables contains codes that are explained in ***Table 6-5***.

Table 6-5 Explanation of "notes" (Column I) for excess dam impact in ***Table 6-6*** through ***Table 6-10***

Note	Explanation
1	Boundary location for model and/or TMDL. Provided for information only.
2	Load allocation exceedance, and the cumulative dam impact is less than or equal to the target exceedance. The "load allocation exceedance" (Column H) is the source contribution to impairment and equals the cumulative dam impact (Column F) minus the load allocation (0.1).
3	Load allocation exceedance, and cumulative dam impact is greater than the target exceedance. The "load allocation exceedance" (Column H) is the source contribution to impairment and equals the measured target exceedance (Column G).
4	The cumulative dam impact (Column F) is equal to the load allocation (0.1).
5	Not exceeding target temperature at target site or supplemental analysis location for dam assessment.
6	Dams do not have a cumulative warming impact at analysis location.
7	No measurements at the analysis location and/or time frame. Model results for lower Snake River show impact due to dams at confluence with Columbia River.
8	Temperature reduction equals the dam impact without application of a 0.1°C load allocation in September and October when Spokane Tribal standards are applied.

Table 6-6 Cumulative excess dam impact on Columbia and lower Snake Rivers temperatures – June

Location	Dam Number	RBM10 Current (°C)	RBM10 Free Flowing (°C)	RBM10 Reach Impact (Δ°C)	RBM10 Cumulative Impact (Δ°C)	Measured Target Exceedance (Δ°C)	Allocation Exceedance (Δ°C)	Notes
A	B	C	D	E	F	G	H	I
Columbia River								
Canadian Border	NA	12.97	12.99	NA	NA	1.9	NA	1
Lake Roosevelt	NA	13.31	13.45	-0.1	-0.1	0.8	None	6
Grand Coulee	1	13.07	13.71	-0.5	-0.6	0.2	None	6
Chief Joseph	2	13.27	13.80	0.1	-0.5	-1.2	None	6
Wells	3	13.51	13.91	0.1	-0.4	-0.2	None	6
Rocky Reach	4	14.07	14.10	0.4	0.0	0.1	None	6
Rock Island	5	14.09	14.15	0.0	-0.1	0.2	None	6
Wanapum	6	14.57	14.28	0.4	0.3	0.8	0.2	2
Priest Rapids	7	14.85	14.41	0.1	0.4	1.2	0.3	2
Hanford Reach	NA	15.53	15.04	0.1	0.5	-0.2	None	5
Snake Confluence	NA	15.56	15.19	-0.1	0.4	NA	NA	7
McNary	8	15.91	15.41	0.1	0.5	0.6	0.4	2
John Day	9	16.45	15.85	0.1	0.6	1.4	0.5	2
Dalles	10	16.55	15.96	0.0	0.6	1.3	0.5	2
Bonneville	11	16.66	16.09	0.0	0.6	1.6	0.5	2
Snake River								
Anatone	NA	15.95	15.95	NA	NA	3.5	NA	1
Clearwater Confluence	NA	14.79	14.77	NA	NA	NA	NA	1
Lower Granite	12	14.98	15.01	0.0	0.0	-0.4	None	6
Little Goose	13	15.12	15.24	-0.1	-0.1	0.4	None	6
Lower Monumental	14	15.21	15.44	-0.1	-0.2	0.9	None	6
Ice Harbor	15	15.61	15.69	0.1	-0.1	1.9	None	6

Table 6-7 Cumulative excess dam impact on Columbia and lower Snake Rivers temperatures – July

Location	Dam Number	RBM10 Current (°C)	RBM10 Free Flowing (°C)	RBM10 Reach Impact (Δ°C)	RBM10 Cumulative Impact (Δ°C)	Measured Target Exceedance (Δ°C)	Allocation Exceedance (Δ°C)	Notes
A	B	C	D	E	F	G	H	I
Columbia River								
Canadian Border	NA	16.22	16.23	NA	NA	3.0	NA	1
Lake Roosevelt	NA	16.49	16.60	-0.1	-0.1	2.9	None	6
Grand Coulee	1	15.92	16.77	-0.7	-0.8	3.2	None	6
Chief Joseph	2	16.06	16.84	0.1	-0.8	1.1	None	6
Wells	3	16.43	17.17	0.0	-0.7	1.5	None	6
Rocky Reach	4	17.00	17.37	0.4	-0.4	1.8	None	6
Rock Island	5	17.09	17.41	0.0	-0.3	2.2	None	6
Wanapum	6	17.57	17.53	0.4	0.0	2.1	None	6
Priest Rapids	7	17.85	17.72	0.1	0.1	2.0	None	4
Hanford Reach	NA	18.48	18.31	0.0	0.2	1.3	0.1	2
Snake Confluence	NA	18.81	18.50	0.1	0.3	NA	NA	7
McNary	8	19.23	18.73	0.2	0.5	2.1	0.4	2
John Day	9	19.64	19.11	0.0	0.5	3.1	0.4	2
Dalles	10	19.66	19.18	-0.1	0.5	3.1	0.4	2
Bonneville	11	19.68	19.30	-0.1	0.4	3.0	0.3	2
Snake River								
Anatone	NA	21.09	21.09	NA	NA	4.3	NA	1
Clearwater Confluence	NA	17.94	17.91	NA	NA	NA	NA	1
Lower Granite	12	18.73	18.24	0.5	0.5	1.1	0.4	2
Little Goose	13	19.21	18.60	0.1	0.6	1.9	0.5	2
Lower Monumental	14	19.39	18.84	-0.1	0.6	2.0	0.5	2
Ice Harbor	15	19.89	19.20	0.1	0.7	2.8	0.6	2

Table 6-8 Cumulative excess dam impact on Columbia and lower Snake Rivers temperatures – August

Location	Dam Number	RBM10 Current (°C)	RBM10 Free Flowing (°C)	RBM10 Reach Impact (Δ°C)	RBM10 Cumulative Impact (Δ°C)	Measured Target Exceedance (Δ°C)	Allocation Exceedance (Δ°C)	Notes
A	B	C	D	E	F	G	H	I
Columbia River								
Canadian Border	NA	17.77	17.78	NA	NA	4.2	NA	1
Lake Roosevelt	NA	18.31	18.13	0.2	0.2	4.0	0.1	2
Grand Coulee	1	18.11	18.29	-0.4	-0.2	3.6	None	6
Chief Joseph	2	18.20	18.39	0.0	-0.2	2.2	None	6
Wells	3	18.45	18.66	0.0	-0.2	2.4	None	6
Rocky Reach	4	18.87	18.83	0.2	0.0	2.8	None	6
Rock Island	5	18.98	18.86	0.1	0.1	2.7	None	4
Wanapum	6	19.40	19.05	0.2	0.3	2.9	0.2	2
Priest Rapids	7	19.62	19.15	0.1	0.5	3.2	0.4	2
Hanford Reach	NA	20.02	19.64	-0.1	0.4	1.6	0.3	2
Snake Confluence	NA	20.36	19.69	0.3	0.7	NA	NA	7
McNary	8	20.86	19.87	0.3	1.0	1.9	0.9	2
John Day	9	21.54	20.29	0.3	1.3	2.5	1.2	2
Dalles	10	21.50	20.32	-0.1	1.2	2.6	1.1	2
Bonneville	11	21.57	20.51	-0.1	1.1	2.7	1.0	2
Snake River								
Anatone	NA	22.50	22.50	NA	NA	3.9	NA	1
Clearwater Confluence	NA	18.32	18.28	NA	NA	NA	NA	1
Lower Granite	12	19.47	18.64	0.8	0.8	0.2	0.2	3
Little Goose	13	20.24	19.05	0.4	1.2	0.9	0.9	3
Lower Monumental	14	20.62	19.27	0.2	1.3	1.1	1.1	3
Ice Harbor	15	21.42	19.68	0.4	1.7	2.1	1.6	2

Table 6-9 Cumulative excess dam impact on Columbia and lower Snake Rivers temperatures – September

Location	Dam Number	RBM10 Current (°C)	RBM10 Free Flowing (°C)	RBM10 Reach Impact (Δ°C)	RBM10 Cumulative Impact (Δ°C)	Measured Target Exceedance (Δ°C)	Allocation Exceedance (Δ°C)	Notes
A	B	C	D	E	F	G	H	I
Columbia River								
Canadian Border	NA	16.38	16.38	NA	NA	3.4	NA	1
Lake Roosevelt	NA	18.44	16.48	2.0	2.0	7.5	2.0	8
Grand Coulee	1	18.78	16.69	0.1	2.1	4.1	2.0	2
Chief Joseph	2	18.67	16.70	-0.1	2.0	2.3	1.9	2
Wells	3	18.58	16.85	-0.2	1.7	2.6	1.6	2
Rocky Reach	4	18.61	16.89	0.0	1.7	2.7	1.6	2
Rock Island	5	18.62	16.90	0.0	1.7	3.1	1.6	2
Wanapum	6	18.84	17.01	0.1	1.8	3.3	1.7	2
Priest Rapids	7	18.89	17.03	0.0	1.9	3.4	1.8	2
Hanford Reach	NA	18.76	17.26	-0.4	1.5	NA	NA	7
Snake Confluence	NA	19.06	17.34	0.2	1.7	NA	NA	7
McNary	8	19.47	17.44	0.3	2.0	1.9	1.9	3
John Day	9	20.31	17.78	0.5	2.5	2.2	2.2	3
Dalles	10	20.17	17.90	-0.3	2.3	2.4	2.2	2
Bonneville	11	20.26	18.09	-0.1	2.2	2.6	2.1	2
Snake River								
Anatone	NA	20.19	20.19	NA	NA	3.1	NA	1
Clearwater Confluence	NA	17.81	17.79	NA	NA	NA	NA	1
Lower Granite	12	18.14	17.81	0.3	0.3	0.3	0.2	2
Little Goose	13	18.88	17.72	0.8	1.2	0.5	0.5	3
Lower Monumental	14	19.26	17.63	0.5	1.6	0.8	0.8	3
Ice Harbor	15	19.77	17.58	0.6	2.2	1.5	1.5	3

Table 6-10 Cumulative excess dam impact on Columbia and lower Snake Rivers temperatures – October

Location	Dam Number	RBM10 Current (°C)	RBM10 Free Flowing (°C)	RBM10 Reach Impact (Δ°C)	RBM10 Cumulative Impact (Δ°C)	Measured Target Exceedance (Δ°C)	Allocation Exceedance (Δ°C)	Notes
A	B	C	D	E	F	G	H	I
Columbia River								
Canadian Border	NA	13.01	13.01	NA	NA	0.0	None	1
Lake Roosevelt	NA	15.39	12.68	2.7	2.7	7.4	2.7	8
Grand Coulee	1	17.22	12.78	1.7	4.4	2.8	2.8	3
Chief Joseph	2	17.19	12.72	0.0	4.5	1.1	1.1	3
Wells	3	16.78	12.76	-0.5	4.0	0.9	0.9	3
Rocky Reach	4	16.39	12.75	-0.4	3.6	0.9	0.9	3
Rock Island	5	16.20	12.69	-0.1	3.5	0.7	0.7	3
Wanapum	6	16.13	12.75	-0.1	3.4	0.6	0.6	3
Priest Rapids	7	15.99	12.72	-0.1	3.3	0.5	0.5	3
Hanford Reach	NA	15.39	12.71	-0.6	2.7	0.0	None	5
Snake Confluence	NA	15.61	12.80	0.1	2.8	0.0	NA	7
McNary	8	15.89	12.79	0.3	3.1	0.0	None	5
John Day	9	16.58	12.98	0.5	3.6	0.0	None	5
Dalles	10	16.41	13.16	-0.4	3.3	0.0	None	5
Bonneville	11	16.39	13.31	-0.2	3.1	4.6	3.0	2
Snake River								
Anatone	NA	14.93	14.93	NA	NA	0.0	NA	1
Clearwater Confluence	NA	13.85	13.84	NA	NA	NA	NA	1
Lower Granite	12	15.20	13.68	1.5	1.5	0.0	None	5
Little Goose	13	15.81	13.43	0.9	2.4	0.0	None	5
Lower Monumental	14	16.02	13.19	0.4	2.8	0.0	None	5
Ice Harbor	15	16.21	12.98	0.4	3.2	0.0	None	5

6.5.2 NPDES Permitted Point Sources

The NPDES point sources discharging directly to the mainstems of Columbia and lower Snake Rivers are allocated a temperature increase of 0.1°C, or one third of the 0.3°C allowable temperature increment for all sources. EPA used RBM10, with data from 2011 – 2016, to estimate the impacts of current non-stormwater point source discharges at each target site. NPDES permitted stormwater discharges are discussed separately in Section 6.5.3.

