Total Maximum Daily Loads for the Lower Columbia-Sandy Subbasin

Technical Support Document

Temperature

August 2024

State of Oregon
DEQ Department of Environmental Quality

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1 Introduction

1.1 Document purpose and organization

This technical support document (TSD) provides comprehensive supporting information on technical analyses completed for the Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP) to address temperature impairments in the waters of the Lower Columbia-Sandy Subbasin (**Figure 1-1**). This TSD provides explanation of TMDL concepts and analysis and support for conclusions and requirements included in the Lower Columbia-Sandy Subbasin TMDL and WQMP, which were adopted by Oregon's Environmental Quality Commission, by reference, in Oregon Administrative Rules (OAR) 340-42-0090.

This TSD is organized into sections with titles matching the TMDL elements required by OAR 340-042-0040(4) in the Lower Columbia-Sandy Subbasin TMDL for temperature. This organization is intended to facilitate readers' access to information needed for TMDL element-specific determinations.

1.2 Overview of TMDL elements

According to OAR 340-042-0030(15) Definitions: "Total Maximum Daily Load" means a written quantitative plan and analysis for attaining and maintaining water quality standards and includes the elements described in OAR 340-042-0040. Determinations on each element are presented in the Lower Columbia-Sandy Subbasin TMDL for temperature. Technical and policy information supporting those determinations are presented in this TSD at the section headings that correspond to each TMDL element.

In plain language, a TMDL is a water quality budget plan to ensure that a receiving water body can attain the water quality standards that protect its designated beneficial uses. This budget calculates and assigns maximum allowable pollutant loads to discharges from point (end-of-pipe) and nonpoint (diffuse/landscape) sources, in consideration of natural background levels and determinations of a margin of safety and reserve capacity.

A margin of safety (MOS) accounts for uncertainty in predicting pollutant reduction effectiveness at meeting water quality standards, and can be expressed either explicitly (as a portion of the allocations) or implicitly (by incorporating conservative assumptions into the analyses).

Reserve capacity (RC) sets aside a portion of the loading capacity for future pollutant discharges that may result from growth and new or expanded sources.

A key element of analysis is the amount of pollutant that a waterbody can receive and still meet the applicable water quality standard, and is referred to as the "loading capacity" (LC) of a waterbody. Because the LC must not be exceeded by pollutant loads from all existing sources, plus the MOS and RC, it can be considered the maximum load. Hence, the LC is often referred to as the TMDL. A loading capacity, or TMDL, is calculated on each assessment unit (AU) for each applicable temperature criteria in the TMDL project area. An AU is a partition (segment) of the state's waterbodies (streams, river, lakes, estuaries, etc.) into manageable units. The Integrated Report makes assessment conclusions for each AU.

Another key analysis element is allocating portions of the LC (TMDL) to known sources. “Allocations” are quantified maximum pollutant loads distributed among nonpoint, point, and background sources that assure water quality standards will be met. “Load allocations” (LA) are LC portions allocated to (1) nonpoint sources such as urban, agriculture, rural residential or forestry activities; and (2) natural background sources such as soils or wildlife. “Wasteload allocations” (WLA) are LC portions allocated to point sources of pollution, such as permitted discharges from sewage treatment plants, industrial facilities, and/or stormwater systems. As noted above, allocations can also be reserved for future uses, termed “reserve capacity” (RC).

This general TMDL concept is represented by the following equation:

$$TMDL = \sum \text{Wasteload Allocations} + \sum \text{Load Allocations} + \text{Reserve Capacity} + \text{Margin of Safety}$$

Together, these elements establish the maximum allowed pollutant loads necessary to meet applicable water quality standards for impaired pollutants and protect beneficial uses.

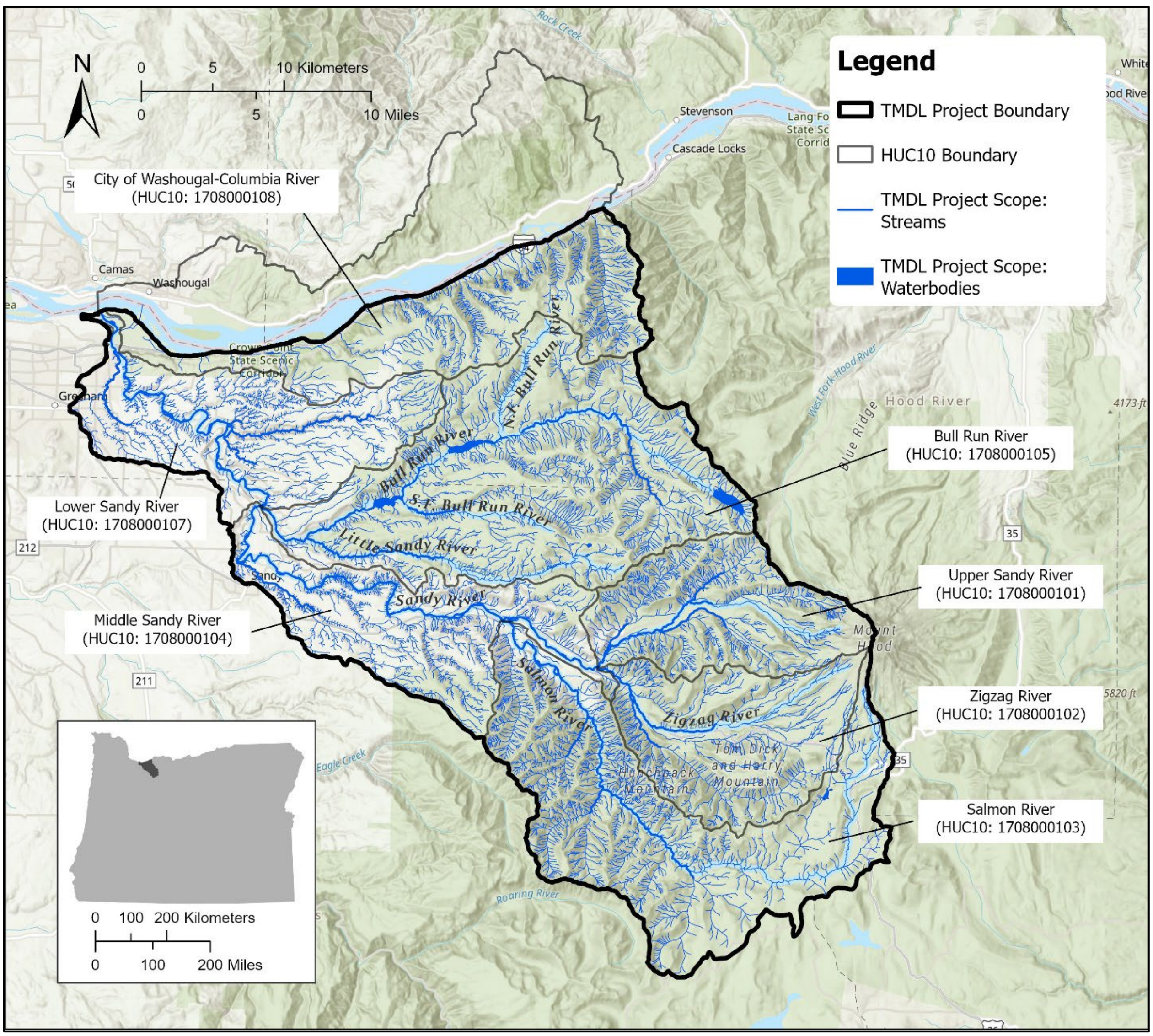

Figure 1-1: Lower Columbia-Sandy Subbasin temperature TMDLs project area overview.

2 TMDL location and scope

Per Oregon Administrative Rule 340-042-0040(a), this element describes the geographic area for which the TMDL was developed. The Lower Columbia-Sandy Subbasin is located on the west slopes of the Cascade Range of northwestern Oregon, east of the Portland metropolitan area.

DEQ developed this TMDL to address all Category 5 listed AUs impaired for temperature located in the Lower Columbia-Sandy Subbasin and, as applicable, any AUs identified as temperature-impaired in the future. Likewise, this TMDL includes a protection plan for all other assessment categories including AUs identified as a potential concern, attaining, or unassessed. In total, the TMDL applies to 58 AUs. Appendix H of this TSD provides a list of all AUs addressed by this TMDL.

The loading capacity and allocations, including surrogate measures, and implementation framework apply to all waters determined to be waters of the state as defined under ORS 468B.005(10), including all perennial and intermittent streams that have surface flow or residual pools during the TMDL allocation period, located in the Lower Columbia-Sandy Subbasin (17080001). The temperature TMDLs do not include the section of the Columbia River that flows through the Lower Columbia-Sandy Subbasin (17080001). However, this TMDL implements EPA's Columbia and Lower Snake Rivers temperature TMDL (EPA, 2021) allocation to anthropogenic sources in Columbia River tributaries, including the Sandy River. The map in **Figure 1-1** provides an overview of where the temperature TMDLs are applicable.

In Oregon, the Lower Columbia-Sandy Subbasin is comprised of seven smaller 10-digit watersheds as listed in **Table 2-1**, and 23 12-digit subwatersheds as listed in **Table 2-2.**

Table 2-1: Watersheds within the Lower Columbia-Sandy Subbasin.

HU10 code	Watershed name
1708000101	Upper Sandy River
1708000102	Zigzag River
1708000103	Salmon River
1708000104	Middle Sandy River
1708000105	Bull Run River
1708000107	Lower Sandy River
1708000108	City of Washougal-Columbia River

Table 2-2: Subwatersheds within the Lower Columbia-Sandy Subbasin.

HU12 code	Subwatershed name
170800010101	Headwaters Sandy River
170800010102	Clear Creek-Sandy River
170800010201	Still Creek
170800010202	Zigzag Canyon
170800010301	Linney Creek
170800010302	Upper Salmon River
170800010303	Middle Salmon River
170800010304	Lower Salmon River
170800010401	Wildcat Creek-Sandy River

HU12 code	Subwatershed name
170800010402	Cedar Creek-Sandy River
170800010501	Blazed Alder Creek
170800010502	Upper Bull Run River
170800010503	Middle Bull Run River
170800010504	South Fork Bull Run River
170800010505	Little Sandy River
170800010506	Lower Bull Run River
170800010701	Gordon Creek
170800010702	Trout Creek-Sandy River
170800010703	Beaver Creek-Sandy River
170800010801	Tanner Creek-Columbia River
170800010802	Woodard Creek-Columbia River
170800010803	Bridal Veil Creek-Columbia River
170800010804	Latourell Creek-Columbia River

2.1 Impaired waters

Table 2-3: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report.

Assessment unit name	Assessment unit	Use period
Beaver Creek	OR_SR_1708000107_02_103612	Year-round
Beaver Creek	OR_SR_1708000107_02_103612	Spawning
Benson Lake	OR_LK_1708000108_15_100639	Year-round
Bull Run River	OR_SR_1708000105_11_103611	Year-round
Bull Run River	OR_SR_1708000105_11_103611	Spawning
Cedar Creek	OR_SR_1708000104_02_103607	Year-round
Clear Creek	OR_SR_1708000101_02_103597	Year-round
Clear Creek	OR_SR_1708000101_02_103597	Spawning
Clear Fork	OR_SR_1708000101_02_103596	Spawning
Gordon Creek	OR_SR_1708000107_02_103615	Spawning
Gordon Creek	OR_SR_1708000107_02_103617	Spawning
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	Spawning
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	Year-round
HUC12 Name: Bridal Veil Creek-Columbia River	OR_WS_170800010803_15_103654	Year-round
HUC12 Name: Cedar Creek-Sandy River	OR_WS_170800010402_02_103644	Year-round
HUC12 Name: Headwaters Sandy River	OR_WS_170800010101_02_103635	Year-round
HUC12 Name: Little Sandy River	OR_WS_170800010505_11_103669	Year-round
HUC12 Name: Lower Bull Run River	OR_WS_170800010506_11_103650	Year-round
HUC12 Name: Lower Salmon River	OR_WS_170800010304_02_103642	Year-round
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	Spawning
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	Year-round
HUC12 Name: Wildcat Creek-Sandy River	OR_WS_170800010401_02_103643	Spawning
Little Sandy River	OR_SR_1708000105_11_103609	Year-round
Little Sandy River	OR_SR_1708000105_11_103609	Spawning
Lost Creek	OR_SR_1708000101_02_103598	Spawning
Salmon River	OR_SR_1708000103_02_103606	Year-round
Salmon River	OR_SR_1708000103_02_103606	Spawning

Assessment unit name	Assessment unit	Use period
Sandy River	OR_SR_1708000101_02_103595	Year-round
Sandy River	OR_SR_1708000101_02_103599	Year-round
Sandy River	OR_SR_1708000101_02_103599	Spawning
Sandy River	OR_SR_1708000104_02_103608	Year-round
Sandy River	OR_SR_1708000104_02_103608	Spawning
Sandy River	OR_SR_1708000107_02_103616	Year-round
South Fork Salmon River	OR_SR_1708000103_02_103604	Spawning
Still Creek	OR_SR_1708000102_02_103601	Spawning
Zigzag River	OR_SR_1708000102_02_103600	Spawning

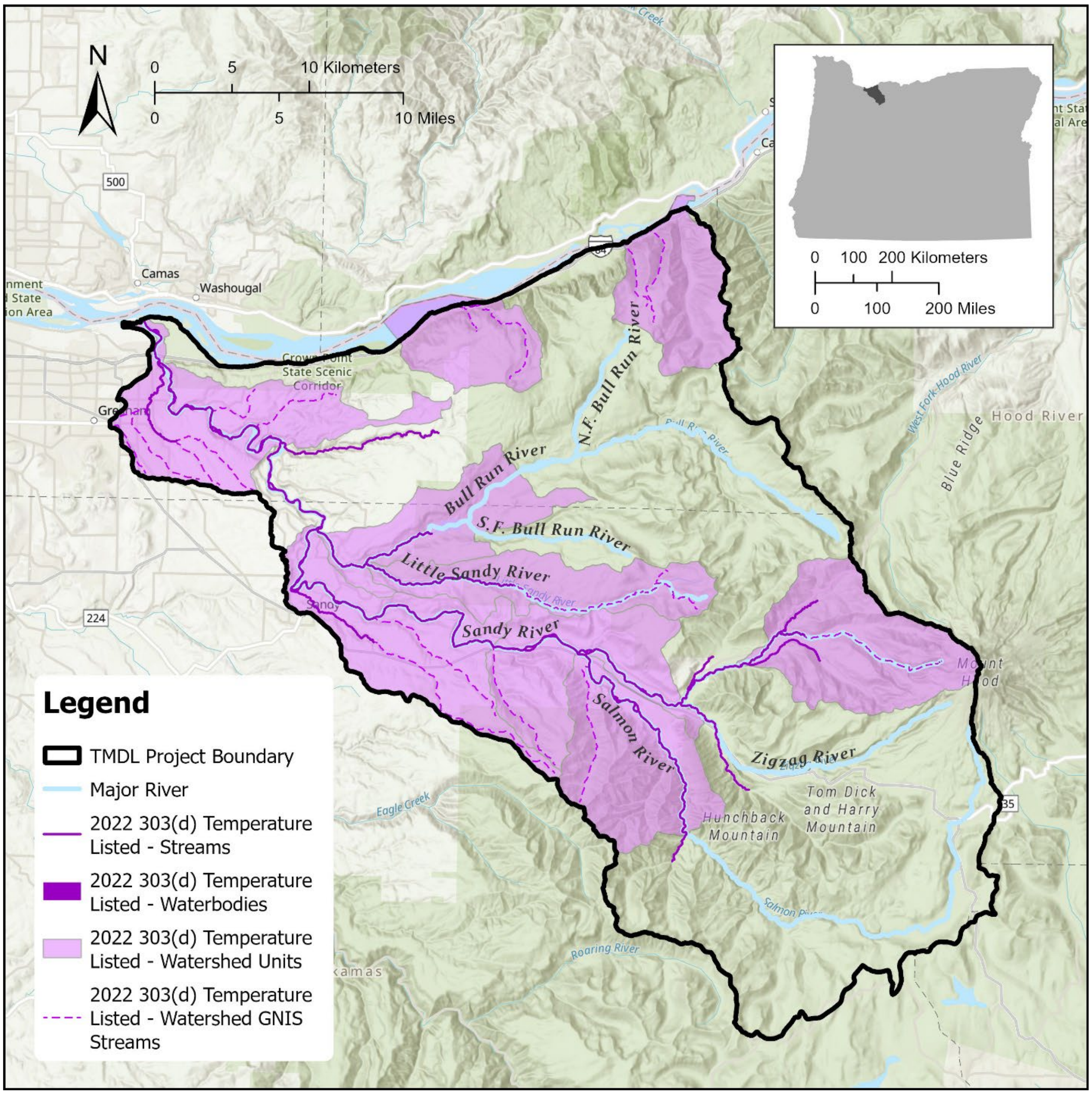

Figure 2-1: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report.

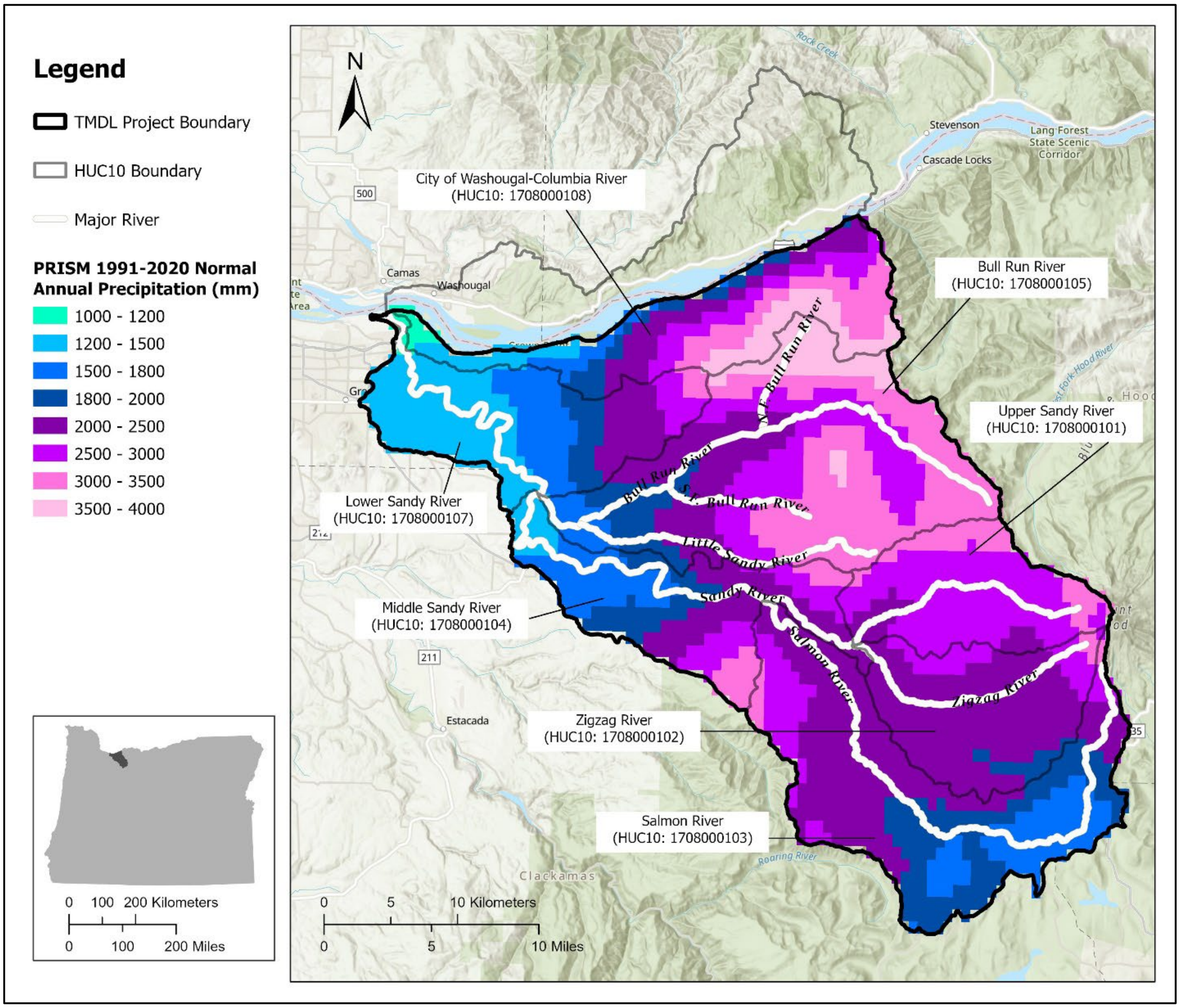

Figure 2-2: PRISM 1991-2020 Normal Annual Precipitation in the Lower Columbia-Sandy Subbasin (Data Source: PRISM Climate Group, 2022).

Table 2-3 presents stream AUs within the Lower Columbia-Sandy Subbasin that were listed as impaired for temperature on DEQ's 2022 Clean Water Act Section 303(d) List (as part of Oregon's Integrated Report), which was approved by the Environmental Protection Agency on September 1, 2022. Status category designations are prescribed by Sections 305(b) and 303(d) of the Clean Water Act. AUs listed in Category 5 (designated use is not supported or a water quality standard is not attained) require development of a TMDL. Locations of these listed segments are depicted in **Figure 2-1**.

In total, the 2022 Integrated Report identifies 36 Category 5 temperature impairments in the Lower Columbia-Sandy Subbasin. Some of these AUs have both year-round and spawning use designations impaired. If both use designations are impaired, it is considered two listings. There are 27 unique AUs with Category 5 temperature impairments if counting AUs only.

2.2 Climate

The Lower Columbia-Sandy Subbasin is characterized by a temperate maritime climate with mild temperatures and a relatively high level of precipitation. According to PRISM normals of annual conditions over the past 30 years (1991-2020), average annual precipitation generally varies with elevation and from west to east, ranging from 1,148 mm (45”) near Troutdale to 3,917 mm (154”) near the North Fork Bull Run River (**Figure 2-2**). Most precipitation occurs from November-January. Precipitation is lower in July-August. Average annual maximum air temperatures in the Lower Columbia-Sandy Subbasin range from 1.3°C (34°F) at Mt. Hood to about 17°C (63°F) at Troutdale (**Figure 2-3**). Generally, July and August are the hottest months of the year (average air temperature: 24°C (75.2°F)) (PRISM Climate Group, 2022).

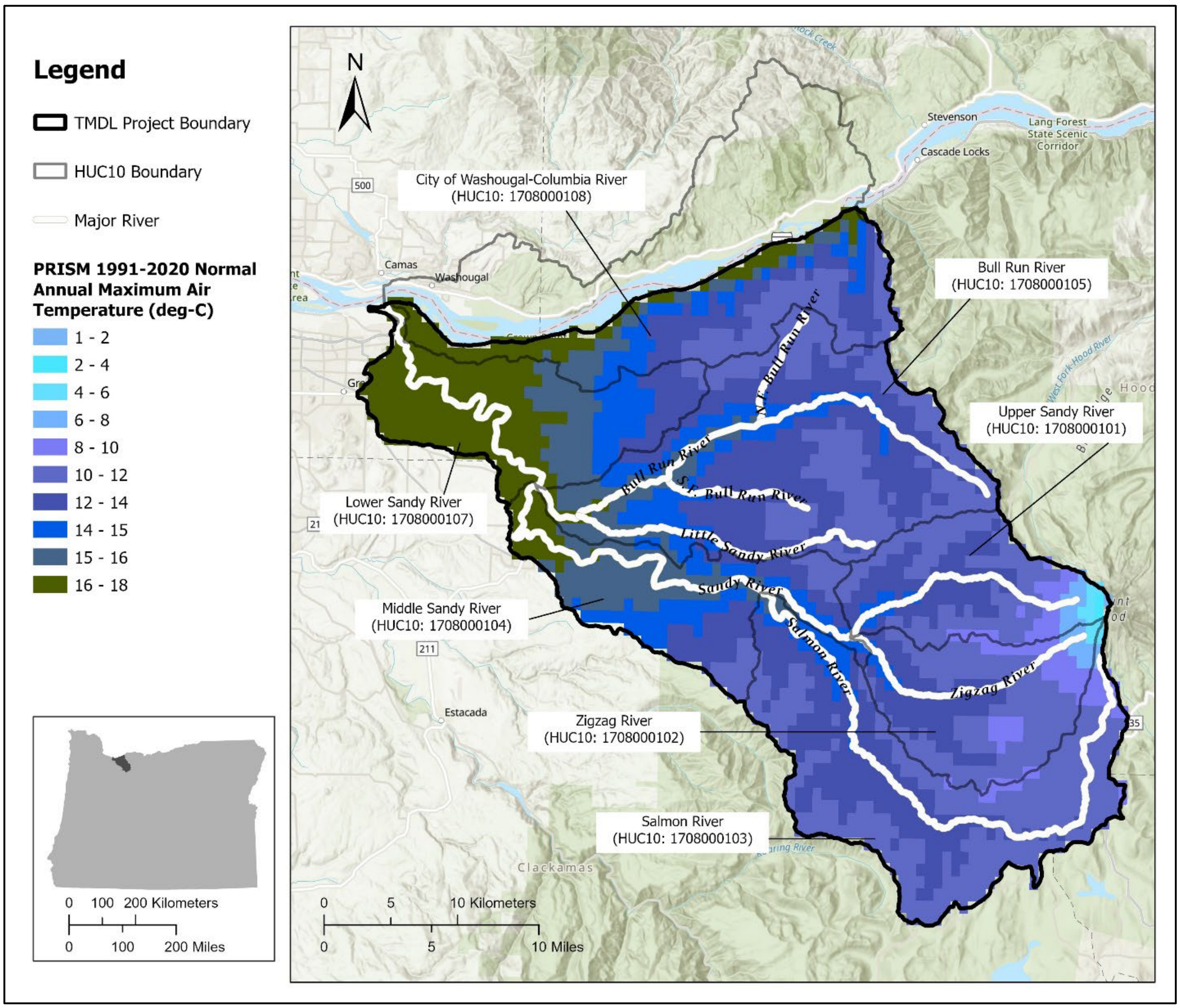

Figure 2-3: PRISM 1991-2020 Normal Annual Maximum Air Temperature in the Lower Columbia-Sandy Subbasin (Data Source: PRISM Climate Group, 2022).

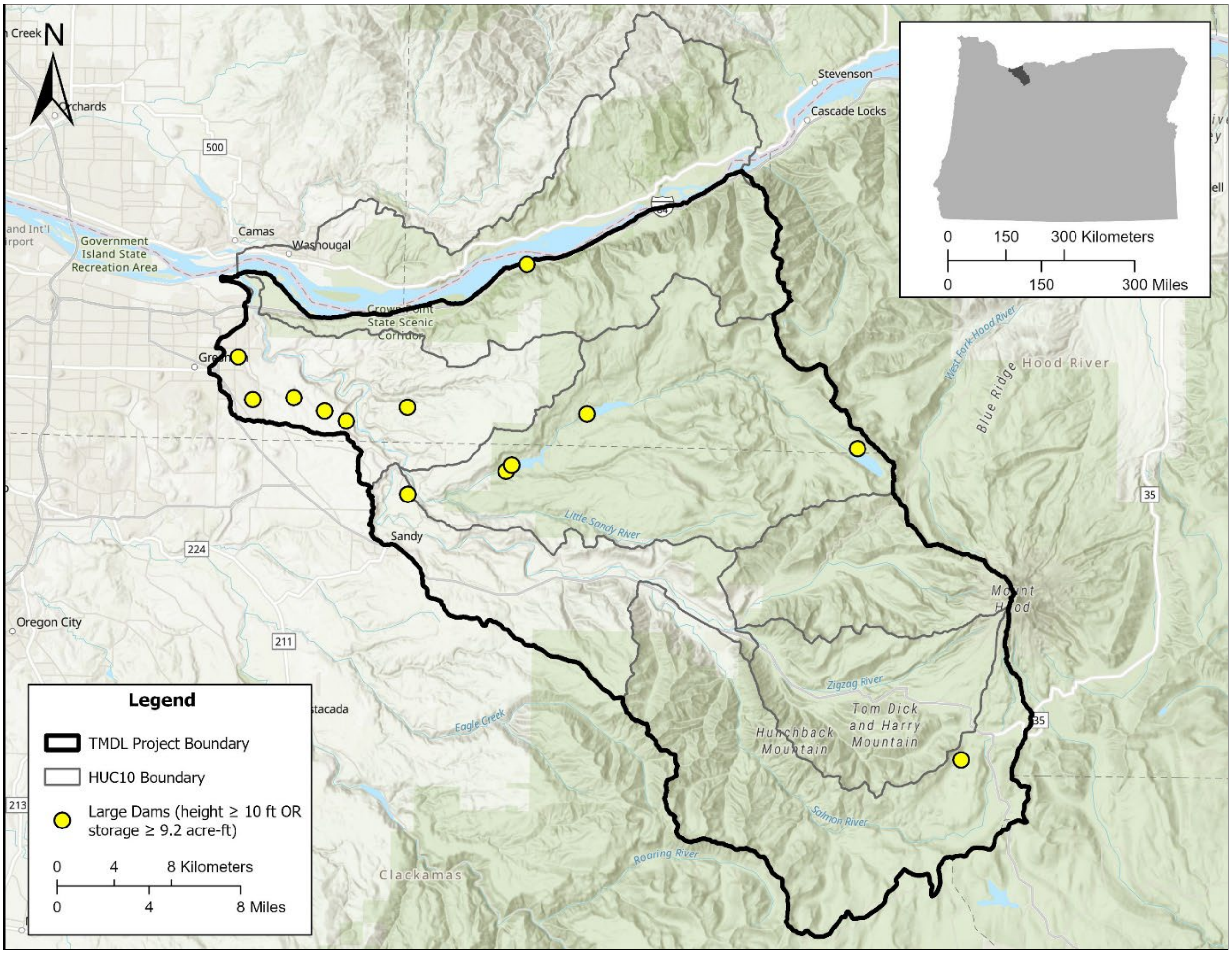

Figure 2-4: Large dams located within the Lower Columbia-Sandy Subbasin temperature TMDL project area.

2.3 Hydrology

The Lower Columbia-Sandy Subbasin drains approximately 1,315 km^2 (508 mi^2) in northwestern Oregon. The Sandy River originates from Reid Glacier on the western slopes of Mt. Hood and extends about 90 km (56 mi) before flowing into the Columbia River near Troutdale, OR. The Sandy River is the only major glacial river draining the western Cascades in Oregon. Glacially-derived fine particulate matter known as “glacial flour” gives the Sandy River its distinctive milky-grey color in summer. Major Sandy River tributaries include the Bull Run River, Little Sandy River, Salmon River, and Zigzag River. The Little Sandy River is the largest tributary to the lower Bull Run River.

Figure 2-4 shows the locations of large dams within the TMDL project area. Data for these dams were downloaded from the federal National Inventory of Dams (NID) website, a repository maintained by USACE. The 13 dams shown in **Figure 2-4** are either ≥10 ft high or have ≥9.2 acre-ft storage capacities. They serve a variety of purposes, including irrigation, water supply, hydroelectric power, and recreation. These dams are owned and operated by local governments, state agencies, private entities, and public utilities. Most of the dams are in the Beaver Creek and Bull Run Watersheds.

The City of Portland manages the dams and reservoirs on the Bull Run River as part of its drinking water supply project; these comprise Bull Run Reservoir & Dam 1, Reservoir & Dam 2, and a dam structure on Bull Run Lake. Dam 1 was the first large dam constructed (completed in 1929) and is the largest by dam height and capacity in the TMDL project area. It is a 200 ft high concrete gravity arch dam that created Reservoir 1, which has a 10 billion gallon (38 million m^3) maximum water capacity. It has a selective withdrawal structure that allows water withdrawal at various reservoir depths, which allows some control over discharge temperatures. Reservoir 1's surface elevation varies between 295-319 m (970-1,045 ft) above MSL. Dam 2, located downstream of Dam 1, is an earthfill dam project completed in 1962 with a 6.8 billion gallon (26 million m^3) maximum storage capacity. In 2014, a selective withdrawal structure was completed for Dam 2. The City attempts to maximize Reservoir 2 storage volumes throughout the year (including summer). Reservoir 2's surface elevation varies between 256-262 m (840-860 ft) above MSL. The project has a Federal Energy Regulatory Commission license to produce electricity (FERC License No. 2821, currently valid until 2029). Water is routed through powerhouses before returning to the Bull Run River; any winter storm overflow is routed over spillways.

Table 2-4: Monthly water availability based on the median (50th percentile) exceedance probability at the Sandy River mouth as calculated by Oregon Department of Water Resources, June 2023.

Month	Median natural streamflow (cfs)	Consumptive use (cfs)	Percent of natural streamflow used for consumptive uses (%)	Expected streamflow (cfs)	Reserved streamflow (cfs)	Instream requirement (cfs)	Net water available (cfs)
Jan	3190	1100	34	2090	0	1900	187
Feb	3130	1080	35	2050	0	1900	147
Mar	2760	992	36	1770	0	2000	-232
Apr	3120	1150	37	1970	0	2000	-32
May	2740	1010	37	1730	0	2000	-272
June	1620	533	33	1090	0	1400	-313
July	950	268	28	682	0	800	-118
Aug	633	183	29	450	0	400	49.9
Sept	682	231	34	451	0	500	-48.9
Oct	843	359	43	484	0	650	-166
Nov	2210	978	44	1230	0	1500	-268
Dec	3230	1130	35	2100	0	1500	597

Bull Run Lake is a natural lake above the Bull Run River headwaters that was formed by a landslide before European settlement. Although the lake and river have no surface water connection, groundwater seepage contributes significantly to Bull Run River flows. The U.S. Forest Service (USFS) issues a special use permit to the City of Portland to withdraw water from the lake for municipal supplies. The permit restricts withdrawals to ensure that adequate water is available to support the local ecosystem. Thus, lake water is only used in dry years. A 10 ft dam structure was installed to increase the lake surface elevation and storage capacity.

The Oregon Department of Water Resources reports that there are approximately 681 active water right permits in the Sandy administrative basin. From May through October, consumptive uses account for 28%-43% of median monthly natural flow at the Sandy River mouth. During most months, there is net negative water availability (**Table 2-4**).

2.4 Intermittent streams

An intermittent stream as defined by Nadeau (2015) is a channel that contains water for only part of the year, typically during winter and spring when the streambed may be below the water table or when snowmelt from surrounding uplands provides sustained flow. The channel may or may not be well defined. The flow may vary greatly with stormwater runoff. An intermittent stream may lack the biological and hydrological characteristics commonly associated with the continuous conveyance of water. Intermittent streams contribute to maintenance of cold water in downstream tributaries, even during periods when there is no surface flow (Ebersole et al., 2015).

The TMDL applies to intermittent streams for three primary reasons:

1) To protect aquatic life that may reside in intermittent streams. Intermittent streams can be "dry" but continue to support aquatic life in residual pools that remain during the dry periods. Residuals pools are often fed by subsurface flow. There is at least one published study in Oregon documenting the presence of juvenile salmonids in these residual pools over the summer (May and Lee, 2004). The temperature water quality standards apply to residual pools and the aquatic life that use them.

2) To protect downstream temperatures. Stream warming is cumulative and is not limited only to human activities within the impaired reaches. Activities in upstream tributaries, including intermittent streams, can influence stream temperatures downstream. For this reason, the Environmental Quality Commission (EQC) has developed standards protecting cold water that already meets the biologically-based criteria and may not be currently listed as impaired (see OAR 340-0421-0028 (11)). In particular, intermittent streams are important for downstream temperatures because they can:

    a) Be flowing when temperature TMDLs apply. Streams classified as intermittent may only be "dry" in the summer or during low-precipitation years. Temperature TMDLs apply to periods when downstream tributary temperatures exceed the applicable temperature standard. In the Lower Columbia-Sandy Subbasin, the TMDL allocations apply May 1 to October 31 in most watersheds. Some watersheds require longer allocation periods (see Section 5). The TMDL allocation period includes months when intermittent streams may be flowing, such as in the spring or early fall when the spawning criteria apply.

    b) Become perennial or have longer flow periods following timber harvest. Multiple studies have documented the increase to summer flow and annual water yield following a timber harvest (Hibbert, 1967; Bowling et al., 2000; Harr et al., 1982; Keppeler and Ziemer, 1990; Rothacher, 1965; Segura et al., 2020; Surfleet and Skaugset, 2013). Insufficient shade over these streams contributes to excessive solar loading, temperature increases, and may contribute to downstream warming.

    c) Be limited to subsurface flow because of current degradation. In Eastern Oregon there are examples of degraded intermittent streams becoming perennial after riparian restoration. Restoring the riparian vegetation will allow the system to aggrade, raising the water table and returning flow to the surface (Elmore and Beschta, 1987).

3) As a margin of safety to address the current inaccuracies associated with classification and mapping of intermittent streams, and their period of flow in relation to the period when TMDL allocations apply. There are multiple approaches to identify and map stream flow permanence and duration. Some of the more recent methods used in Oregon (Jaeger et al., 2019 and Nadeau, 2015) are improvements over previous methods and the classifications included in past versions of the National Hydrography Dataset (NHD). Fritz et al. (2013) demonstrated that the flow permanence classifications included in the NHD had only about 50% agreement with field-based observations. DEQ believes the current classifications are not sufficiently accurate for reliable application and use for the TMDL.

For these reasons, the TMDL allocations apply to intermittent streams unless field-based data are assembled to document that a stream neither contains residual pools nor has surface flow during the entire period of TMDL applicability.

2.5 Land use

The Lower Columbia-Sandy Subbasin is characterized by a variety of land uses (e.g., forested lands, agriculture, and urban development), which are summarized in **Table 2-5** and **Figure 2-5** based on the 2019 National Land Cover Database (Dewitz and USGS, 2021). Note that Shrub/Scrub and Herbaceous land uses can occur in areas where forest clearcuts have occurred and would be classified as forest after regrowth. Most of the land area (approximately 86%) is forested. Timber harvesting and related activities (e.g., road construction) were the primary land uses in forested areas in the 19th-20th centuries, but were dramatically reduced after Northwest Forest Plan implementation in 1994 (SRBWG, 2007). Agricultural land uses (e.g., grazing, hay production, and berry farming) occur primarily in the subbasin's lower regions. Urban development is concentrated along the lower Sandy River, including the cities of Gresham, Sandy, and Troutdale.

Table 2-5: Lower Columbia-Sandy Subbasin land use summary based on the 2019 National Land Cover Database.

2019 NLCD Land Cover	Acres	Percent of total area
Evergreen Forest	284581.3	78.1
Herbaceous	14412.1	4.0
Mixed Forest	13642.8	3.7
Hay/Pasture	12424.7	3.4
Shrub/Scrub	11637.9	3.2
Developed, Open Space	7145.1	2.0
Developed, Low Intensity	3579.4	1.0
Barren Land	3490.3	1.0
Woody Wetlands	3166.9	0.9
Developed, Medium Intensity	3016.3	0.8
Open Water	2540.2	0.7
Emergent Herbaceous Wetlands	1769.4	0.5
Perennial Snow/Ice	1279.9	0.4
Developed, High Intensity	677.9	0.2
Deciduous Forest	579.1	0.2
Cultivated Crops	218.6	0.1

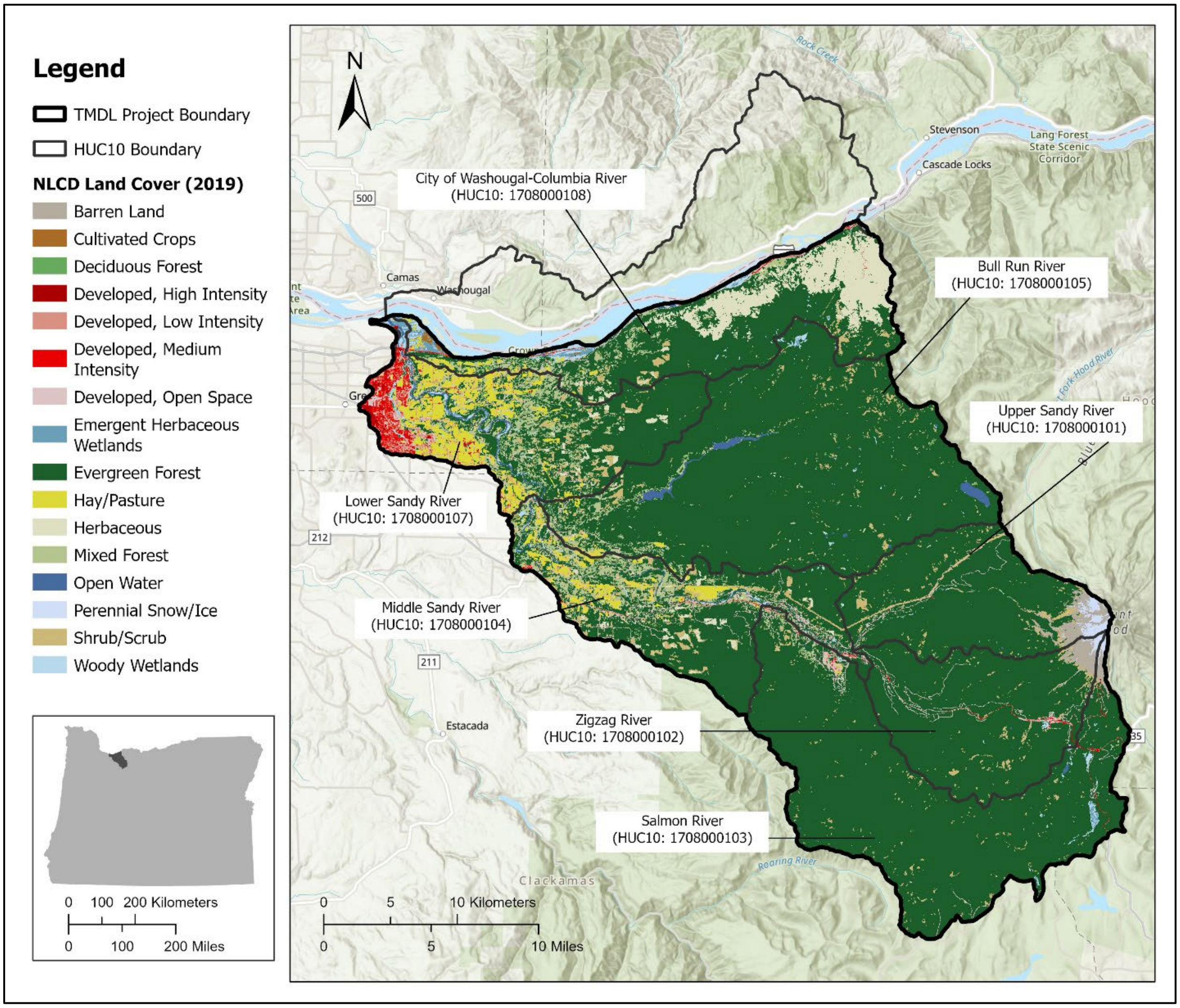

Figure 2-5: Land cover in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

2.6 Land ownership and jurisdiction

The Lower Columbia-Sandy Subbasin is within Multnomah and Clackamas counties. Approximately 70% of the basin consists of Mt. Hood National Forest, which is owned and managed by the USFS; 22% is privately owned, and 4% is owned and managed by the Bureau of Land Management (BLM). The remainder is owned by state, local or regional governments (SRBWG, 2007). The Lower Columbia-Sandy Subbasin land ownership and jurisdiction, also referred to as the designated management agencies (DMAs), are shown in **Figure 2-6**.

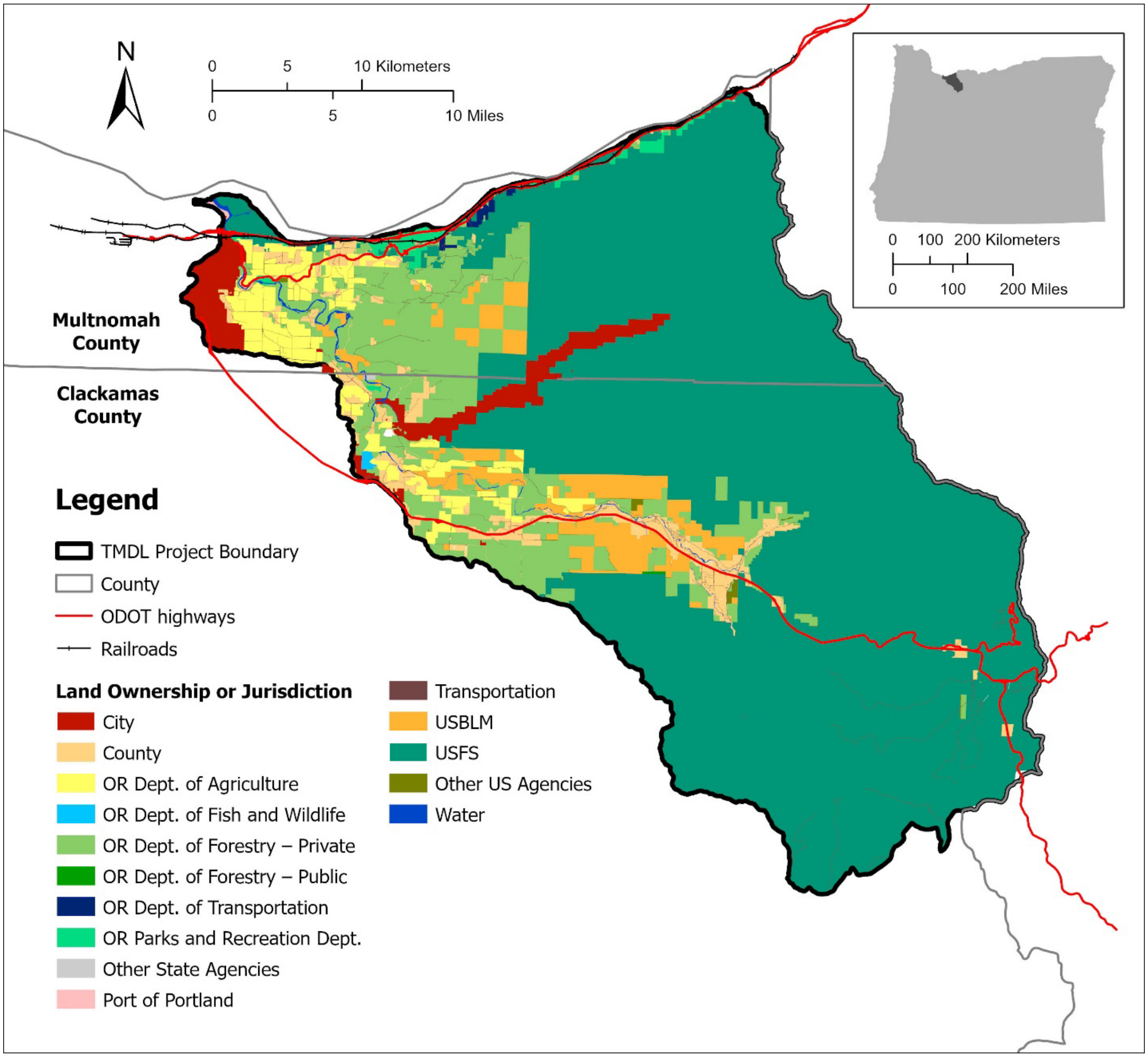

Figure 2-6: Designated management agencies (DMAs) in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

3 Pollutant identification

As stated in OAR 340-042-0040(4)(b), this element identifies the pollutants causing impairment of water quality that are addressed by these TMDLs.

Temperature is the water quality parameter of concern, but heat from thermal loading is the pollutant of concern causing impairment. Heat caused by human activities is of particular concern. Water temperature change (ΔT_w) is a function of the heat transfer in a discrete volume and may be described in terms of changes in heat per unit volume. Conversely, a change in volume can also result in water temperature change for a defined amount of heat exchange:

$$\Delta T_w = \frac{\Delta Heat}{Density \times Specific\ Heat \times \Delta Volume}$$

The pollutants addressed by this temperature TMDL are heat or thermal loads, with surrogate measures of effective shade and percent consumptive use.

EPA regulations (40 CFR 130.2(i)) and OAR 340-042-0040(O)(5)(b) allow for TMDLs to utilize other appropriate measures (or surrogate measures). Surrogate measures are defined in OAR 340-042-0030(14) as “substitute methods or parameters used in a TMDL to represent pollutants.” In accordance with OAR 340-042-0040(5)(b), DEQ used effective shade and a percent consumptive use target as surrogate measures for thermal loading caused by solar radiation and other fluxes that introduce heat. Implementation of the surrogate measures ensures achievement of necessary pollutant reductions and the nonpoint load allocations for these temperature TMDLs.

4 Temperature water quality standards and beneficial uses

EQC issued, and EPA approved, numeric and narrative water quality standards to protect designated *beneficial use*s in the in the Lower Columbia-Sandy Subbasin (Oregon Administrative Rules OAR 340-041-0344-0350, November 2003), and antidegradation policies to protect overall water quality. **Table 4-1** specifies the designated beneficial uses in Lower Columbia-Sandy Subbasin surface waters.

Table 4-1: Designated beneficial uses in the Lower Columbia-Sandy Subbasin as identified in OAR 340-041-0286 Table 286A.

Beneficial uses	Streams forming waterfalls near Columbia River highway	Sandy River	Bull Run River and all tributaries	All other tributaries to Sandy River
Public Domestic Water Supply		X	X	X
Private Domestic Water Supply		X		X
Industrial Water Supply		X		X
Irrigation		X		X
Livestock Watering		X		X
Fish and Aquatic Life	X	X	X	X
Wildlife and Hunting	X	X		X
Fishing	X	X		X
Boating		X		X
Water Contact Recreation	X	X		X
Aesthetic Quality	X	X	X	X
Hydro Power		X	X	X
Commercial Navigation & Transportation				

Water quality criteria have been set at a level to protect the most sensitive beneficial uses. These TMDLs are designed such that meeting water quality standards for the most sensitive beneficial uses will be protective of all other uses. Fish and aquatic life is the most sensitive beneficial use for temperature. Oregon’s water temperature criteria use salmonids’ life cycles as indicators. If temperatures are protective of these indicator species, other species will also be protected. The locations and periods of criteria applicability are determined from designated fish use maps in rule at OAR 340-041-0286 Figure 286A and Figure 286B. The maps from the rule have been reproduced as shown in **Figure 4-1** and **Figure 4-2**. **Figure 4-1** shows various designated fish uses and applicable criteria, while **Figure 4-2** shows salmon and steelhead spawning use designation, based on the NHD.

The temperature water quality standards for the Lower Columbia-Sandy Subbasins are based on the rolling seven-day average daily maximum (7DADM) temperature and include the following numeric criteria:

- Salmon and steelhead spawning: 13.0°C (55.4°F) (OAR 340-041-0028(4)(a))
- Core cold water habitat: 16.0°C (60.8°F) (OAR 340-041-0028(4)(b))
- Salmon and trout rearing and migration: 18.0°C (64.4°F) (OAR 340-041-0028(4)(c))

The following narrative temperature water quality standards and other rule provisions also apply in the Lower Columbia-Sandy Subbasins:

- Human use allowance (OAR 340-041-0028(12)(b))
- Minimum duties (OAR 340-041-0028(12)(a))
- Natural Lakes (OAR 340-041-0028(6))
- Protecting cold water (OAR 340-041-0028(11))
- Antidegradation (OAR 340-041-0004)

Details of each rule are described in the following sections (4.1 to 4.7).

4.1 Salmon and steelhead spawning use

OAR 340-041-0028(4)(a) specifies that waters designated as having salmon and steelhead spawning use are identified in rule at OAR 340-041-0286 Figure 286B (shown in **Figure 4-2**). During the spawning period, these waters may not exceed 13.0°C (55.4°F) expressed as a 7DADM.

4.2 Core cold water habitat use

OAR 340-041-0028(4)(b) specifies that waters designated as having core cold water habitat use are identified in OAR 340-041-0286 Figure 286A (shown in **Figure 4-1**). These waters may not exceed 16.0°C (60.8°F) expressed as a 7DADM.

4.3 Salmon and trout rearing and migration

OAR 340-041-0028(4)(c) specifies that waters designated as having salmon and trout rearing and migration use are identified in OAR 340-041-0286 Figure 286A (shown in **Figure 4-1**). These waters may not exceed 18.0°C (64.4°F) expressed as a 7DADM.

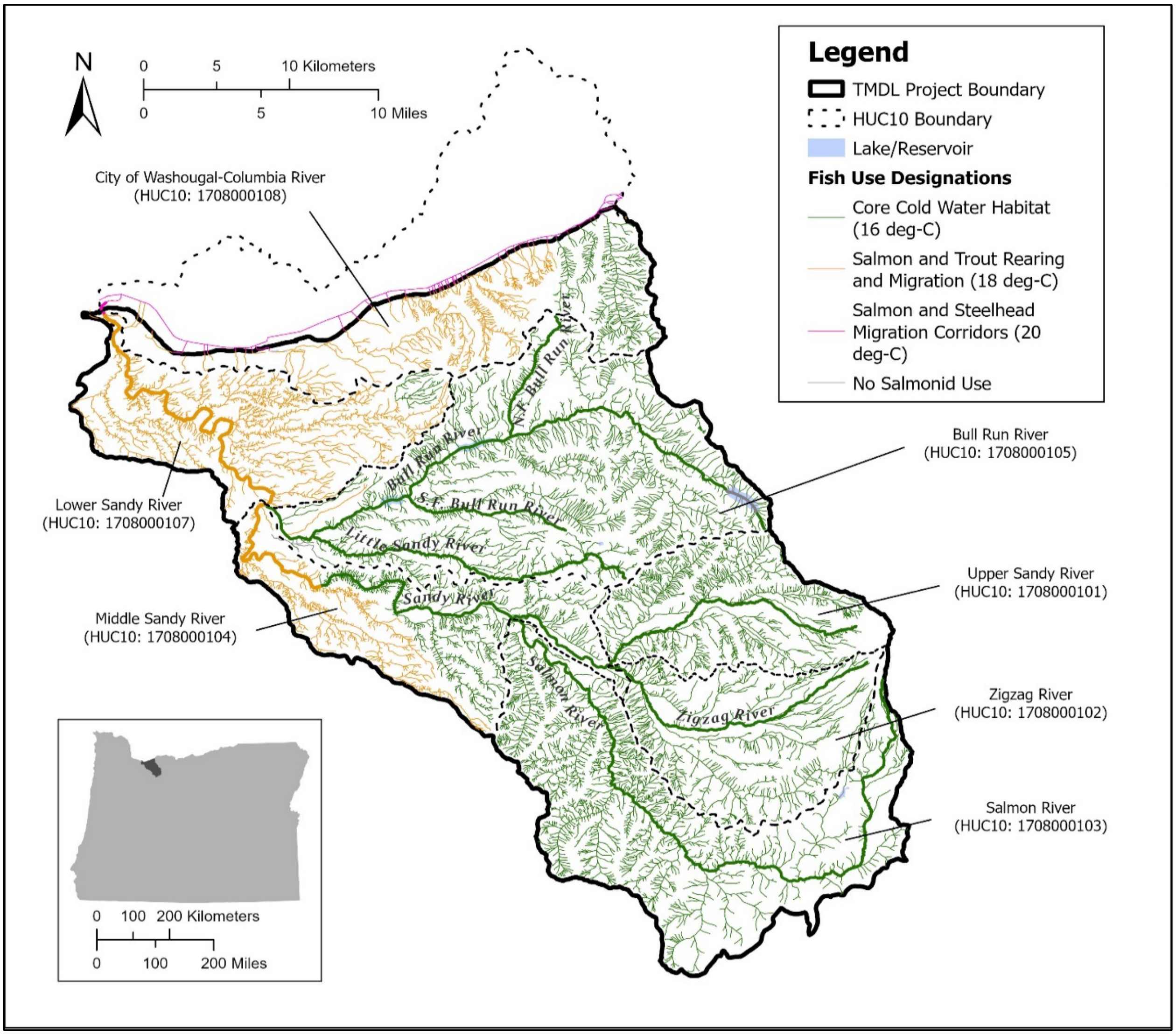

Figure 4-1: Fish use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

4.4 Human use allowance

Oregon water quality standards have provisions for human use (OAR 340-041-0028(12)(b)). The human use allowance (HUA) is an insignificant addition of heat (0.30°C) authorized in waters that exceed the applicable temperature criteria. 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 0.30°C (0.5°F) above the applicable biological criterion after complete mixing in the waterbody, and at the point of maximum impact (POMI). The rationale behind selection of 0.30°C for the HUA and how DEQ implements this portion of the standard can be found in DEQ (2003) and the Temperature IMD (DEQ, 2008).

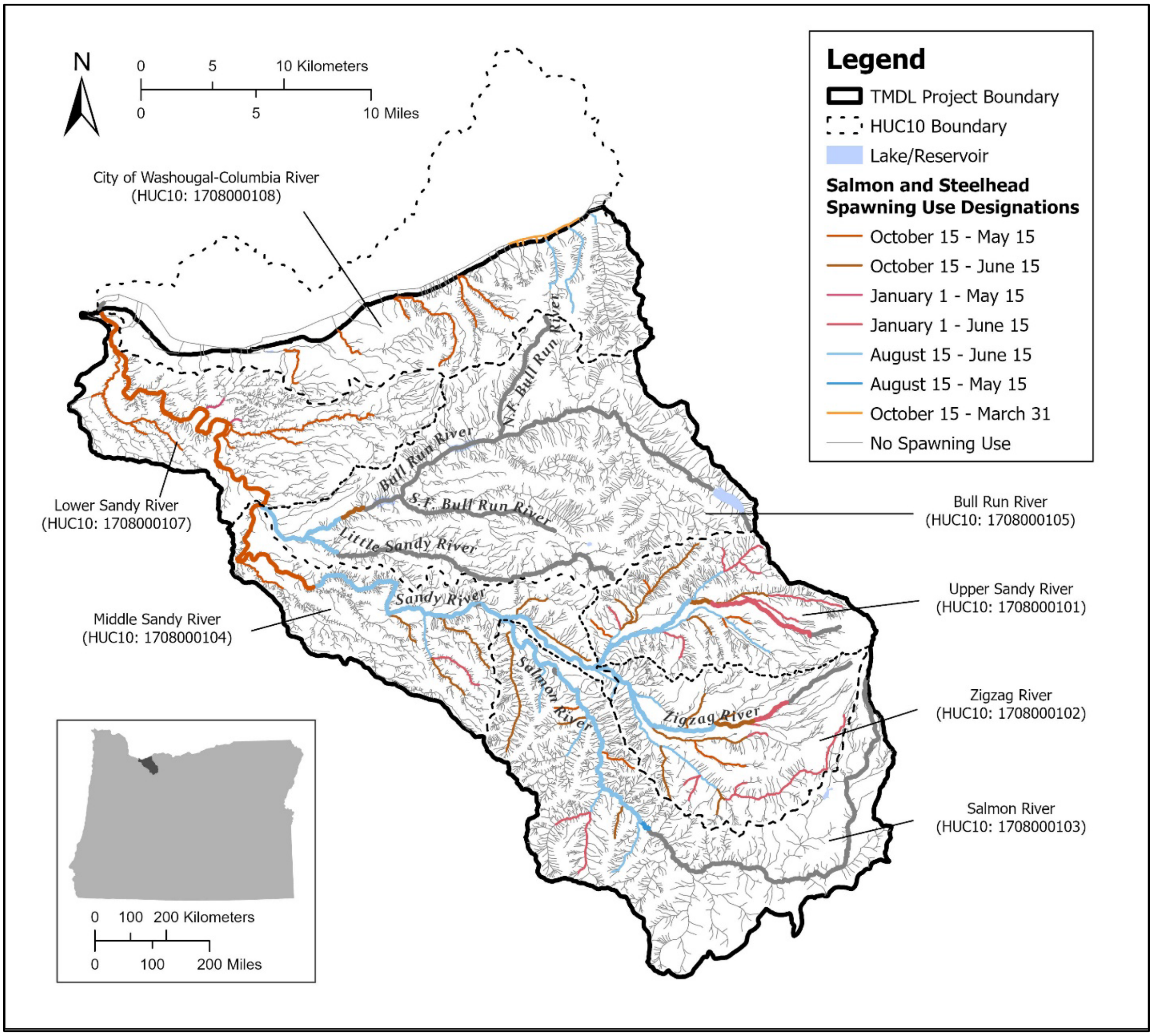

Figure 4-2: Salmon and steelhead spawning use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

4.5 Natural lakes

OAR 340-041-0028(6) specifies that natural lakes may not be warmed by more than 0.30°C (0.5°F) above the natural condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life. Absent a discharge or human modification that would reasonably be expected to increase temperature, DEQ will presume that the ambient temperature of a natural lake is the same as its natural thermal condition.

4.6 Protecting cold water

The “protecting cold water” (PCW) criterion in OAR 340-041-0028(11) applies to waters of the state that have ambient summer 7DADM temperatures that are always colder than the biologically-based criteria. With some exceptions (**Figure 4-3**), these waters may not be warmed cumulatively by anthropogenic point and nonpoint sources by more than 0.30°C (0.5°F) above the colder water ambient 7DADM temperature. This applies to all anthropogenic sources taken together at the POMI where salmon, steelhead or bull trout are present. A summary of how DEQ implements this portion of the standard can be found in the protecting cold water IMD (DEQ, 2011) and the Temperature IMD (DEQ, 2008a).

4.7 Statewide narrative criteria

Statewide narrative criteria at OAR 340-041-0007(1) apply to all waters of the state. The highest and best practicable treatment and/or control of wastes, activities, and flows must in every case be provided to maintain dissolved oxygen and overall water quality at the highest possible levels and maintain water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor and other deleterious factors at the lowest possible levels.

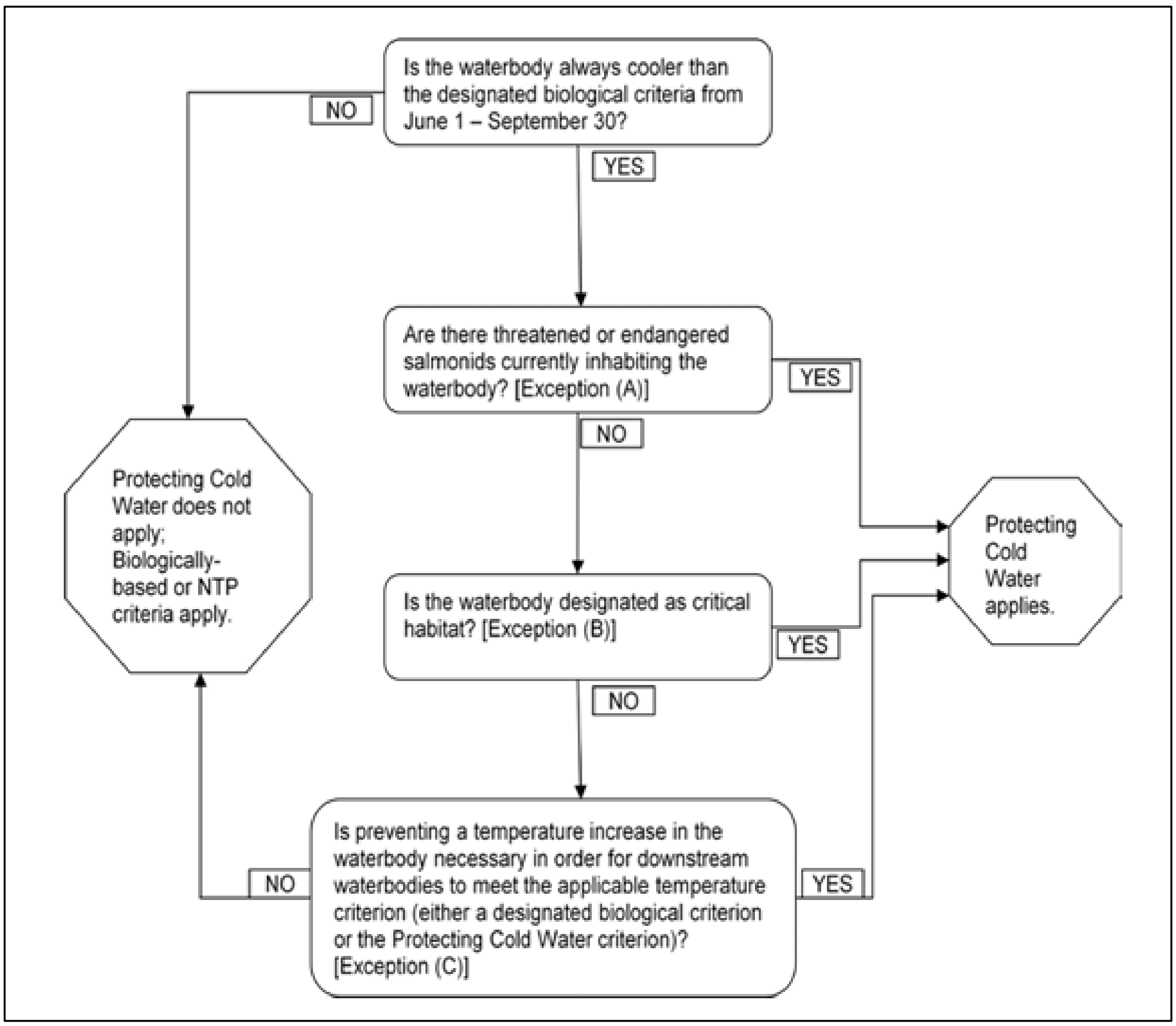

Figure 4-3: Flowchart to determine applicability of the protecting cold water criterion. Extracted from DEQ, 2011.

5 Seasonal variation and critical period for temperature

Per OAR 340-042-0040(4)(j) and 40 Code of Federal Regulation130.7(c)(1), TMDLs must identify any seasonal variation and the critical condition or period of each pollutant, if applicable.

DEQ reviewed available temperature data (**Table 5-2**) to determine seasonal temperature variation and the critical period (**Table 5-1**). The critical period is based on when 7DADM stream temperatures exceed the applicable temperature criteria.

Figure 5-1 through **Figure 5-32** show box-and-whisker plots (boxplots) of the seasonal 7DADM temperature variation and the critical period at select monitoring locations identified as having Category 5 temperature impairments on the 2022 Integrated Report. When multiple monitoring sites were available, the sites with multiple years of data were selected. Temperature data were grouped by the first and second half of each month. The month was split on the 15th with the first group including all results measured on the 1st through the 14th day and the second group including all results measured on the 15th through the end of the month. The boxplots are Tukey style boxplots with the middle line representing the median and the lower and upper ends of the box representing the temperature range between the first and third quartiles (25th to 75th percentile). The whiskers extend to values no further than 1.5 times the interquartile 7DADM temperature range (i.e., 1.5 times the difference between 25th and 75th percentiles). Any points beyond the whiskers represent individual 7DADM values beyond 1.5 times the interquartile range. The dashed line corresponds to the applicable temperature criteria. The shaded yellow area identifies the period when maximum 7DADM temperatures exceeded the applicable temperature criteria.

These plots show that maximum stream temperatures typically occur in July or August. This period usually coincides with the lowest monthly average stream flows, maximum solar radiation fluxes, and warmest ambient air temperature conditions. The warmest 7DADM temperatures were observed in the in the Beaver Creek Watershed. Monitoring data at Beaver Creek at Stark Street (**Figure 5-2**) show the median 7DADM temperature in 2014 and 2015 exceeded 25°C in the first half of July.

The period and frequency of temperature criteria exceedance vary by monitoring location. Monitoring locations in Beaver Creek and on the Bull Run River had the longest periods of exceedance. Near the mouth of Beaver Creek, 7DADM temperatures exceeded the applicable criteria from approximately March 15 through the end of November (**Figure 5-1**). Exceedances occurred approximately May 1 through November 15 in the Bull Run River at Larson's bridge (**Figure 5-12**). At other monitoring sites the earliest exceedances occurred in May (e.g., Gordon Creek (**Figure 5-22**), Big Creek (**Figure 5-10**), Sandy River (**Figure 5-29**), and Salmon River (**Figure 5-28**)), and the latest exceedances occurred at the end of October (e.g., Kelly Creek (**Figure 5-9**), Bull Run River (**Figure 5-11**), and Little Sandy River (**Figure 5-26**)).

DEQ uses the critical period to determine when allocations apply. In setting this period, DEQ relied upon monitoring sites with the longest periods of exceedance. When downstream monitoring sites have longer exceedance periods relative to upstream waters, the longer period is used as the critical period for upstream waterbodies. This is a margin of safety to ensure warming of upstream waters does not contribute to downstream exceedances.

The frequency of exceedance was also considered. If any individual 7DADM temperatures beyond 1.5 times the interquartile range exceeded the criterion (shown as points on the boxplots), that period was not always included in the critical period. These 7DADM values represent approximately 2% or fewer of all observations in that 15-day period.

The critical periods for waterbodies in the Lower Columbia-Sandy Subbasin are presented in **Table 5-1**. Based on review of available temperature data, the overall critical period is May 1 through October 31 on all waterbodies in the Lower Columbia-Sandy Subbasin except those within the Bull Run River Watershed (HUC 1708000105) and Beaver Creek-Sandy Subwatershed (HUC 170800010703). For waterbodies in the Bull Run River Watershed, the critical period is May 1 through November 15. For waterbodies located in the Beaver Creek-Sandy Subwatershed, the critical period is March 15 through November 15. Allocations presented in the TMDL apply during these periods.

Table 5-1: Designated critical periods for Lower Columbia-Sandy Subbasin waterbodies.

HUC	Watershed name	Critical period
17090001	Lower Columbia-Sandy Subbasin except Bull Run River Watershed and Beaver Creek-Sandy Subwatershed	May 1 – October 31
1708000105	Bull Run River Watershed	May 1 – November 15
170800010703	Beaver Creek-Sandy Subwatershed	March 15 – November 15

Table 5-2: Water temperature monitoring locations and periods used to determine seasonal temperature variation and critical periods for the Lower Columbia-Sandy Subbasin.