Using RBM10, EPA estimates that the greatest cumulative temperature impact of these sources during the critical period of June through October, after full dilution with the receiving water, is less than 0.1°C, if current sources continue discharging their existing heat loads. Because additional heat loading from point sources can be allowed within the 0.1 °C allocation, EPA has designated relatively small loadings throughout the TMDL area as reserve allocations for new sources, future growth, and wasteload allocation adjustments based on new information. The cumulative impact of the point sources and the reserve allocations in the summer is constrained to a 90^{th} percentile temperature increase of 0.1°C. The reserve allocations are described in detail in Section 6.5.4.

As noted in Section 6.3, wasteload allocations are expressed as heat loads (kcal/day) because many point source facilities can manage effluent flow to reduce the impact of their discharge on the receiving water. In expressing the wasteload allocation as heat loads, the TMDL gives point sources the flexibility to manage temperature and/or effluent flow to achieve their wasteload allocations. The individual WLAs, used as inputs to the model and necessary to achieve the 0.1°C aggregate allocation, are provided in ***Table 6-11*** through ***Table 6-13***. EPA used facility-specific design flow and maximum temperature data (or temperatures representative of the industry sector if effluent data were not available) to derive wasteload allocations for each facility using the following equation:

$$\text{Heat Load (kcal/day)} = \text{Flow (mgd)} \times \text{Temperature (°C)} \times 3.78\times10^{6} \quad \text{(Equation 6-1)}$$

The assumptions of the modeling assessment can be considered in determining how to translate the TMDL wasteload allocations into permit limits. In the model, a point source is input as a continuous heat load; this is analogous to a source discharging continuously at its monthly average permit limit. Collectively, if all the sources discharge this load on average, the cumulative wasteload allocation for point sources will be achieved.

Permit limits must be consistent with the assumptions and requirements of a TMDL [40 CFR 122.44(d)(1)(vii)(B)]. Given the modeling assumptions, permit writers may translate wasteload allocations to monthly average permit limits. WLAs apply from June 1 through October 31 to all facilities discharging to the Columbia and Snake rivers upstream of Columbia River mile 141.5. Below river mile 141.5, the WLAs apply to discharges from June 1 through September 30. Considerations for permit writers when implementing the TMDL WLAs are included in Appendix J. The appendix also includes recommendations for potential future coordination among Oregon Department of Environmental Quality, Washington Department of Ecology, and EPA regarding management of the reserve allocation and any potential point source trading.

Table 6-11 through ***Table 6-13*** are organized according to the NPDES program designation for major[18] and minor permits (EPA 1990). For discharges to the Columbia River, major facilities are listed in ***Table 6-11*** and minor facilities are listed in

Table 6-12. Discharges to the lower Snake River are listed in ***Table 6-13***. The agency responsible for issuing each NPDES permit is indicated by two letters preceding the permit number (e.g., "WA0020621" was issued by Washington), except for EPA-permitted facilities, which are identified by footnotes. These tables include point sources with existing NPDES permits, as well as sources that have applied for and are expected to receive NPDES permits.

Table 6-11 WLAs for "Major facility" NPDES permitted facilities on the Columbia River

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
Wenatchee	WA0023949	466.6	5.5	26.2	5.44E+08
E Wenatchee Sewage Treatment Plant (STP)	WA0020621	465.7	3.0	26.2	2.97E+08
Alcoa Wenatchee	WA0000680	455.2	5.5	25.6	5.31E+08
Columbia Generating Sta / Energy Northwest	WA0025151	351.8	9.4	35.9	1.27E+09
Richland STP	WA0020419	337.1	11.4	29.4	1.27E+09
Kennewick Wastewater Treatment Plant	WA0044784	328.0	12.2	27.0	1.24E+09
Pasco	WA0044962	327.6	10.8	27.3	1.11E+09
Agrium Hedges	WA0003699	323.3	0.03	17.2	1.95E+06
Agrium Kennewick	WA0003671	322.6	23.4	30.8	2.72E+09
Agrium Finley	WA0003727	321.5	18.9	27.2	1.94E+09
Packaging Corporation of America	WA0003697	316.0	37.5	37.1	5.25E+09
The Dalles STP	OR0020885	186.5	4.2	27.0	4.23E+08
Hydro Extrusion USA, LLC	OR0001708	186.0	6.0	34.0	7.70E+08
Hood River OR STP	OR0020788	165.0	2.0	27.0	2.04E+08
Georgia Pacific / GP Consumer Operations LLC	WA0000256	120.0	76.0	37.7	1.08E+10
Gresham OR Wastewater Treatment Plant (WWTP)	OR0026131	117.5	15.9	23.9	1.44E+09
Marine Park / Vancouver Marine Park Reclamation Facility	WA0024368	109.2	16.1	25.1	1.53E+09
Portland STP OR	OR0026905	105.5	150.0	24.9	1.41E+10
Vancouver Westside STP	WA0024350	105.1	28.3	26.0	2.78E+09
Salmon Creek STP	WA0023639	96.0	17.0	23.3	1.50E+09
Boise/St Helens OR STP	OR0020834	86.0	12.7	28.5	1.37E+09

[18] Major municipal dischargers include all facilities with design flows of greater than one million gallons per day and facilities with EPA/state-approved industrial pretreatment programs. Major industrial facilities are determined based on specific ratings criteria developed by EPA or are classified as such by EPA in conjunction with the state (EPA 1996).

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
Dyno Nobel Inc.	OR0001635	82.0	24.6	34.0	3.16E+09
Emerald Kalama Chemical	WA0000281	74.0	15.0	34.7	1.97E+09
Steelscape, Inc.	WA0040851	72.2	0.2	35.0	2.38E+07
Westrock Longview	WA0000078	67.4	57.0	38.4	8.28E+09
Three Rivers Regional	WA0037788	66.0	26.0	32.5	3.19E+09
Nippon Dynawave Packaging Corporation	WA0000124	64.0	79.6	45.0	1.35E+10
Millenium Bulk Terminals	WA0000086	63.0	6.6	28.9	7.25E+08
Port of St. Helens	OR0034231	53.0	3.3	32.0	3.99E+08
GP Wauna OR Mill	OR0000795	42.0	39.6	35.4	5.29E+09
Astoria OR STP	OR0027561	18.0	6.2	25.0	5.85E+08

Table 6-12 WLAs for “Minor facility” NPDES permitted facilities located on the Columbia River

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
Avista – Kettle Falls	WA0045217	702.4	0.34	32.2	4.12E+07
Coulee Dam Electric Facility (WA)[19,20]	WA0026867	596	178.0	16.8	1.13E+10
Grand Coulee WWTP[19]	WA0044857	596.6	0.3	24.1	2.73E+07
City of Coulee Dam[19]	WA0020281	596.0	0.5	23.9	4.51E+07
Interior, Reclamation[19]	WA0024163	596.0	0.018	24.7	1.68E+06
Colville Confederated Tribes[19]	WAG130016	580.0	4.86	16.8	3.08E+08
Confederated Tribes of the Colville Reservation[19]	WAG130025	580.0	25.4	16.8	1.61E+09
Chief Joseph Dam[19,20]	WA0026891	545	92.5	18.2	6.36E+09
Chelan Fruit Cooperative Pateros South Plant	WAG435265	--	0.2	18.8	1.42E+07
Wells Fish Hatchery	WAG135009	--	36.2	17.7	2.42E+09
Bridgeport STP	WA0024066	543.7	0.36	24.2	3.33E+07
Brewster	WA0021008	529.8	0.61	26.0	5.99E+07
Pateros STP	WA0020559	524.1	0.10	24.0	8.91E+06
Wells Dam	WA0991031	515.5	28.5	35.4	3.81E+09
Chelan Fruit Cooperative Beebe Plant	WAG435270	--	0.2	23.7	1.79E+07
Chelan POTW	WA0020605	503.5	2.6	25.0	2.49E+08
Entiat STP	WA0051276	485.0	0.15	26.0	1.47E+07
Rocky Reach Dam	WA0991033	473.5	34.3	27.0	3.50E+09

[19] EPA is the NPDES permitting agency.
[20] The NPDES permit application has been submitted.

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
Stemlit Growers Euclid	WAG435172	--	0.1	26.1	9.87E+06
Stemlit Growers Olds Station 2	WAG435157	--	0.1	21.3	8.05E+06
Eastbank Hatchery	WAG135011	--	29.5	17.5	1.95E+09
Chelan Hatchery	WAG135006	--	17.3	17.5	1.14E+09
Tree Top Inc Wenatchee	WA0051527	470.8	0.18	26.6	7.03E+07
Naumes Processing / Keyes Fibre Corp	WA0051811	470.5	1.4	24.7	1.32E+08
Lineage Logistics	WA0052400	466.8	1.9	24.7	1.74E+08
KB Alloys/ AMG Al North Amer.	WA0002976	458.5	0.3	40.0	4.53E+07
Specialty Chemical	WA0002861	456.3	0.35	16.1	2.13E+07
City of Rock Island	WA0501487	455.9	0.34	20.5	2.62E+07
Rock Island Dam	WA0991032	453.5	26.9	26.0	2.64E+09
Crescent Bar WWTP	WA0991013	440	0.06	26.0	5.89E+06
Vantage STP	WA0050474	420.6	0.09	26.1	8.57E+06
Wanapum Dam	WA0991028	416	29.8	30.0	3.38E+09
Priest Rapids Dam	WA0991029	397	27.8	29.2	3.07E+09
Priest Rapids Hatchery	WAG137013	397	76.5	19.8	5.72E+09
Twin City Foods Kennewick	WA0021768	328.3	0.01	24.4	7.37E+05
Sanvik Metals	WA0003701	321.0	0.24	37.8	3.45E+07
McNary Dam (OR)[20]	ODEQ	291	28.8	26.0	2.83E+09
Richland Water Treatment Plant	WAG645000	--	0.8	23.9	7.23E+07
Umatilla STP	OR0022306	285.0	1.1	26.1	1.08E+08
Oregon Fish and Wildlife (Umatilla Hatchery)	ORG137011	275	7.1	17.5	4.71E+08
Oregon Fish and Wildlife (Irrigon Hatchery)	ORG137017	275	18.1	16.6	1.13E+09
Arlington STP	OR0020192	238.0	0.13	25.0	1.18E+07
John Day Project (WA)[19,20]	WA0026832	214	51.9	21.4	4.19E+09
John Day Dam (OR)[20]	ODEQ	214	68.5	27.1	7.01E+09
Biggs OR WWTP	OR0041246	205.5	0.039	26.1	3.79E+06
Wishram POTW	WA0051292	200.9	0.10	23.9	8.75E+06
The Dalles Dam (WA)[19,20]	WA0026701	190	39.5	26.9	4.01E+09
Underwood Fruit & Warehouse	WAG435043	--	0.0014	12.7	6.72E+04
Dalles/Oregon Cherry OR	OR0000736	189.5	0.74	23.0	6.43E+07
Oregon Cherry (Riverside)	OR0000116	189.5	3.24	24.0	2.94E+08
Lyle POTW	WA0050482	183.2	0.098	23.9	8.84E+06
Mosier OR	OR0028045	174.5	0.085	25.6	8.22E+06