Monitoring location ID	Monitoring location	Monitoring period	Number of 7DADM values
14140000	Bull Run River Near Bull Run (River Only), OR	01/01/02 - 09/30/06	1734
14140020	Bull Run R at Larson's Bridge, Near Bull Run, OR	05/30/06 - 12/31/22	5858
14141500	Little Sandy River Near Bull Run, OR	06/01/06 - 12/31/22	5957
COG_BeaveratGlenO	Beaver Creek @ Glen Otto park	06/08/13 - 10/01/19	680
COG_BeaveratStark	Beaver Creek @ Stark Street	05/17/14 - 10/20/15	309
COG_BeaverUSKelly	Beaver Creek upstream of confluence with Kelly Creek	05/29/15 - 10/05/21	1070
COG_BurlatHogan	Burlingame Creek @ Hogan Road	06/14/12 - 10/01/19	680
COG_KCl1	Kelly Creek downstream of MHCC pond	07/22/08 - 10/05/21	1262
CRGNSA-001	Benson Lake_be20_LTWT	07/01/08 - 08/06/08	37
CRGNSA-008	McCord Water Temp Monitor	07/23/14 - 10/15/14	85
CRGNSA-009	Moffett Water Temperature Monitor	07/23/14 - 10/15/14	85
CRGNSA-011	Multnomah Creek mu15_LTWT	07/01/08 - 10/24/11	325
CRGNSA-012	Multnomah Creek Upper mu40_LTWT	06/04/08 - 08/29/17	200
EMSWCD_BCB	Beaver Creek North Fork @ 302nd Ave	06/20/13 - 10/10/19	558
EMSWCD_Beaver_Cory	Beaver Creek @ confluence of North and South Forks	05/30/14 - 10/10/19	943
EMSWCD_Beaver_Freuler	Beaver Creek South Fork downstream of BCC	05/19/16 - 10/10/19	438
EMSWCD_Big_Black	Big Creek @ Hurlburt Rd.	05/19/16 - 10/10/19	445
MHNF-016	Cedar Cr. Water Temp Probe #1	07/03/12 - 10/03/12	93
MHNF-050	Little Sandy R at Bull Run_LTWT	07/09/04 - 10/06/20	1618
MHNF-052	Little Sandy R Homestead_LTWT	07/07/04 - 10/19/20	2735
MHNF-077	Salmon R at Forest Boundary_LTWT	07/18/04 - 09/25/20	1854
MHNF-078	Salmon River trap WT site	10/26/11 - 06/09/20	2057
MHNF-080	Sandy R at Forest Boundary_LTWT	07/17/04 - 09/13/19	1640
MHNF-099	ZigZag R at Forest Boundary_LTWT	05/17/06 - 09/29/20	1845

Monitoring location ID	Monitoring location	Monitoring period	Number of 7DADM values
PWB_Beavr_Canyn	In Beaver Creek Canyon near site of old upstream footbridge	10/20/11 - 05/06/19	2506
PWB_BR_BWMN_BR	20 feet downstream of Bowman's Bridge	06/29/15 - 10/28/18	352
PWB_BR_DODGE	Approximately 500 feet upstream of Sandy River confluence	08/18/15 - 10/18/17	225
PWB_BR_SS_BR	Approximately 60 feet upstream of Rd 14 (Southside) bridge	07/17/14 - 10/26/18	455
PWB_D2_LampB	Immediately upstream of Lamprey Barrier	02/26/14 - 09/09/20	1880
PWB_Gordon_Mouth	Approximately 600 feet upstream of Gordon Creek Rd bridge	07/08/12 - 11/03/19	2252
PWB_SR_US_BR	Approximately 1,900 ft upstream of Bull Run River confluence	08/18/15 - 10/24/18	332
Sandy_3.0	Sandy River Above Beaver Creek	07/16/16 - 09/22/16	69

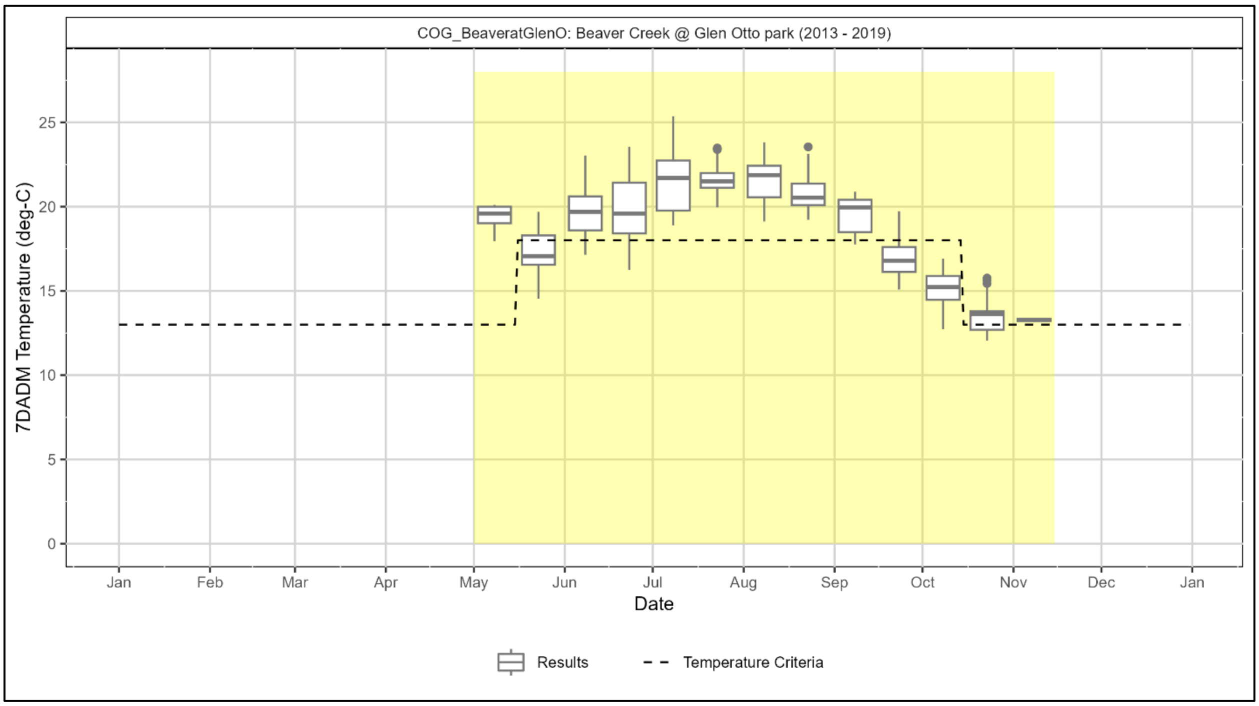

Figure 5-1: Seasonal variation at the Beaver Creek at Glen Otto Park temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

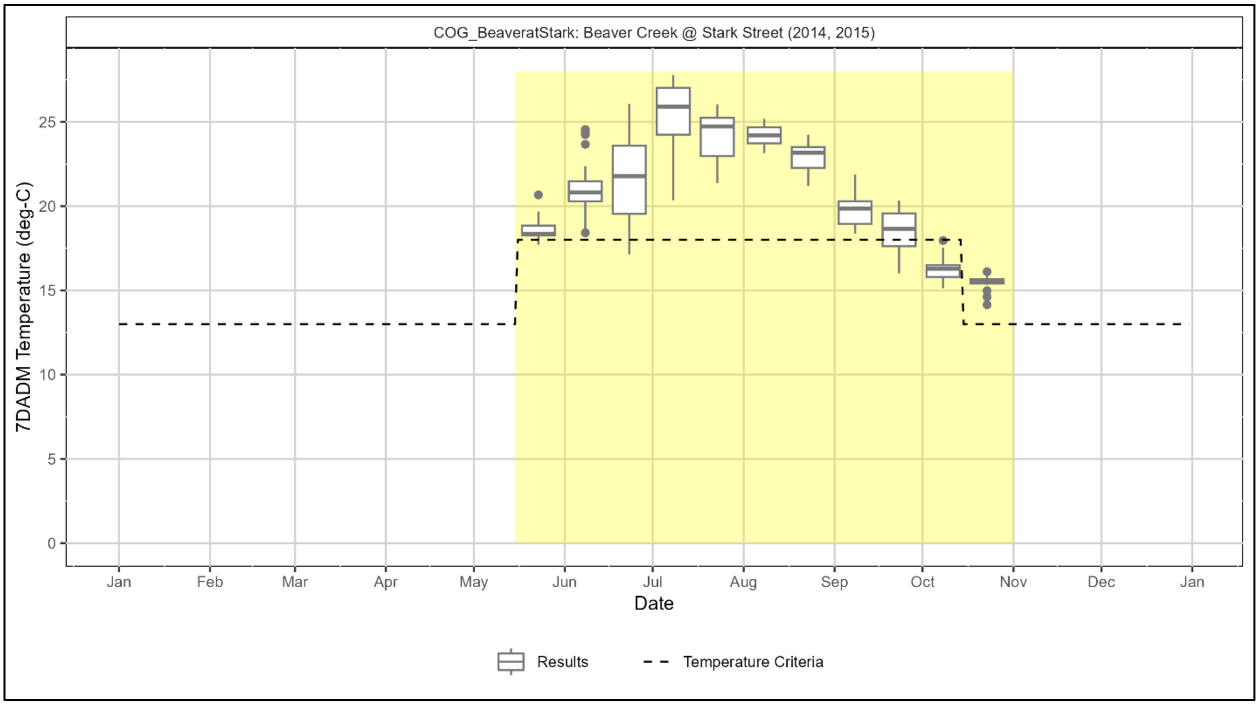

Figure 5-2: Seasonal variation at the Beaver Creek at Stark Street temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

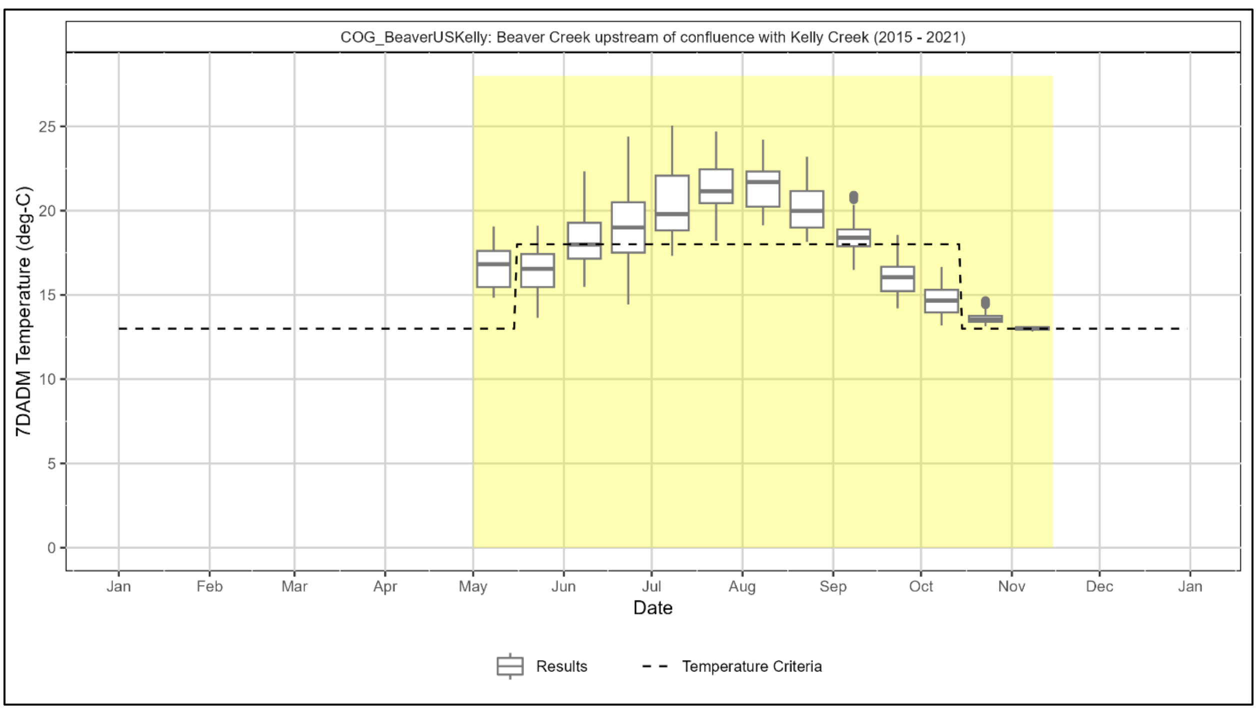

Figure 5-3: Seasonal variation at the Beaver Creek upstream of Kelly Creek temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

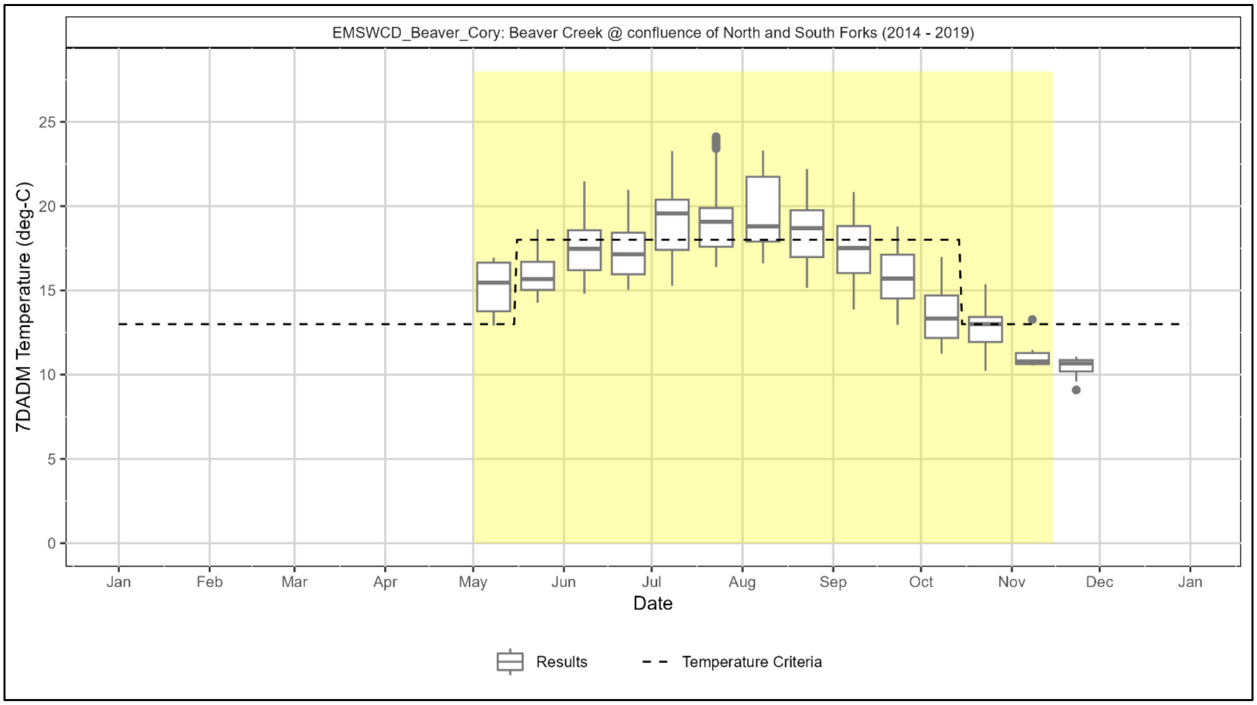

Figure 5-4: Seasonal variation at the Beaver Creek at the confluence of the North and South Forks temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

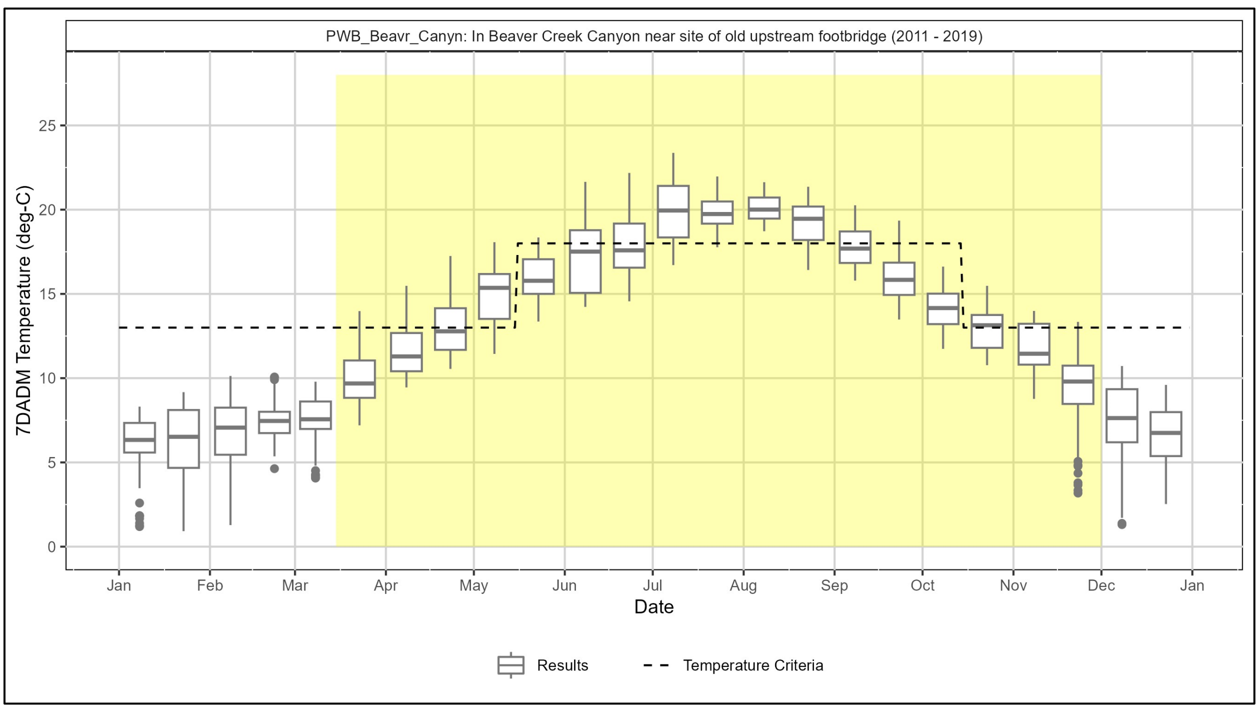

Figure 5-5: Seasonal variation at the Beaver Creek in Beaver Canyon temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

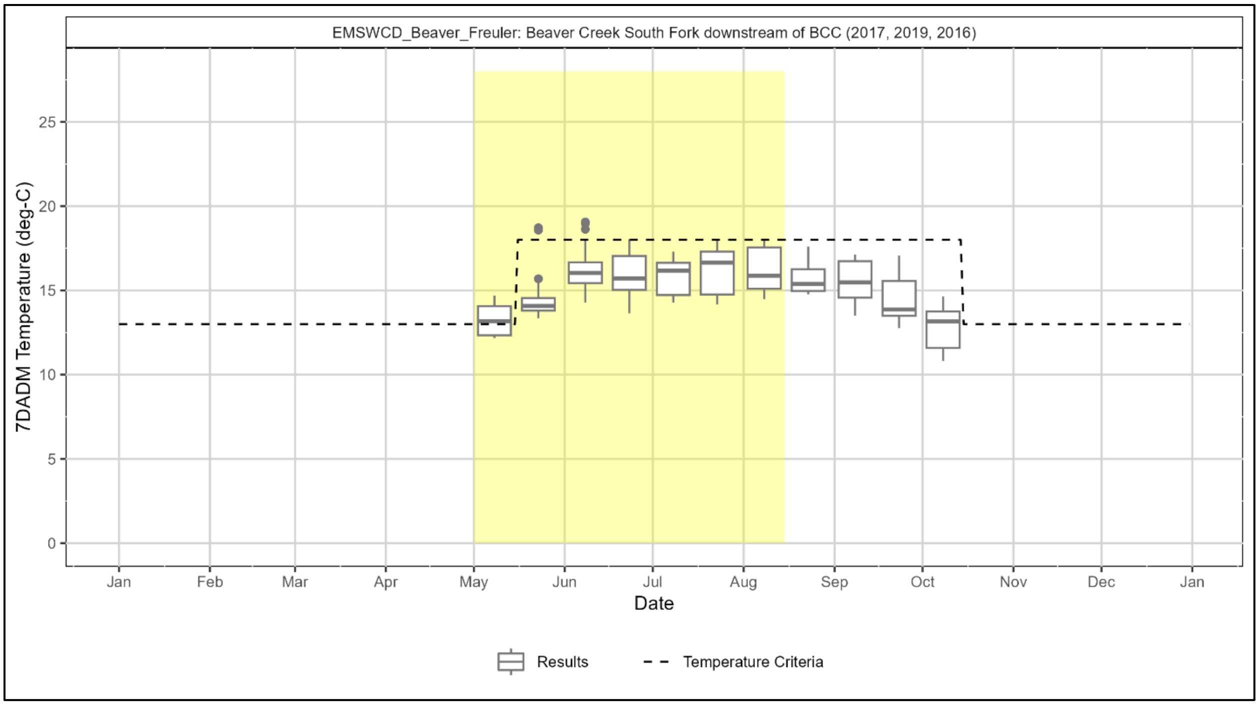

Figure 5-6: Seasonal variation at the South Fork Beaver Creek downstream of confluence with Middle Fork Beaver Creek temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

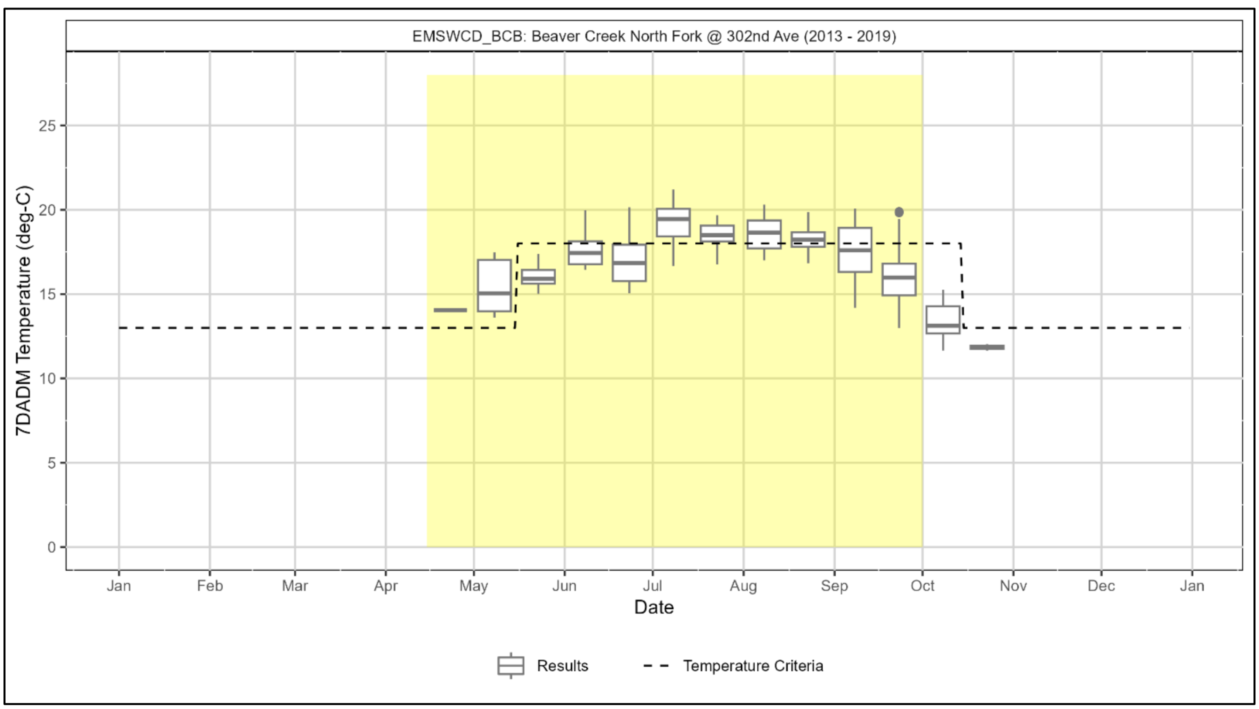

Figure 5-7: Seasonal variation at the Beaver Creek North Fork at 302nd Avenue temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

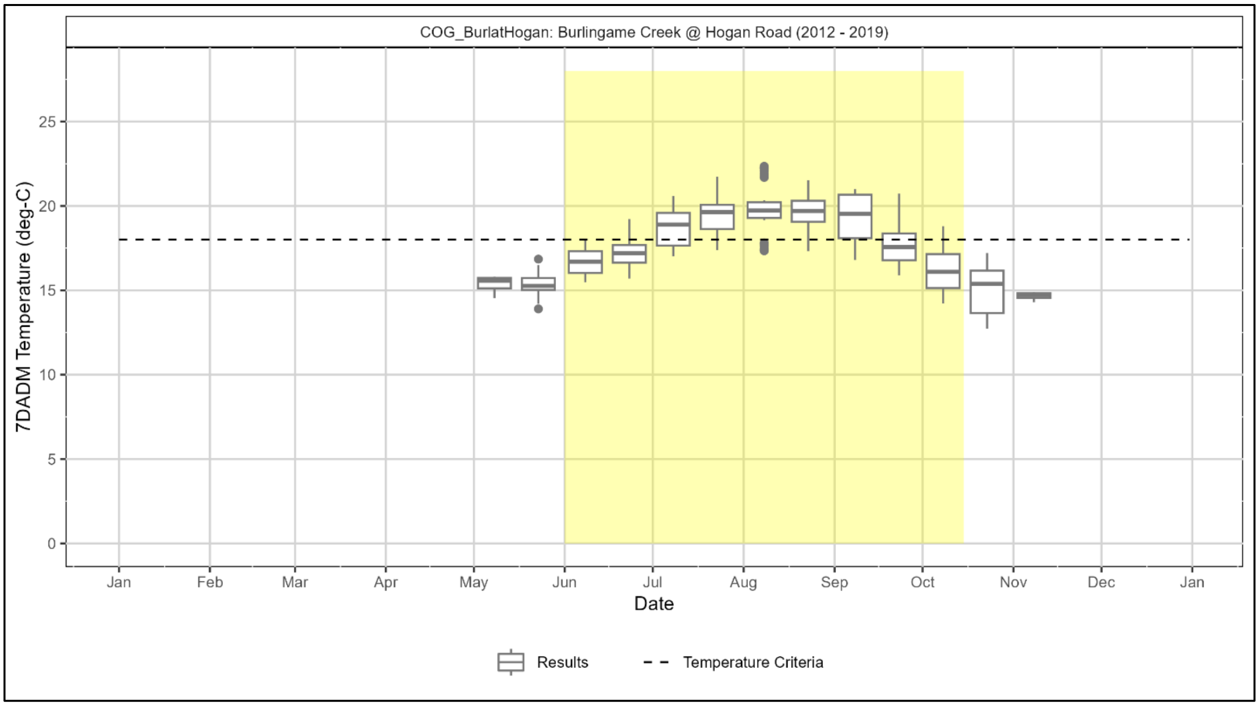

Figure 5-8: Seasonal variation at the Burlingame Creek at Hogan Road temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

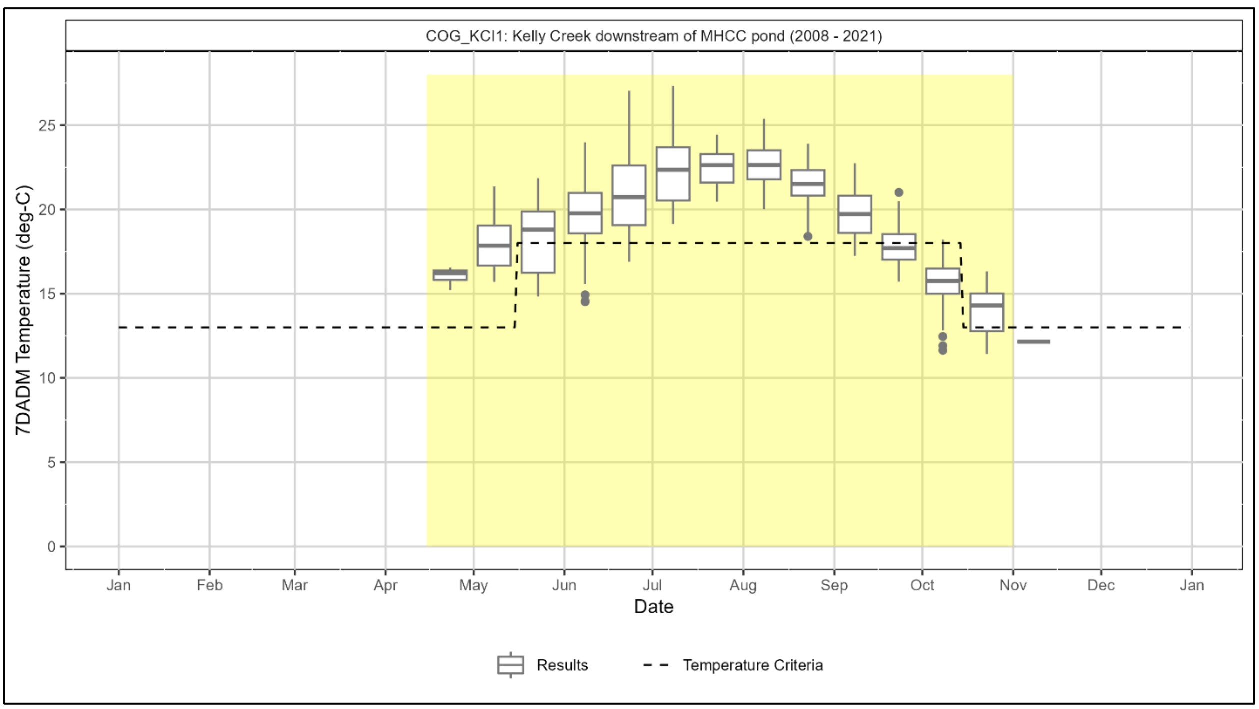

Figure 5-9: Seasonal variation at the Kelly Creek downstream of Mount Hood Community College Pond temperature monitoring site in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

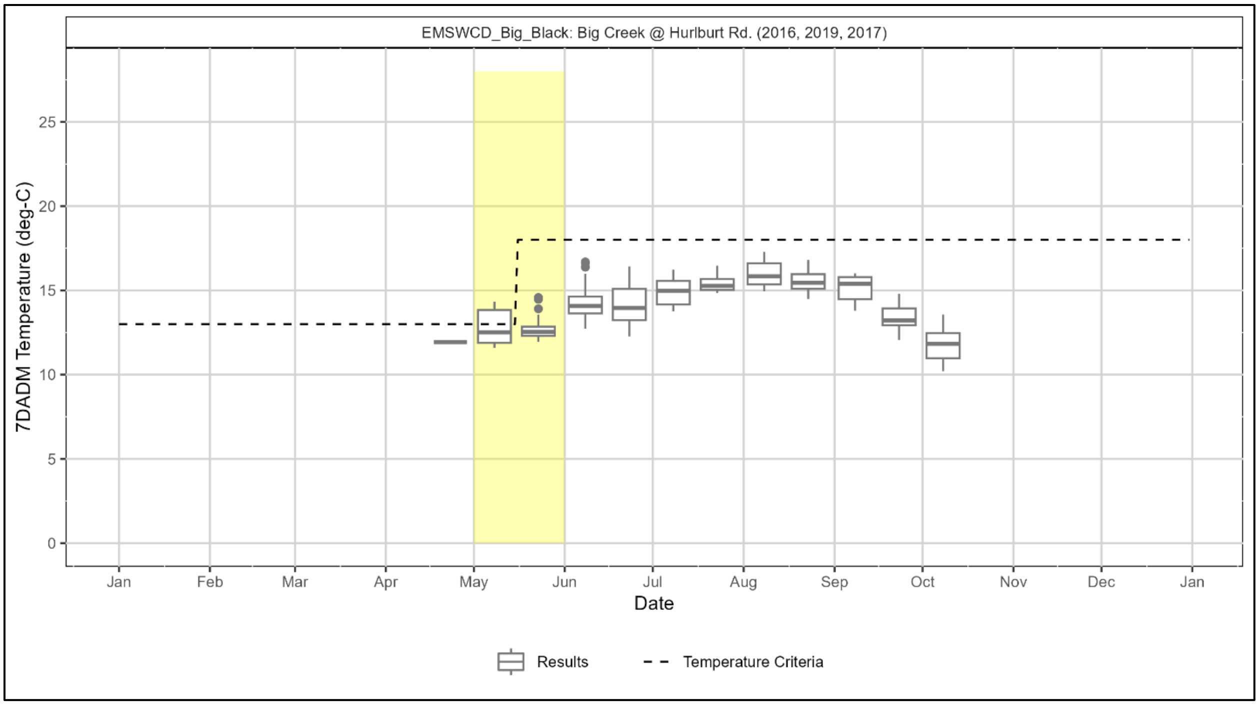

Figure 5-10: Seasonal variation at the Big Creek at Hurlburt Road temperature monitoring site on Big Creek.

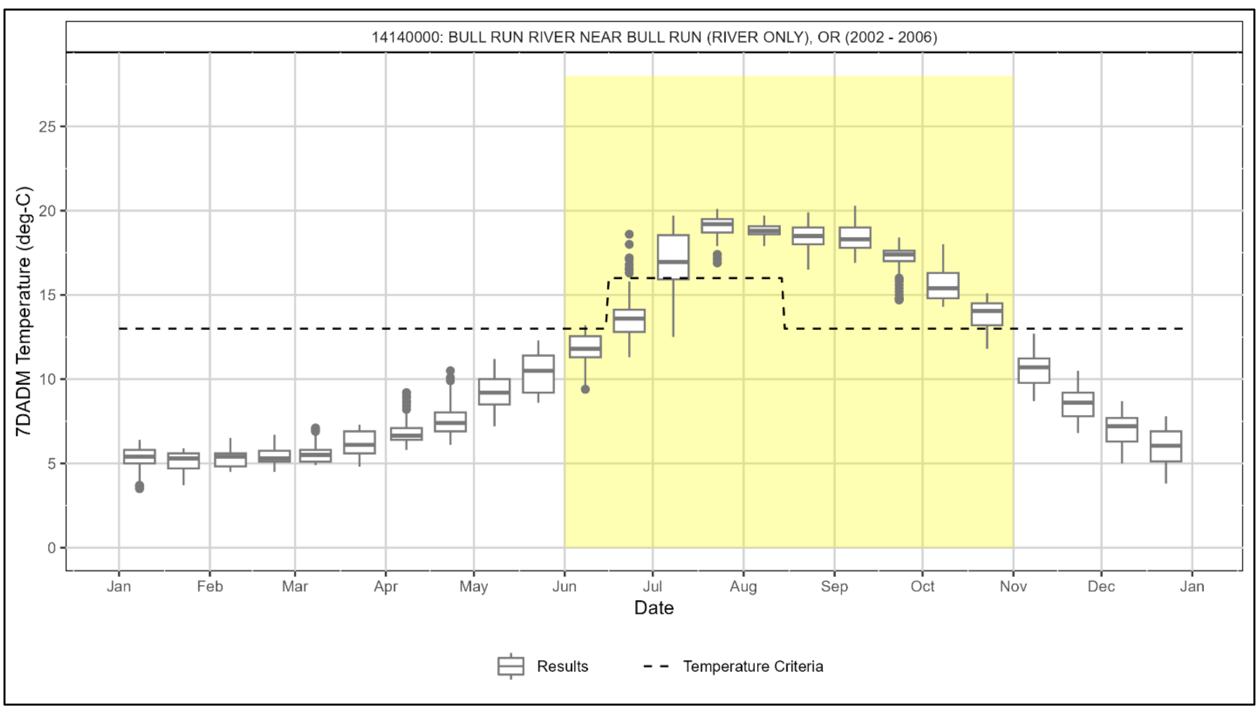

Figure 5-11: Seasonal variation at the Bull Run River near Bull Run temperature monitoring site on the Bull Run River.

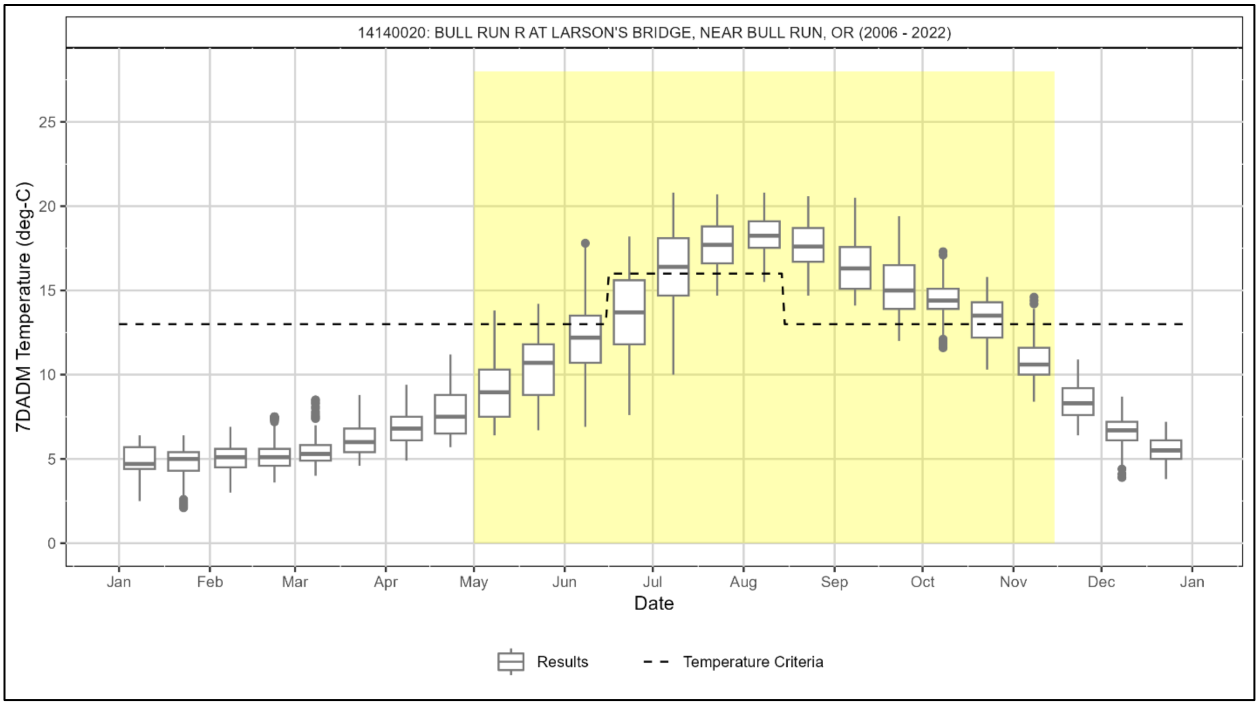

Figure 5-12: Seasonal variation at the Bull Run River at Larson's Bridge temperature monitoring site on the Bull Run River.

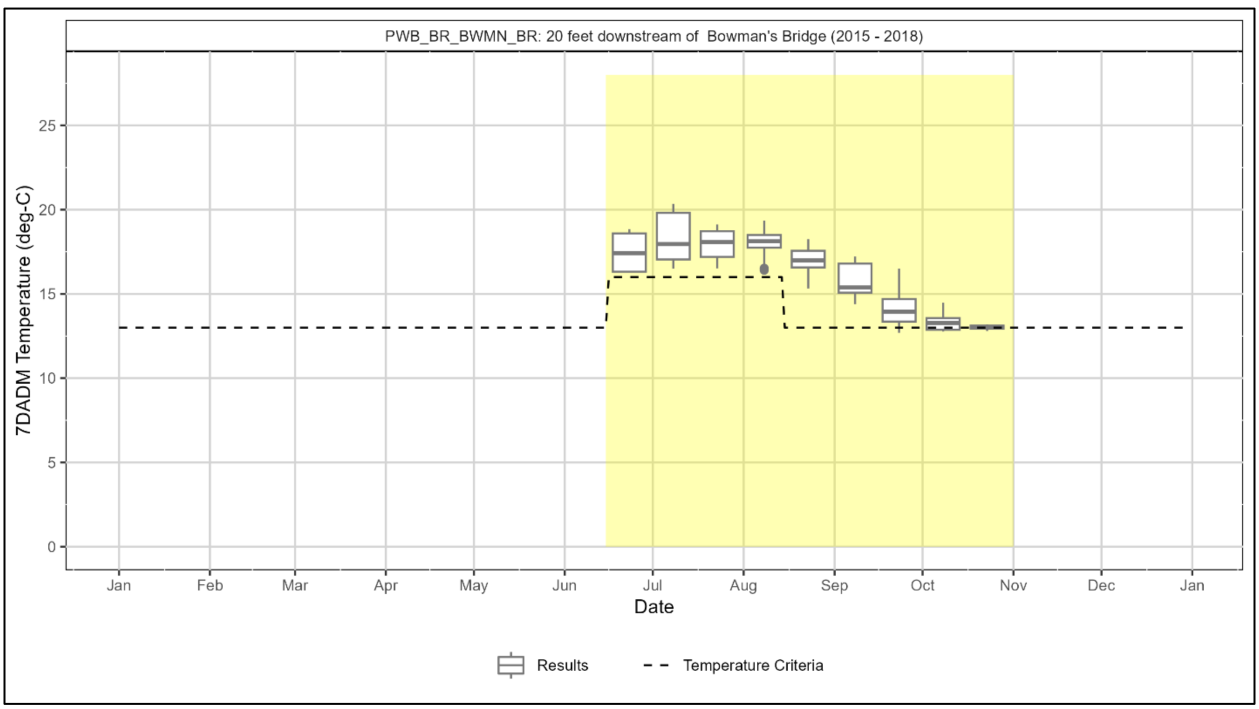

Figure 5-13: Seasonal variation at the Bull Run River downstream of Bowman's Bridge temperature monitoring site on the Bull Run River.

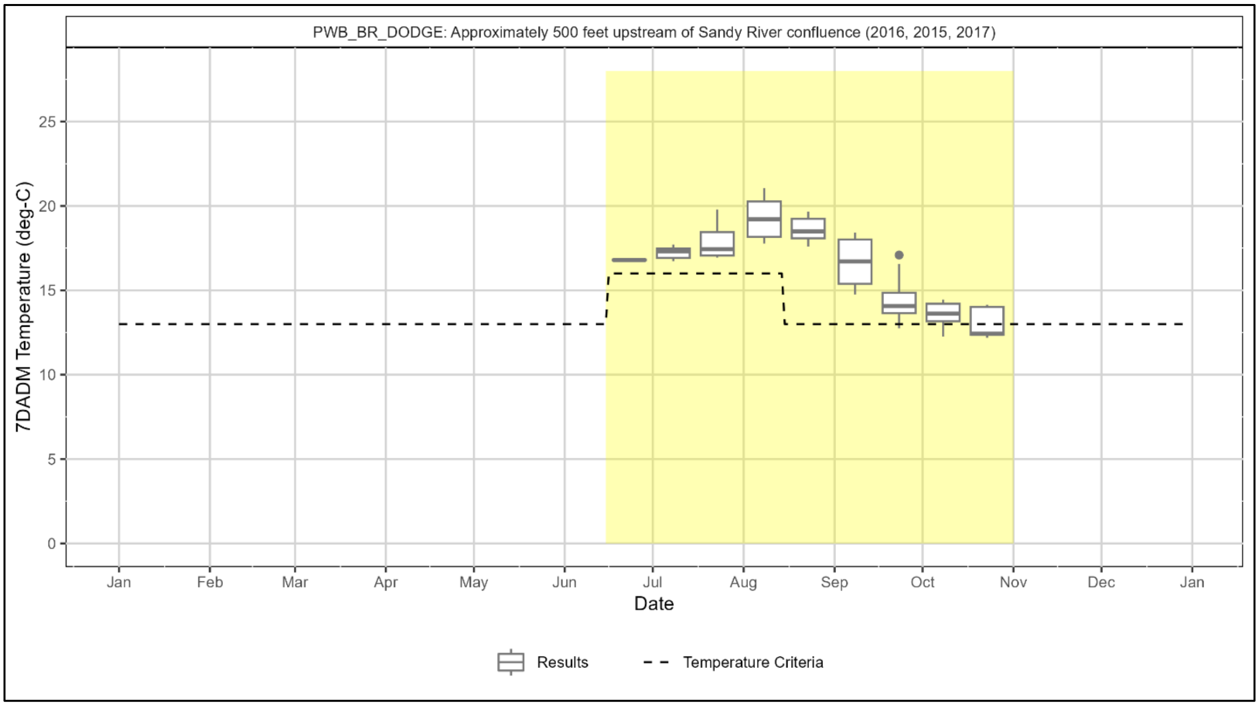

Figure 5-14: Seasonal variation at the Bull Run River upstream of Sandy River confluence temperature monitoring site on the Bull Run River.

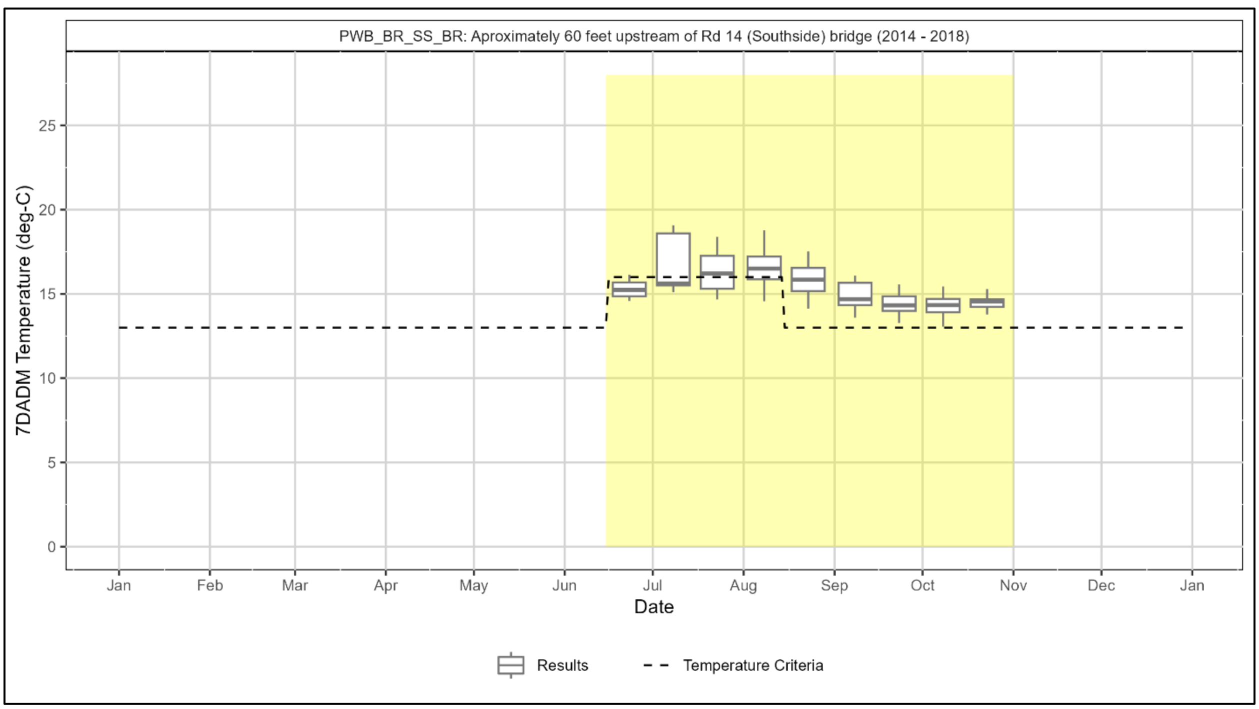

Figure 5-15: Seasonal variation at the Bull Run River upstream of Road 14 temperature monitoring site on the Bull Run River.

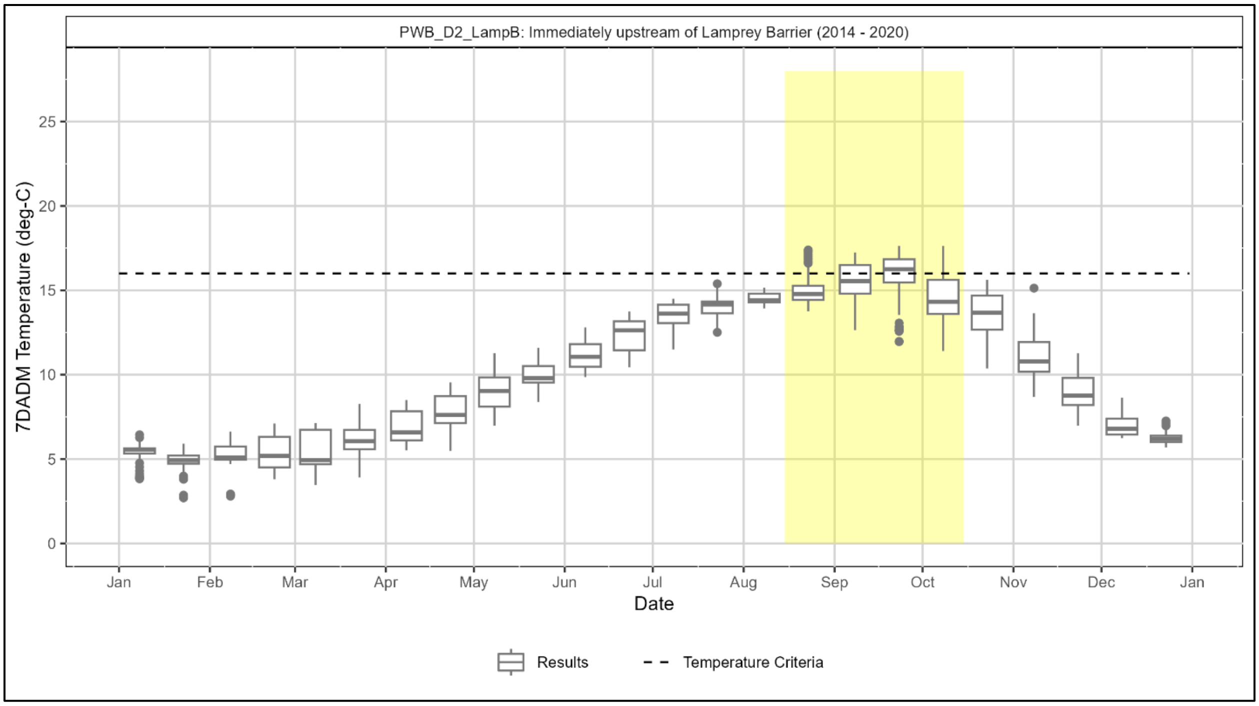

Figure 5-16: Seasonal variation at the Bull Run River downstream of lamprey barrier temperature monitoring site on the Bull Run River.

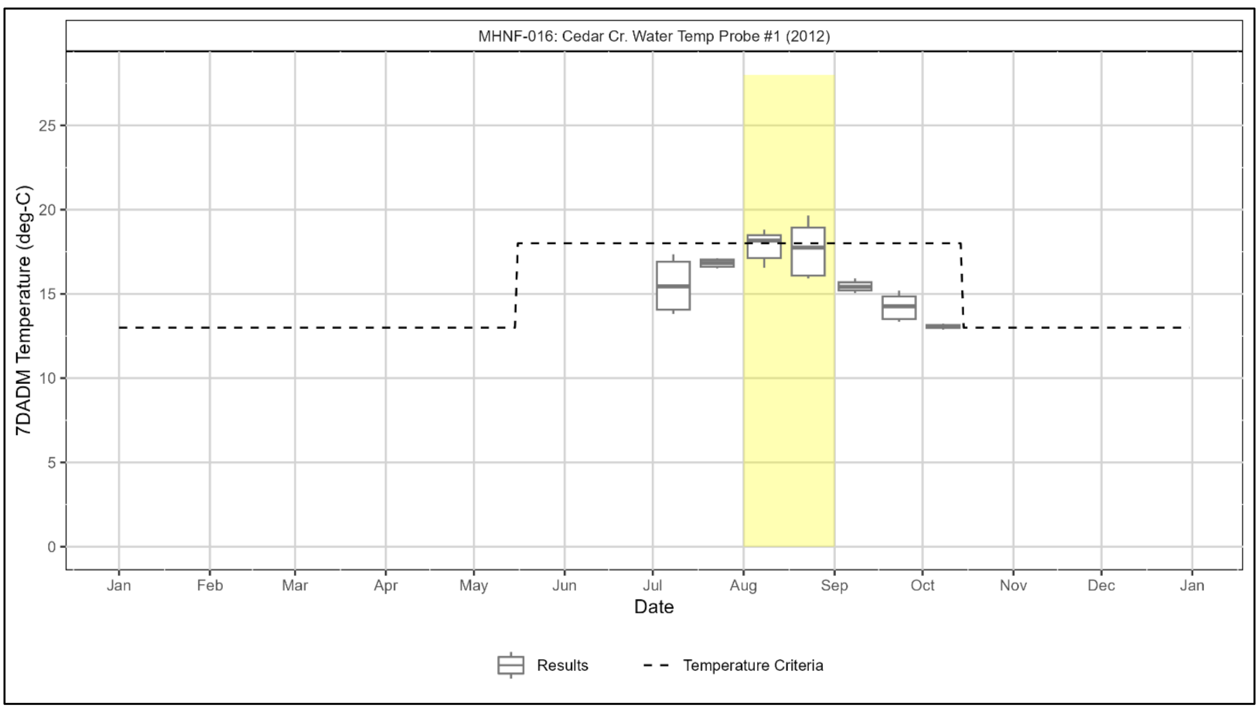

Figure 5-17: Seasonal variation at the Cedar Creek Water Temp Probe #1 temperature monitoring site on Cedar Creek.

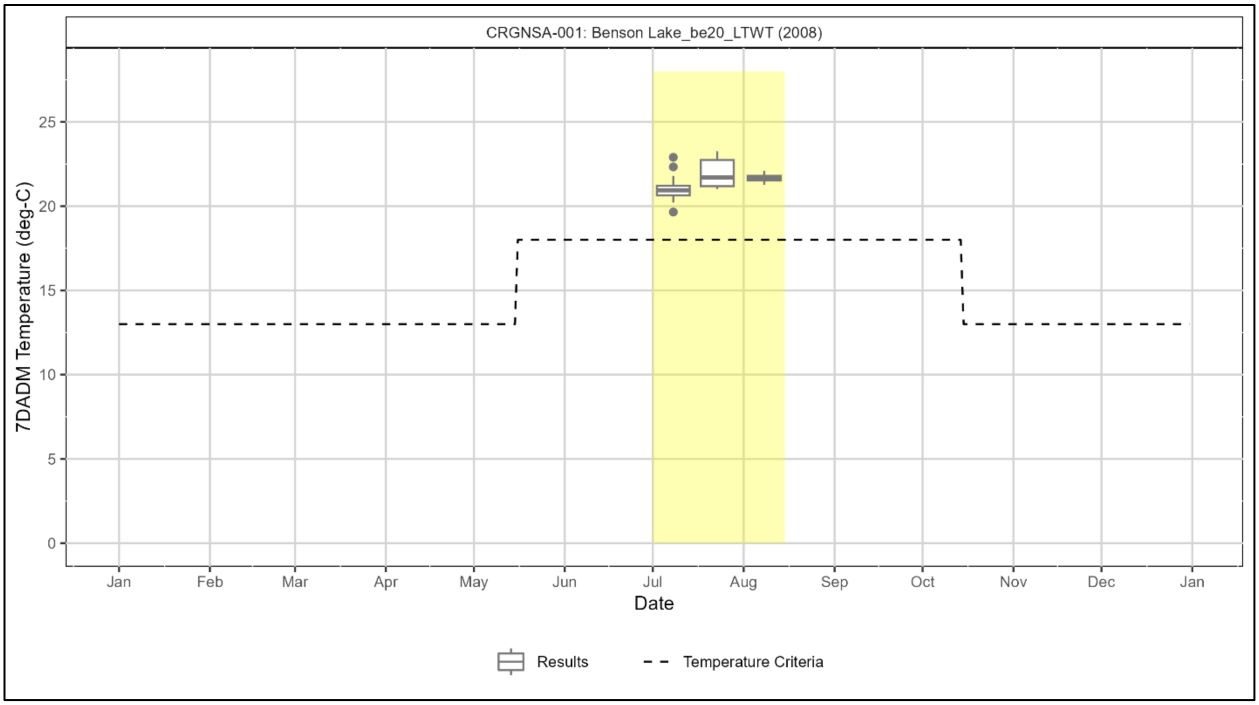

Figure 5-18: Seasonal variation at the Benson Lake temperature monitoring site on a Columbia gorge tributary flowing into the Columbia River.

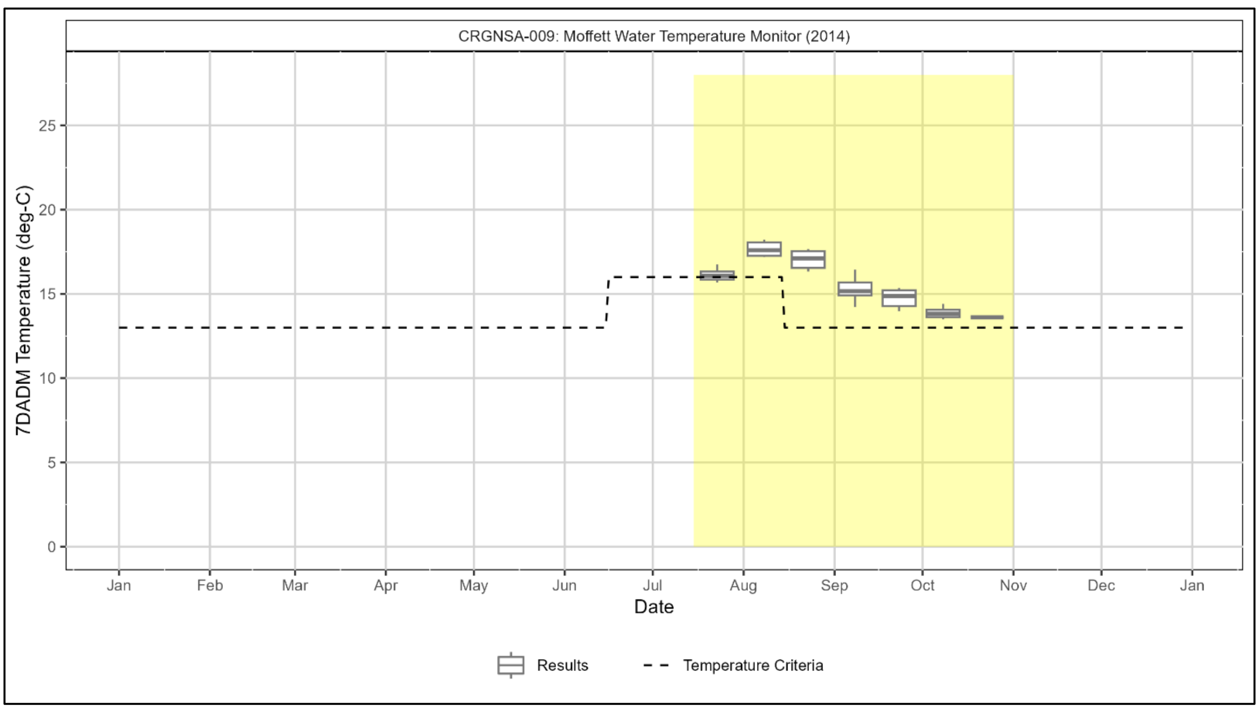

Figure 5-19: Seasonal variation at the Moffett Creek near mouth temperature monitoring site on the Moffett Creek tributary flowing into the Columbia River.

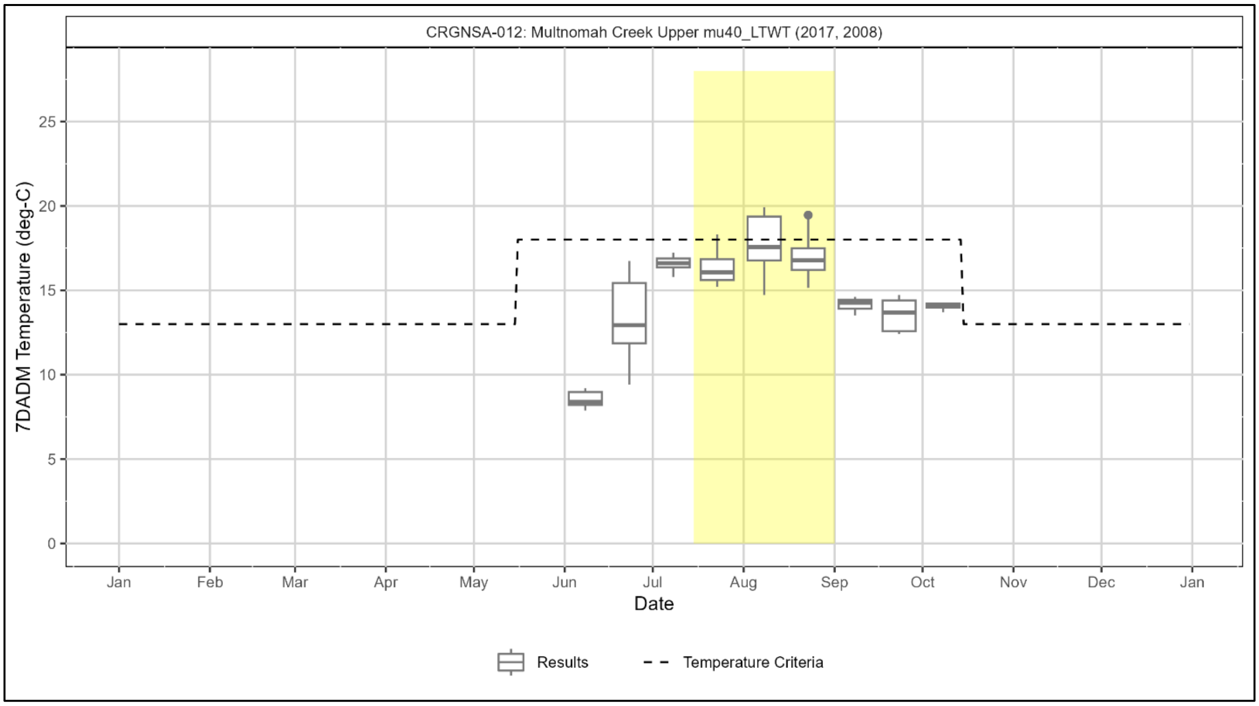

Figure 5-20: Seasonal variation at the Multnomah Creek upstream of Benson Lake temperature monitoring site on a Columbia gorge tributary flowing into the Columbia River.

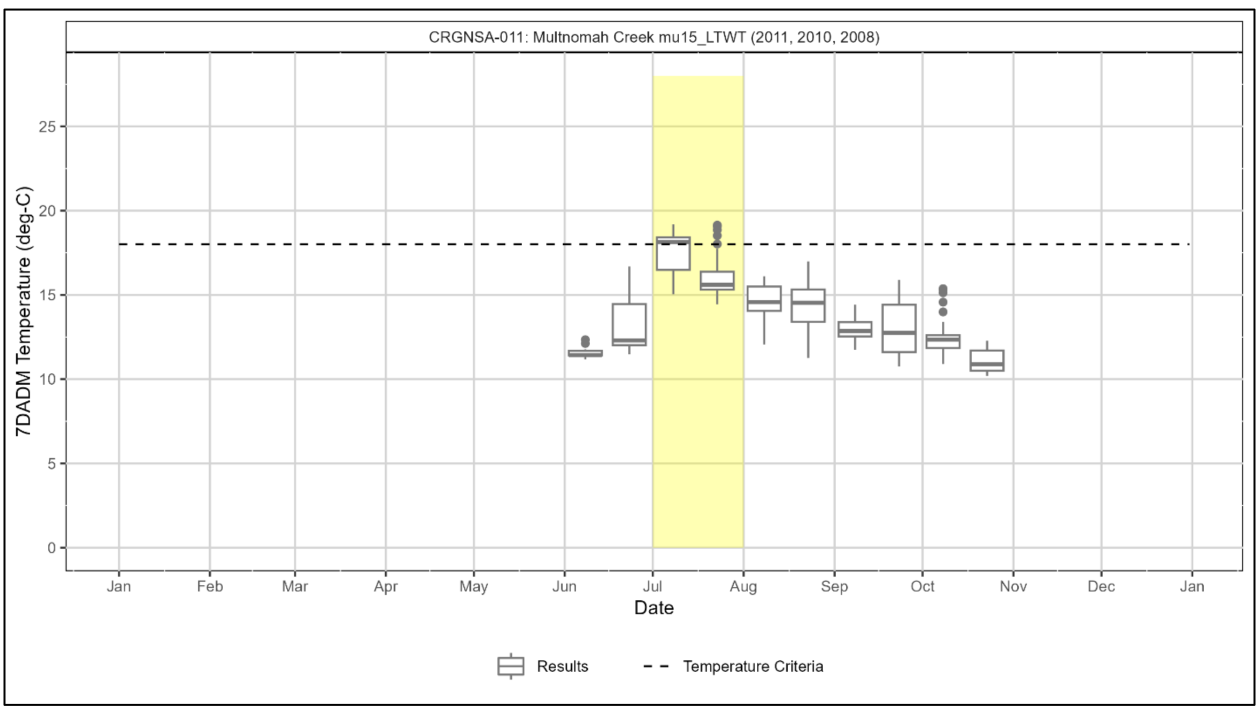

Figure 5-21: Seasonal variation at the Multnomah Creek downstream of Benson Lake temperature monitoring site on a Columbia gorge tributary flowing into the Columbia River.

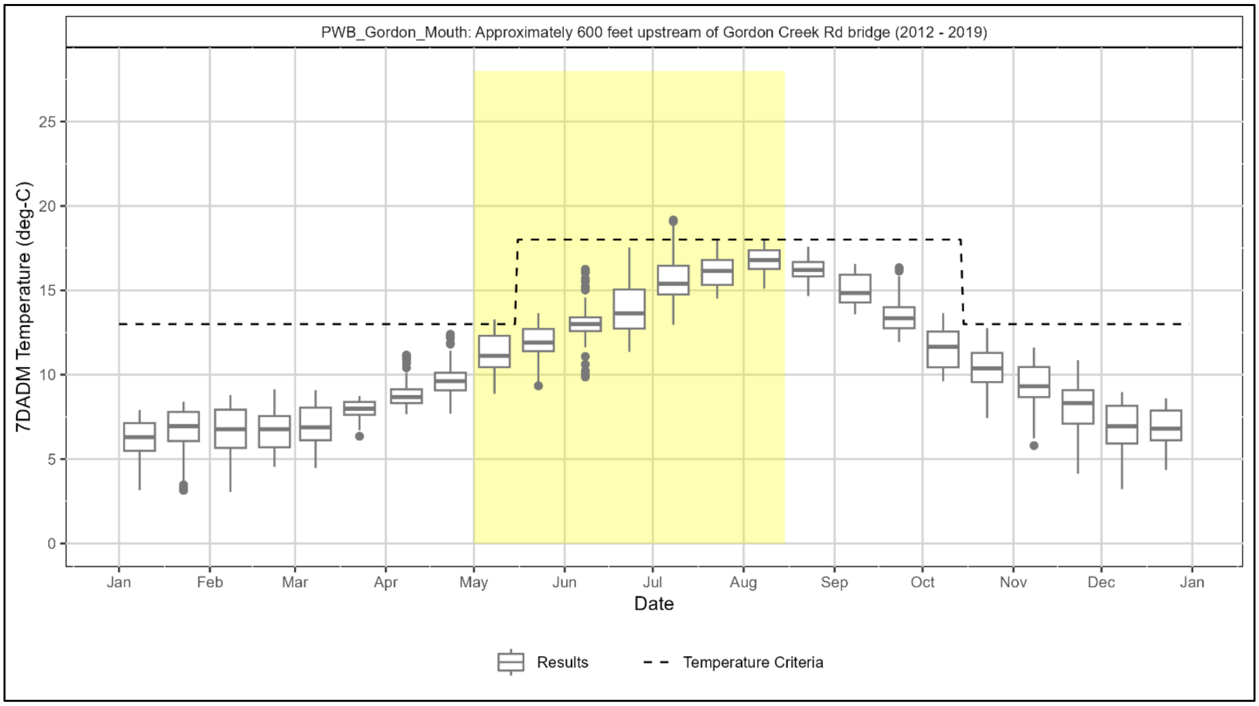

Figure 5-22: Seasonal variation at the Gordon Creek upstream of mouth temperature monitoring sites on Gordon Creek.

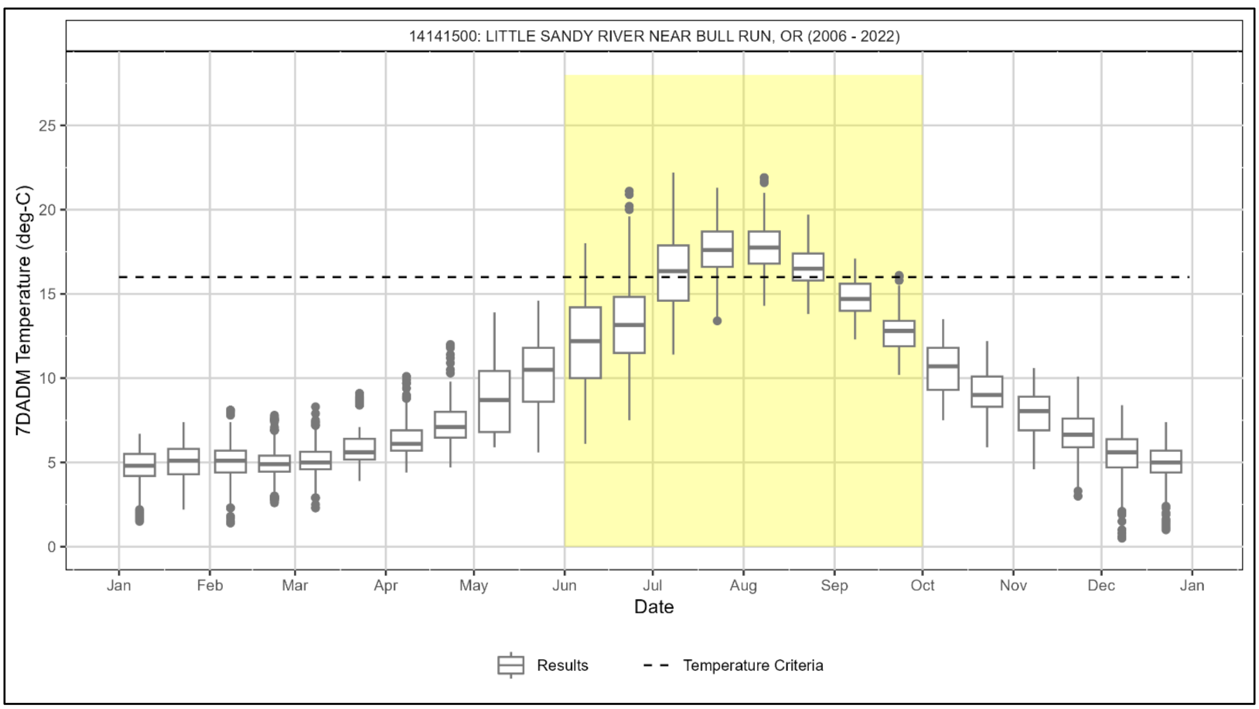

Figure 5-23: Seasonal variation at the Little Sandy River near Bull Run temperature monitoring site on the Little Sandy River.

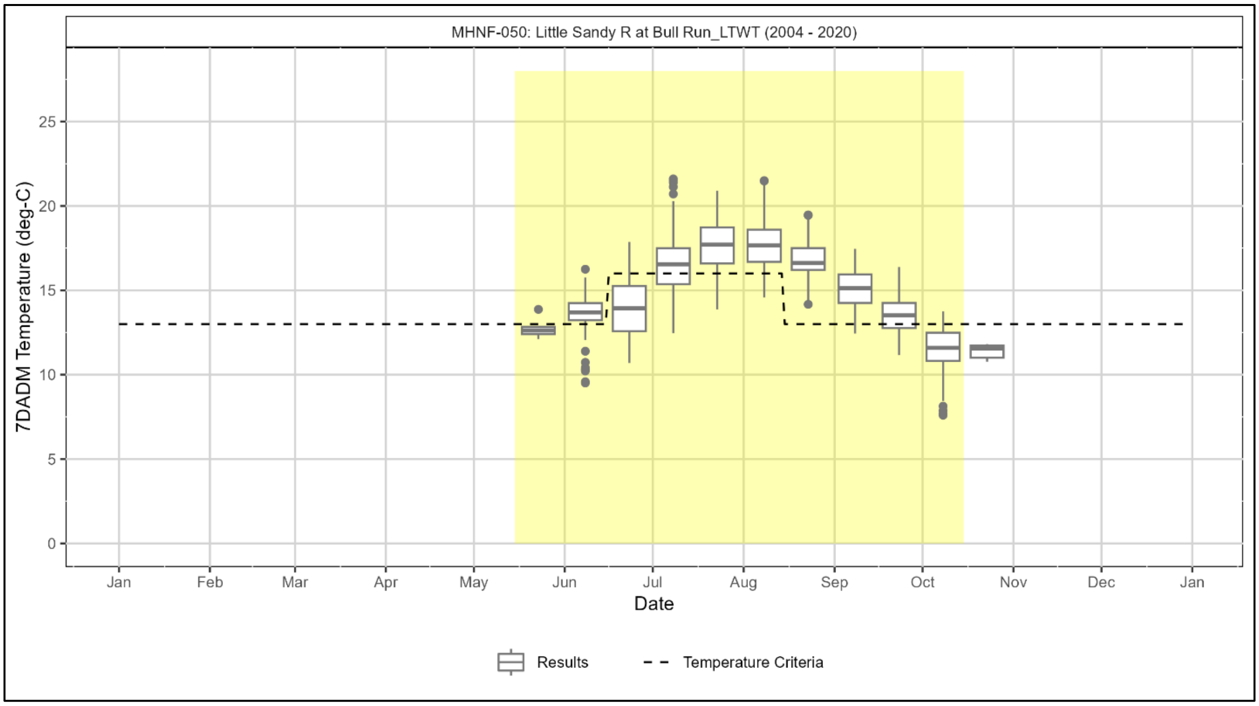

Figure 5-24: Seasonal variation at the Little Sandy River at the confluence with the Bull Run River temperature monitoring site on the Little Sandy River.

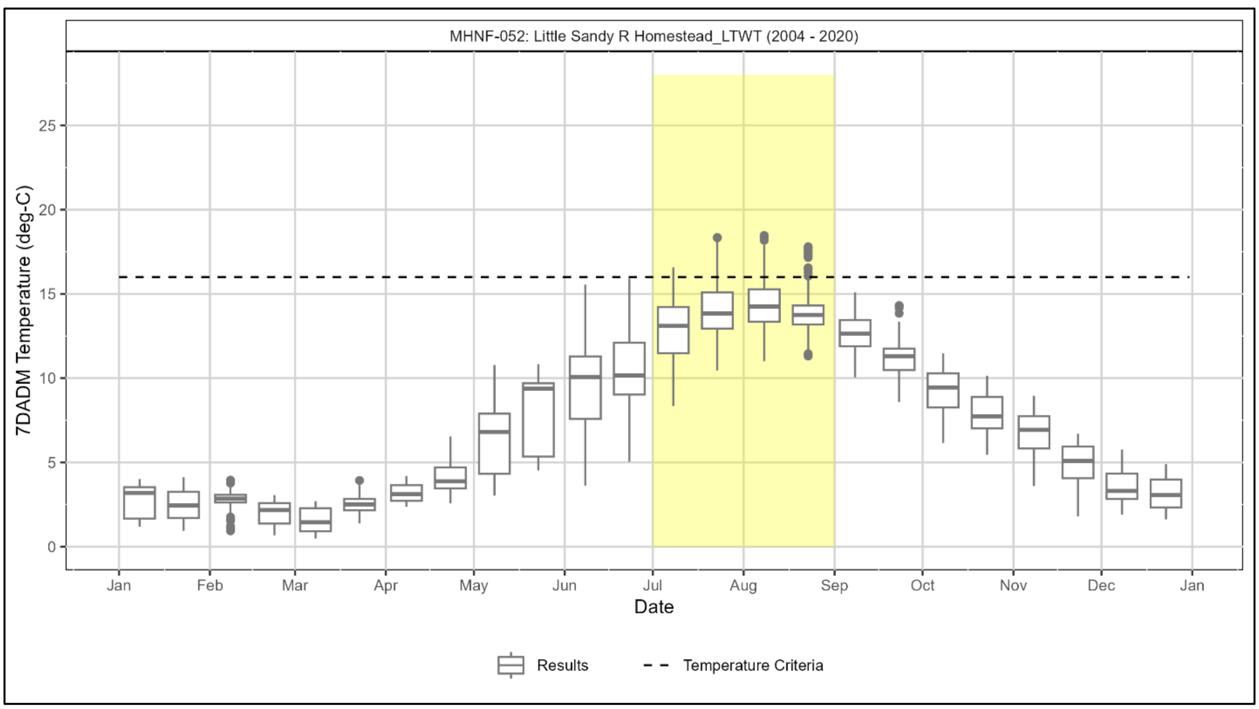

Figure 5-25: Seasonal variation at the Little Sandy River near Bull Run temperature monitoring site on the Little Sandy River.