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
SDS Lumber	WA0051152	170.2	25.0	29.4	2.78E+09
Bingen STP	WA0022373	170.2	0.8	24.0	7.25E+07
Spring Crk Natl Fish Hatchery[19]	WAG130006	165.0	5.1	16.8	3.25E+08
Cascade Locks OR STP	OR0041271	148.2	0.49	28.0	5.21E+07
Stevenson STP	WA0020672	150.0	0.45	27.4	4.66E+07
Oregon Fish and Wildlife (Bonneville Fish Hatchery)	ORG130001	143	32.0	15.5	1.87E+09
Tanner Creek Water Treatment Plant – USACE	OR0022624	146.1	0.1	22.0	8.31E+06
North Bonneville STP	WA0023388	144.0	0.25	20.1	1.90E+07
Bonneville Dam (OR)[20]	OR0034355	141.5	28.5	24.1	2.59E+09
Bonneville Project (WA)[19,20]	WA0026778	141.5	25.1	24.4	2.31E+09
Multnomah Falls OR Lodge STP	OR0040410	135.9	0.5	31.6	5.97E+07
Washougal STP	WA0037427	123.5	2.2	24.1	2.04E+08
Camas STP	WA0020249	121.2	6.1	25.5	5.87E+08
Toyo Tanso USA OR	OR0034916	118.1	0.2	25.3	1.91E+07
Port of Portland	OR0000060	116.9	3.0	20.0	2.27E+08
Knife River Corporation – NW	OR0044652	116.7	9.0	25.0	8.50E+08
Sundial Marine Construction & Repair, Inc.	OR0044601	116.7	0.022	24.7	2.01E+06
Portland Water Bureau	OR0031135	115.0	4.2	20.0	3.13E+08
River Road Generating Plant	WA0040932	103.2	0.7	38.5	9.45E+07
Columbia River Carbonates	WA0039721	83.5	0.31	14.1	1.67E+07
Kalama STP	WA0020320	75.0	0.8	23.9	7.22E+07
Port of Kalama	WA0040843	72.2	0.02	24.7	1.86E+06
Riverwood OR Mobile Home Park / Magar E Mager	OR0031143	70.6	0.013	24.0	1.18E+06
Rainier OR STP	OR0020389	67.0	1.0	25.0	9.35E+07
Stella STP	WA0039152	56.4	0.0035	23.9	3.16E+05
PGE Beaver OR	OR0027430	53.0	1.4	35.0	1.90E+08
Cathlamet STP	WA0022667	32.0	0.38	24.0	3.47E+07
Bio-Oregon Protein	OR0000612	10.8	0.52	28.0	5.50E+07
Pacific Surimi Co., Inc.	OR0034657	10.0	0.38	24.7	3.54E+07
Fort Columbia State Park	WA0038709	10.0	0.005	20.5	3.87E+05
Warrenton WWTP	OR0020087	7.8	1.0	24.2	9.14E+07
Point Adams Packing Co. / California Shellfish Co.	OR0000868	6.6	0.68	12.8	3.31E+07
Bell Buoy Crab Co. (Now South Bend Products LLC)	WA0000159	6.0	0.2	18.4	1.39E+07
Ilwaco STP	WA0023159	2.0	1.0	23.0	8.77E+07

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
Jessies Ilwaco Fish Co.	WA0000361	2.0	0.75	18.3	5.18E+07

Table 6-13 WLAs for "Minor facility" NPDES permitted facilities located on the lower Snake River

Facility Name	Permit Number	Location (RM)	Flow (MGD)	Temp (°C)	WLA (kcal/day)
Clarkston STP	WA0021113	138.0	2.2	27.4	2.28E+08
Lower Granite Dam and Locks (WA)[19,20]	WA0026794	106	27.6	21.6	2.25E+09
Little Goose Lock and Dam (WA)[19,20]	WA0026786	69	40.7	21.0	3.23E+09
Lyon's Ferry (hatchery)	WAG137006	59.1	91.9	16.8	5.84E+09
Lower Monumental Lock and Dam (WA)[19,20]	WA0026808	41	26.9	21.8	2.21E+09
Ice Harbor Lock and Dam (WA) [19,20]	WA0026816	9	39.2	23.8	3.52E+09

There are no major NPDES facilities on the lower Snake River within the TMDL study area. Two major facilities are located just upstream of the TMDL study area: Clearwater Paper and the City of Lewiston. One minor facility, the City of Asotin, is also located upstream. Loading assumptions for these facilities are included in the model scenarios for estimation of point source impact and allocation (0.1°C gross impact) to ensure that the boundary conditions account for these nearby sources (***Table 6-14***). The future NPDES permit conditions for these facilities should be consistent with these assumptions; future permit conditions should also apply relevant temperature standards and mixing zone requirements at the point of discharge. This TMDL does not preclude future assessment approaches and decisions by the NPDES permitting program.

Table 6-14 Modeled point sources located outside TMDL study area not receiving WLAs

Facility Name	Permit Number	Location RM	Flow (MGD)	Temp (°C)
Clearwater Paper	ID0001163	139.3	44.7	33.0
City of Lewiston	ID0022055	140.1	5.7	23.6
City of Asotin	WA0020818	145.0	0.16	23.8

Table 6-15 identifies NPDES facilities in the study area that are not assigned a WLA. EPA believes these facilities either do not discharge heat during the critical season, or there is inadequate information to determine a WLA. This list includes some facilities authorized to discharge into the TMDL study area under an industrial general permit. Examples of industrial general permits include Confined Animal Feeding Operations (CAFOs), in-stream placer mining, pesticide discharge, fruit packer, seafood processing, net pen aquaculture, fish hatchery permits, 500J boiler boildown, 1700A washwater, 400J log ponds, and 1500A petroleum hydrocarbon cleanup permits. In the future, if it is determined that these facilities are a heat load source of concern, the permitting authorities will work with the permittees to access a portion of the reserve allocation (if available) to receive a WLA (Appendix J).

Table 6-15 NPDES permitted facilities not receiving WLAs

Facility Name	Permit Number	Additional Information
Pacific Aquaculture Incorporated[19]	WA0026328	Net pen aquaculture general permit; Assumed to not discharge heat
Pacific Aquaculture Incorporated[19]	WA0026336	Net pen aquaculture general permit; Assumed to not discharge heat
Faith Frontier Ministries[19]	WA0026379	Net pen aquaculture general permit; Assumed to not discharge heat
Pacific Aquaculture Incorporated[19]	WA0026719	Net pen aquaculture general permit; Assumed to not discharge heat
Piezometer Installation and Hyporheic Studies, U.S. Department of Energy[19]	WA0026859	Assumed to not discharge heat
Pacific Aquaculture Incorporated[19]	WAG130027	Net pen aquaculture general permit; Assumed to not discharge heat
PCL Construction Services[19]	WAR12AO9I	Assumed not to discharge heat
Chelan Fruit Cooperative Chelan Station	WAG435269	Fruit packer general permit; Have not been discharging
Gee Whiz II, LLX Orondo Plant	WAG435162	Fruit packer general permit; Have not been discharging
Chelan Falls Rearing Facility Hatchery	WAG137019	Upland fish hatchery general permit; Operates in Mid-Winter to mid-April during non-critical time period
Oregon Parks and Recreation Department	ORG387007	Filter backwash permit; No flow information
City of Dalles	ORG387005	Filter backwash permit; No flow information
Pacific Coast Seafoods Company LLC	ORG520001	Seafood processing general permit; No flow information
Astoria Pacific Seafoods LLC	ORG520007	Seafood processing general permit; No flow information
Fishhawk Fisheries, Incorporated	ORG520011	Seafood processing general permit; No flow information
Bornstein Seafoods, Incorporated	ORG520014	Seafood processing general permit; No flow information
Flint Group Packaging Inks North America LLC	ORG250003	Cooling water permit; No flow information

6.5.3 NPDES Permitted Stormwater

Stormwater discharges designated as point sources to the Columbia and lower Snake Rivers are regulated by the NPDES programs at ODEQ, Ecology, and EPA. Each of these three agencies has issued NPDES general stormwater permits for municipal, industrial, and construction stormwater discharges. Temperature TMDLs developed by ODEQ and Ecology have not considered stormwater discharges a significant source of heat load during the summer critical period, primarily because of minimal precipitation in most of the Pacific Northwest - including the TMDL area - during the summer and early fall. For example, in the Klamath River temperature TMDL, ODEQ estimated that stormwater discharge from one industrial facility results in a change in temperature of 0.0001°C or less (ODEQ 2019).

EPA estimated impacts from stormwater to confirm that stormwater discharges are negligible. A summary of results is provided below, and details of the analysis are provided in Appendix D.

Because the estimated temperature impacts from these sources are negligible, as explained below, EPA has not assigned a WLA to point source stormwater discharges in this TMDL and has determined that no heat limits are needed in stormwater permits. The permits and number of facilities covered by each general permit, summarized in ***Table 6-16*** and ***Table 6-17***, fall into the following categories:

- Municipal Separate Storm Sewer System (MS4) Permits. Municipalities that need to obtain an MS4 permit are classified as either "Phase I" or "Phase II." Phase I MS4s cover areas with populations greater than 100,000 and regulated Phase II (or "small") MS4s typically serve populations less than 100,000. There are multiple MS4 permits within the TMDL area that discharge directly to the Columbia and lower Snake Rivers. (see ***Table 6-16***).
- Industrial stormwater permits are used to authorize stormwater discharges from specific industrial activities. There are approximately 334 industrial stormwater permittees in the TMDL area that discharge directly to the Columbia and lower Snake Rivers.
- Construction stormwater permits are used to authorize stormwater discharges for construction projects that disturb one or more acres. Because construction projects are transitory, the number and location of construction stormwater permittees varies from year to year. The issuing agency and number of open permits (as of January 2020) are listed in ***Table 6-17***. Please refer to the following databases for current permit information:

  ODEQ: www.deq.state.or.us/wq/sisdata/sisdata.asp
  Ecology: apps.ecology.wa.gov/paris/PermitLookup.aspx