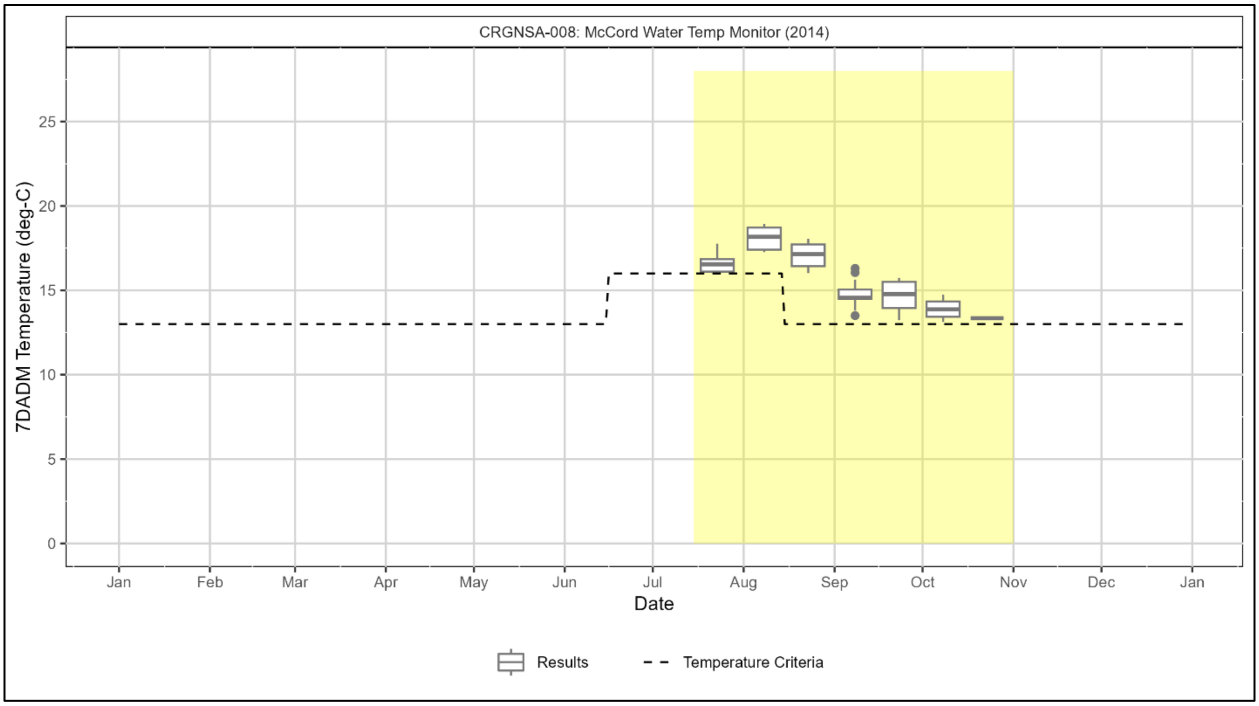

Figure 5-26: Seasonal variation at the Little Sandy River near Homestead temperature monitoring site on the Little Sandy River.

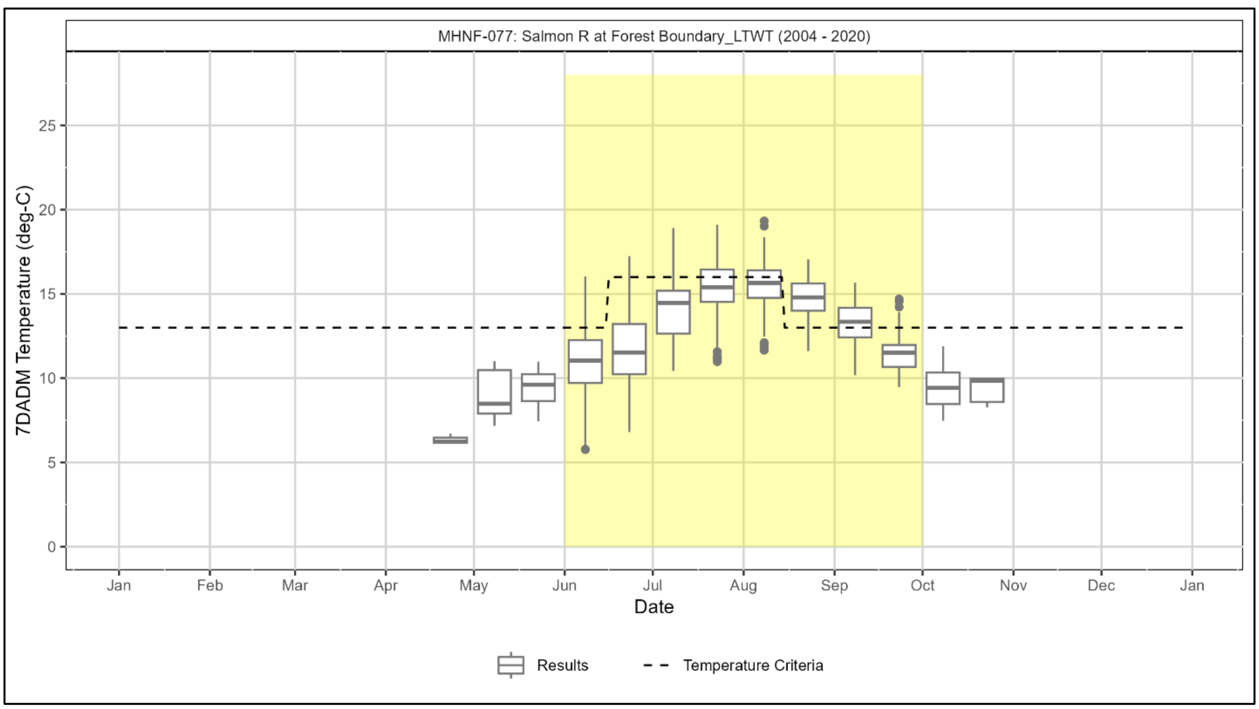

Figure 5-27: Seasonal variation at the Salmon River at forest boundary temperature monitoring site on the Salmon River.

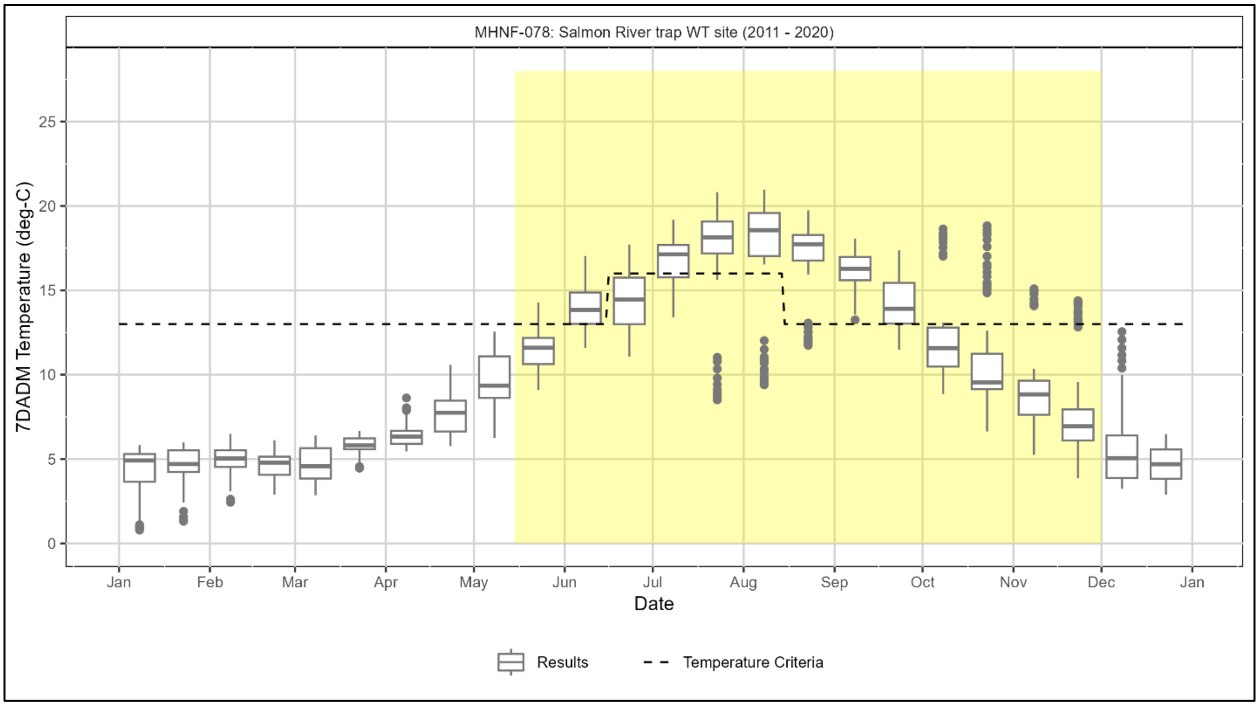

Figure 5-28: Seasonal variation at the Salmon River trap temperature monitoring site on the Salmon River.

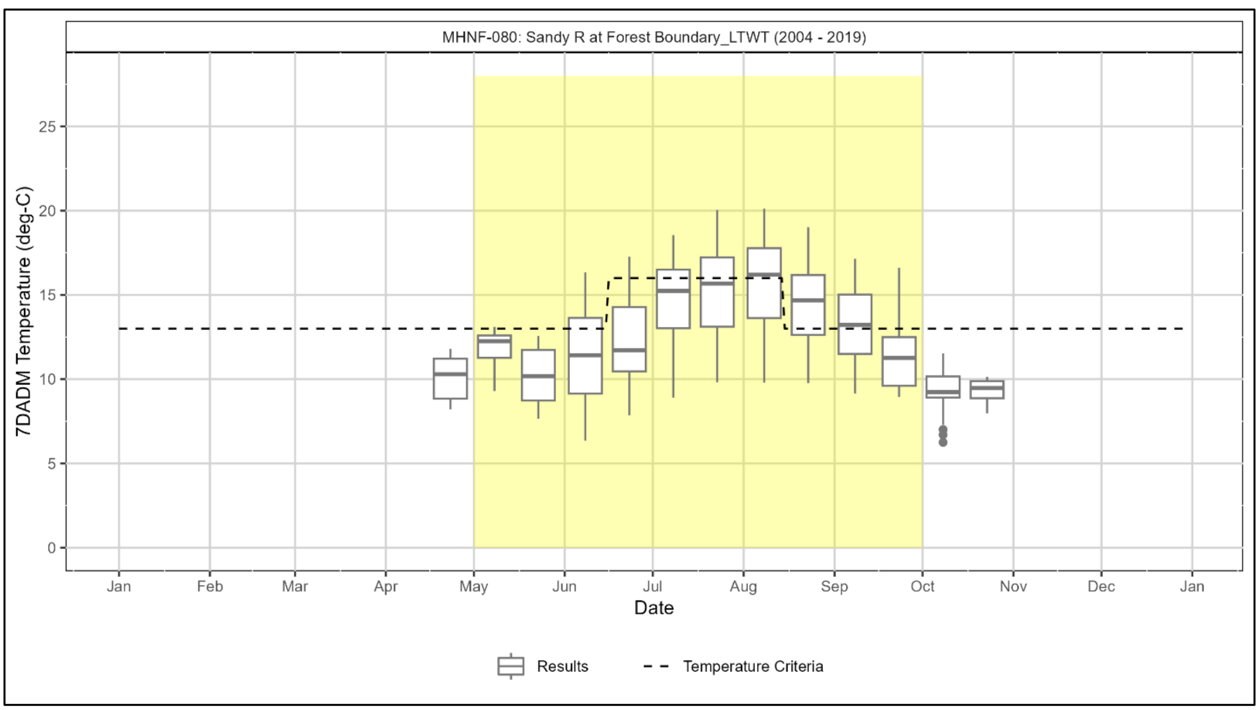

Figure 5-29: Seasonal variation at the Sandy River at forest boundary temperature monitoring site on the Sandy River.

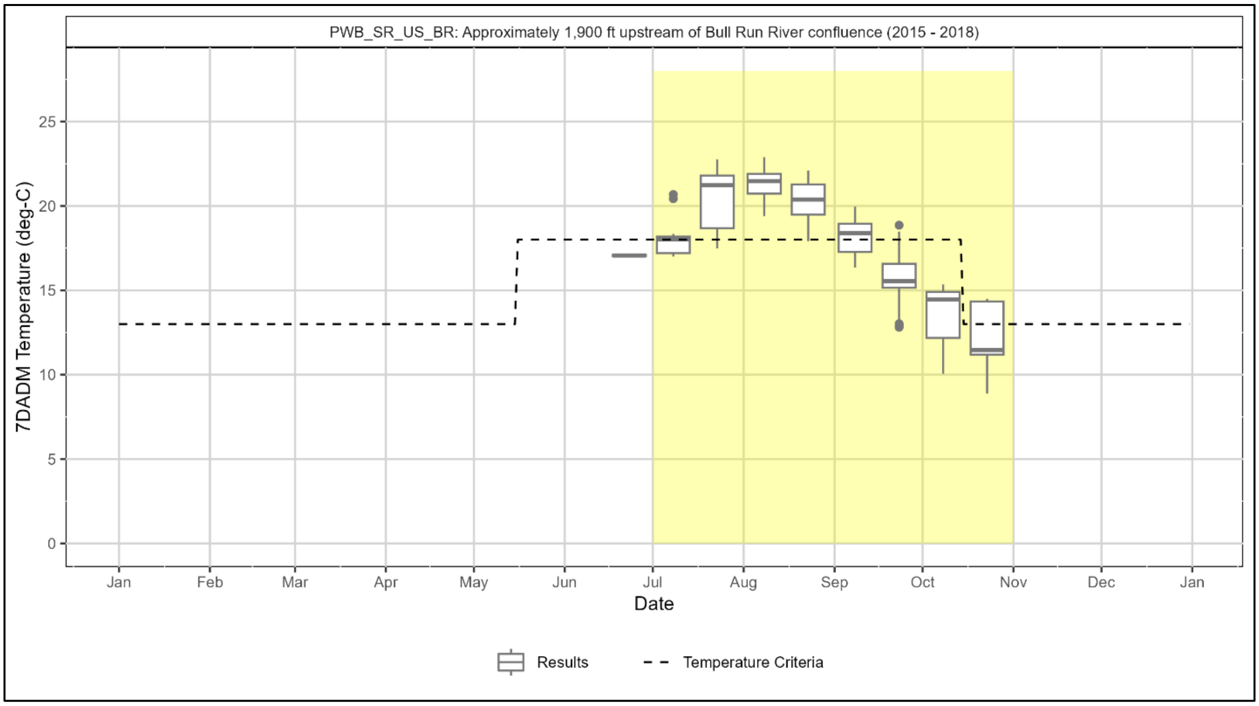

Figure 5-30: Seasonal variation at the Sandy River upstream of Bull Run River confluence temperature monitoring site on the Sandy River.

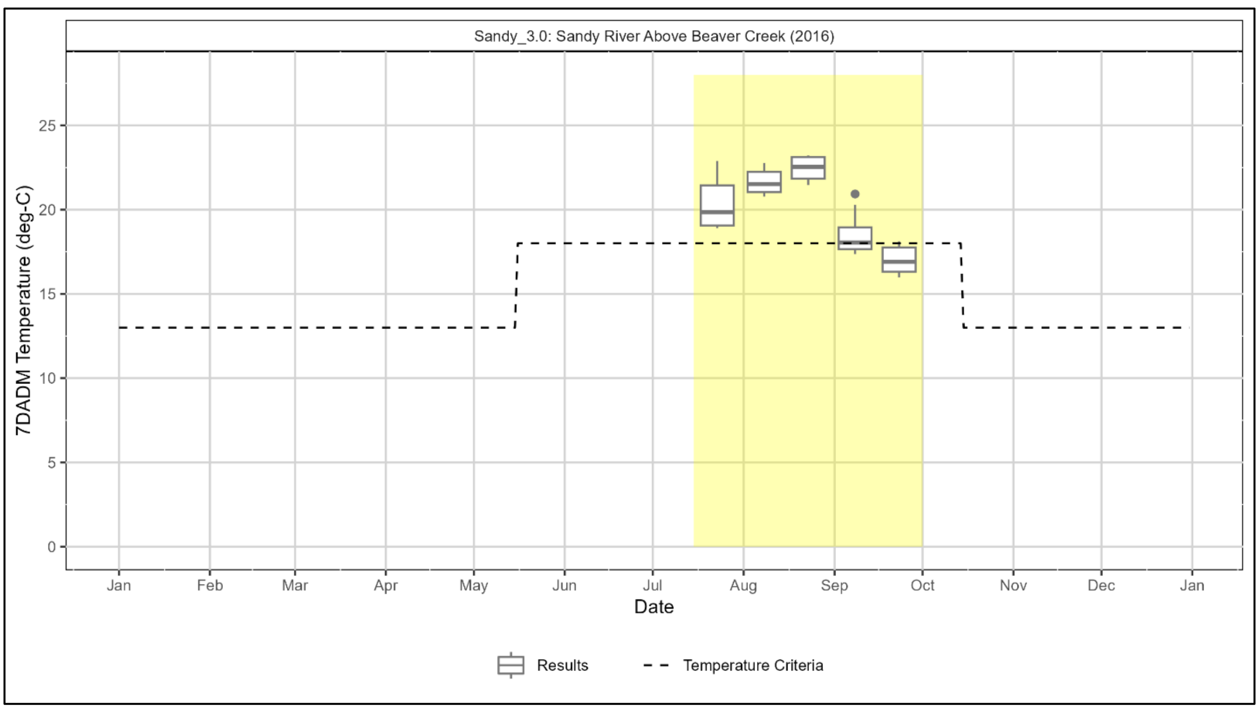

Figure 5-31: Seasonal variation at the Sandy River above Beaver Creek temperature monitoring site on the Sandy River.

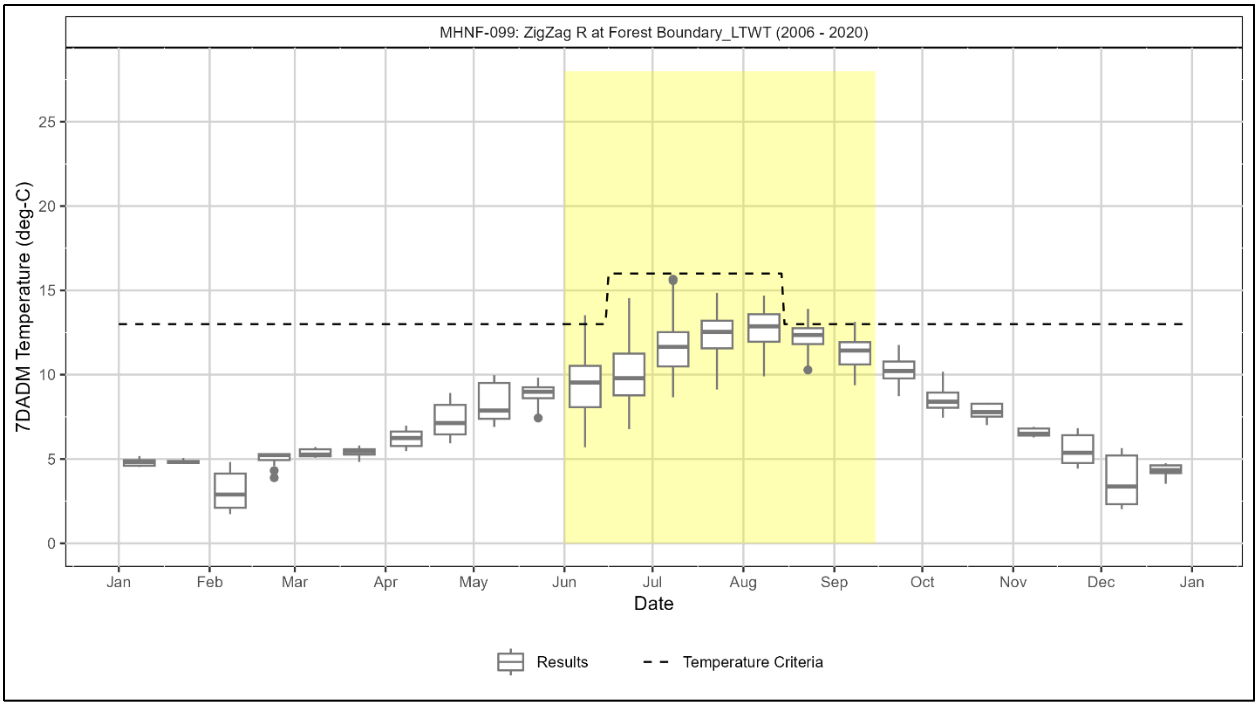

Figure 5-32: Seasonal variation at the Zigzag River at forest boundary temperature monitoring site on the Zigzag River.

6 Temperature water quality data evaluation and analyses

Evaluation and analysis of water quality data to the extent that existing data allow is a critical TMDL element. To understand the water quality impairment, quantify the LC, and assess the ability of various possible scenarios to achieve the TMDL and applicable water quality standards, the analysis requires a predictive component. DEQ uses models to evaluate potential stream warming sources and, to the extent existing data allow, their current and TMDL allocation pollutant loading. Heat Source and CE-QUAL-W2 models were used in this effort and are described in Appendices A-D of this document.

6.1 Analysis overview

The modeling requirements for this project included the abilities to predict/evaluate hourly:

1. Stream temperatures spanning months at ≤500 m longitudinal resolution.
2. Solar radiation fluxes and daily effective shade at ≤100 m longitudinal resolution.
3. Stream temperature responses due to changes in:
    a. Streamside vegetation,
    b. Water withdrawals and upstream tributaries' stream flows,
    c. Channel morphology,
    d. Effluent temperatures and flows discharged from NPDES-permitted facilities.

Figure 6-1 provides an overview of the types of analyses completed for this TMDL. Water quality models were used to support analyses on major streams. These models have specific input and calibration data requirements. Data types and how they supported the TMDL analysis are summarized in **Table 6-1** and described more fully in Appendices A-D. All data are available upon request.

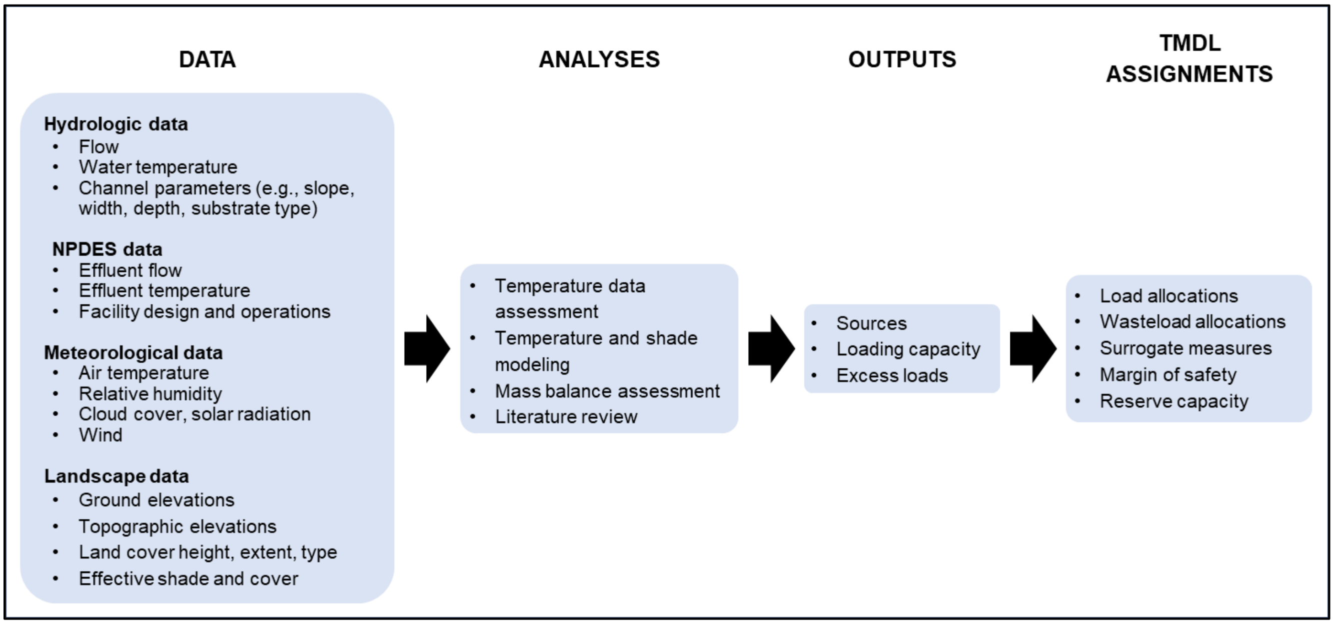

Figure 6-1: Lower Columbia-Sandy River Subbasin temperature analysis overview.

6.2 Data overview

As illustrated in **Figure 6-1**, data for numerous hydrologic, meteorologic, and landscape/ geographic parameters within the TMDL's spatial and temporal boundaries are required to conduct effective analysis for TMDL development. For the Sandy River and Salmon River models, respectively, Appendix B (Section 3) and Appendix A (Section 2) to this document describe these parameters, their applications in this TMDL development, and provide information on the specific datasets and sources utilized in this effort. For the Bull Run River, a CE-QUAL-W2 model previously developed by the City of Portland was updated and used for this TMDL (see Appendix D). For the Sandy River and Salmon River, the following data types were used. All data are available upon request.

Table 6-1: Data types used in Lower Columbia-Sandy Subbasin Temperature TMDL modeling.

Data source type	Dataset types	Data sources
Field-acquired	• Continuous stream temperature • Stream flow rate: continuous & instantaneous • Point source discharge temperatures & flows	DEQ Ambient Water Quality Monitoring System (AWQMS); USGS National Water Information System (NWIS); DEQ data solicitation responses; Portland Water Bureau; NPDES Discharge Monitoring Reports
GIS and/or remotely sensed	• 3 ft Digital Elevation Model (DEM) • Light Detection and Ranging (LiDAR) • Aerial imagery: Digital Orthophoto Quads (DOQs) • Thermal Infrared Radiometry (TIR) temperature data	Oregon Department of Geology and Mineral Industries (DOGAMI); Oregon LiDAR Consortium (OLC); Watershed Sciences, Inc.

Derived from above data types via: (a) quantitative methods or (b) proxy substitution (for certain tributary flows & temps.)	• Stream position, channel width, channel bottom width, elevation, gradient • Topographic shade angles • Land cover mapping • Tributary flows & temperatures	DEMs, LiDAR, DOQs (for stream morphology, land cover, topography, & geography); USGS StreamStats, historical data, proxy site data, estimated (constant) data (for tributary flows & temperatures if direct 2016 monitoring data were unavailable)

6.3 Model setup and application overview

As described in Appendices A-D, DEQ and its partners configured and calibrated models for the Sandy River, Salmon River, Bull Run River, Little Sandy River, and Zigzag River. The models were adjusted iteratively until acceptable goodness-of-fit was achieved relative to the conditions observed in 2001 (Zigzag and Little Sandy Rivers) or 2016 (Salmon, Bull Run, and Sandy Rivers). These results are provided in the appendices and were used in tandem with applicable water quality standard data to predict (7DADM) standard exceedances and derive the LCs, excess loads, and allocations presented in the TMDL report. To predict the effects of various changes in riparian conditions and other management scenarios, the model parameters were adjusted accordingly, and the results were evaluated to determine if those management strategies would result in attainment of water quality standards.

6.4 The 7Q10 low-flow statistic

The “7Q10” summary low-flow statistic is the lowest seven-day average flow that occurs once every ten years (on average). For the Lower Columbia-Sandy Subbasin temperature TMDL, estimated 7Q10s were used to calculate numeric loading capacities and allocations. DEQ calculated annual 7Q10s for temperature-impaired streams in the Sandy Subbasin (**Table 6-2**), and for the receiving waterbodies that have NPDES-permitted discharges with a WLA (**Table 6-3**).

The 7Q10 estimates were based on the following approaches:

1) If sufficient daily mean flow data from USGS or OWRD gaging stations were available for a given waterbody, 7Q10 estimates were calculated using these data. Available flow data were retrieved for up to a 30-year period (October 1, 1992, to September 31, 2022). DEQ relied on quality control protocols implemented by USGS and OWRD. Only data with a result status of “Approved” (USGS) or “Published” (OWRD) were included in 7Q10 calculations. 7Q10s were calculated by the method of EPA’s DFLOW program (Rossman, 1990), which computes extreme design flows using the log-Pearson Type III probability distribution. A minimum of 10 years of flow data were used with some exceptions. For ungaged locations, if there were sufficient gage data from confluent streams, 7Q10s were estimated from (a) the sum of mean daily flows (for upstream gages), or (b) the difference of mean daily flows (for downstream gages), prior to application of the DFLOW procedure. The 7Q10s calculated based on gage data are reported to the nearest tenth of a cubic foot per second (cfs) for values less than 10 cfs and to whole numbers for values greater than or equal to 10 cfs.
2) If insufficient daily mean flow data from USGS and OWRD stream flow gaging stations were available, the web-based tool StreamStats (USGS) was used to estimate 7Q10s. The 7Q10s are reported with the same level of significant figures as the values calculated using the gage method, except for values equal to or greater than 1000 cfs,

which are reported to three significant figures. Details of StreamStats are described below.

3) 7Q10s calculated and reported elsewhere (e.g., consultant studies, water quality permits, TMDLs) may have been used. In such cases, DEQ relied on the source's data quality and reported the values as they were provided.

4) For Hoodland STP (WES) (39750), the 7Q10 was calculated based on USGS gage data 14137000 minus 14135500. The 7Q10 period is October 1, 1992, to September 30, 2022. Discharge was not measured during this period on the Salmon River at 14135500 and was estimated using simple linear regression. Both 14137000 and 14135500 have discharge measurements from September 1, 1936, to September 29, 1952. During this period, a simple linear regression was developed to predict Salmon River flow at 14135500 using the flow rate at 14137000 ($R2 = 0.98$, $F(1, 5841) = 376700$, $p < 0.001$). The flow rates were transformed using the natural log prior to fitting. The regression coefficient is 1.115948 and the intercept is -1.933182. Days with missing data were removed. The regression equation is shown in **Equation 6-1**.

$$Q_{14135500} = exp(1.115948 \cdot \ln(Q_{14137000}) - 1.933182) \qquad \textbf{Equation 6-1}$$

where,

$Q_{14135500} =$	The daily mean river flow rate (cfs) at USGS gage 14135500, Sandy River Near Marmot, OR.
$Q_{14137000} =$	The daily mean river flow rate (cfs) at USGS gage 14137000, Salmon River above Boulder Creek near Brightwood, OR.

StreamStats version 4 is a web-based geographic information system (GIS) application developed by the USGS (https://streamstats.usgs.gov/ss/, USGS, 2019). StreamStats has a map-based interface that allows the user to determine drainage area delineations, basin characteristics, and estimates of stream flow statistics for user-selected locations along available streams. The program also provides users with access to stream monitoring data by selecting USGS data collection stations in the map application and providing access to flow statistics and other information for the stations. StreamStats provides estimates of various stream flow statistics for user-selected sites by solving site-specific regression equations. The regression equations were developed through a process, known as regionalization, which involves use of regression analysis to relate stream flow statistics computed for a group of selected stream gages (usually within a state) to basin characteristics measured for the stream gages. Basin characteristics are used to obtain estimates of the stream flow statistics for ungaged sites.

StreamStats regression equations for Oregon were developed by Cooper (2005) and Risley et al. (2008). These equations were based on basin characteristics and flow statistics (e.g., historical percentile flow-exceedance values and annual and monthly 7Q10s). Flow statistics were computed at 466 gaging stations across Oregon and proximal out-of-state areas. This study area was divided into 10 regions based on ecological, topographic, geologic, hydrologic, and climatic criteria. StreamStats includes 910 annual and monthly regression equations to estimate 7Q10s for ungaged stream sites in the 10 aforementioned regions. These equations were developed for unregulated streams (without major dams, constructed reservoirs, catchment development, or significant diversions/withdrawals). If the equations are applied to ungaged streams subject to such influences, the resultant estimates may require adjustment to approximate actual flows.

The StreamStats user selects a stream location of interest, and the program estimates the associated drainage area and summary flow statistics. For this TMDL, DEQ's procedure specified that selected stream locations should be the most downstream location on each stream for which DEQ required flow estimates; the exception was if DEQ required 7Q10 estimates for NPDES-permitted point source receiving waters, in which case the selected stream location was immediately upstream of the point source outfall. StreamStats also estimates basin characteristics for the selected catchment, including drainage area, mean annual precipitation, mean slope, and climatic characteristics (Cooper, 2005; Risley et al., 2008). If estimates are outside suggested parameter ranges, the warning message "extrapolated with uncertainty" appears in the StreamStats report.

Table 6-2: The 7Q10 low-flow estimates for modeled temperature-impaired rivers in the Lower Columbia-Sandy Subbasin.

Assessment unit name	Assessment unit ID	Estimated 7Q10 (cfs)	Flow estimation method	Gage/StreamStats location	Gage period
Bull Run River	OR_SR_1708000105_11_103611	20	USGS: 14140000	45.437, -122.180	2000-10-01 ~ 2022-09-30
Cedar Creek	OR_SR_1708000104_02_103607	4.9	StreamStats	45.405, -122.253	
Little Sandy River	OR_SR_1708000105_11_103609	11	USGS: 14141500	45.415, -122.171	1992-10-01 ~ 2022-09-30
Salmon River	OR_SR_1708000103_02_103606	174	StreamStats	45.376, -122.030	
Sandy River	OR_SR_1708000101_02_103599	50	StreamStats	45.349, -121.944	
Sandy River	OR_SR_1708000104_02_103608	217	USGS: 14137000	45.400, -122.137	1992-10-01 ~ 2022-09-30
Sandy River	OR_SR_1708000107_02_103616	278	USGS/OWRD: 14142500 + 14142800	45.449, -122.245 45.519, -122.389	1992-10-01 ~ 2022-09-30
Zigzag River	OR_SR_1708000102_02_103600	48	StreamStats	45.348, -121.945	

Table 6-3: The 7Q10 low-flow estimates for NPDES-permitted discharges receiving a numeric wasteload allocation in this TMDL.

Facility name (File number)	Stream	Estimated 7Q10 (cfs)	Flow estimation method	Gage/StreamStats location	Gage period
City of Troutdale WPCF (89941)	Sandy River	278	USGS/OWRD: 14142500 + 14142800	45.449, -122.245 45.519, -122.389	1999-10-01 ~ 2022-09-30
Government Camp STP (34136)	Camp Creek	5.7	Curran-McLeod (1993), Sandy River Basin TMDL (DEQ, 2005)		
Sandy WWTP (78615)	Sandy River*	217	USGS: 14137000	45.400, -122.137	1992-10-01 ~ 2022-09-30
ODFW Sandy River Fish Hatchery (64550)	Sandy River*	217	USGS: 14137000	45.400, -122.137	1992-10-01 ~ 2022-09-30
ODFW Sandy River Fish Hatchery (64550)	Cedar Creek	4.9	StreamStats	45.405, -122.253	
Hoodland STP (WES) (39750)	Sandy River	158	USGS: 14137000 - 14135500	45.400, -122.137 45.361, -122.012	1992-10-01 ~ 2022-09-30

*This is a potential/alternative discharge location that does not currently receive discharge.

7 Pollutant sources and load contributions

A key element of TMDL development is a complete, comprehensive source assessment for the relevant water quality pollutant(s). This includes identification of all relevant point and nonpoint sources to the impaired waterbody, characterization/quantification of their pollutant load contributions, determination of seasonal variation, and delineation of periods when applicable temperature criteria are exceeded at various locations, to the extent that existing data allow. This section, along with the TMDL report and its appendices, describes the significant thermal pollutant sources identified within the Lower Columbia Sandy Subbasin temperature TMDL area and the data sources that DEQ utilized for TMDL modeling.

7.1 Point Sources

Individual NPDES permittees and a 300-J general permit registrant were identified as significant sources of thermal loading to streams in the Lower Columbia-Sandy Subbasin.

7.1.1 Individual NPDES-permitted point sources

Three individual NPDES-permitted point source discharges were identified as significant sources of thermal load in the Lower Columbia-Sandy Subbasin, and a fourth, the City of Sandy WWTP, was identified as a potential source (**Table 7-1**). The current thermal loading from each of these point sources was assessed individually using a mass balance approach (**Equation 9-2** and **Equation 9-3**) with river flows listed in **Table 7-1** and effluent flow and temperature data obtained from Discharge Monitoring Reports (DMRs) or provided by the facilities. The mass balance approach provides estimates of loading at the point of discharge and temperature increases above applicable temperature criteria. To evaluate cumulative impacts of sources that discharge to the Sandy River, the Sandy River model was used.

Table 7-1: Summary of maximum warming and thermal loading at the point of discharge from individual NPDES point sources in the Lower Columbia-Sandy Subbasin project area.

NPDES permittee WQ file number : EPA number	Receiving water name	Max. warming at point of discharge (°C)	Max. thermal load (kcals/day)	Notes
Government Camp STP 34136 : OR0027791	Camp Creek	0.16	2,39E+6	Effluent data from 2020 DMRs. River flow set at 7Q10.
Hoodland STP (WES) 39750 : OR0031020	Sandy River	0.05	19.50E+6	Effluent data from 2016-2017 and 2019-2020 DMRs. River flow set at 7Q10.
City of Troutdale WPCF 89941 : OR0020524	Sandy River	0.05	34.57E+6	Effluent data from City of Troutdale and DMRs (2014-2022). River flow based on USGS 14142500 + USGS 14142800.
City of Sandy WWTP 78615 : OR0026573	Sandy River*	0.04	21,33E+6	Effluent characterization provided by Parametrix and reflects estimated 2040 discharge. River flow set at 7Q10.

*This is a potential/alternative discharge location that does not currently receive discharge.

The City of Sandy WWTP currently holds an individual NPDES permit for discharge to Tickle Creek (Clackamas Subbasin) but is under an EPA consent decree to upgrade and add treatment capacity. The city submitted an NPDES permit application to DEQ to upgrade and construct a new outfall to the Sandy River. The discharge to the Sandy River is estimated to be a significant source of thermal load based on effluent discharge estimates provided to DEQ by the City of Sandy's contractor, Parametrix.

7.1.2 General NPDES-permitted point sources

There are multiple types of general NPDES permits with registrants in the Lower Columbia-Sandy, including:

- 300-J Industrial Wastewater, NPDES fish hatcheries
- 1200-A Stormwater: NPDES sand & gravel mining
- 1200-C Stormwater: NPDES construction
- 1200-Z Stormwater: NPDES specific Standard Industrial Classification codes
- MS4 – Phase II: Stormwater, NPDES: Municipal Separate Storm Sewer System

The 300-J general permit covers treated discharges from aquatic animal production facilities that produce at least 20,000 pounds of fish per year but have less than 300,000 pounds on hand at any time. There is currently one registrant to the 300-J general permit in the Lower Columbia-Sandy Subbasin project area (**Table 7-2**). The current thermal loading was assessed using a mass balance approach (**Equation 9-2** and **Equation 9-3**) using data provided by ODFW. The mass balance analysis found maximum temperature increases in Cedar Creek of up to 0.383°C.

Table 7-2: Summary of maximum warming and thermal loading at the point of discharge from 300-J general permit registrants in the Lower Columbia-Sandy Subbasin project area.

NPDES permittee WQ file number : EPA number	Receiving water name	Max. warming at point of discharge (°C)	Max. thermal load (kcals/day)	Notes
ODFW Sandy River Fish Hatchery 64550 : ORG130009	Cedar Creek	0.383	7,590,289	Effluent data provided by ODFW and reflects data collected in 2016. River flow estimated and set the same as the input to the Sandy River model.

In the Lower Columbia-Sandy, there are approximately 26 registrants on the 1200-A, 1200-C, and 1200-Z permits and one registrant to the general MS4 phase II permit (City of Troutdale). DEQ completed a review of published literature and other studies related to stormwater runoff and stream temperature in Oregon and concluded that stormwater discharges authorized under the current municipal (MS4), construction (1200-C) and industrial (1200-A and 1200-Z) general stormwater permits are unlikely to contribute to exceedances of the temperature standard. Therefore, no additional TMDL requirements are needed for stormwater sources to control temperature, other than those included in the current permits. More specific WLAs can be considered if subsequent data and evaluation demonstrates a need and if reserve capacity is available. The substantive literature review findings are summarized below.

A review of available studies from the midwestern and eastern United States indicated that, under certain conditions, runoff from impervious pavement or runoff retained in uncovered open ponds can produce short-duration warm discharges (Herb et al., 2008; Jones and Hunt, 2009; UNH Stormwater Center, 2011; Winston et al., 2011; Hester and Bauman, 2013). Yet, runoff temperature changes are highly dependent on many factors including air temperature, dewpoint, pavement type, percent imperviousness, and the amount of impervious surface shielded from solar radiation (Nelson and Palmer, 2007; Herb et al., 2008; Thompson et al., 2008; Winston et al., 2011; Jones et al., 2012; Sabouri et al., 2013; Zeiger and Hubbert, 2015). When they occur, such warmed runoff discharges can create “surges” associated with typically short-duration stream temperature increases (Hester and Bauman, 2013; Wardynski et al., 2014; Zeiger and Hubbert, 2015). However, studies that evaluated stormwater discharges over longer (e.g., 7-day) averaging periods such as those used in assessing TMDL attainment (i.e., 7DADM) did not indicate exceedances above biologically-based benchmarks (Wardynski et al., 2014; WDOE, 2011a; WDOE, 2011b).

Additionally, DEQ evaluated rainfall, cloud cover, air temperature, and stream temperature data from warm seasons for three years in the Miles Creeks area of the Middle Columbia-Hood Subbasin (DEQ, 2008b). DEQ concluded that stormwater discharges likely do not to contribute to temperature standard exceedances in the study area. This is because (1) the standard is based on 7DADM temperatures, such that most days in each 7-day period would need to have precipitation-runoff influences to affect the 7DADM, (2) exceedances are assessed for the critical summer period, and (3) 95% of summertime 7-day periods had fewer than 3 days of rain, while 80% had less than one day of rain. Thus, there are generally not enough runoff events to significantly influence 7DADMs for temperature in the critical period of this TMDL.

7.2 Nonpoint and background sources

OAR 340-41-0002(42) defines nonpoint sources as “diffuse or unconfined sources of pollution where wastes can either enter, or be conveyed by the movement of water, into waters of the state.” Generally, nonpoint thermal sources in the Lower Columbia-Sandy Subbasin include activities associated with agriculture, forestry, dam and reservoir management, and development. Example sources and/or activities that contribute nonpoint thermal loads that increase stream temperature include:

- Human-caused increases in solar radiation loading to streams from stream-side vegetation disturbance or removal,
- Channel modification and widening,
- Dam and reservoir operation,
- Activities that modify flow rate or volume, and
- Background sources, including natural sources and anthropogenic sources of warming through climate change and other factors.

Anthropogenically influenced thermal loads are targeted for reduction to attain the applicable temperature water quality criteria. The following actions are needed to attain the TMDL allocations:

- Restoration of stream-side vegetation to reduce thermal loading from exposure to solar radiation,
- Management and operation of dams and reservoirs to minimize temperature warming, and
- Maintenance of minimum instream flows.

7.2.1 Background sources

By definition (OAR 340-042-0030(1)), background sources include all sources of pollution or pollutants not originating from human activities. Background sources may also include anthropogenic sources of a pollutant that DEQ or another Oregon state agency does not have authority to regulate, such as pollutants emanating from another state, tribal lands, or sources otherwise beyond the jurisdiction of the state. Stream temperature warming from climate change is thus considered a background source, as the majority of the climate change-causing pollutants emanate from outside of Oregon.

The background thermal loading a stream receives is influenced by multiple landscape and meteorological characteristics, such as: substrate and channel morphology conditions, streambank and channel elevations, near-stream vegetation, groundwater, hyporheic flow, tributary inflows, precipitation, cloudiness, air temperature, relative humidity, and others. Many of these parameters, however, are influenced by anthropogenic factors. As such, it was not possible to develop a model in which all human influences were controlled or accounted for. As a best estimate, background thermal sources were quantified in the modeled rivers by accounting for delineable anthropogenic influences (i.e., dams and reservoirs, vegetation alterations, point source discharges), thus isolating the remaining background sources. In each modeled river, thermal loads from background sources contributed to exceedances of the applicable temperature criteria and thus were identified as significant sources of thermal loading. Reductions from background sources will be required to attain the applicable temperature criteria. The background sources contribution for each model stream is summarized in section 7.2.4 through section 7.2.8.

7.2.2 Climate change

DEQ completed a literature review to assess climate change-driven stream temperature impacts (TSD Appendix F). Based on that review, stream temperature impacts from climate change can range from +0.05°C to +0.27°C per decade on unregulated streams and -0.48°C to +0.52°C per decade on regulated streams. Stream temperature trends in regulated systems are more variable, as upstream flow and temperature management can confound natural long-term warming trends in the data (Isaak et al., 2012).

7.2.3 Dams and reservoirs

Reservoirs attenuate flood flows and retain spring runoff. Stored water is released when reservoir capacity is met or to augment stream flows during summer and early fall dry periods. As currently constructed and operated, water released from many reservoirs modifies natural downstream temperature patterns in late summer and early fall, but also in spring and early summer. The seasonal temperature shifts occur because water stored in reservoirs stratifies, and existing reservoirs were typically constructed with regulating outlets near the bottom of each structure.

Seasonal pattern shifts are of concern because water temperature regulates aquatic life activities such as spawning, incubation period, and fry emergence. Moreover, salmonid food supplies (i.e., macroinvertebrates) are affected by seasonal temperature shifts. Reservoirs are drawn down in late summer and early autumn to provide flood storage capacity for upcoming winter precipitation. During this time, reservoirs destratify but their water temperatures remain warmer than upstream tributary inflows. This is also when fall-spawning fish move into reaches below reservoirs to await spawning. Salmon and trout remain in the coldest water they find to await stream temperatures cool enough to trigger their spawning migration.

Alternately, colder winter waters are released in spring and early summer when upstream tributary inflow temperatures are warmer than stored reservoir waters. This is when fall-spawned fry should emerge, but the colder water shifts their emergence timing. Spring spawning is also delayed until water temperatures are warm enough to trigger spawning. Late spring spawning may result in summertime fry emergence when waters are too warm for them.

DEQ and the City of Portland modeled the thermal effects of the Bull Run Dam and Reservoirs and found minor but measurable effects on downstream water temperatures. On the Bull Run River, the maximum 7DADM increase due to dam and reservoir operations was 0.87°C.

In the Lower Willamette and Lower Columbia-Sandy Subbasins, multiple studies have examined the thermal impacts of in-channel ponds on water temperature and found that human-built in-channel ponds showed trends of increasing downstream temperature (Holzer, 2020; Fairbairn, 2022). For example, Holzer (2020) demonstrated that most in-channel ponds increased the total time period that a stream segment exceeded the temperature standard by several weeks. Fairbairn (2022) found that human-constructed ponds in the Johnson Creek (n=14), Columbia Slough (n=1) and Sandy River (n=2) Watersheds increased median 7DADM stream temperatures by -1.0 to 6.0 (°C). Nine (53%) of the 17 human-constructed in-channel ponds raised the median 7DADM stream temperature by more than 1°C.

7.2.4 Salmon River

Thermal pollutant sources identified for the Salmon River included reduction or removal of shade-producing streamside vegetation and background sources on the mainstem and its tributaries. A subcategory of anthropogenically reduced shade due to infrastructure (i.e., roads, buildings, bridges, and utility corridors) was also assessed. No significant thermal point sources were identified. Refer to TSD Appendix A for details. Briefly, along the Salmon River model extent:

- Anthropogenic streamside vegetation reduction or removal (other than for infrastructure) was associated with a mean effective shade gap of 12%, corresponding to a maximum 7DADM water temperature increase of 1.21°C at the POMI (model km 6.10).
- Anthropogenic streamside vegetation reductions (other than for infrastructure) in areas currently protected by federal, state, or local management plans or ordinances were associated with a mean effective shade gap of 10% (along the entire Salmon River model extent), corresponding to a maximum 7DADM water temperature increase of 0.97°C at the POMI (model km 2.70).
- Anthropogenic infrastructure-related shade reductions were associated with a mean effective shade change of less than 0.5%, corresponding to a maximum 7DADM water temperature increase of 0.06°C at the POMI (model km 5.95).
- Temperature standard exceedances on Salmon River tributaries included in the model were associated with a maximum 7DADM water temperature increase of 4.00°C at the POMI, model km 13.10 (the upstream model boundary).
- Background factors were associated with a maximum 7DADM water temperature standard exceedance of 5.11°C above the applicable numeric criterion (i.e., the 13.0°C spawning criterion) at the POMI (model km 0.00).

7.2.5 Bull Run River

Thermal pollutant sources identified for the Bull Run River included reduction or removal of shade-producing streamside vegetation, dam and reservoir operations, and background sources. Refer to TSD Appendices A and D for details. Briefly, along the Bull Run River model extent:

- Reduction or removal of streamside vegetation was associated with a maximum 7DADM water temperature increase of 0.85°C at model segment 56 (POMI) on August 27, 2016 (TSD Appendix A, Section 4.6.2).
- The Bull Run dams and reservoirs were associated with a maximum 7DADM water temperature increase of 1.31°C at model segment 98 (POMI, mouth) on September 7, 2016 (TSD Appendix A, Section 4.6.1). During the summer period the dam operations typically cooled the Bull Run River compared to temperatures without the dam.
- The estimated effects of delineable background factors were associated with a maximum 7DADM water temperature standard exceedance of 7.67°C just upstream of the Little Sandy River at model segment 68 on August 18, 2016. The maximum 7DADM background water temperature was 21.46°C (TSD Appendix A, Section 4.6.3).
- The combined effects of anthropogenic vegetation/shade reductions and dam operations were associated with a maximum 7DADM water temperature increase (i.e., the maximum difference of current conditions minus background conditions) of 1.44°C near the mouth (model segment 98) on September 7, 2016 (TSD Appendix A, Section 4.6.3).

7.2.6 Little Sandy River

Thermal pollutant sources identified for the Little Sandy River included reduction or removal of shade-producing streamside vegetation and background sources. On the Little Sandy River, reduction or removal of streamside vegetation was associated with a mean effective shade gap of 6%, corresponding to a maximum daily water temperature increase of 0.72°C at model kilometer 2.9 (TSD Appendix A, Section 4.4).

Background factors were associated with a maximum daily water temperature of 20.03°C at the Little Sandy mouth, river kilometer 0.00 (POMI), corresponding to an applicable temperature standard exceedance of 4.03°C (OAR 340-041-0028(4)(b)).

7.2.7 Zigzag River

Thermal pollutant sources identified for the Zigzag River included reduction or removal of shade-producing streamside vegetation, background sources, and an NPDES point source on a tributary (Camp Creek). On the Zigzag River, streamside vegetation reduction or removal was associated with a mean effective shade gap of 13%, corresponding to a maximum daily water temperature increase of 0.55°C at the mouth (model km 0.0). See TSD Appendix A, Section 4.5 for details.

The maximum modeled Zigzag River temperature change above the applicable criterion due to the Government Camp STP WLA discharge on Camp Creek was 0.03°C. The only modeled Zigzag River temperature criterion (16.0°C) exceedances occurred toward its mouth (i.e., river km 0.0 to 0.6), thus the 0.03°C POMI is located in this region (TSD Appendix A, Section 4.5.1).

Background factors were associated with a maximum daily water temperature of 16.08°C at the mouth (model km 0.00), corresponding to an applicable temperature standard exceedance of 0.08°C (OAR 340-041-0028(4)(b)). See TSD Appendix A, Section 4.5 for details.

7.2.8 Sandy River

Thermal pollutant sources identified for the Sandy River included reduction or removal of shade-producing streamside vegetation, consumptive use water withdrawals, point source discharges, Bull Run dam and reservoir operations, temperature standard exceedances on Sandy River tributaries, and background sources. As with the Salmon River, a subcategory of anthropogenically reduced shade due to infrastructure (i.e., roads, bridges, buildings, and utility corridors) was assessed. Refer to TSD Appendices B and C for details. See Section 7.1 for a summary of Sandy River thermal loading from point sources. Briefly, along the Sandy River model extent:

- Point source discharges, as operated in the year 2016 during the model period, have a maximum 7DADM water temperature increase of 0.02°C at the POMI located at the City of Troutdale WPCF outfall and downstream (river km 1.6, August 18, 2016). See Appendix C, Section 4.0. In other years and at low 7Q10 flows, point sources have a maximum 7DADM increase as high as 0.05°C at their point of discharge (**Table 7-1**).
- The proposed discharge by the City of Sandy WWTP is estimated to have a maximum 7DADM water temperature increase 0.01°C during the 2016 model year (Appendix C, Section 3.0). At 7Q10 flows the maximum increase could be as high as 0.04°C (**Table 7-1**).
- Reduction or removal of streamside vegetation (other than for infrastructure) was associated with a mean effective shade gap of 5%, corresponding to a maximum 7DADM water temperature increase of 0.97°C at the POMI (river km 61.10, August 29, 2016).
- Anthropogenic infrastructure-related shade reductions were associated with a mean effective shade gap of <0.5%, reflecting a maximum 7DADM water temperature increase of 0.05°C at the POMI (river km 2.80, August 29, 2016). See Appendix C, Section 6.0.
- Current dam and reservoir operations on the Bull Run River were associated with a modeled maximum 7DADM water temperature increase of 0.60°C at the POMI (Sandy River km 4.70, August 4, 2016). See Appendix C, Section 7.0.
- Tributary temperature standard exceedances were associated with a maximum 7DADM water temperature increase of 6.34°C at the POMI (river km 71.05 (the upstream model boundary), July 23, 2016). See Appendix C, Section 12.0.

Two unique consumptive water use scenarios (WW_A & WW_B) were developed and compared to a natural streamflow model scenario to determine the maximum consumptive withdrawal rates that would still attain the HUA for permitted withdrawals (0.05°C (WW_A)) and the overall HUA (0.30°C (WW_A)) at a stream reference location (stream km 29.10). A third consumptive use scenario (WW_C) that included current consumptive use estimates was developed and compared to the natural streamflow model scenario to estimate the current consumptive use impacts. See Appendix C, Section 9.0 for details.

- For WW_A, the maximum consumptive use withdrawal rate was 1.90%, and associated with a maximum 7DADM water temperature increase of 0.05°C at the reference location on August 18, 2016.

- For WW_B, the maximum consumptive use withdrawal rate was 10.1%, and associated with a maximum 7DADM water temperature increase of 0.30°C at the reference location on August 18, 2016.
- For WW_C, the estimated consumptive use withdrawal rates (i.e., 28% (July), 29% (Aug.), and 34% (Sept.)) were associated with a maximum 7DADM water temperature increase of 1.10°C at the reference location on August 18, 2016.

The background conditions scenario was identical to the current conditions model but with no anthropogenic vegetation alterations, dams, or point sources. The background (BG) scenario evaluates the stream temperature response from background sources only. The BG scenario was compared to the applicable temperature criteria to estimate temperature standard exceedances due to background (non-anthropogenic) sources. See Appendix C, Section 10.0 for details.

- The maximum background conditions temperature standard exceedance was 5.96°C at the POMI (river km 54.35) on August 21, 2016 (OAR 340-041-0028(4)(a)). This corresponds to a 7DADM of 18.96°C.
- The maximum 7DADM background scenario water temperature was 22.85°C and occurred at the mouth (river km 0.00) on August 21, 2016. This corresponds to an applicable temperature standard exceedance of 4.85°C (OAR 340-041-0028(4)(c)).
- Results indicated that background sources would be associated with temperature standard exceedances on most (i.e., at least 50% of) days within the model period at all Sandy River nodes except those from river kilometers 69.85 to 65.20 and 43.25 to 27.35; all model nodes had at least two days that exceeded applicable 7DADM temperature standards. These results indicate that temperature standard exceedances are likely even in the absence of human disturbance.

8 Loading capacity and excess loads

As described in the TMDL report, the maximum pollutant load that a waterbody can receive and still meet water quality standards is called the loading capacity. For temperature, thermal LC is assigned to all AUs in the Lower Columbia-Sandy Subbasin. LC is calculated using **Equation 8-1**.

$$LC = (T_C + HUA) \cdot Q_R \cdot C_F \qquad \textbf{Equation 8-1}$$

where,

$LC =$ Loading Capacity (kcal/day), expressed as a rolling seven-day average.

$T_C =$ The applicable river temperature criterion (°C).

$HUA =$ The 0.30°C human use allowance allocated to point sources, nonpoint sources, margin of safety, or reserve capacity.

$Q_R =$ The daily mean river flow rate (cfs).
When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow.

$C_F =$ Conversion factor using flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\text{C}} = 2{,}446{,}665$$

Table 8-1 presents LCs for select AUs with an NPDES discharge or that were modeled for the TMDL analysis. The LCs presented were calculated based on the 7Q10 low-flow. **Equation 8-1** should be used to calculate the LC for any AU or stream location in the Lower Columbia-Sandy Subbasin not identified in **Table 8-1** or when river flows are greater than 7Q10. If two year-round temperature criteria apply to the same AU, the more stringent criterion shall be used for the LC.

Table 8-1: Thermal loading capacity for select assessment units by applicable fish use period at 7Q10 flow.

AU name, extent, and ID	Annual 7Q10 (cfs)	Year-round criterion + HUA (°C)	Spawning criterion + HUA (°C)	7Q10 LC year-round (kcal/day)	7Q10 LC spawning (kcal/day)
Bull Run River - Bull Run Reservoir Number Two to confluence with Sandy River OR_SR_1708000105_11_103611	20	16.3	13.3	797.61E+6	650.81E+6
Cedar Creek - Beaver Creek to confluence with Sandy River OR_SR_1708000104_02_103607	4.9	18.3	13.3	219.39E+6	159.45E+6
Little Sandy River - Bow Creek to confluence with Bull Run River OR_SR_1708000105_11_103609	11	16.3	13.3	438.69E+6	357.95E+6
Salmon River - South Fork Salmon River to confluence with Sandy River OR_SR_1708000103_02_103606	174	16.3	13.3	6,939.23E+6	5,662.07E+6
Sandy River - Bull Run River to confluence with Columbia River OR_SR_1708000107_02_103616	278	18.3	13.3	12,447.16E+6	9,046.30E+6
Sandy River - Clear Fork to Zigzag River OR_SR_1708000101_02_103599	50	18.3	13.3	2,238.70E+6	1,627.03E+6
Sandy River - Zigzag River to Bull Run River OR_SR_1708000104_02_103608	217	16.3	13.3	8,654.10E+6	7,061.32E+6
Zigzag River - Still Creek to confluence with Sandy River OR_SR_1708000102_02_103600	48	16.3	13.3	1,914.27E+6	1,561.95E+6

The excess load is the difference between the actual pollutant load in a waterbody and the LC of that waterbody. In accordance with OAR 340-042-0040(4)(e), Oregon TMDLs must include the excess load to the extent existing data allow.

Because flow monitoring data were unavailable at most temperature monitoring locations, it was not possible to calculate the excess thermal load (ETL). Instead, the excess temperature and percent load reduction were calculated for each AU where temperature data were available. Temperature data collected in the Lower Columbia-Sandy Subbasin between January 1, 2012, and December 31, 2022, were downloaded from DEQ's AWQMS database. All data were reviewed and filtered for acceptable quality; subsequently, there were 84 monitoring stations where excess temperature could be calculated. The maximum excess temperature and corresponding percent reduction are summarized in **Table 8-2** for all applicable temperature criteria on each AU.

Excess temperature is the maximum difference between the monitored 7DADM river temperature and the applicable numeric criterion including the HUA. The percent load reduction (**Table 8-2**) represents the maximum portion of the actual thermal load that must be reduced to attain the TMDL LC.

The percent load reduction is mathematically equal to the percent temperature reduction calculated from monitoring data. This is because, to calculate a thermal load reduction, the same streamflow rate is used in both the numerator and denominator, which thus cancel out when calculating the percent reduction. The percent load reductions shown in **Table 8-2** were calculated from temperatures in degrees Celsius.

$$PR = \frac{(T_R - T_C - HUA)}{T_R} \cdot 100 \quad \textbf{Equation 8-2}$$

where,

$PR =$ Percent load reduction (%). If PR < 0, PR = 0

$T_R =$ The maximum 7DADM ambient river temperature (°C).

$T_C =$ The applicable river temperature criterion (°C).

$HUA =$ The 0.30°C human use allowance allocated to point sources, nonpoint sources, margin of safety, or reserve capacity.

Table 8-2: Excess temperature and percent load reduction for various assessment units in the Lower Columbia-Sandy Subbasin.

AU name	AU ID	Maximum 7DADM river temp.	Applicable criterion + HUA (°C)	Excess temp. (°C)	Percent load reduction
Clear Fork	OR_SR_1708000101_02_103596	14.7	13.3	1.4	9.2
Clear Fork	OR_SR_1708000101_02_103596	14.9	16.3	0	0
Clear Creek	OR_SR_1708000101_02_103597	17.4	13.3	4.1	23.5
Clear Creek	OR_SR_1708000101_02_103597	17.8	16.3	1.5	8.2
Lost Creek	OR_SR_1708000101_02_103598	13.6	13.3	0.3	2.1
Lost Creek	OR_SR_1708000101_02_103598	15.2	16.3	0	0
Sandy River	OR_SR_1708000101_02_103599	19.4	13.3	6.1	31.5
Sandy River	OR_SR_1708000101_02_103599	20.1	16.3	3.8	19
Zigzag River	OR_SR_1708000102_02_103600	13.9	13.3	0.6	4.3
Zigzag River	OR_SR_1708000102_02_103600	15.7	16.3	0	0
Still Creek	OR_SR_1708000102_02_103601	16	13.3	2.7	16.8
Still Creek	OR_SR_1708000102_02_103601	16.3	16.3	0	0.2
Zigzag River	OR_SR_1708000102_02_103602	12.1	13.3	0	0
Zigzag River	OR_SR_1708000102_02_103602	12.5	16.3	0	0
Salmon River	OR_SR_1708000103_02_103605	11.4	16.3	0	0
Salmon River	OR_SR_1708000103_02_103606	19.7	13.3	6.4	32.6
Salmon River	OR_SR_1708000103_02_103606	21	16.3	4.7	22.3
Cedar Creek	OR_SR_1708000104_02_103607	19.7	18.3	1.4	6.9
Sandy River	OR_SR_1708000104_02_103608	19.3	13.3	6	31.2
Sandy River	OR_SR_1708000104_02_103608	19.5	16.3	3.2	16.3
Little Sandy River	OR_SR_1708000105_11_103609	19.1	13.3	5.8	30.3
Little Sandy River	OR_SR_1708000105_11_103609	22.2	16.3	5.9	26.6
South Fork Bull Run River	OR_SR_1708000105_11_103610	18.3	16.3	2	10.9
Bull Run River	OR_SR_1708000105_11_103611	20.6	13.3	7.3	35.4
Bull Run River	OR_SR_1708000105_11_103611	21.1	16.3	4.8	22.6
Bull Run River	OR_SR_1708000105_11_103688	17.8	16.3	1.5	8.4
Beaver Creek	OR_SR_1708000107_02_103612	20.1	13.3	6.8	33.8
Beaver Creek	OR_SR_1708000107_02_103612	27.8	18.3	9.5	34.2

AU name	AU ID	Maximum 7DADM river temp.	Applicable criterion + HUA (°C)	Excess temp. (°C)	Percent load reduction
Gordon Creek	OR_SR_1708000107_02_103615	13.3	13.3	0	0
Gordon Creek	OR_SR_1708000107_02_103615	19.2	18.3	0.9	4.5
Sandy River	OR_SR_1708000107_02_103616	14.5	13.3	1.2	8.2
Sandy River	OR_SR_1708000107_02_103616	23.2	18.3	4.9	21.2
HUC12 Name: Upper Salmon River	OR_WS_170800010302_02_103640	15.7	16.3	0	0
HUC12 Name: Wildcat Creek-Sandy River	OR_WS_170800010401_02_103643	16.5	13.3	3.2	19.3
HUC12 Name: Wildcat Creek-Sandy River	OR_WS_170800010401_02_103643	15.5	16.3	0	0
HUC12 Name: Upper Bull Run River	OR_WS_170800010502_11_103647	7	16.3	0	0
HUC12 Name: Middle Bull Run River	OR_WS_170800010503_11_103648	16.9	16.3	0.6	3.6
HUC12 Name: Little Sandy River	OR_WS_170800010505_11_103669	24.2	16.3	7.9	32.5
HUC12 Name: Lower Bull Run River	OR_WS_170800010506_11_103650	17.6	16.3	1.3	7.5
HUC12 Name: Gordon Creek	OR_WS_170800010701_02_103651	13	16.3	0	0
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	21.4	13.3	8.1	37.8
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	26.2	18.3	7.9	30
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	18.1	13.3	4.8	26.3
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	18.9	16.3	2.6	13.9
HUC12 Name: Woodard Creek-Columbia River	OR_WS_170800010802_15_103653	17.5	18.3	0	0
HUC12 Name: Bridal Veil Creek-Columbia River	OR_WS_170800010803_15_103654	19.9	18.3	1.6	8.1

9 Allocation approach

Figure 9-1 provides three different but interrelated conceptual representations of the total load to a temperature-impaired water. These three representations reflect the general sequence of analyses and results completed during the TMDL process: load/standard exceedance assessment (left block), source identification (middle block), and TMDL allocations and load reduction (right block). The left block ("Current Conditions 303(d) list") shows the total load, with the bisecting lines representing the loads that would meet the biologically-based numeric criteria and the temperature standard. The middle block ("Source Identification") represents the portions of the total load contributed by the different source categories (point, nonpoint, and background). The right block ("TMDL and Load Reductions") illustrates how the TMDL is distributed among background sources, HUAs, and excess load.

Wasteload allocations (shown as WLA) are the portion of the TMDL LC allocated to point sources. Load allocations (shown as LA_{nps} and LA_{bg}) are the portions attributed to nonpoint sources and background sources, respectively. OAR 340-042-0040(6) identifies the factors that DEQ or EQC may consider when distributing wasteload and load allocations.

The factors include:

a) Contributions from sources;
b) Costs of implementing measures;
c) Ease of implementation;
d) Timelines for attainment of water quality standards;
e) Environmental impacts of allocations;
f) Unintended consequences;
g) Reasonable assurances of implementation;
h) Any other relevant factor.

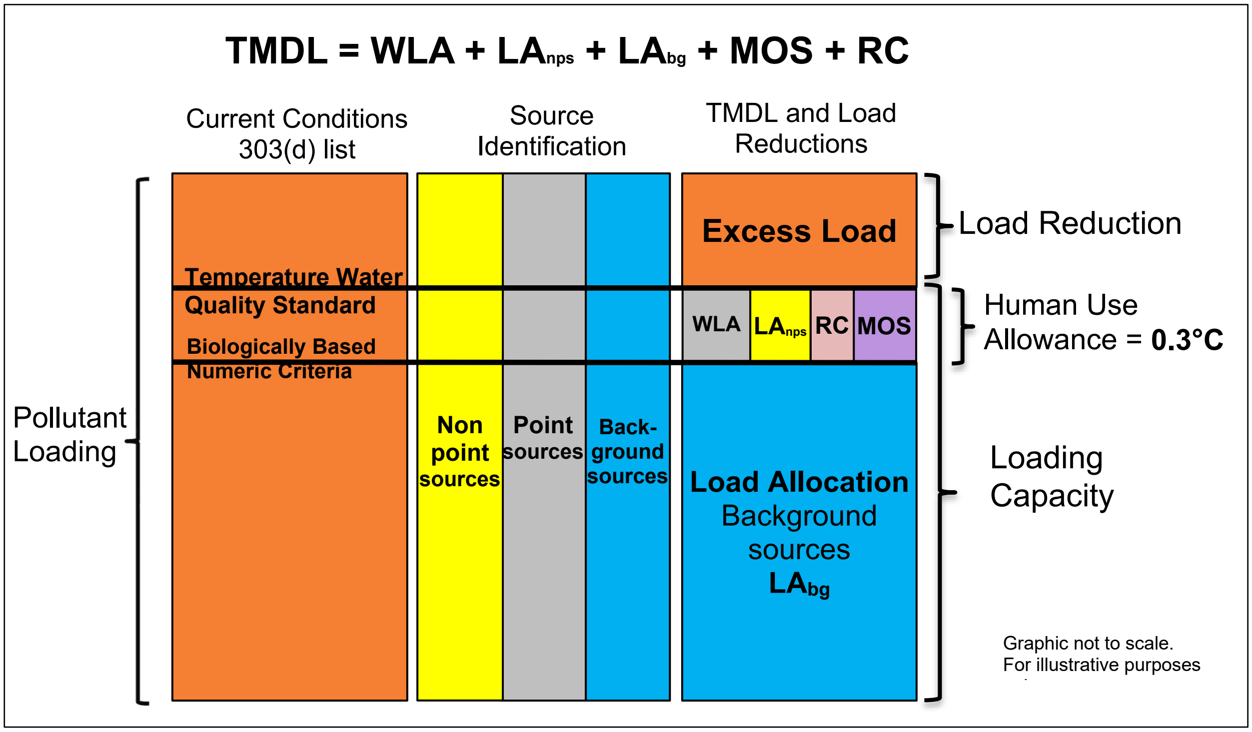

Figure 9-1: Conceptual representation and breakdown of total pollutant loading to a temperature-impaired waterbody.

Oregon's temperature standard provides a framework for how the LC is distributed between human sources of warming and background sources. The HUA at OAR 340-041-0028(12)(b)(B) identifies the portion of the LC reserved for human uses. The rule requires that wasteload and load allocations restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.30°C (0.5°F) above the applicable criteria after complete mixing in the water body, and at the POMI. DEQ assigned a thermal load equivalent to 0.30°C to human sources and the remainder of the LC to background sources.

When distributing the thermal loads associated with a 0.30°C increase, DEQ considered the magnitudes of thermal loads contributed by known sources; the ease of implementing the allocations; and the environmental impact of those thermal load contributions, including their effects on cumulative warming and the impact locations. **Figure 9-2** shows the portion of the HUA assigned to NPDES point sources for each AU within the TMDL project area.

DEQ assigned portions of the HUA to individual point sources that discharge to the Sandy River. The City of Sandy WWTP and the Hoodland STP portions were assigned based on a 15% increase above their respective current temperature impacts; this resulted in respective allocations of 0.05°C and 0.06°C. The City of Troutdale WPCF was allocated 0.09°C to avoid noncompliance and expected future growth. Compliance was based on evaluation of the WLAs against available effluent discharge data. Allocations to Sandy River tributaries are discussed in the following paragraphs.

On Cedar Creek, DEQ assigned the entire 0.30°C to the ODFW Sandy River Fish Hatchery's (NPDES-permitted) discharge to Cedar Creek. Available effluent discharge data indicated the facility would be in immediate noncompliance even with an allocation of the entire 0.30°C HUA. Other source categories on Cedar Creek were assigned a zero HUA. This decision was based upon the limited extent of riparian restoration needed upstream, and the complexity and associated cost required for ODFW to achieve the allocation. DEQ also provided an alternative allocation to ODFW for discharge to the Sandy River equal to 0.08°C. This allocation almost doubles the allowed thermal load relative to Cedar Creek and would reduce or eliminate days of noncompliance.

DEQ evaluated land use activities upstream of the ODFW fish hatchery to assess potential sources of warming. Immediately upstream of ODFW facility for approximately 2 miles, the land uses adjacent to the stream are primarily rural residential. Based on aerial imagery analysis, some locations within this reach appear to lack sufficient riparian vegetation. For another two miles upstream, the land use is a mix of forestry and agriculture. Here, the riparian areas appear relatively intact or in a state of regrowth with limited restoration potential. Then land use transitions back to rural residential paralleling Highway 26. Upstream of Highway 26, the USFS manages most of the land.

On Camp Creek, DEQ allocated 0.20°C to the Government Camp STP. Through analysis of available effluent discharge data from the year 2020, it was determined that a point of discharge WLA equal to a 0.20°C increase would not result in required thermal load reductions. Analysis conducted for this TMDL showed an allocation equal to 0.16°C during low river flows could require thermal load reduction below current operations and put the facility in immediate noncompliance. The allocation is consistent with the current NPDES permit and the 2005 Sandy TMDL. To account for the Government Camp STP's downstream impacts on modeled Zigzag River temperatures, DEQ assigned a 0.09°C HUA for point sources on the Zigzag River. See Appendix A Section 4.5.1 for model results.

Clackamas County manages the streamside vegetation requirements in its rural residential areas. Clackamas County ordinances already require a buffer width between 50 and 150 ft depending on site conditions. Federal management agencies (i.e., BLM, USFS) currently require a 300 ft buffer. Based on the Salmon River's current conditions, DEQ determined that implementation of the currently required buffer widths (100 ft for Clackamas County and 300 ft for federal agencies, referred to as "Protected Vegetation A" scenario) would result in effective shade values (37%) within two percentage points of shade targets (39%; see TSD Appendix A, Section 4.2.2 for details). In contrast, current Salmon River current effective shade values (27%) account for a maximum 7DADM temperature increase of 0.97°C (at river km 2.70 on August 26, 2016) compared to the Protected Vegetation A scenario. Assuming these requirements are enforced and areas lacking shade are addressed, DEQ determined that these rural residential areas will have limited potential for stream warming. On USFS land in most cases and except for intermittent streams, current streamside vegetation management does not lead to thermal increases (see WQMP Section 5.2.4).

On the Bull Run River, DEQ assigned the entire 0.30°C to the City of Portland for operation and management of the Bull Run dams and reservoirs. The assigned human use allowance includes any warming that may result from discharges of cooling water or sump pump wastewater associated with the dam or two powerhouses. The TMDL analysis assessed the combined discharge of cooling water together with the overall reservoir releases. The entire HUA was assigned because no other significant thermal sources to the Bull Run River are evident. There are some private forestland properties by the Bull Run River mouth, but the remainder of the Bull Run River watershed is owned by the City of Portland or USFS. There are some areas with young age-class trees that do not provide optimal shade, but DEQ expects that as these trees mature, sufficient shade will be achieved. DEQ determined that, in most cases and except for intermittent streams on USFS lands, the City of Portland and USFS's current streamside vegetation management in the watershed does not lead to thermal increases (see WQMP Section 5.2.4). On City of Portland-owned lands along the Lower Bull Run River, the city maintains a 200 ft no-cut buffer measured from the river's average high-water level (City of Portland, 2008).

In the Sandy River, DEQ assigned 0.02°C of the HUA to operation and management of the Bull Run dams and reservoirs, based on modeled Sandy River warming due to implementation of the Bull Run River surrogate measure temperature targets. The impact is small because the Bull Run River is usually cooler than the Sandy River.