Table 6-16 MS4 NPDES permits on the Columbia and lower Snake River

City	Permittee	Type	Permit Number
Columbia River			
Pasco, WA	Pasco City	Municipal SW Phase II Eastern WA General Permit (GP)	WAR046503
Kennewick, WA	Kennewick City	Phase II Eastern WA GP	WAR046005
Richland, WA	City of Richland	Phase II Eastern WA GP	WAR046006
	Port of Benton	Phase II Eastern WA GP	WAR046203
	WSU Tri Cities	Phase II Eastern WA GP	WAR046207
	West Richland City	Phase II Eastern WA GP	WAR046007
Wenatchee, WA	Chelan County	Phase II Eastern WA GP	WAR046002
	Chelan County PUD No 1	Phase II Eastern WA GP	WAR046208
	Wenatchee City	Phase II Eastern WA GP	WAR046011
	Wenatchee Valley College	Phase II Eastern WA GP	WAR303571
East Wenatchee, WA	East Wenatchee City	Phase II Eastern WA GP	WAR046012
	Eastmont Metropolitan Park District	Phase II Eastern WA GP	WAR046200
Washougal, WA	Clark County	Phase I GP	WAR044001
	Washougal City	Phase II Western WA GP	WAR045023
Camas, WA	Clark County	Phase I GP	WAR044001
	Camas City	Phase II Western WA GP	WAR045004
Vancouver, WA	Clark County	Phase I GP	WAR044001
	Clark College	Phase II Western WA GP	WAR045212
	Port of Vancouver	Phase II Western WA GP	WAR045201
	Vancouver City	Phase II Western WA GP	WAR045022
	WSU Vancouver	Phase II Western WA GP	WAR045716
Longview, WA	Cowlitz County Consolidated Diking 1	Phase II Western WA GP	WAR045204
	Longview City	Phase II Western WA GP	WAR046208
	Longview School District	Phase II Western WA GP	WAR046012
	Lower Columbia College	Phase II Western WA GP	WAR046200
Portland, OR	Portland, City of	Individual Phase I MS4	ORS108015
Fairview, OR	Multnomah County	Individual Phase I MS4	ORS120542
	Gresham, City of; Fairview, City of	Individual Phase I MS4	ORS108013
Gresham, OR	Gresham, City of; Fairview, City of	Individual Phase I MS4	ORS108013
Troutdale, OR	Multnomah County	Individual Phase I MS4	ORS120542
	Troutdale, City of	Phase II GP	ORS110793
Wood Village, OR	Multnomah County	Individual Phase I MS4	ORS120542
	Wood Village, City of	Phase II GP	ORS098909
Snake River			
Clarkston, WA	Clarkston City	Phase II Eastern WA GP	WAR046502

Table 6-17 Construction and industrial stormwater NPDES permits on the Columbia and lower Snake Rivers

Agency Issuing Permit	Permit Name & Description	Approximate Number of Permittees within TMDL area
EPA	Construction General Permit (as modified June 2019) covers Indian Country within Washington (WAR10I000) and Oregon (ORR10I000); and areas in Washington subject to construction activity by a Federal Operator (WAR10F000)	16
Oregon	Construction General Permits covers activity on Oregon lands (1200-C, 1200-CA, and 1200-C(AGENT))	232
Washington	Construction General Permit covers activity on Washington lands, excluding activity by a Federal Operator (WAR300000)	17
Oregon	Industrial Stormwater Permits (1200-Z and 1200-A)	298
Washington	Industrial Stormwater Permit (WAR1200000)	36

Temperature data collection is not typically required by general stormwater permits, so it was not possible for EPA to characterize the potential temperature impacts from stormwater discharges by assessing existing data as EPA did for the individual NPDES permits discussed in Section 6.5.2. Consequently, EPA evaluated impacts from stormwater on heat using analyses similar to those conducted for other temperature TMDLS in the Pacific Northwest (e.g., ODEQ's Upper Klamath and Lost Subbasins Temperature TMDLs, 2019).

As discussed in Appendix D, EPA estimated the heat loading from stormwater for each of the reaches in the TMDL area. The most urbanized portions of the TMDL are in and around the Tri-Cities (between Priest Rapids and the lower Snake River confluence) and Portland (Bonneville to the coast). EPA estimated the potential impact of stormwater in these two reaches to be a maximum increase in the temperature of the Columbia River of 0.0066°C (July) and 0.0045°C (August) from Priest Rapids to the Snake River confluence (Tri-Cities); and 0.0072°C (July) and 0.0088°C (August) from Bonneville to the coast (Portland). In the remainder of the reaches, the estimated temperature increases are significantly less, ranging from 0°C to 0.0003°C. Because the estimated temperature impacts from these sources are negligible and intermittent, EPA has not assigned a WLA to stormwater sources in this TMDL. It is assumed that stormwater discharges will continue at current levels and that no heat limit is necessary for stormwater permits.

If additional data indicate that any of the various sources of stormwater are a significant source of thermal loading, then the States or EPA may access a portion of the reserve allocation within the appropriate reach to explicitly account for continued discharge from stormwater facilities.

6.5.4 Reserve Allocations

A reserve allocation is a portion of the loading capacity that is reserved for future use. EPA used RBM10, with data from 2011 to 2016, to determine the reserve allocation at each target site. The initial model scenario for the existing NPDES facilities with no reserve allocation estimated a maximum temperature impact of approximately 0.08°C at the critical location (RM 42). EPA is reserving the remainder of the 0.1°C point source allocation for future use for the following purposes:

- Future growth;
- New point source dischargers of heat;
- Adjustments to the calculated WLAs if, for example, the data that EPA considered during TMDL development are not representative of the existing discharge; and
- All other nonpoint sources on the mainstems that were not considered during TMDL development.

To calculate the reserve allocation, a heat load was inserted in the model at the midpoint of each TMDL reach/impoundment and two additional reaches in the lower Columbia River that bracket the location of maximum impact (RM42 for existing discharges for most of the summer/fall).

The model was then run iteratively, increasing the reserve heat load until the maximum cumulative impact equaled 0.1°C. The resulting reserve load for each reach is 4.8×10^9 kcal/day. This loading is equivalent to a 49 mgd discharge at 26°C and similar to the heat load discharged by the largest individual point sources in the study area. The three critical locations for impact from the full allocated loading (existing discharges plus the reserve loading in each reach) are the Priest Rapids and McNary target sites and the RM42 assessment location. All of the Snake River target sites approach the allowable 0.1°C impact in September with application of the uniform reserve loading.

There is an exception to the application of a uniform reserve loading over the assessment period. In October, the reserve heat loading must be lower (2.0×10^9 kcal/day) in the reaches of the Columbia River upstream of the Priest Rapids target site to meet the allowable 0.1°C impact.

The reserve allocations are provided in ***Table 6-18***, and model results showing the combined temperature impacts of the wasteload allocations and reserve allocations are provided in ***Table 6-19*** and ***Table 6-20***.

Table 6-18 Reserve Allocations

Reserve Reach	River Miles	Reserve Allocation (June – September)	Reserve Allocation (October)
		(kcal/day)	(kcal/day)
COLUMBIA RIVER			
Grand Coulee	738-591	$4.8x10^9$	$2.0x10^9$
Chief Joseph	591-544	$4.8x10^9$	$2.0x10^9$
Wells	544-512	$4.8x10^9$	$2.0x10^9$
Rocky Reach	512-472	$4.8x10^9$	$2.0x10^9$
Rock Island	472-453	$4.8x10^9$	$2.0x10^9$
Wanapum	453-413	$4.8x10^9$	$2.0x10^9$
Priest Rapids	413-396	$4.8x10^9$	$2.0x10^9$
McNary	396-291	$4.8x10^9$	$4.8x10^9$
John Day	291-215	$4.8x10^9$	$4.8x10^9$
Dalles	215-189	$4.8x10^9$	$4.8x10^9$
Bonneville	189-140	$4.8x10^9$	$4.8x10^9$
RM42	140-42	$4.8x10^9$	$4.8x10^9$
RM0	42-0	$4.8x10^9$	$4.8x10^9$
SNAKE RIVER			
Lower Granite	140-107	$4.8x10^9$	$4.8x10^9$
Little Goose	107-70	$4.8x10^9$	$4.8x10^9$
Lower Monumental	70-40	$4.8x10^9$	$4.8x10^9$
Ice Harbor	40-0	$4.8x10^9$	$4.8x10^9$

Note: River Miles are referenced to RBM10 model structure

Table 6-19 Estimated impacts of point source wasteload allocations and reserve allocations to the Columbia River (2011 – 2016)

		Estimated Increase in Temperature (°C)									
		Mean					90th Percentile				
Location	**RM**	**June**	**July**	**Aug**	**Sept**	**Oct**	**June**	**July**	**Aug**	**Sept**	**Oct**
Lake Roosevelt	639	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00
Grand Coulee	595	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01
Chief Joseph	546	NA	0.01	0.01	0.01	0.01	NA	0.02	0.01	0.02	0.02
Wells	515	NA	0.03	0.02	0.03	0.03	NA	0.04	0.03	0.05	0.05
Rocky Reach	474	0.04	0.03	0.02	0.03	0.03	0.06	0.04	0.03	0.05	0.04
Rock Island	453	0.05	0.04	0.04	0.05	0.05	0.08	0.06	0.05	0.08	0.07
Wanapum	416	0.06	0.05	0.04	0.06	0.05	0.08	0.06	0.06	0.08	0.08
Priest Rapids	397	0.07	0.05	0.05	0.07	0.07	0.10	0.07	0.06	0.10	0.10
McNary	291	0.08	0.06	0.05	0.07	NA	0.10	0.07	0.06	0.09	NA
John Day	216	0.07	0.05	0.04	0.04	NA	0.08	0.06	0.05	0.05	NA
Dalles	192	0.07	0.05	0.04	0.05	NA	0.08	0.06	0.05	0.06	NA
Bonneville	146	0.07	0.05	0.04	0.05	0.07	0.08	0.06	0.05	0.06	0.08
RM 42	42	0.08	0.07	0.06	0.08	NA	0.09	0.08	0.07	0.09	NA
RM 21	21	0.08	0.07	0.06	0.08	NA	0.09	0.08	0.06	0.09	NA

NA – Not applicable. River is not impaired at this target site/month

Table 6-20 Estimated impacts of point source wasteload allocations and reserve allocations to the Snake River (2011 – 2016)

Location	RM	Estimated Increase in Temperature (°C)							
		Mean				90th Percentile			
		June	July	Aug	Sept	June	July	Aug	Sept
Lower Granite	107	0.03	0.03	0.05	0.06	0.04	0.05	0.06	0.08
Little Goose	70	0.04	0.04	0.04	0.06	0.05	0.05	0.05	0.08
Lower Monumental	41	0.05	0.03	0.03	0.05	0.06	0.05	0.04	0.07
Ice Harbor	6	0.06	0.04	0.04	0.06	0.08	0.07	0.05	0.08

The reserve will be managed by the three permitting authorities (EPA, Washington, and Oregon) during implementation, which will include establishing a process for granting a portion of the reserve to individual point sources and maintaining a system to track its usage over time.

6.5.5 Tributaries

There are hundreds of tributaries to the mainstems of the Columbia and lower Snake rivers within the TMDL study area. The TMDL allocates a cumulative temperature increase of 0.1°C in the Columbia and lower Snake Rivers to 23 major tributaries (see listing in ***Table 6-23***) including the point and nonpoint sources within those tributaries.

A comprehensive set of models for all major tributaries would be required to identify specific source impacts within the tributary watersheds that are affecting tributary temperatures at their confluences with the Columbia and Snake rivers. Development of the tributary models was outside the scope and available resources for this TMDL. There are a limited number of temperature TMDLs completed for tributaries (discussed below), as well as general assessments of tributary conditions, available for consideration. For example, an assessment of restoration potential in Columbia River tributaries indicates that the estimated average summer impact of riparian shade loss is an average temperature increase of 0.4°C in these tributaries (See Appendix F).