DEQ allocated 0.05°C to water diversions and consumptive uses in most of the subbasin. Based on model results, DEQ estimated that a consumptive use flow rate reduction of 1.90% will attain this HUA (see TSD Appendix C, Section 9.0). Current consumptive uses are much greater than 1.90%: OWRD reported that consumptive uses account for 28% to 44% of median monthly natural flow at the Sandy River mouth (**Table 2-4**).

Sandy River modeling showed a maximum 7DADM temperature increase due to existing transportation corridors, buildings, and utility infrastructure of 0.03°C from the headwaters (river km 71.05) to river km 3.10 (just upstream of the I-84 bridge); the POMI (0.05°C) occurred downstream of the I-84 bridge (river km 2.80) on Aug. 29, 2026. At the Sandy River mouth (river km 0.00), the maximum increase was <0.005°C. Increased solar loading due to anthropogenic removal of streamside vegetation increased the 7DADM temperature between 0.5°C and 1°C on the Sandy River model extent (see TSD Appendix C, Section 6.0).

On the Sandy and Salmon Rivers, the portion of the HUA assigned to existing transportation corridors, buildings, and utility infrastructure is equal to the current temperature impacts (0.05°C and 0.06°C respectively), meaning that current solar loading from these existing uses does not require reduction. Other nonpoint sources of solar loading were assigned a zero (0.00°C) HUA, meaning streamside vegetation reduction may not cause temperature increases above applicable criteria. DEQ opted to assign a portion of the HUA to existing infrastructure (roads, railroads, buildings, and utility corridors) instead of other nonpoint sources because (a) the modeled effective shade gap for this infrastructure over the model extent was <0.5% and (b) moving, rebuilding, or modifying such infrastructure to restore streamside vegetation is very complex and potentially costly in comparison to streamside vegetation restoration or protection in areas without infrastructure constraints. DEQ heard comments from municipalities on the TMDL that such infrastructure-constrained land uses are difficult to restore.

Moreover, other (nonpoint source) land use types account for much greater stream extent (than infrastructure) in this TMDL. Based on results presented in Appendix G, very small absolute shade changes at the site level (not watershed means or percentages) produce measurable temperature increases. Based on data review, DEQ concluded that the vegetation reduction required in these areas to limit temperature increases to, e.g., < 0.05°C, and not cause downstream temperature standard exceedances, is similar to that required to maintain no temperature increase. Therefore, a zero HUA was assigned to other nonpoint sources to limit the cumulative warming potential and as a margin of safety. DEQ noted that existing pasture/cultivated field land use types included in the Sandy River and Salmon River models currently attain the assigned HUA (zero), which may be due to sufficient existing vegetated buffers between the rivers and existing pastures/cultivated fields. Overall, the total HUA portion assigned to nonpoint sources collectively is an increase from the 2005 Sandy River Basin temperature TMDL (DEQ, 2005). DEQ set aside any remaining HUA for reserve capacity to accommodate future growth or new sources.

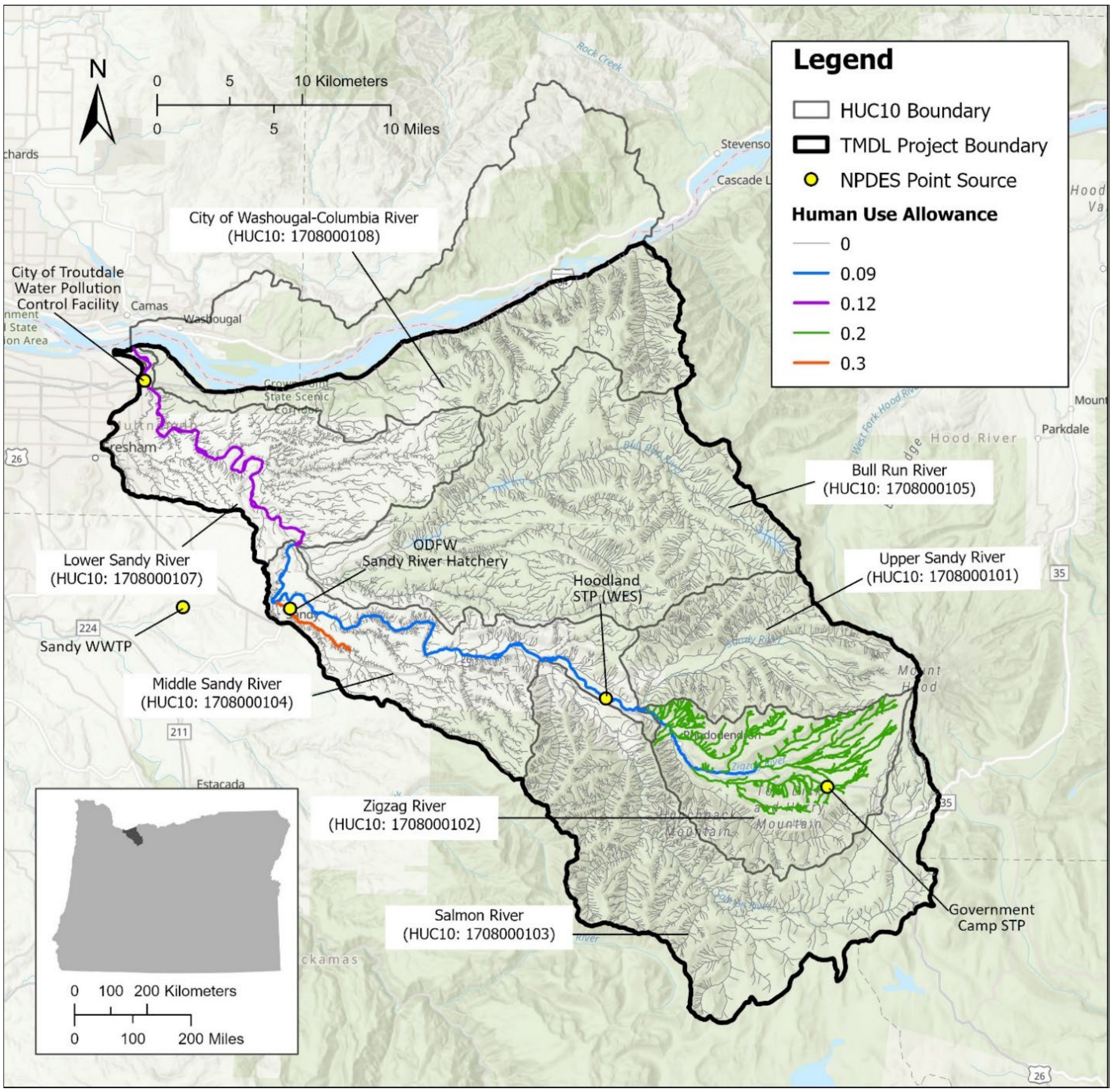

Figure 9-2: Assigned HUAs for NPDES point sources in each assessment unit within the TMDL project area.

9.1 Point source wasteload allocations (WLAs)

9.1.1 Wasteload allocations and equation

Equation 9-1 was used to calculate 7Q10-based WLAs for NPDES-permitted point sources (**Table 9-1**). The effluent flows for all permitted point sources (**Table 9-1**) were based on average (mean) dry-weather facility design flow, except for the ODFW Sandy River Fish Hatchery, where the effluent flow value was the maximum effluent discharge characterized from discharge data provided by ODFW. Average dry weather facility design flows were obtained from the current NPDES permit or permit evaluation report. WLAs may be implemented in NPDES permits in any of the following ways:

(1) Incorporate the 7Q10-based WLA in **Table 9-1** as a static numeric limit. Permit writers may recalculate the limit with **Equation 9-1** using different values for 7Q10 (Q_R) and effluent discharge (Q_E), if better estimates are available (including the use of seasonal values, as appropriate).
(2) Incorporate **Equation 9-1** directly into the permit with effluent flow (Q_E), river flow (Q_R), and the wasteload allocation (WLA) being dynamic and calculated on a daily basis. The assigned portion of the HUA (ΔT) is static and based on the value in **Table 9-1**. Permit writers may recalculate the 7Q10 using seasonal or annual values, as appropriate, if better estimates are available.

Table 9-1: Thermal wasteload allocations for point sources.

NPDES permittee WQ File number : EPA number	Assigned HUA (°C)	WLA period start	WLA period end	Annual 7Q10 river flow (cfs)	Effluent discharge (cfs)	7Q10 WLA[1] (kcal/day)
Government Camp STP 34136 : OR0027791	0.20	5/1	10/31	5.7	0.4	2.98E+6
Hoodland STP (WES) 39750 : OR0031020	0.06	5/1	10/31	158	1.4	23.40E+6
City of Troutdale WPCF 89941 : OR0020524	0.09	5/1	10/31	278	4.6	62.23E+6
City of Sandy WWTP 78615 : OR0026573	0.05	5/1	10/31	217	1.9	26.78E+6
ODFW Sandy River Fish Hatchery 64550 : ORG130009 Option A – Discharge to Cedar Creek	0.30	5/1	10/31	4.9	3.2	5.95E+6
ODFW Sandy River Fish Hatchery 64550 : ORG130009 Option B – Discharge to Sandy River	0.08	5/1	10/31	217	3.2	43.10E+6

[1] Listed WLAs were calculated based on the 7Q10 flow.
Notes: Applicable criterion = Biologically-based numeric criteria WLA = wasteload allocation; kcals/day = kilocalories/day
* When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ODFW Sandy River Fish Hatchery ΔT = 0.0 and the WLA = 0 kcal/day. Minimum duties provision does not apply under WLA Option B.

$$WLA = (\Delta T) \cdot (Q_E + Q_R) \cdot C_F$$ **Equation 9-1**

where,

$WLA =$ Wasteload allocation (kilocalories/day), expressed as a rolling seven-day average.

$\Delta T =$ The assigned portion of the human use allowance and the maximum temperature increase (°C) above the applicable temperature criterion using 100% of river flow not to be exceeded by each individual source from all outfalls combined. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0. **Equation 9-7** was used to determine if the minimum duties provision applies.

$Q_E =$ The daily mean effluent flow (cfs).
When effluent flow is in million gallons per day (MGD) convert to cfs:

$$\frac{1{,}000{,}000\ gallons}{1\ day} \cdot \frac{0.13368 ft^3}{1\ gallon} \cdot \frac{1\ day}{86{,}400\ sec} = 1.5472\ ft^3/sec$$

$Q_R =$ The daily mean river flow rate (cfs), upstream (of the NPDES discharge).
When flow is <= 7Q10, Q_R = 7Q10. When flow is > 7Q10, Q_R equals the daily mean river flow, upstream.

$C_F =$ Conversion factor using flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\text{C}} = 2{,}446{,}665$$

9.1.2 WLA attainment equation

To evaluate current discharges, DEQ used **Equation 9-2** to determine the actual ETL. The ETL was compared to the WLA from **Equation 9-1** to assess attainment.

$$ETL = (T_E - T_C) \cdot Q_E \cdot C_F$$ **Equation 9-2**

where,

$ETL =$ The daily excess thermal load (kilocalories/day), expressed as a rolling seven-day average.

$T_{C,i} =$ The point of discharge applicable river temperature criterion (°C) (T_c); or when the minimum duties provision at OAR 340-041-0028(12)(a) applies $T_{C,i}$ = the 7DADM measured at the facility intake (T_i). **Equation 9-7** was used to determine if the minimum duties provision applies.

$T_E =$ The daily maximum effluent temperature (°C)

$Q_E =$ The daily mean effluent flow (cfs or MGD)

$C_F =$ Conversion factor for flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\text{C}} = 2{,}446{,}665$$

Conversion factor for flow in millions of gallons per day (MGD): 3,785,411

$$\frac{1\ m^3}{264.17\ gal} \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{1000000\ gal}{1\ million\ gal} \cdot \frac{1\ kcal}{1\ \text{kg}\ \cdot 1°\text{C}} = 3{,}785{,}441$$

9.1.3 Calculating current change in temperature

Equation 9-3 was used to assess current temperature changes based on point source discharges, river flows, and applicable temperature criteria.

$$\Delta T_{Current} = \left(\frac{Q_E}{Q_E + Q_R}\right) \cdot (T_E - T_C)$$ **Equation 9-3**

where,

$\Delta T_{Current} =$ The current river temperature increase (°C) above the applicable river temperature criterion using 100% of river flow.

$Q_E =$ The daily mean effluent flow (cfs).
When effluent flow is in million gallons per day (MGD) convert to cfs:

$$\frac{1\ million\ gallons}{1\ day} \cdot \frac{1.5472\ ft^3}{1\ million\ gallons} = 1.5472$$

$Q_R =$ The daily mean river flow rate, upstream (cfs).
When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow, upstream.

$T_E =$ The daily maximum effluent temperature (°C)

$T_C =$ The point of discharge applicable river temperature criterion (°C). When the minimum duties provision at OAR 340-041-0028(12)(a) applies T_C = the 7DADM measured at the facility intake.

9.1.4 Calculating TMDL allocation river temperature

Equation 9-4 was used to determine the ambient river temperature downstream of a point of discharge based on the allocated portion of the HUA (ΔT) or WLA in the TMDL. **Equation 9-4** assumes 100% mixing between river and effluent discharge. The equation was used to assess ODFW's Sandy River Fish Hatchery impact on Cedar Creek and to develop the Cedar Creek tributary input temperatures for the Sandy River WLA model scenario (See TSD Appendix C, Section 5.0).

$$T_{R\_WLA} = Q_R \cdot \frac{\left(T_{R\_up} - T_C\right)}{(Q_E + Q_R)} + (T_C + \Delta T)$$ **Equation 9-4a (using ΔT)**

$$T_{R\_WLA} = T_{R\_up} + \frac{Q_E}{(Q_E + Q_R)} \cdot \left(\left(\frac{WLA}{(Q_R \cdot C_F)} + T_C\right) - T_{R\_up}\right)$$ **Equation 9-4b (using WLA)**

$$T_{R\_WLA} = T_{R\_up} + \left(\frac{Q_E}{Q_E + Q_R}\right) \cdot \left(T_{E\_WLA} - T_C\right)$$ **Equation 9-4c (using effluent temp)**

where,

$T_{R\_WLA} =$ Ambient river temperature (°C) downstream of the point of discharge assuming 100% mix.

$\Delta T =$ The assigned portion of the human use allowance and the maximum temperature increase (°C) above the applicable river temperature criterion, using 100% of river flow, not to be exceeded by each individual source from all outfalls combined. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0.

$WLA =$ Wasteload allocation (kilocalories/day) from **Equation 9-1**.

$Q_E =$ The daily mean effluent flow (cfs).
When effluent flow is in million gallons per day (MGD), convert to cfs:
$$\frac{1\ million\ gallons}{1\ day} \cdot \frac{1.5472\ ft^3}{1\ million\ gallons} = 1.5472$$

$Q_R =$ The daily mean river flow rate, upstream (cfs).
When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow, upstream.

$T_{E\_WLA} =$ Daily maximum effluent temperature (°C) allowed under the wasteload allocation from **Equation 9-4a** or **Equation 9-4b**. When T_{E_WLA} is > 32°C, T_{E_WLA} = 32°C as required by the thermal plume limitations in OAR 340-041-0053(2)(d)(B).

$T_C =$ The point of discharge applicable river temperature criterion (°C). When the minimum duties provision at OAR 340-041-0028(12)(a) applies, T_C = the 7DADM measured at the facility intake.

$T_{R\_up} =$ Ambient river temperature upstream of the point of discharge (°C).

9.1.5 Calculating acceptable effluent temperatures

Equation 9-5 was used to calculate the daily maximum effluent temperatures (°C) acceptable under allocated portion of the HUA (ΔT) and the WLA.

$$T_{E\_WLA} = \frac{(Q_E + Q_R) \cdot (T_C + \Delta T) - (Q_R \cdot T_C)}{Q_E}$$ **Equation 9-5a (using ΔT)**

$$T_{E\_WLA} = \frac{(WLA)}{Q_E \cdot C_F} + T_C$$ **Equation 9-5b (using WLA)**

where,

$T_{E\_WLA} =$ Daily maximum effluent temperature (°C) allowed under the wasteload allocation. When T_{E_WLA} is > 32°C, T_{E_WLA} = 32°C as required by the thermal plume limitations in OAR 340-041-0053(2)(d)(B).

$WLA =$ Wasteload allocation (kilocalories/day) from **Equation 9-1**.

$\Delta T =$ The assigned portion of the human use allowance and the maximum temperature increase (°C) above the applicable river temperature criterion, using 100% of river flow, not to be exceeded by each individual source from all outfalls combined. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ∆T = 0.0.

$Q_E =$ The daily mean effluent flow (cfs). When effluent flow is in million gallons per day (MGD) convert to cfs:

$$\frac{1\ million\ gallons}{1\ day} \cdot \frac{1.5472\ ft^3}{1\ million\ gallons} = 1.5472$$

$Q_R =$ The daily mean river flow rate, upstream (cfs). When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow, upstream.

$T_{C,i} =$ The point of discharge applicable river temperature criterion (°C) (T_c); or when the minimum duties provision at OAR 340-041-0028(12)(a) applies $T_{C,i}$ = the 7DADM measured at the facility intake (T_i).

$C_F =$ Conversion factor for flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\text{ m}}{3.2808\text{ ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1℃} = 2{,}446{,}665$$

9.1.6 Calculating acceptable effluent flows

Equation 9-6 was used to calculate the daily mean effluent flow (cfs) acceptable under allocated portion of the HUA (∆T) and WLA.

$$Q_{E\_WLA} = \frac{(Q_R \cdot T_C) - ((T_C + \Delta T) * Q_R)}{T_C + \Delta T - T_E}$$ **Equation 9-6a (using ∆T)**

$$Q_{E\_WLA} = \frac{(WLA)}{(T_E - T_C) * C_F}$$ **Equation 9-6b (using WLA)**

where,

$Q_{E\_WLA} =$ Daily mean effluent flow (cfs) allowed under the wasteload allocation.

WLA = Wasteload allocation (kilocalories/day) from

$\Delta T =$ The assigned portion of the human use allowance and the maximum temperature increase (°C) above the applicable river temperature criterion, using 100% of river flow, not to be exceeded by each individual source from all outfalls combined. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ∆T = 0.0.

$T_E =$ The daily maximum effluent temperature (°C).

$Q_R =$ The daily mean river flow rate, upstream (cfs). When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow, upstream.

$T_{C,i} =$ The point of discharge applicable river temperature criterion (°C) (T_c); or when the minimum duties provision at OAR 340-041-0028(12)(a) applies $T_{C,i}$ = the 7DADM measured at the facility intake (T_i).

$C_F =$ Conversion factor for flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\text{ m}}{3.2808\text{ ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1℃} = 2{,}446{,}665$$

9.1.7 Determination of when minimum duties provision applies

The minimum duties provision at OAR 340-041-0028(12)(a) states that anthropogenic sources are only responsible for controlling the thermal effects of their own discharge or activity in accordance with its overall heat contribution.

For point sources, DEQ is implementing the minimum duties provision if a facility operation meets acceptable operation and design requirements. The facility must be operated as a “flow through” facility where intake water moves through the facility and is not processed as part of an industrial or wastewater treatment operation. If a facility mixes the intake water with other wastewater or as a method to cool equipment, DEQ considers the thermal effects of this operation to be part of the facility’s own activity and the minimum duties provision is not applicable. The intake water must also be returned to the same stream where the intake is located. If the water is not returned to the same stream the thermal effects do not originate from the receiving stream and therefore are considered as part of the facility’s own discharge.

When the minimum duties provision applies, the facility cannot add any additional thermal loading to the intake temperatures when the intake temperatures are warmer than the maximum effluent discharge temperatures allowed by the WLA. The purpose is to ensure the facility controls for thermal effects resulting from passing the water through and not from upstream sources.

In the Lower Columbia-Sandy, DEQ determined that ODFW’s Sandy River Fish Hatchery is the only NPDES-permitted point source facility that operates as a flow through facility. DEQ used the approach described in **Equation 9-7** to implement the minimum duties provision for ODFW’s WLA option A. WLA option B was developed in case ODFW moves the discharge location from Cedar Creek to the Sandy River. ODFW holds a water right permit on Cedar Creek and indicated the intake will likely continue to be located on Cedar Creek even if the outfall is moved to the Sandy River. Because the intake and discharge location are on different streams, DEQ will not implement the minimum duties provision under WLA option B.

For new facilities or facilities where the intake or outfall locations have been moved, DEQ will use the approach described above to determine if the minimum duties provision is applicable.

The minimum duties provision applies on days when $T_{E\_WLA} < T_i$.

When the minimum duties provision applies, there may be no increase in temperature above the intake temperature (T_i) and the assigned portion of the human use allowance is zero ($\Delta T = 0.0$). **Equation 9-7**

where,

$T_{E\_WLA} =$ Daily maximum effluent temperature (°C) allowed under the wasteload allocation as calculated using **Equation 9-5**

$T_i =$ The daily maximum influent temperature (°C) measured at the facility intake.

9.2 Nonpoint source load allocations (LAs)

LAs are assigned to background and anthropogenic nonpoint sources on all waters in the Lower Columbia-Sandy Subbasin. LAs apply during the critical periods identified in **Table 5-1**. LAs for background sources are calculated using **Equation 9-8**.

$$LA_{BG} = (T_C) \cdot (Q_R) \cdot C_F$$ **Equation 9-8**

where,

$LA_{BG} =$ Load allocation to background sources (kilocalories/day).

$T_C =$ The applicable temperature criteria, not including the human use allowance. When there are two year-round applicable temperature criteria that apply to the same assessment unit, the more stringent criterion shall be used.

$Q_R =$ The daily average river flow rate (cfs).

$C_F =$ Conversion factor using flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\ \mathrm{m}}{3.2808\ \mathrm{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\mathrm{C}} = 2{,}446{,}665$$

Table 9-2 presents the 7Q10-based LAs for background sources on temperature-impaired Category 5 AUs that have current NPDES discharge(s) within the AU extent or were modeled for this TMDL. The LAs are based on the minimum applicable year-round criterion and the spawning criterion in the respective AU, and the 7Q10 low river flows. **Equation 9-8** shall be used to calculate the LAs assigned to background sources on all other AUs or stream location in the Lower Columbia-Sandy Subbasin not identified in **Table 9-2**, or for AUs identified in **Table 9-2** when river flows are greater than 7Q10.

If the applicable temperature criteria are updated and approved by EPA, the background LAs assigned to any AU or stream location where the temperature criterion changed shall be recalculated using the updated criteria and **Equation 9-8**.

Table 9-2: Thermal load allocations for background sources.

AU name, extent and ID	Annual 7Q10 flow (cfs)	Year-round criterion (°C)	Spawning criterion (°C)	LA period start	LA period end	7Q10 LA[1] – year-round (kcal/day)	7Q10 LA[1] – spawning (kcal/day)
Bull Run River - Bull Run Reservoir Number Two to confluence with Sandy River OR_SR_1708000105_11_103611	20	16.0	13.0	5/1	11/15	782.93E+6	636.13E+6
Cedar Creek - Beaver Creek to confluence with Sandy River OR_SR_1708000104_02_103607	4.9	18.0	13.0	5/1	10/31	215.80E+6	155.85E+6
Little Sandy River - Bow Creek to confluence with Bull Run River OR_SR_1708000105_11_103609	11	16.0	13.0	5/1	10/31	430.61E+6	349.87E+6
Salmon River - South Fork Salmon River to confluence with Sandy River OR_SR_1708000103_02_103606	174	16.0	13.0	5/1	10/31	6,811.52E+6	5,534.36E+6
Sandy River - Bull Run River to confluence with Columbia River OR_SR_1708000107_02_103616	278	18.0	13.0	5/1	10/31	12,243.11E+6	8,842.25E+6
Sandy River - Clear Fork to Zigzag River OR_SR_1708000101_02_103599	50	18.0	13.0	5/1	10/31	2,202.00E+6	1,590.33E+6
Sandy River - Zigzag River to Bull Run River OR_SR_1708000104_02_103608	217	16.0	13.0	5/1	10/31	8,494.82E+6	6,902.04E+6
Zigzag River - Bow Creek to confluence with Bull Run River OR_SR_1708000102_02_103600	48	16.0	13.0	5/1	10/31	1,879.04E+6	1,526.72E+6

[1] Listed LAs were calculated based on the 7Q10 river flow.
Notes: Applicable criterion = Biologically-based numeric criteria (to protect cold water fish); LA = load allocation; kcals/day = kilocalories/day.

LAs assigned to anthropogenic nonpoint sources on any AU or stream location in the Lower Columbia-Sandy Subbasin are calculated using **Equation 9-9**. The portions of the HUA (ΔT) assigned to nonpoint source categories are presented in the Lower Columbia-Sandy TMDL (Tables 9-1 through 9-7).

$$LA_{NPS} = (\Delta T) \cdot (Q_R) \cdot C_F$$ **Equation 9-9**

where,

$LA_{NPS} =$ Load allocation to anthropogenic nonpoint sources (kilocalories/day).

$\Delta T =$ The portion of the human use allowance assigned to each nonpoint source category representing the maximum cumulative temperature increase (°C) from all source activity in the nonpoint source category. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0.

$Q_R =$ The daily average river flow rate (cfs).

$C_F =$ Conversion factor using flow in cubic feet per second (cfs): 2,446,665

$$\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^3 \cdot \frac{1\ m^3}{35.31\ ft^3} \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1℃} = 2{,}446{,}665$$

9.3 Surrogate measures

EPA regulations 40 CFR 130.2(i) and OAR 340-042-0040(O)(5)(b) allow for TMDLs to utilize other appropriate measures (or surrogate measures). This section presents surrogate measures that implement the LAs.

9.3.1 Dam and reservoir operations

Dam and reservoir operations in the Lower Columbia-Sandy have been assigned a portion of the HUA as presented in **Table 10-2**, and the equivalent load allocation as calculated using **Equation 9-8**. Monitoring stream temperatures, rather than thermal loads, is an easier and more meaningful approach to reservoir management. Temperature increases are mathematically related to excess thermal loading and directly linked to the temperature water quality standard. For these reasons, DEQ is using a surrogate measure to implement the LA for dam and reservoir operations.

DEQ has developed the following surrogate measure temperature approach to implement the LA. The surrogate measure compliance point is located immediately downstream of the dam where impounded water is returned to the free-flowing stream. The surrogate measure is:

a) The 7DADM temperatures immediately upstream of the reservoirs. If multiple streams flow into the reservoir, 7DADM temperatures upstream of the reservoirs may be calculated as a flow-weighted mean of temperatures from each inflowing tributary. The estimated free-flowing (no dam) temperatures may be calculated using a mechanistic or empirical model to account for any warming or cooling that would occur through the reservoir reaches absent the dam and reservoir operations. The results may be applied as the temperature surrogate measure or to adjust the 7DADM temperatures monitored immediately upstream of the reservoirs. Use of the model approach for the surrogate measure must be approved by DEQ.

b) Additional adjustments to the surrogate temperature target calculated or measured under item a) may be allowed when all the following are true:

I. Monitoring data show 7DADM temperatures do not exceed the applicable temperature criteria in the AU downstream of the dam;
II. The protecting cold water (PCW) criterion at OAR 340-041-0028(11) does not apply. DEQ completed an initial screen (section 9.3.1.1) and determined the PCW criterion likely does not apply to dams in the Lower Columbia-Sandy;
III. A cumulative effects analysis, approved by DEQ, demonstrates that dam release water temperatures warmer than the surrogate measure calculated or measured under item a) will result in attainment of the dam and reservoir assigned HUA above the applicable criteria in downstream waters.

The dam and reservoir surrogate measure will attain the assigned HUA and LA because it targets 7DADM temperatures no warmer than those upstream of the reservoir. The surrogate measure also implements the minimum duties provision in rule at OAR 340-041-0028(12)(a). This provision states that anthropogenic sources are only responsible for controlling the thermal effects of their own discharge or activity in accordance with their overall heat contribution. For dam and reservoir operations, the surrogate measure reflects temperatures upstream of the reservoir (or no dam temperatures), thus ensuring dam operators are only responsible for temperature increases caused by the dam and reservoir operations.

For implementation of the low flow conditions provision at OAR 340-041-0028(12)(d), the 7Q10 shall be calculated at a gage upstream of the reservoir or at nearby monitoring gage that isn't influenced by the dam's operations.

9.3.1.1 Protecting cold water criterion and dams in the Lower Columbia-Sandy Subbasin

There are approximately 12 large instream dams located within the Lower Columbia-Sandy Subbasin temperature TMDL project area. The list of dams was obtained from the USACE NID database. For each of these dams, DEQ was interested in determining whether the PCW criterion applied to immediate downstream and upstream reaches.

The PCW criterion has multiple components to determine applicability. These components include:

a) having summer 7DADM ambient temperatures that are always colder than the biologically-based criteria;
b) salmon, steelhead, or bull trout presence;
c) no threatened or endangered salmonid presence;
d) no critical habitat designation; and
e) the colder ambient water is not necessary to ensure that downstream temperatures achieve and maintain compliance with the applicable temperature criteria.

DEQ evaluated components a) to d) using available information following the process outlined in **Figure 4-3**. Several sources were examined to determine if summer 7DADM ambient temperatures were always colder than the biologically-based criteria. The results of Oregon's 2022 Integrated Report were first used to determine if the dam was located on a Category 5 temperature-impaired AU. A Category 5 temperature impairment (either year-round or spawning) precludes qualification for the PCW criterion. As such, if downstream or upstream AUs were listed as impaired for temperature, it was noted that the PCW did not apply. If an AU was identified as attaining for temperature (Category 2), it was assumed ambient 7DADM ambient temperatures are always colder than the biologically-based criteria.

The NorWeST SSN stream temperature models developed by Isaak et al. (2017) were also used to determine if temperatures are always colder than the biologically-based criteria. These models use covariates derived from NHD and other sources to predict temperatures for all river and stream reaches in various subregions in the Pacific Northwest. DEQ used the model outputs for the Oregon Coast processing unit. The specific model outputs were from the MWMT S2_02_11 composite scenario, which is the prediction of the 10-year average (2002-2011) August Maximum Weekly Maximum (MWMT) stream temperature. The MWMT is similar to the 7DADM.

The NorWeST model outputs consists of point temperature predictions as well as reach-average temperature predictions. Where available, NorWeST temperatures upstream and downstream of each reservoir were compared to the applicable year-round (non-spawning) 7DADM temperature criterion. If the MWMT S2_02_11 scenario temperatures exceeded the applicable temperature criterion immediately upstream or downstream of the dam and reservoir, it was reported that the PCW did not apply. Conversely, if the MWMT S2_02_11 temperature was less than the criterion both up and downstream, it was assumed ambient 7DADM ambient temperatures are always colder than the biologically-based criteria. In the rare instance of a discrepancy between the Integrated Report and the NorWeST data, priority for PCW determination was given to the Integrated Report. One major limitation in the Norwest data is that the model does not make predictions during the fall when the spawning criterion apply.

The applicability of the PCW criterion was not always immediately apparent. In multiple instances, while the NHD stream network showed an upstream reach flowing into a reservoir, no upstream NorWeST data existed. In these cases, it was noted that the applicability of the PCW criterion was unclear. For other dams, there existed a short downstream NHD line with no corresponding NorWeST data until the stream flowed into a connecting stream. In these cases, it was noted that the applicability of the PCW was unclear. For off-channel lagoons associated with treatment systems, N/A was reported. For reservoirs with no inflowing streams such as offstream irrigation ponds, N/A was selected for upstream and Integrated Report/NorWeST data were evaluated for the downstream reach. When it was unclear whether the reservoir connected to a downstream flowline, it was noted that the applicability of the PCW was unclear.

ODFW's fish habitat distribution (FHD) GIS database was used to evaluate presence of salmon, steelhead, or bull trout. NOAA's National Marine Fishery Service and U.S. Fish & Wildlife Service GIS features were used to evaluate threatened or endangered salmonid presence and critical habitat designations.

Based on these methods, DEQ determined that the PCW criterion is unlikely to apply at any of the dams in the Lower Columbia-Sandy Subbasin.

9.3.2 City of Portland Bull Run drinking water and hydroelectric project

The City of Portland Bull Run drinking water and hydroelectric project has been assigned 0.30°C of the HUA and the equivalent LA on the Bull Run River as calculated with **Equation 9-9**. In the Sandy River, warming from this project has been assigned 0.02°C of the HUA.

For the TMDL analysis, a temperature data analysis and model-based cumulative effects analysis were completed to evaluate the sufficiency of the surrogate measure temperature target to attain the assigned HUA on the Bull Run River. Based on these analyses, DEQ determined that dam release temperatures that are below the most restrictive applicable criteria but above ambient temperatures will not increase downstream 7DADM temperatures beyond the 0.30°C HUA assigned to the Bull Run project. The model assumed free-flowing conditions and surrogate measure temperature target attainment.

The transition to the 13.0°C spawning use varies spatially and temporally in the Bull Run River. To protect these downstream spawning uses, DEQ applied the most restrictive temporal period to determine the spawning criterion applicable to the surrogate measure target. Based on these results, the surrogate measure temperature target at the lamprey barrier just downstream of Reservoir #2 is:

(a) The estimated free-flowing (no dam) 7DADM temperatures at the lamprey barrier as calculated with **Equation 9-10**; or

(b) The applicable value in I or II below on days when the value under item (a) is cooler than the applicable value in I or II below.

I. 16.3°C (June 16 to August 14)
II. 13.3°C (May 1 to June 15 and August 15 to November 15).

If the most restrictive applicable temperature criteria on the Bull Run River between Reservoir #2 and the confluence of the Bull Run River and Sandy River are updated and approved by EPA, the updated criteria and applicable period shall be used instead.

The low-flow conditions provision at OAR 340-041-0028(12)(d) may apply when the daily mean flow at USGS gage 14138850 is less than the 7Q10 (33 cfs).

DEQ developed a regression equation (**Equation 9-10**) to predict the free-flowing (no dam) daily maximum temperatures at the lamprey barrier. The methodology and data for development of the regression is documented in the TSD Appendix E. With DEQ approval, an alternative approach may be used to calculate the free-flowing no dam temperatures.

$$T_{Max} = 0.1405173 + 1.1572642\overline{T_{LS}} + -0.3588068\log\overline{Q_{LS}} + \left(\frac{3.7557135 + 1.1668769T_{dLS} + -0.5969993\log\overline{Q_{LS}}}{2}\right) \quad \textbf{Equation 9-10}$$

Where,

$T_{Max} =$ The no dam daily max. stream temperature at the lamprey barrier downstream of Reservoir #2.
$\overline{T_{LS}} =$ The daily mean temperature (°C) at USGS Gage 14141500 Little Sandy River Near Bull Run.
$\overline{Q_{LS}} =$ The mean daily discharge (cfs) at USGS Gage 14141500 Little Sandy River Near Bull Run.
$T_{dLS} =$ The daily temperature range (°C) calculated as the daily maximum minus the daily minimum at USGS Gage 14141500 Little Sandy River Near Bull Run.

9.3.3 Site-specific effective shade surrogate measure

For each DMA listed in **Table 9-3**, the effective shade surrogate measure values (current and target) equal the means across all model nodes assigned to that DMA (**Equation 9-11**). **Equation 9-11** may be used to recalculate mean effective shade values if DMA boundaries change or need correction. **Equation 9-11** may also be used to recalculate mean effective shade targets based on an updated shade gap assessment per the process and methods outlined in the WQMP Section 5.3.1.

Changes in target effective shade may result in redistribution of the sector or source responsible for excess load reduction. If the shade target increases, the equivalent portion of the excess load is reassigned from background sources to nonpoint sources. If the shade target decreases, the portion of the excess load is reassigned from nonpoint sources to background sources. The exact portion reassigned can only be determined in locations where temperature models have been developed. In locations without temperature models, the reassignment remains unquantified. Changes to the target effective shade do not impact the LC, HUA, or load allocations. They remain the same as presented in this TMDL.

$$\overline{ES} = \frac{\sum ES_{n_i}}{n_i} \qquad \textbf{Equation 9-11}$$

Where,

$\overline{ES} =$ The mean effective shade for designated management agency *i.*

$\sum ES_{n_i} =$ The sum of effective shade from all model nodes or measurement points assigned to designated management agency *i.*

$n_i =$ Total number of model nodes or measurement points assigned to designated management agency *i.*

Table 9-3: Shade surrogate measure targets to meet nonpoint source load allocations on model stream extents.

DMA	Stream name	Current shade (%)	TMDL target[1] (%)	Shade gap
Oregon Department of Forestry - Private	Little Sandy River	74	74	0
U.S. Bureau of Land Management	Little Sandy River	54	66	12
U.S. Forest Service	Little Sandy River	69	71	2
Clackamas County	Zigzag River	32	52	20
Oregon Department of Forestry - Private	Zigzag River	22	37	15
U.S. Forest Service	Zigzag River	50	62	12
Clackamas County	Salmon River	25	37	12
Oregon Department of Forestry - Private	Salmon River	27	43	16
U.S. Bureau of Land Management	Salmon River	27	36	9
U.S. Forest Service	Salmon River	41	56	15
City of Portland	Sandy River	9	13	4
City of Sandy	Sandy River	21	23	2
City of Troutdale	Sandy River	15	19	4
Clackamas County	Sandy River	17	26	9
Multnomah County	Sandy River	16	18	2
Oregon Department of Agriculture	Sandy River	23	28	5
Oregon Department of Fish and Wildlife	Sandy River	22	26	4
Oregon Department of Forestry - Private	Sandy River	19	23	4
Oregon Parks and Recreation Department	Sandy River	6	7	1
Port of Portland	Sandy River	3	9	6
State of Oregon	Sandy River	13	17	4
U.S. Bureau of Land Management	Sandy River	24	27	3
U.S. Forest Service	Sandy River	3	6	3

[1] TMDL shade targets for the Sandy River and Salmon River are based on Restored Vegetation “B” shade values.