Human activity within a tributary watershed can impact mainstem Columbia and Snake river temperatures by altering the flow and/or temperature of the tributary where it enters the mainstem. Similar to the mainstem modeling assessment, the tributary assessment assumes existing flows and focuses on human-caused impacts to tributary temperatures. Because water quality models are not available for many of the tributaries, EPA lacked the analytical tools necessary to assess current impacts and identify specific temperature targets for tributaries. Nevertheless, EPA was able to use the RBM10 model to evaluate the sensitivity of mainstem Columbia and Snake river temperatures to tributary temperature changes at their mouths. The model was run multiple times with varied tributary temperatures, until the change in the mainstem temperature matched the load allocation of 0.1°C. After multiple trials of model runs increasing change in tributary temperatures (e.g., 0.1°C, 0.2°C, 0.3°C), it was found that a uniform change in tributary temperatures of 0.5°C resulted in a change of 0.1°C at the point of maximum impact in the lower Columbia River.

This result indicates that temperature impacts at the tributary mouths need to be at or below 0.5°C to achieve the load allocation of 0.1°C in the mainstem Columbia and Snake rivers. The baseline for evaluating impacts is the natural condition, so tributary temperatures need to be within 0.5°C of the natural condition to meet the 0.1°C load allocation in the mainstems. The TMDL sets this condition as the load allocation for the temperature of each tributary at its mouth. The tributary load allocations allow for anthropogenic heat contributions in the tributaries but do so without identifying or assessing specific anthropogenic heat sources in the tributaries. EPA recognizes that there are multiple sources of impairment in each tributary, such as riparian shade loss, point sources, dams, flow diversions, and geomorphological changes. It will be necessary to use water quality models to evaluate implementation of the tributary load allocation.

Table 6-21 and ***Table 6-22*** show the model-estimated sensitivity of mainstem temperatures to a 0.5°C change at the mouths of all tributaries. Across all target sites, the estimated change in mainstem temperatures is less than the allocated temperature of 0.1°C. The maximum cumulative impact on the Columbia River is 0.09°C and occurs in June at River Mile 453. The maximum impact on the Snake River is very small (0.002°C maximum impact), because there are only two small tributaries to the lower Snake River in the study area (Tucannon and Palouse rivers).

Table 6-21 Estimated impacts of 0.5°C tributary temperature impact on Columbia River temperature (2011 – 2016)

		Estimated Mean Impact on Columbia River (°C)				
Location	**RM**	**June**	**July**	**Aug**	**Sept**	**Oct**
Lake Roosevelt	639	0.05	0.02	0.02	0.01	0.01
Grand Coulee	595	0.03	0.03	0.01	0.02	0.01
Chief Joseph	546	NA	0.03	0.00	0.02	0.01
Wells	515	NA	0.05	0.02	0.02	0.03
Rocky Reach	474	0.07	0.06	0.03	0.03	0.04
Rock Island	453	0.09	0.07	0.03	0.03	0.05
Wanapum	416	0.08	0.06	0.03	0.03	0.04
Priest R.	397	0.07	0.06	0.03	0.02	0.04
McNary	291	0.04	0.04	0.02	0.02	NA
John Day	216	0.03	0.04	0.02	0.01	NA
Dalles	192	0.04	0.05	0.03	0.04	NA
Bonneville	146	0.04	0.05	0.03	0.04	0.04
RM 42	42	0.07	0.08	0.07	0.08	NA

NA - Not Applicable. River is not impaired at this location/month

Table 6-22 Estimated impacts of 0.5°C tributary temperature impact on Snake River temperature (2011 – 2016)

Location	**RM**	**Estimated Mean Impact on Snake River (°C)**				
		June	**July**	**Aug**	**Sept**	**Oct**
Lower Granite	107	0.000	0.000	0.000	0.000	NA
Little Goose	70	0.000	0.000	0.000	0.000	NA
Lower Monumental	41	0.002	0.002	0.001	0.002	NA
Ice Harbor	6	0.002	0.001	0.001	0.001	NA

NA - Not Applicable. River is not impaired at this location in October

For each of the 23 tributaries, EPA identifies whether the tributary is impaired for temperature and whether a TMDL has been completed in ***Table 6-23***. EPA identifies tributaries as impaired if the tributary is included on Washington or Oregon's current CWA section 303(d) list of impaired waters; or if TMDLs or other pollution control plans are in place, but temperature criteria have not yet been attained. The criteria identified in ***Table 6-23*** are the criteria that apply to the lower portion of the tributary, nearest the mainstems of the Columbia or lower Snake Rivers, during the summer and early fall months. The summer numeric criteria for 20 of the 23 tributaries are cooler than the numeric criteria for the lower Columbia and lower Snake Rivers (all tributaries except the John Day, Yakima, and Willamette Rivers). That is, the tributaries would cool – rather than heat – the mainstem rivers if the tributary met the applicable water quality criterion. As discussed in Appendix D, EPA ran a model scenario to estimate this potential improvement by capping tributary temperatures at the summer water quality criterion values. The results indicate that the cumulative impact of those tributary improvements would result in a maximum improvement of 0.2°C in the Columbia River at RM 42. As Washington and Oregon continue to develop and implement TMDLs for tributaries, EPA expects modest improvements in mainstem Columbia River temperatures.

Table 6-23 23 major tributaries: temperature impairments and WQC

Tributary Name	Inflow Location (RM)	Temperature Impaired?	TMDL?	Water Quality Criteria (°C)
Columbia River				
Kettle, WA	706	Yes	No	16.0
Colville, WA	699	Yes	No	17.5
Spokane, WA	639	Yes	No	17.5
Okanogan, WA	533	Yes	No	17.5
Methow, WA	524	Yes	No	17.5
Chelan, WA	503	No	N/A	17.5
Entiat, WA[21]	483	Yes	No	17.5
Wenatchee, WA	468	Yes	Yes	17.5
Crab Creek, WA	410	Yes	No	17.5
Yakima, WA	335	Yes	No	21.0
Walla Walla, WA	314	Yes	Yes	17.5
Umatilla, OR	289	Yes	Yes	18.0
John Day, OR	218	Yes	Yes	20.0
Deschutes, OR	204	Yes	No	18.0
Klickitat, WA	180	Yes	No	16.0
Hood, OR	169	Yes	Yes	16.0
Sandy, OR	120	Yes	Yes	18.0
Willamette, OR	102	Yes	Yes	20.0
Lewis, WA	87	Yes	No	17.5
Kalama, WA	73	Yes	No	17.5
Cowlitz, WA	69	Yes	No	17.5
Snake River				
Tucannon, WA	62	Yes	Yes	17.5
Palouse, WA	60	Yes	Yes	17.5

The allocation established for the 23 major tributaries to the Columbia and lower Snake Rivers implements the applicable numeric criteria and incremental temperature allowance provisions for the mainstem rivers. At the same time, a separate cold water refuge provision in Oregon WQS applies to the coldest tributaries to the lower Columbia River. A subset of the major

[21] Entiat River is a TMDL alternative process (Category 4B Demonstration) Temperature Project site.

tributaries receiving allocations in ***Table 6-23*** also provide CWR. In addition, a number of smaller tributaries have negligible impacts on mainstem temperatures, although are nonetheless important CWRs for fish in the Columbia River, and thus contribute to attainment of the designated uses.

6.6 COLD WATER REFUGES

In order to satisfy Oregon's narrative CWR standard and protect all designated uses applicable to the Columbia River, the TMDL identifies temperature, flow, and CWR volume targets for 13 tributary CWRs identified in **Error! Reference source not found.**. As discussed in Section 2.2, the Oregon WQS include a narrative CWR standard for the lower Columbia River that provides supplementary protection to migrating salmon and steelhead in the lower Columbia River. As presented in Section 2.2, EPA has identified a total of 23 CWR tributaries in the lower Columbia River, 12 of which EPA identified as primary CWR due to their size and known or presumed use by migrating salmon and steelhead. In the *Columbia River Cold Water Refuges Plan* (EPA 2021), EPA concluded that attainment of Oregon's CWR standard will depend on maintaining the volume of the 12 primary CWR and increased CWR in the Umatilla River.

Temperature targets (August mean 5-year average) for the 12 primary CWR shown in Table 6-23 are intended to maintain the temperatures of these important CWR. In addition, to provide increased CWR in the Umatilla River, this TMDL incorporates by reference the temperature targets and associated 18°C (7DADM) temperature criterion in the Oregon Umatilla Basin Temperature TMDL for the Lower Umatilla River. As described in EPA's CWR plan, attainment of Oregon's narrative CWR standard is based on the amount of available CWR or CWR volume, which is a function of both temperature and flow. Therefore, this TMDL also includes flow and CWR volume targets for the 13 CWR, which are reflected in Table 6-23. Table 6-23 also identifies three CWR tributary basins (Sandy, Wind, and Hood Rivers) where temperature TMDLs have been established and two CWR tributary basins (Cowlitz and Deschutes) that are listed on the state's 303(d) list as impaired for temperature and require the establishment of a TMDL in the future. These tributary basin TMDLs are intended to attain the temperature water quality standard numeric criteria, which are reflected as the maximum 7-day average of the daily maximums (7DADM). Therefore, these three existing and two future tributary basin temperature TMDLs, when implemented, will cool these tributaries, which will enhance their CWR function.

Table 6-24 Temperature, flow, and CWR volume targets for 13 CWR in the lower Columbia River

Tributary Name	RM	Water Quality Standard	Tributary Temperature Maximum Target	Listed as Impaired[22]	Flow Target	CWR Volume Target
		7DADM (°C)	August Mean 5-Year Average (°C)		August Mean cfs	August Mean m^3
Cowlitz River	65.2	17.5	16.0	Yes	3634	1,554,230
Lewis River	84.4	17.5	16.6	Yes	1291	613,455
Sandy River	117.1	18	18.8	Yes*	469	31,915
Tanner Creek	140.9	18	11.7	No	38	1713
Eagle Creek	142.7	18	15.1	No	72	2988
Herman Creek	147.5	18	12.0	No	45	169,698
Wind River	151.1	16	14.5	Yes*	293	105,220
Little White Salmon River	158.7	16	13.3	Yes	248	1,108,661
White Salmon R	164.9	16	15.7	No	715	153,529
Hood River	165.7	16	15.5	Yes*	374	28,000
Klickitat River	176.8	16	16.4	Yes	851	222,029
Deschutes River	200.8	18	19.2	Yes	4772	880,124
Umatilla River	284.7	18	18.0[23]	Yes*	250[24]	31,512[25]

6.7 MARGIN OF SAFETY

The margin of safety (MOS) is the portion of the TMDL equation that accounts for a lack of knowledge concerning the relationship between LAs and WLAs and water quality. [CWA § 303(d)(1)(C) and 40 CFR 130.7(c)(1)]. For example, knowledge may be incomplete regarding the exact nature and magnitude of temperature loads from various sources. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. In general, the MOS can be achieved through two approaches: (1)

[22] Asterisks in this column indicate that a temperature TMDL has been completed.

[23] 18.0°C (7-DADM) is the applicable numeric criteria and the target for the Oregon Umatilla River Basin Temperature TMDL and Water Quality Management Plan.

[24] 250 cfs reflects the August 16 – September 30 target flow associated with the Phase 2 Umatilla Basin Water Exchange and the maximum modelled flow in the Oregon Umatilla River Basin Temperature TMDL and Water Quality Management Plan.

[25] Estimated CWR volume when the river is at 18°C with 250 cfs flow.

implicitly using conservative model assumptions to develop allocations, or (2) explicitly specifying a portion of the TMDL load capacity as the MOS (EPA 2002).

The Columbia and lower Snake Rivers TMDL applies an implicit MOS in derivation of the temperature allocations through the use of conservative assumptions. The principal conservative assumptions are as follows:

- EPA is establishing the current conditions benchmark for each 30-day analysis period (June, July, August, September, and October) that is used to evaluate impairments and exceedance magnitude using DM statistics in all locations, even though criteria are expressed as both DM and 7-DADM depending on the location. EPA is also using the monthly maximum recorded for the 2011 – 2016 period to establish the current conditions benchmark.
- EPA used the RBM10 temperature model to conservatively estimate the dam impacts on river temperature by comparing *daily average* river temperatures with and without the presence of dams (the model does not simulate *daily maximum* river temperatures). The diel variation in any river is impacted by river width and flow, seasons, and other factors, but is typically greater in a free-flowing river than when dams are present, particularly during the summer months. The impact of the dams on the daily average temperature is greater than the impact on the daily maximum temperature and is therefore a more conservative indicator of dam impact (Appendix H).
- The point source evaluation assumes discharges at maximum or design flow and maximum effluent temperature and evaluates the 90^{th} percentile impact on river temperatures. By definition, actual discharges from NPDES facilities rarely reach design flows.
- The TMDL assessment focuses on six recent years of data and modeling (2011 – 2016), and this period, compared to the historic record, is characterized by relatively high air temperature and river temperature.

In addition to the above, the extensive development and refinement of the water quality model (RBM10) contributes to its utility in establishing this TMDL. The following are some of the model attributes, explained further in Appendix D, that demonstrate the robust science behind the modeling:

- The technical methodology of the RBM10 model used in EPA's work has been through two peer-review processes. EPA first shared a draft of its 2001 report for review by national experts as well as regional stakeholders' consultants. Later, the developer of the model documented the model methodology in a peer-reviewed paper published by Water Resources Research (Yearsley 2009).
- Since 2009, other organizations have applied the model to rivers in the U.S. and abroad, including published studies by researchers at U.S. Geological Survey, University of Washington, University of California Los Angeles, and Wageningen University (Netherlands). The most recent application was published in 2016.
- EPA Region 10 documented its 2019 update of the RBM10 model in a detailed report. A draft of this report was shared with the three action agencies that operate the Columbia/Snake River mainstem dams (USACE, Bureau of Reclamation, and Bonneville Power Administration). The federal agencies each sent EPA technical comments on the model and report. EPA responded to the comments and conducted a webinar on the model issues with the agencies. In a second round of review on a revised draft report,

the document was shared with the same federal agencies and additional stakeholder organizations, and EPA received comments from the States of Oregon and Washington, Chelan and Grant County PUDs, and the pulp and paper industry.

Taken together, these assumptions and refinements provide support that the implicit MOS is adequate and appropriately conservative.

6.8 WATER QUALITY CRITERIA ATTAINMENT AND EXCESS TEMPERATURE

TMDLs are generally designed to identify a path for attainment of WQS in an impaired waterbody. The CWA instructs that a TMDL "be established at a level necessary to implement applicable water quality standards." This TMDL assigns wasteload allocations and load allocations consistent with meeting the identified loading capacity under WA and OR WQS (0.3°C above the WQC) when waters are not meeting the otherwise applicable numeric criteria.

As explained earlier in the TMDL, EPA used the RBM10 model to estimate the Columbia and lower Snake River temperatures that would occur if point source and dam impacts within the TMDL study area were removed (tributaries were set to current conditions in the RBM10 model runs because EPA had data on current conditions, and natural conditions are currently unknown, as discussed in Section 6.5.5). EPA's estimate of the Columbia and lower Snake River temperature conditions without the 15 dams and point sources are presented in ***Figure 6-6*** through ***Figure 6-8*** for two locations: Bonneville Dam and Ice Harbor Dam. As discussed further in this section and in Section 2.6, these figures do not represent the "natural" river temperatures because the impacts of climate change to date are imbedded in the model outputs for current temperatures within the TMDL area. In addition, the human impacts upstream of the TMDL boundaries in Idaho and Canada are unknown, because there are no available temperature models for these areas.

Figure 6-6 through ***Figure 6-8*** illustrate daily average temperature ranges that are predicted in the free-flowing scenario for multi-year simulation periods. In ***Figure 6-6***, for example, the daily average temperatures at Bonneville Dam during August range from about 16.5°C to 22°C during the 47-year simulation. The daily average temperatures represented in these figures will always be lower than the daily maximums that occur during the same time period; therefore, the daily maximum range is equivalent to or warmer than 16.5°C to 22°C. ***Figure 6-6*** also illustrates that when point sources and dams are removed from the model simulation, Washington's 20°C daily maximum WQC at the Bonneville Dam tailrace will sometimes be met (shown graphically by points below the 20°C line) and sometimes not be met (as represented by point above that line). As discussed in Section 4.3 and Appendix G, the river temperatures have increased during the 47 years included in the model simulation, and the probability of exceedance has likewise increased over that time period. ***Figure 6-7*** illustrates the decadal warming for the free-flowing Columbia River at Bonneville.

Cold water release operations at Dworshak Dam began in the 1990s. In order to illustrate the effect of the cold water releases on temperatures in the mainstems, EPA plotted the estimated lower Snake River free-flowing temperatures without point sources and dams, but with the Dworshak Dam cold water releases for a reduced time period (1995 – 2016) at Ice Harbor Dam. Similar to the Columbia River plot, the model projects that the lower Snake River temperature at this location nonetheless would exceed the 20°C standard at times (***Figure 6-8***).

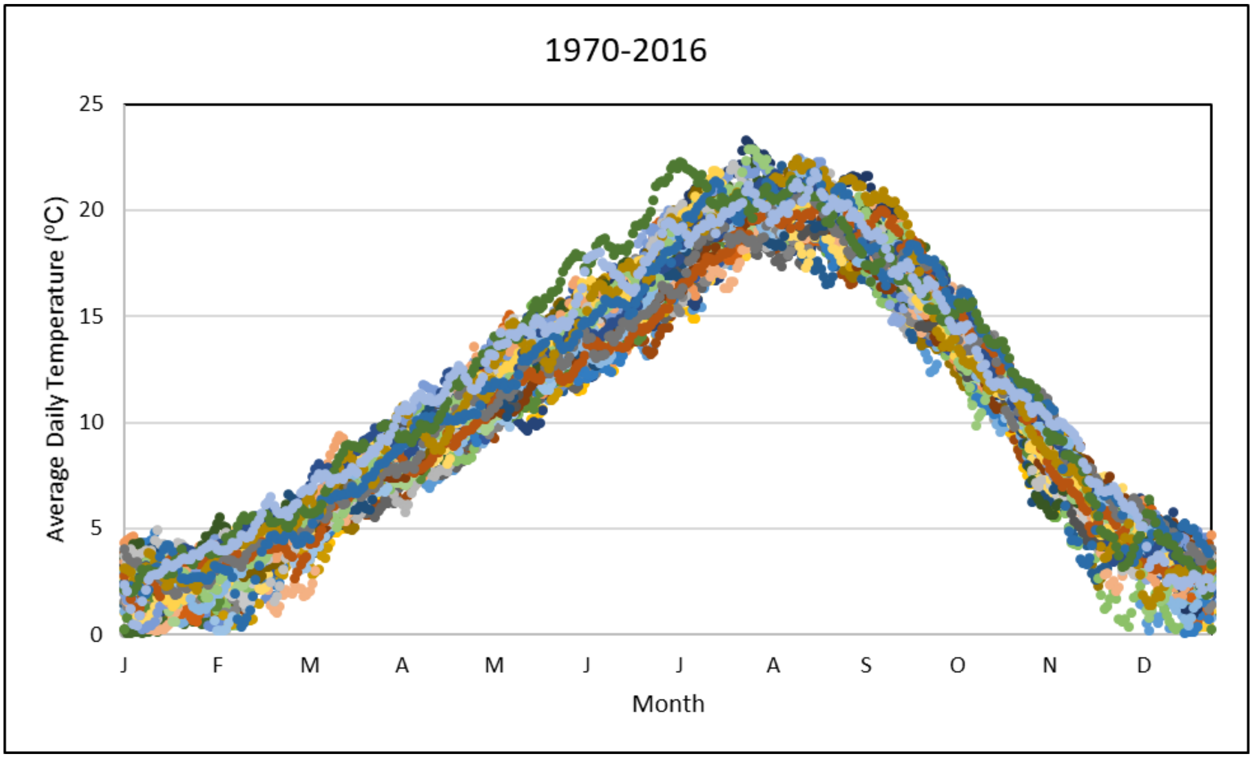

Figure 6-6 RBM10 simulation of free-flowing river temperatures at Bonneville Dam on the Columbia River (all years: 1970 – 2016)

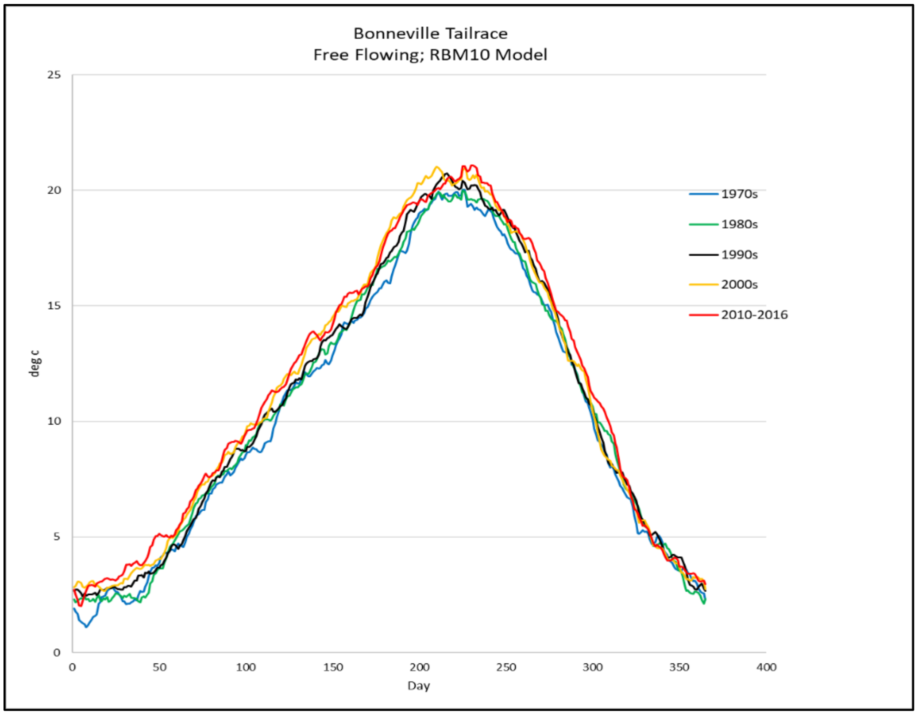

Figure 6-7 Decadal average temperatures from 47-year RBM10 simulation of free-flowing river at Bonneville Dam

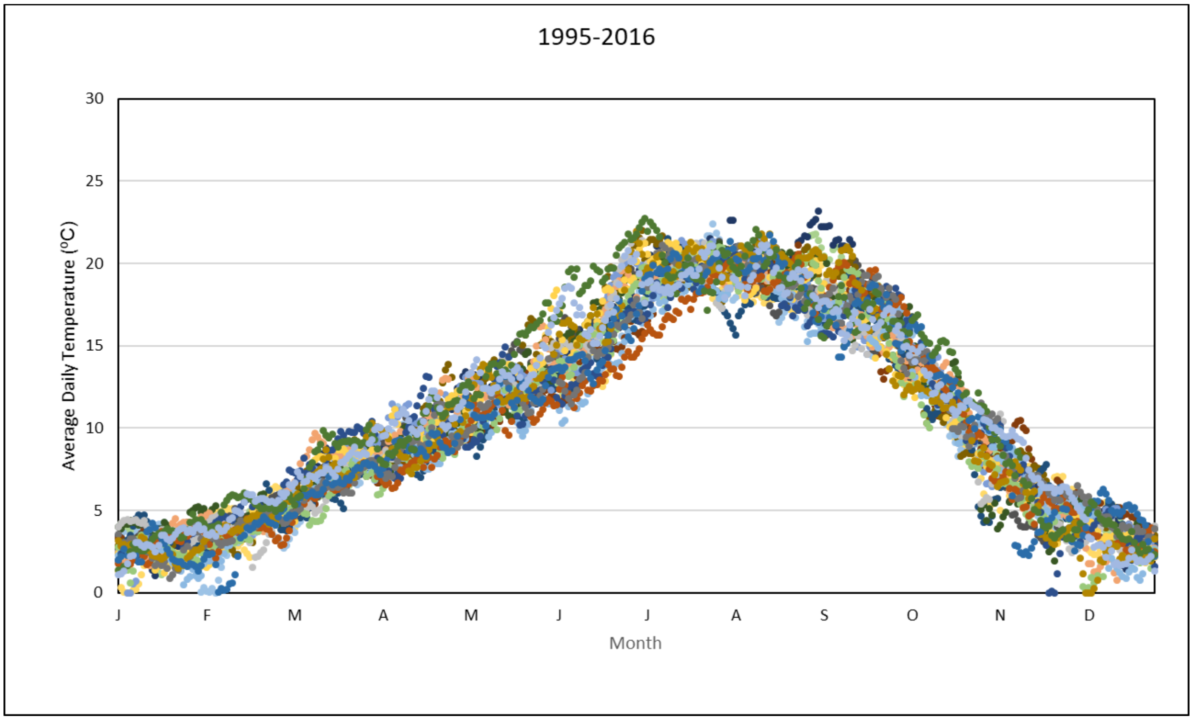

Figure 6-8 RBM10 simulation of free-flowing river temperatures at Ice Harbor Dam on the Snake River (1995 – 2016)

For the purposes of this TMDL, EPA uses the term "excess temperatures" to refer to temperatures above the loading capacity (criteria + 0.3°C) that may be reasonably predicted to occur even with the achievement of the allocations in the TMDL. Viewed as a whole, these figures illustrate the estimated excess temperatures reasonably predicted to occur at two locations in the Columbia and lower Snake Rivers between June and October. The loading capacity at these locations is 20.3°C, and these figures illustrate that EPA expects temperatures to exceed the loading capacity.

The estimated range of temperatures in the Columbia and lower Snake Rivers for the free-flowing scenario are presented in ***Table 6-25***. EPA calculated the range of daily average temperatures – presented as the minimum daily average and the maximum daily average – from the RBM10 model free-flowing scenario. Information presented in this table indicates that the following impairments are likely to continue to exist, even when LAs and WLAs are implemented:

- In June, July, August, and September, when the applicable numeric standard in the lower Columbia (below Priest Rapids) and Snake Rivers is 20°C, the estimated highest daily average temperatures are above 20°C at each location, which means that the daily maximum (DM) or 7-DADM temperatures are also above 20°C. The estimated lowest daily averages are approximately 7°C to 10°C cooler. This range of daily average temperatures indicates that, on any given day in that month, the numeric criteria may be attained, although attainment cannot reasonably be expected to occur every day of that month.
- In October, when the applicable numeric standard below Bonneville is 13°C, the estimated highest daily average temperature is greater than 13°C, which means that the 7-DADM are also above 13°C. The estimated lowest daily averages are approximately 10°C cooler. This 10°C range of daily average temperatures indicates that, on any given day of the month, the numeric criteria may be attained although attainment cannot reasonably be expected to occur every day of that month.

Table 6-25 Minimum and maximum daily average temperatures in RBM10 simulations of free-flowing Columbia and Snake Rivers (1970-2016)

Location	RM	June		July		August		September		October	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Columbia River											
Canadian Border	735	8.0	17.1	10.8	20.7	13.4	20.9	11.9	20.2	8.6	17.1
Lake Roosevelt	639	9.1	18.1	11.2	21.3	13.8	21.6	12.5	20.7	8.4	16.5
Grand Coulee	595	9.3	17.7	11.6	21.7	14.2	21.8	12.2	21.3	8.0	16.8
Chief Joseph	546	9.3	18.1	12.0	21.9	14.6	21.9	12.5	21.1	7.6	16.6
Wells	515	9.6	18.7	12.4	22.0	15.1	22.1	12.6	21.5	7.4	16.7
Rocky Reach	474	10.0	18.7	12.6	22.2	15.5	22.1	12.9	21.4	7.3	16.6
Rock Island	453	10.2	18.8	12.8	22.2	15.5	22.1	12.8	21.4	7.1	16.5
Wanapum	416	10.2	18.9	12.9	22.4	15.8	22.1	12.8	21.7	7.0	16.7
Priest Rapids	397	10.3	19.4	13.1	22.6	15.7	22.1	12.7	21.6	7.5	16.6
Hanford Reach	326	10.7	20.3	13.6	23.2	16.2	22.6	12.5	21.9	7.1	16.8
Snake Confluence	322	11.2	20.6	14.1	22.6	16.3	22.2	12.6	22.1	7.3	16.9
McNary	291	11.2	21.0	14.3	23.0	16.3	22.4	12.3	22.2	7.0	16.8
John Day	216	11.3	21.2	14.2	23.2	16.4	22.6	12.2	22.0	6.4	17.0
Dalles	192	11.4	21.4	14.7	23.2	16.2	22.5	12.3	21.8	6.4	17.4
Bonneville	146	11.5	21.3	14.5	23.2	16.5	22.7	12.4	21.6	7.1	17.4
Snake River											
Anatone	168	9.8	23.1	14.5	24.5	17.8	24.8	15.0	23.5	9.0	19.6
Clearwater Confluence	138	9.8	21.5	13.8	23.1	15.0	24.6	12.6	22.9	7.1	18.9
Lower Granite	107	10.0	21.6	14.0	22.9	15.3	24.6	12.3	22.9	6.5	18.8
Little Goose	70	10.2	21.7	14.3	23.1	15.0	24.7	11.9	23.1	5.6	18.7
Lower Monumental	41	10.2	21.7	14.3	23.1	14.9	24.9	11.6	23.1	5.2	18.6
Ice Harbor	6	10.3	22.4	14.5	22.9	15.2	24.9	11.3	23.1	4.6	18.4

There are numerous sources of warming that contribute to excess temperature in this TMDL. As discussed throughout this TMDL, the TMDL identifies and assigns load reductions to point and nonpoint sources within the TMDL area that restrict cumulative impacts at all locations to 0.3°C. Climate change impacts have not been assigned allocations in this TMDL. As discussed in Section 4.3, climate change effects are estimated to have caused instream temperature increases of 1.5°C ± 0.5 in the TMDL area since the late 1960’s. Figure 6-9 and Figure 6-10 show predicted daily average river temperatures for each year in the 2011-2016 period at Bonneville Dam and Ice Harbor Dam, respectively, in the free-flowing model scenario. These figures indicate that achieving the allocations would achieve the target temperatures on average but not during warmer-than-average weather periods.

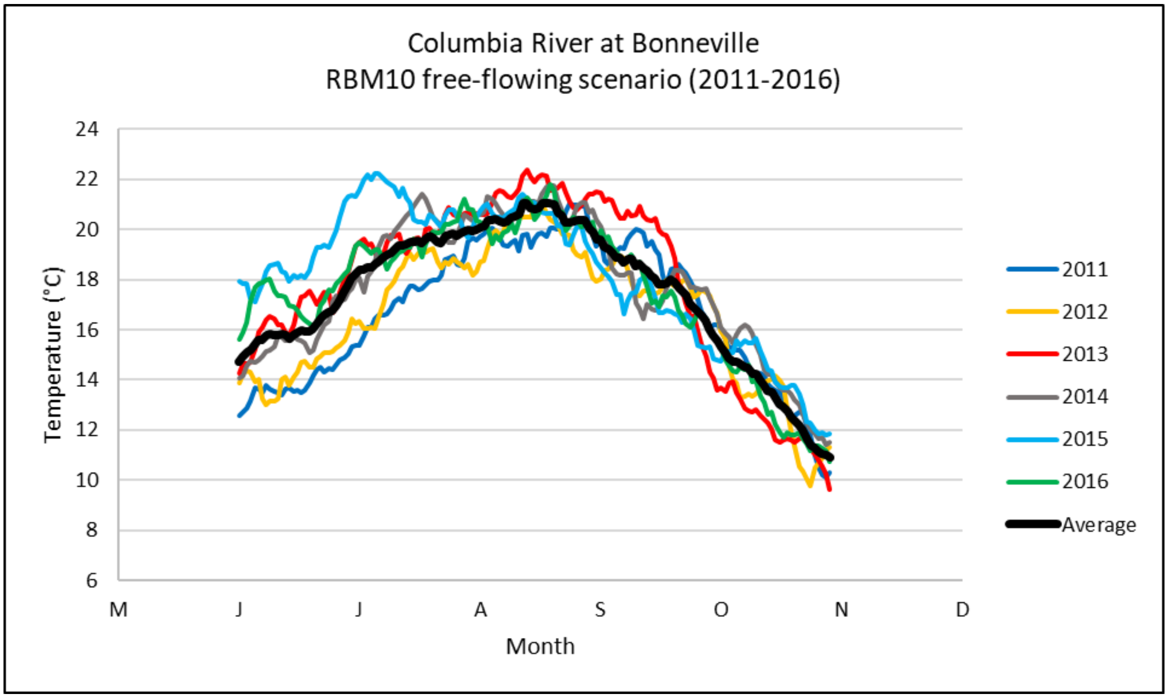

Figure 6-9 RBM10 simulation of free-flowing river temperatures at Bonneville Dam on the Columbia River (2011 – 2016)

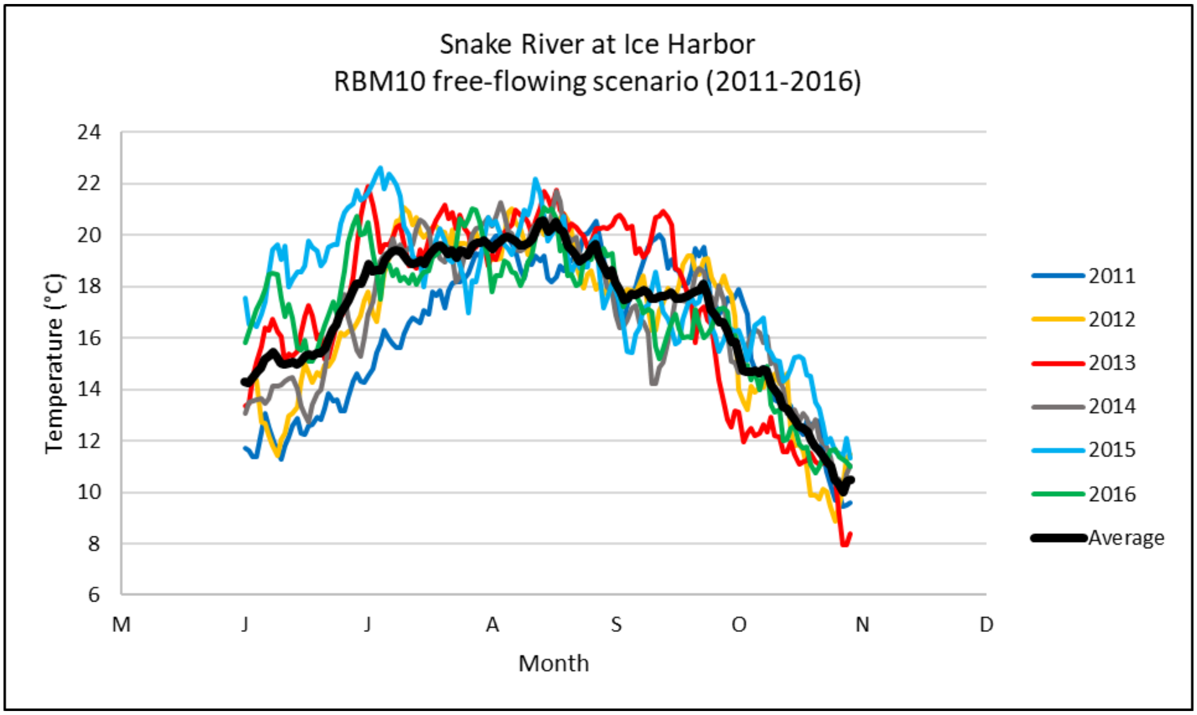

Figure 6-10 RBM10 simulation of free-flowing river temperatures at Ice Harbor Dam on the Snake River (2011 – 2016)

7.0 REASONABLE ASSURANCE

CWA section 303(d) requires that a TMDL be "established at a level necessary to implement the applicable water quality standard." According to 40 C.F.R. §130.2(i), "[i]f best management practices or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent." Providing reasonable assurance that nonpoint source control measures will achieve expected load reductions increases the probability that the pollution reduction levels specified in the TMDL will be achieved, and therefore, that applicable standards will be attained.

In a state issued TMDL, the state documents reasonable assurance in the TMDL (or an implementation plan) through a description of how the load allocations will be met. The TMDL or the implementation plan generally describes both the potential actions for achieving the load allocations and the state's authorities and mechanisms for implementing nonpoint source pollution reductions. A state's implementation plan for nonpoint sources provides reasonable assurance that more stringent WLAs are not necessary in order to implement the applicable water quality standard.

By contrast, this federal TMDL is being issued by EPA, which lacks authority to implement nonpoint source controls or otherwise assure reductions in nonpoint source pollution. Nonpoint sources typically implement their load allocations through a wide variety of programs (which may be regulatory, non-regulatory, or incentive-based, depending on the state or tribal program) and voluntary actions. Implementation of this TMDL will depend on development of implementation plans by the States of Washington and Oregon, dam requirements put in place through 401 certification conditions and river temperature reduction efforts by other federal agencies. The states will need to work within their authorities to implement activities to reduce nonpoint source heat loading. EPA recommends that the states, in developing their implementation plans, consider continued development, revision, and implementation of tributary TMDLs, including protection of CWRs; funding mechanisms to address traditional nonpoint sources of heat; voluntary conservation programs; a collaborative monitoring and tracking program; and other activities designed to reduce water temperature.

The states also promote land and forestry stewardship incentive programs that provide funding for restoration and conservation projects. The states' nonpoint source management programs award project funds to third parties to support program implementation. States and federal agencies use watershed-based funding to work with both private and public landowners to protect soil and water resources, including addressing nonpoint source control measures. Implementation of these projects has a positive impact on reducing heat loading in the Columbia River basin.

The Northwest Power Act requires the Northwest Power and Conservation Council to implement the Columbia River Basin Fish and Wildlife Program to mitigate the impact of the federal hydropower system. As mitigation for the hydropower system, the Fish and Wildlife Program funds tributary improvements. The Council provides an opportunity for state leadership to share information and coordinate with federal agencies on proposed water temperature mitigation actions. The U.S. Army Corps of Engineers' Columbia River Fish Mitigation (CRFM) Program funds passage improvements which could include temperature improvement actions. Members of the Council are appointed by the Governors of Idaho, Montana, Washington, and Oregon. State leadership through the Northwest Power and Conservation Council during implementation planning could provide opportunities to share information and coordinate with federal agencies on proposed actions to mitigate the temperature increases attributable to the federal hydropower system.

In 2021, the states of Idaho, Montana, Oregon and Washington, convened the Columbia River Basin Collaborative, which will include a consensus table of tribal governments, non-governmental organizations, river interests and other groups focused on agreement on actions needed to restore Columbia River Basin fish stocks. Water temperature reduction actions could be a key part of the outcome of this Basin-wide collaboration to achieve fish recovery.

States, federal agencies, Columbia River PUDs, and local organizations have maintained and are likely to increase temperature data collection throughout the Columbia and lower Snake river basins. Federal agencies have maintained and are likely to continue monitoring at the tailraces and forebays of the federal dams. Hourly monitored water temperature data collected by the USACE are uploaded, in real time, to the DART website.

Federal agencies also have responsibility for fish passage mitigation actions, which may address temperature impacts. The U.S. Army Corps of Engineers' Columbia River Fish Mitigation (CRFM) Program includes passage improvements. The NOAA Fisheries 2015 Sockeye Salmon Passage Report and 2020 Columbia River System Biological Opinion identify and recommend water temperature mitigation actions that can be taken in the Columbia River.

The Columbia River Federal Caucus provides an ongoing forum for federal agencies in the Columbia River basin to work together on the coordination, planning, science, and implementation of actions to address water temperature improvements. The 2008 Columbia River Federal Caucus Memorandum of Understanding identifies implementation of Clean Water Act and water temperature actions as a priority focus area for the Caucus. The Columbia River Federal Caucus coordinates with the Columbia River Federal Executives as described in the MOU, including potential coordination on water temperature improvements.

Existing CWA section 401 certifications issued by Ecology for the PUDs have included conditions that require completion of an extensive temperature monitoring plan, including an adaptive management approach to attain the numeric water quality criteria. To date, Ecology has included conditions in CWA section 401 certifications for the Priest Rapids Hydroelectric Project, Rocky Reach Dam, and Wells Dam that require the PUDs to conduct temperature monitoring at the forebays and tailraces of the associated dams for the duration of the license. The Federal Energy Regulatory Commission licenses for these three dams include the States' CWA section 401 certification conditions, making them federally enforceable requirements.

The eight federal dams in the lower Columbia and Lower Snake Rivers must have NPDES permits for their point source discharges. EPA is developing these permits, and they require 401 certifications from the State of Washington. The state has placed conditions in the certifications that require implementation of the load allocations in this TMDL. When EPA issues these permits, the 401 certification conditions, along with the other actions described above, provide reasonable assurance that the temperature impacts of the federal hydropower system will be addressed. Chief Joseph and Grand Coulee Dams also require EPA-issued NPDES permits for their point source discharges. EPA will be requesting 401 certifications from the State of Washington and the Confederated Tribes of the Colville Reservation on these permits as they are developed.

Conditions beyond the borders of Washington and Oregon affect temperatures in the Columbia and lower Snake Rivers. Idaho has a provision of its water quality standards intended to protect the standards of downstream waters, including waters of another state or tribe. Habitat restoration and TMDL development efforts in Idaho will help meet Washington's standards at the point the Snake River crosses into Washington. In addition, the U.S. began negotiations in 2018 with Canada to modernize the Columbia River Treaty, which may affect water flows in the U.S.

Climate change trends are not allocated a portion of the 0.3°C allowable temperature increment. The impact of climate change on temperature loadings to the Columbia and Snake Rivers will require continued efforts at local, state, national, and international levels to address the causes of, adapt to and mitigate the effects of climate change.

Through international collaboration, the Federal Government has made commitments relevant to responding to the adverse effects of climate change. In January 2021, the U.S. rejoined the Paris Agreement, the international treaty within the United Nations Framework Convention that aims to limit global warming, increase climate resiliency, and develop financial channels to assist developing countries implement emission reduction measures. As detailed in Executive Order 14008 (EOP 2021), the U.S. Government will make strategic use of multilateral and bilateral channels and institutions to assist developing countries in implementing ambitious emissions reduction measures, protect critical ecosystems, build resilience against the impacts of climate change, and promote the flow of capital toward climate-aligned investments and away from high-carbon investments.

The Federal Government also has committed to address climate change through a government-wide approach to mitigate and adapt to the adverse effects of climate change under EO 14008. A National Climate Task Force composed of cabinet-level secretaries and chaired by the National Climate Advisor was established to facilitate the organization and deployment of key federal actions to reduce climate pollution and to engage on climate matters with tribal, state, and local governments and leaders of various sectors of the economy (EOP 2021).

The regulatory and non-regulatory measures described above and described in more detail in the states' implementation plans and federal dam operation plans provide adequate reasonable assurance for the temperature wasteload and load allocations in this TMDL.

8.0 TRIBAL CONSULTATION, PUBLIC OUTREACH AND NEXT STEPS

Government-wide and EPA-specific policies call for regular and meaningful consultation with Indian tribal governments when developing policies and regulatory decisions on matters affecting their communities and resources. EPA will continue to coordinate on the TMDL with tribal governments. EPA will work with the Washington Department of Ecology and Oregon Department of Environmental Quality during development of their implementation plans, as needed, and work in coordination with federal agencies through the Columbia River Federal Caucus, the Columbia River Federal Executives, and other forums that may assist the states.

Implementation of this TMDL is the responsibility of state governments because states with applicable water quality standards retain sole authority for development and oversight of implementation plans to meet the wasteload allocations and load allocations included in the TMDL. EPA recommends that a state developed TMDL implementation plan could address topics such as NPDES permit issuance, Section 401 water quality certification, non-point source implementation planning, water temperature reduction measures, development and implementation of TMDLs for tributaries, and protection and restoration of cold water refuges. EPA will continue to collaborate with other federal agencies to identify and implement actions related to the point and nonpoint source dam contributions.

<u>NPDES Permit Issuance</u>
State NPDES permits should continue to address heat load reductions where available and incorporate wasteload allocations in permit reissuance. NPDES permits may provide localized, decreased heat loads to the Columbia and Lower Snake River mainstem. As discussed in Section 6.5.3, EPA does not expect stormwater general permits to be a factor influencing temperature in the Columbia and Snake River mainstems. However, state issuing agencies can use MS4 Permits as an opportunity to provide localized heat load reductions.

<u>Tributaries and Cold Water Refuges</u>
EPA encourages state and tribal governments to continue to develop and implement TMDLs for those tributaries that have received load allocations in this TMDL and for any other tributaries that are currently impaired by excess heat loading. EPA encourages federal agencies, states, tribal governments and other stakeholders to implement the recommendations of EPA's Cold Water Refuge Plan (2021), including protecting and restoring the twelve primary CWR and the Umatilla River through implementation of existing programs, regulatory actions and project funding.

<u>PUD Hydroelectric Facilities</u>
There are five PUD dams in the Columbia River: Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids. The State of Washington has responsibility for issuing the 401 Water Quality Certification associated with the Federal Energy Regulatory Commission license for each of those dams.

<u>Federal Hydroelectric Facilities</u>
In partnership with the states and tribes, EPA plans to work with the National Oceanic and Atmospheric Administration (NOAA) Fisheries, U.S. Army Corps of Engineers, Bureau of Reclamation and Bonneville Power Administration as they develop and implement water temperature reduction actions as part of their water quality plans.

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