9.3.4 General effective shade curve surrogate measure

Effective shade curves are applicable to any stream that does not have site-specific shade targets (Section 9.3.3). Effective shade curves represent the maximum possible effective shade for a given vegetation type. The values presented in **Figure 9-4** to **Figure 9-13** represent the mean effective shade target for different composite vegetation types, stream aspects, and active channel widths. The vegetation height, density, overhang, and buffer width used for each vegetation type are summarized in **Table 9-4**. See TSD Appendix A for the methodology used to calculate shade curves. Note that the vegetation type "555 - Mixed Conifer/Hardwood - Low Density" and "650 - Hardwood - Low Density" shade curves are associated with the vegetation assumptions applicable to infrastructure land uses (e.g., existing buildings, transportation, and utility corridors), and are intended for use only in such areas. Likewise, the "975 - Grasses or wetlands" shade curve is intended for use only in naturally open meadows and wetlands.

Effective shade may be prevented from achieving effective shade targets due to natural factors including local geology, geography, soils, climate, natural disturbances, and other natural phenomena. DEQ will not take enforcement actions for effective shade reductions caused by such natural factors.

Table 9-4: Vegetation height, density, overhang, and horizontal distance buffer widths used to derive generalized effective shade curve targets.

Landcover code	Vegetation type	Height (m)	Height (ft)	Density (%)	Overhang (m)	Buffer width (m)
500	Mixed Conifer/Hardwood - High Density	26.7	87.6	60	3.3	36.8
550	Mixed Conifer/Hardwood - Medium Density	26.7	87.6	30	3.3	36.8
555	Mixed Conifer/Hardwood - Low Density	26.7	87.6	10	3.3	36.8
600	Hardwood - High Density	20.1	65.9	75	3.0	36.8
650	Hardwood - Low Density	20.1	65.9	30	3.0	36.8
700	Conifer - High Density	35.1	115.2	60	3.5	36.8
750	Conifer - Low Density	35.1	115.2	30	3.5	36.8
800	Shrub – High Density	1.8	5.9	75	0.0	36.8
850	Shrub – Low Density	1.8	5.9	25	0.0	36.8
975	Grasses or Wetlands	0.9	2.0	90	0.0	36.8

How to use a shade curve:

1. Determine the applicable vegetation type and corresponding shade curve for your stream location.

2. Determine the stream aspect from north.

   Example: Standing in-stream mid-channel, facing north, you determine the river's aspect as 0º or 180º from north (180º means the river reach runs south to north).

3. Determine the active channel width of the stream reach.

   Example: At your location, you measure the active channel width using a tape measure or laser range finder and determine that it is 25 ft.

4. Using the appropriate vegetation shade curve or shade curve table from the TMDL rule, identify the stream aspect (line) and active channel width (x-axis) that correspond to your measurements to determine the percent effective shade (y-axis) of your site. This is the non-point source load allocation of the stream reach at system potential vegetation.

   Example: You determined that the appropriate shade curve for your site is high density mixed Conifer/Hardwood (**Figure 9-3**). Since your site is on a reach with a north to south stream aspect, you use the dashed line to determine the effective shade. By reading the y-axis value corresponding to an active channel width of 25 ft (blue lines), you determine the effective shade is ~75% when system potential vegetation is achieved on the left and right banks of the reach. System potential vegetation defines the average riparian vegetation height as 87.6 ft (26.7 m) and the stand density (canopy density) as 60%.

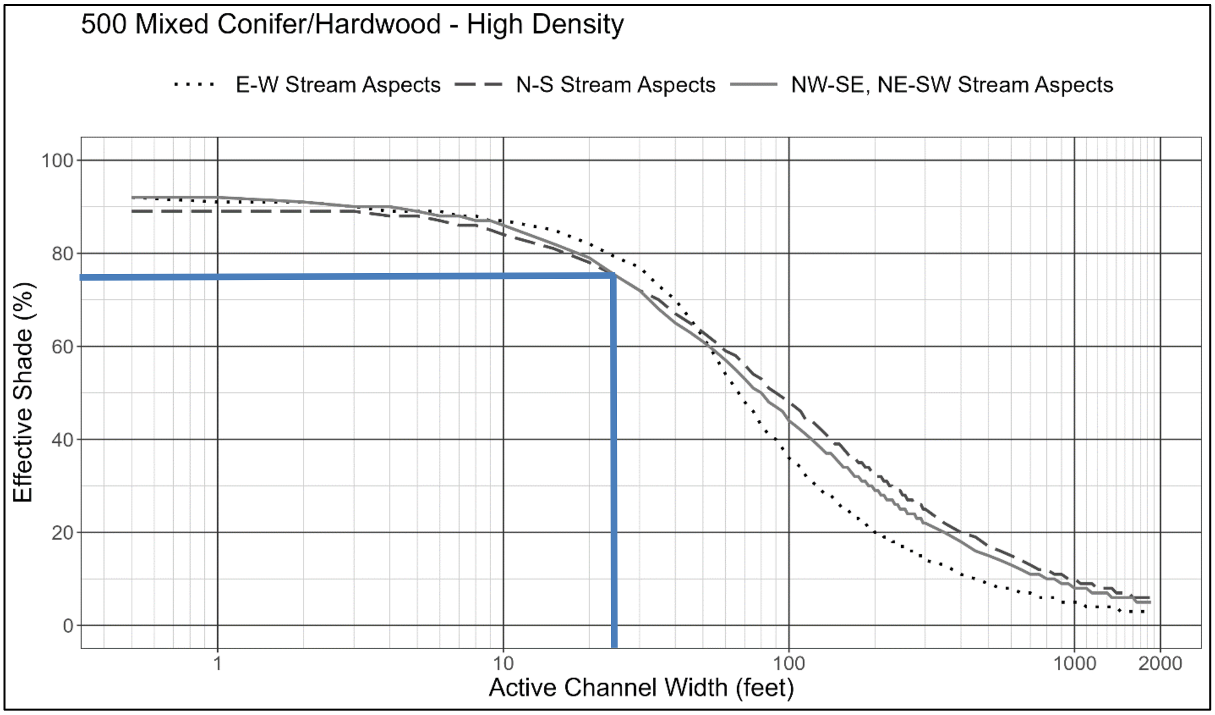

Figure 9-3: Example: Use of the shade curve for a mapping unit based on a north to south aspect and an active channel width of 25 ft.

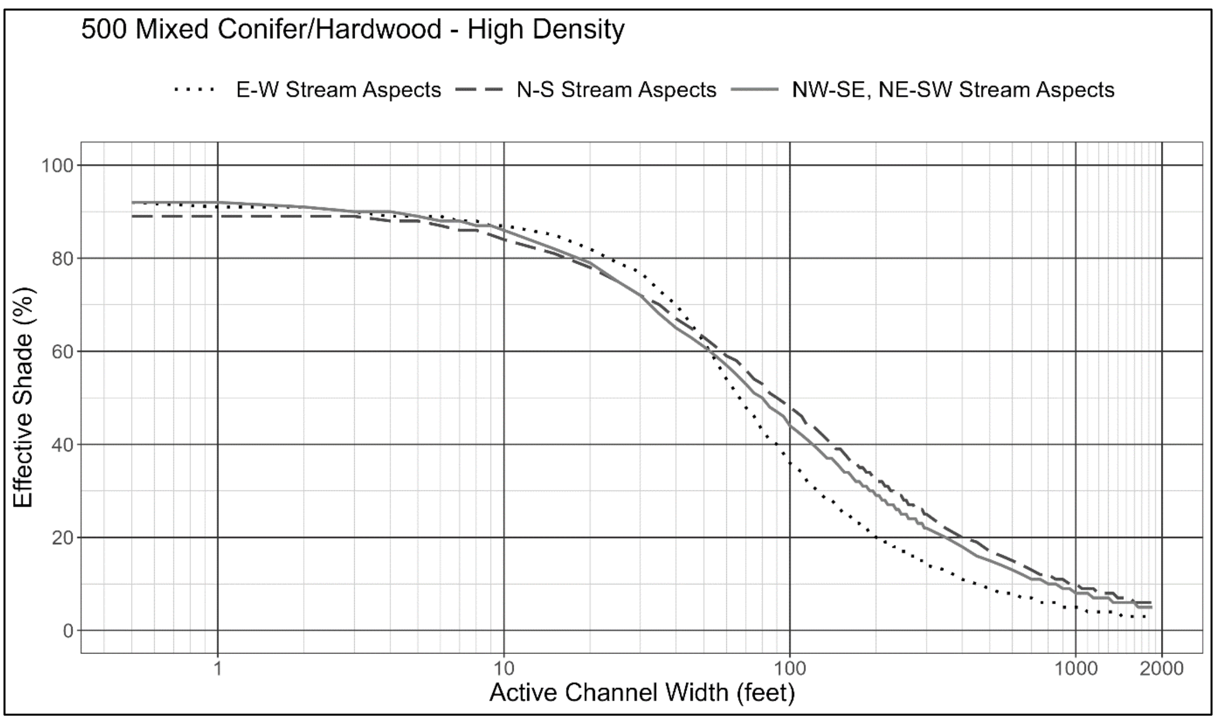

Figure 9-4: Effective shade targets for high density mixed conifer and hardwood stream sites.

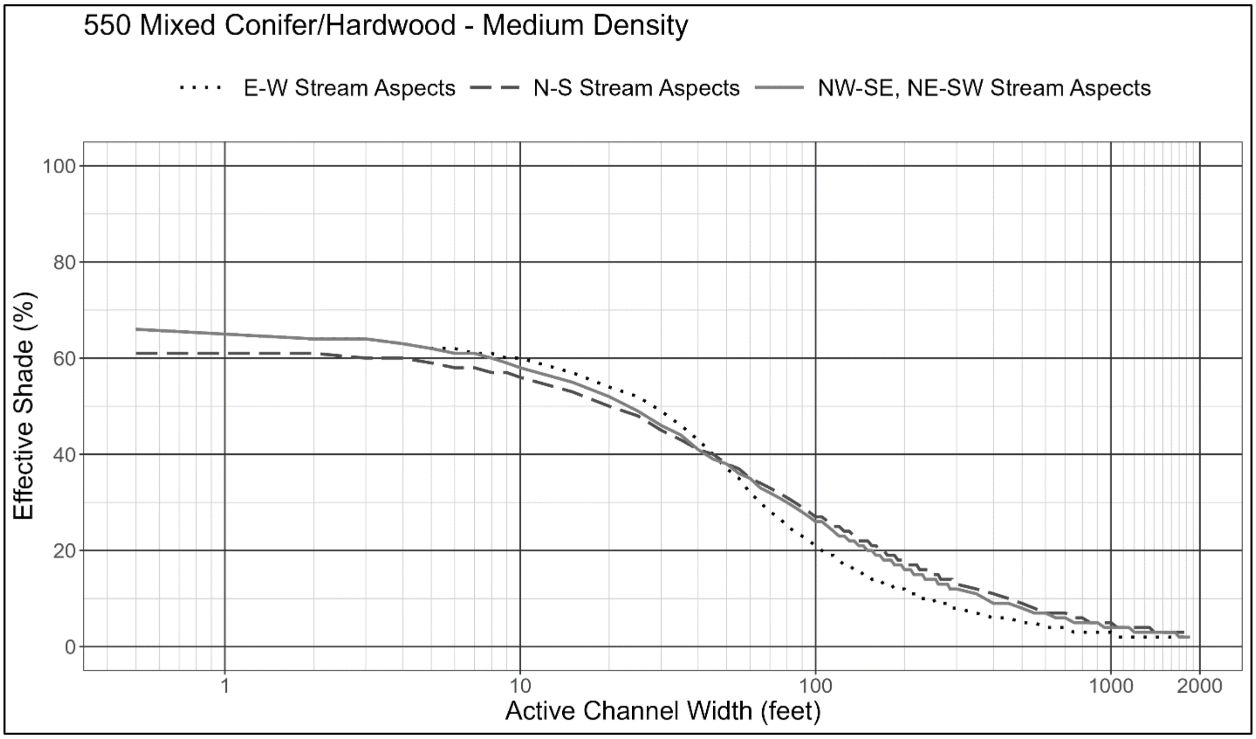

Figure 9-5: Effective shade targets for medium density mixed conifer and hardwood stream sites.

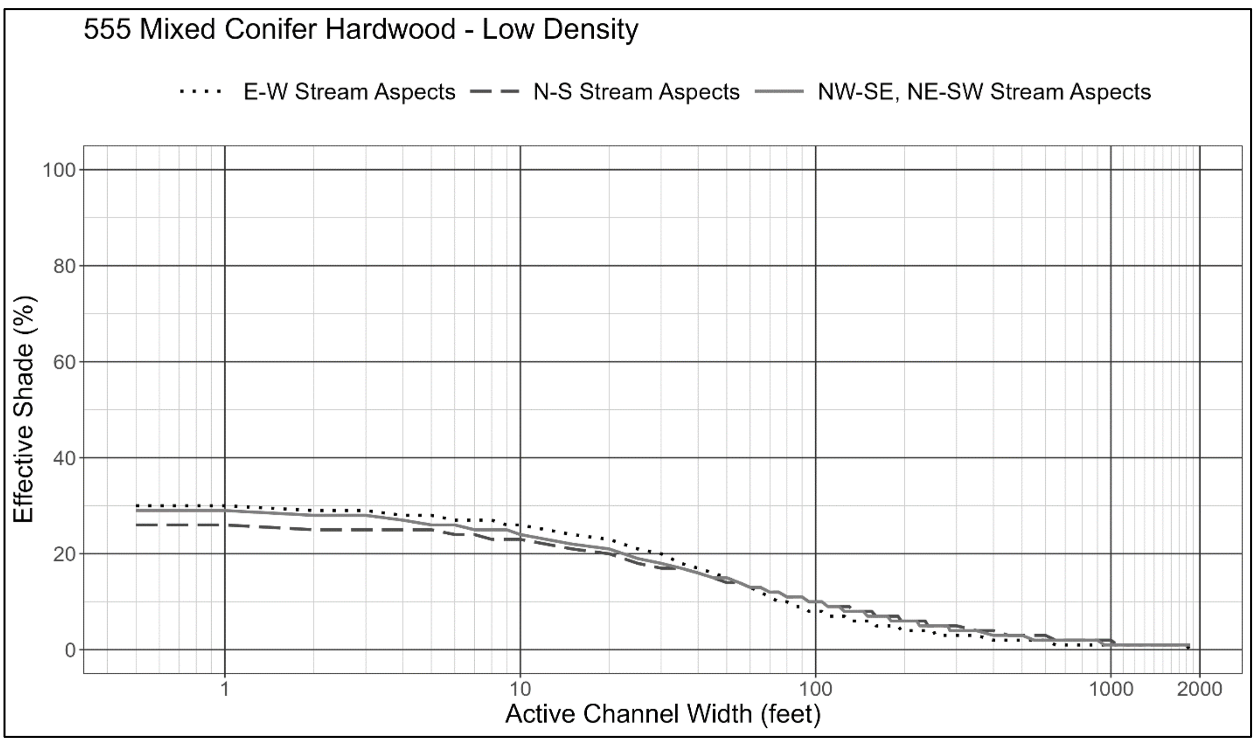

Figure 9-6: Effective shade targets for low density mixed conifer and hardwood stream sites.

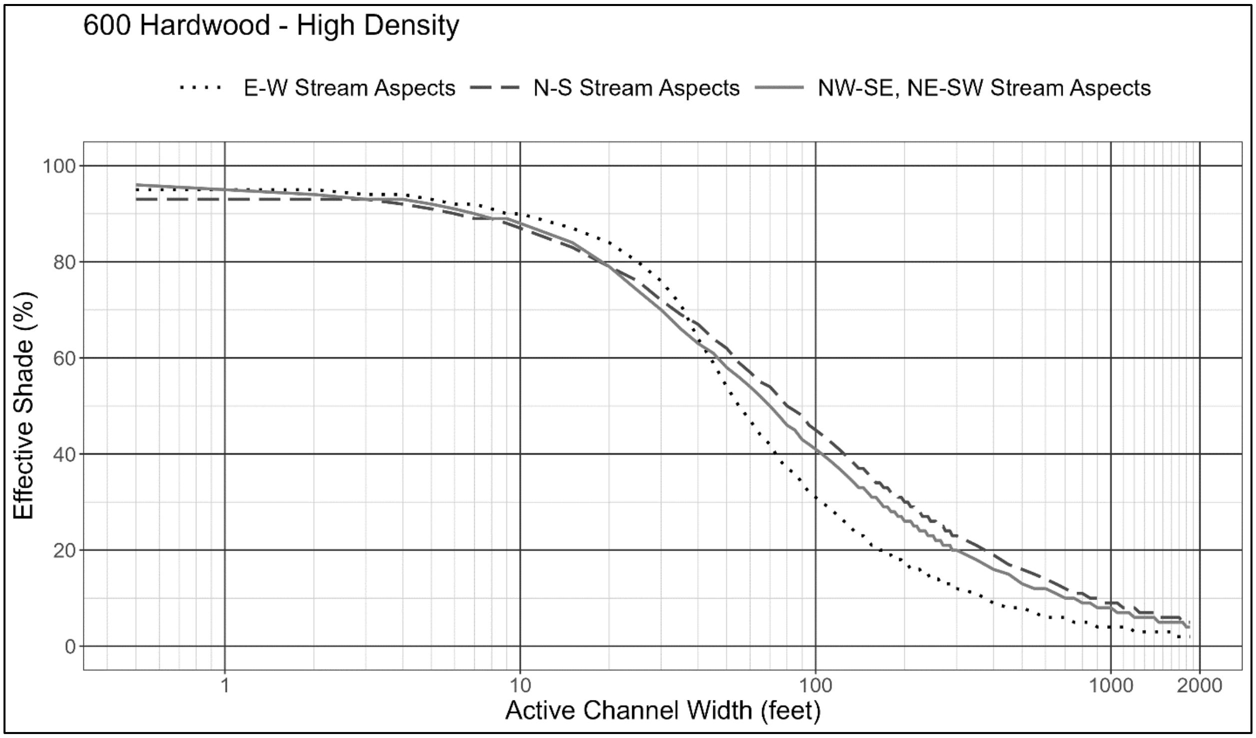

Figure 9-7: Effective shade targets for high density hardwood dominated stream sites.

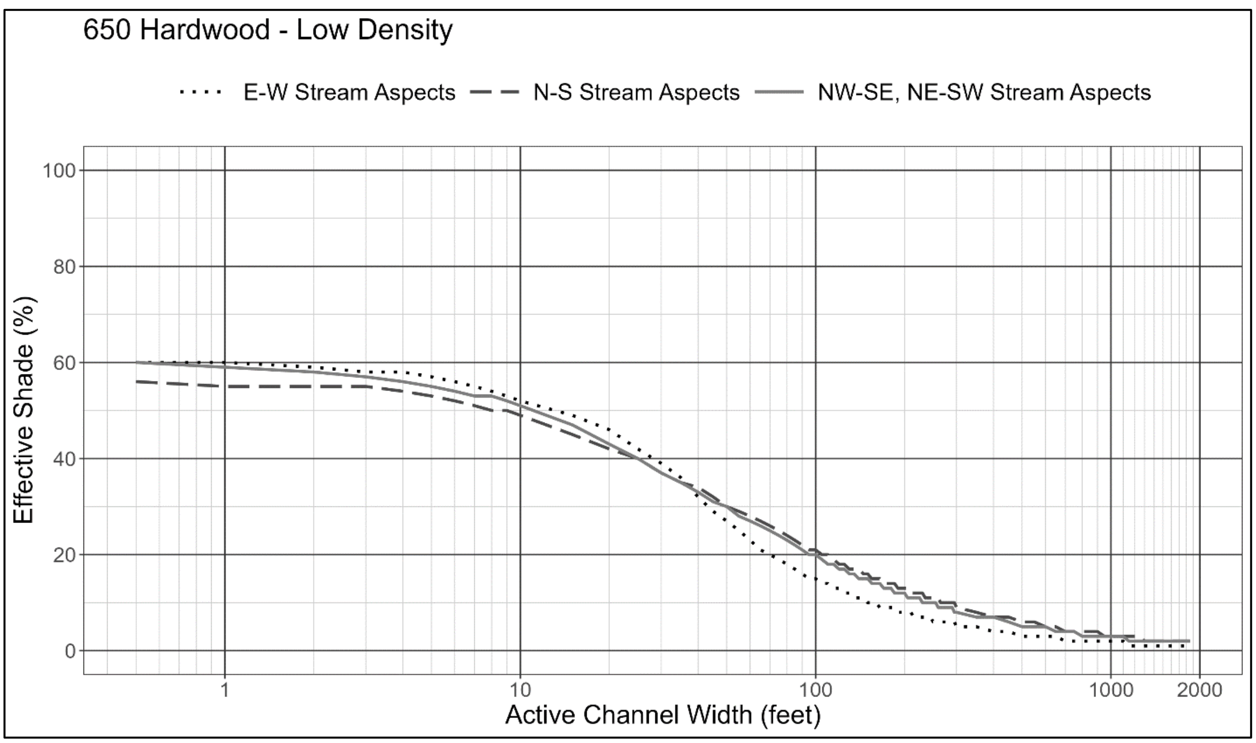

Figure 9-8: Effective shade targets for high density hardwood dominated stream sites.

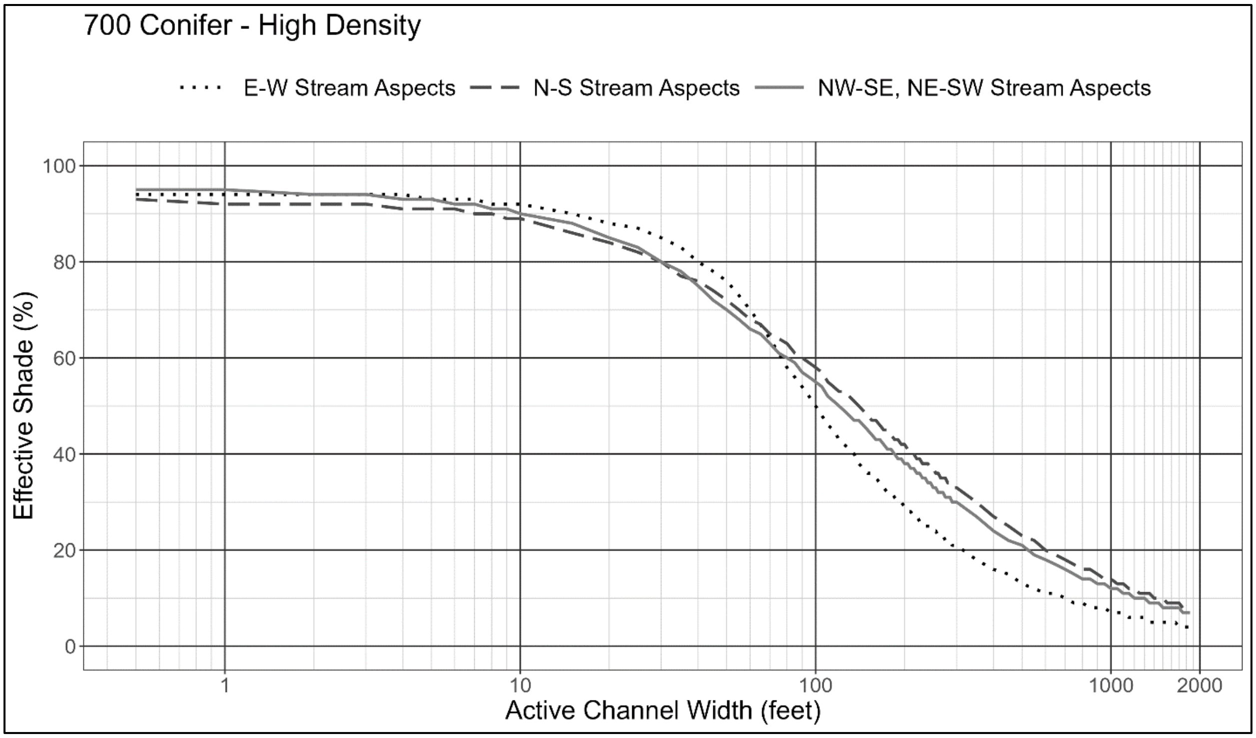

Figure 9-9: Effective shade targets for high density conifer dominated stream sites.

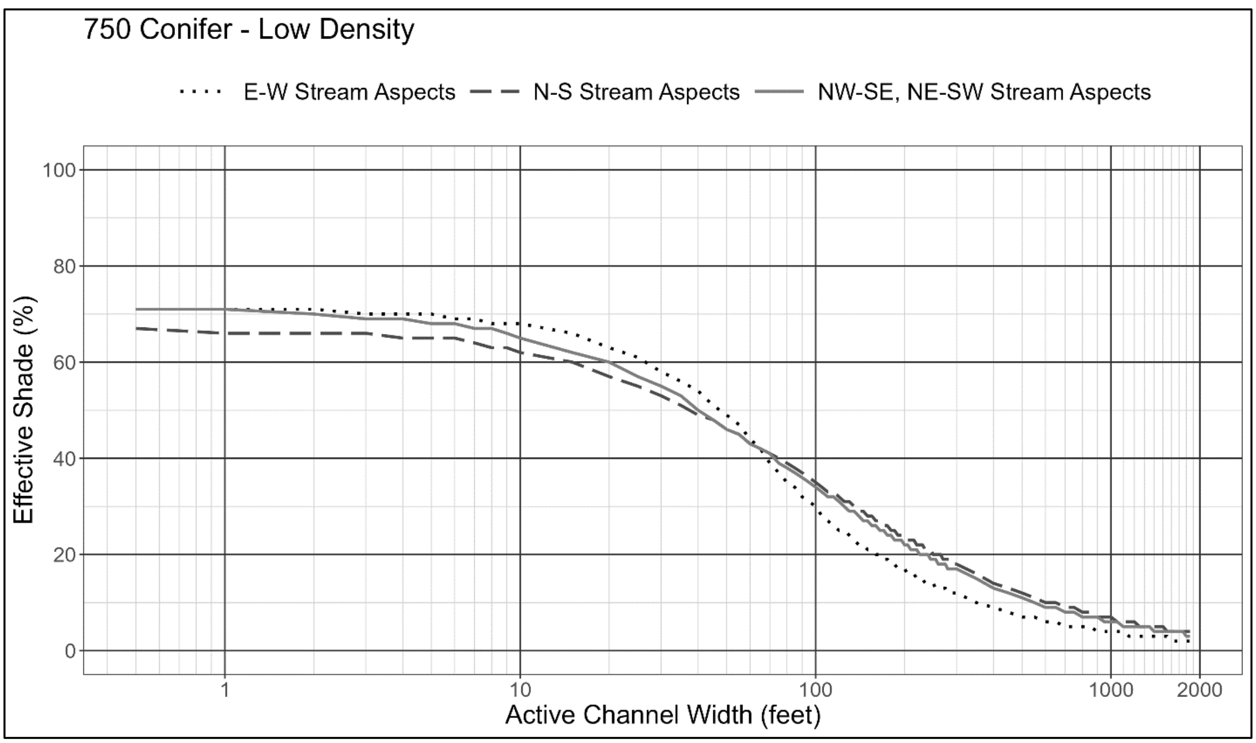

Figure 9-10: Effective shade targets for low density conifer dominated stream sites.

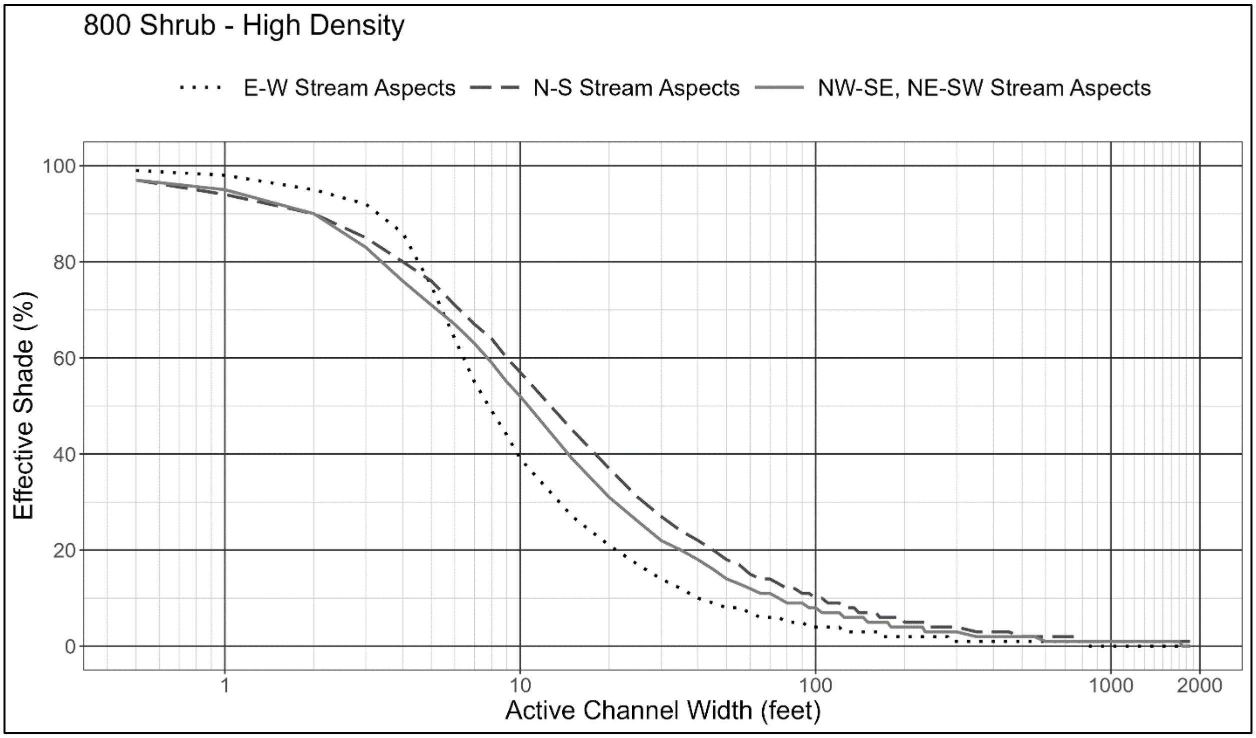

Figure 9-11: Effective shade targets for high density shrub sites.

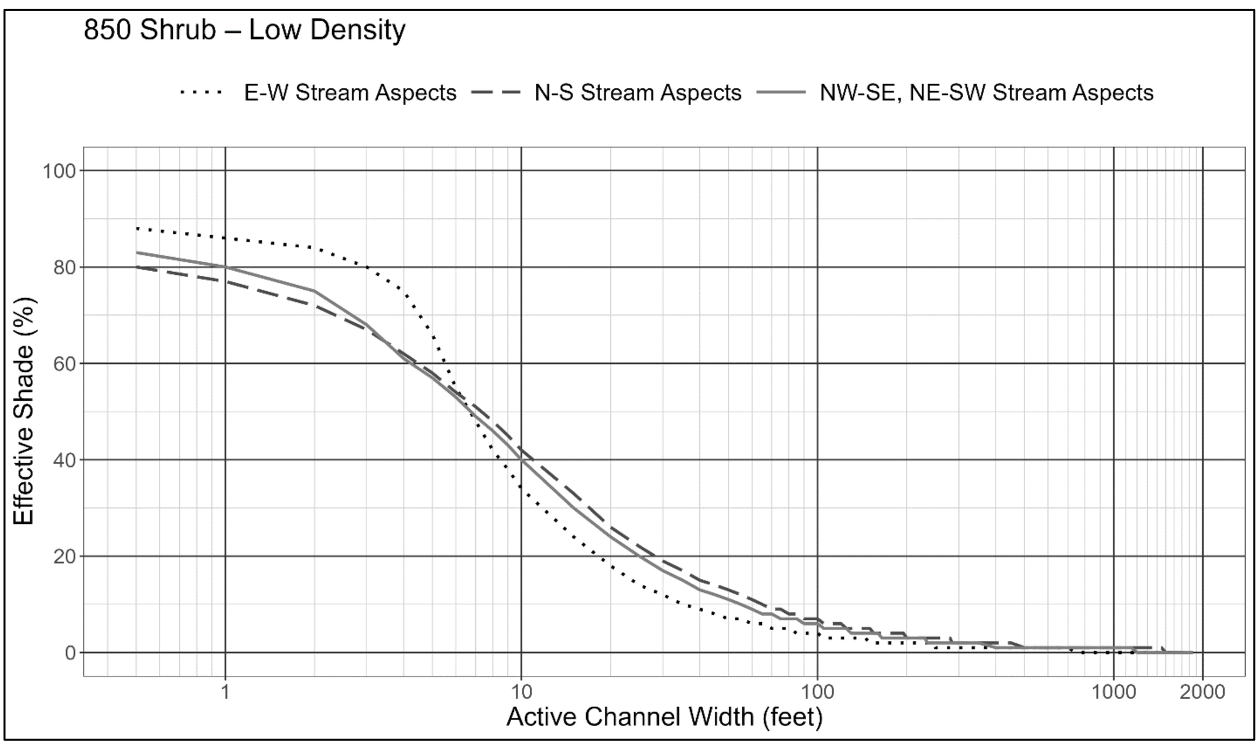

Figure 9-12: Effective shade targets for low density shrub sites.

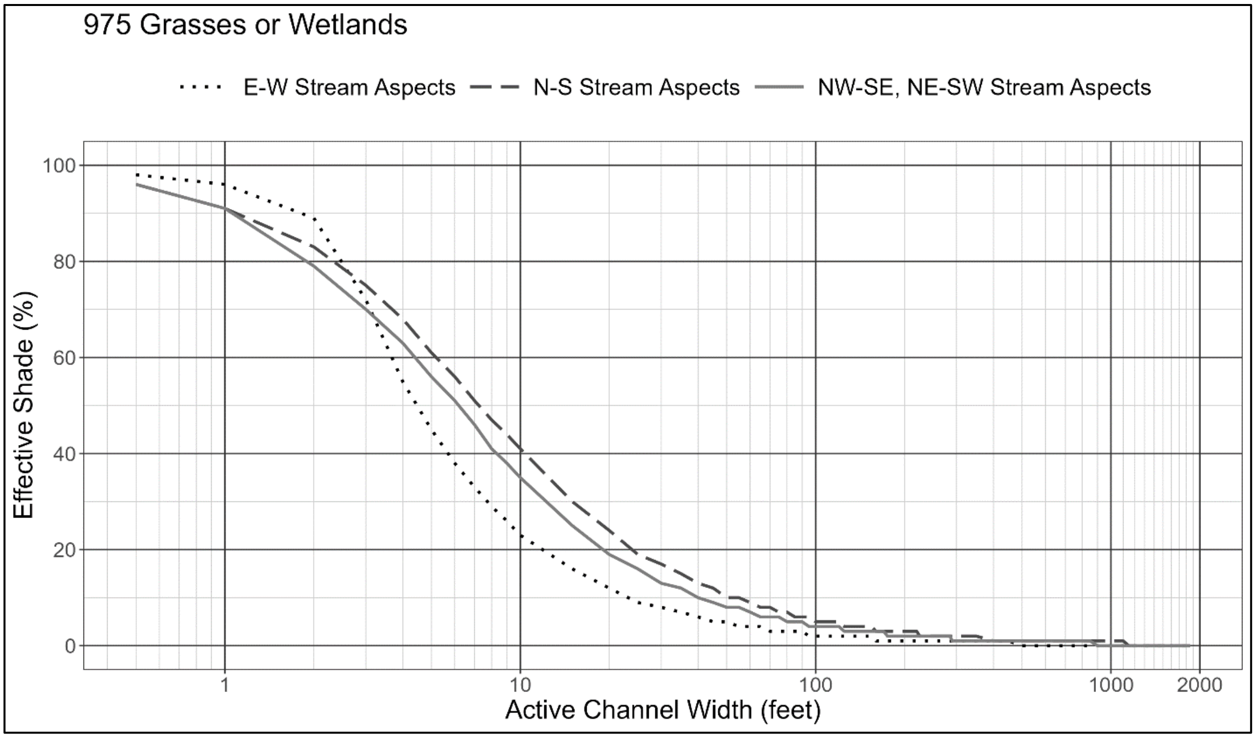

Figure 9-13: Effective shade targets for grass or wetland stream sites.

9.3.5 Percent consumptive use surrogate measure

For most Lower Columbia-Sandy streams, the portion of the HUA assigned to water management activities and consumptive uses is 0.05°C. DEQ completed modeling to estimate the consumptive use percentage that will attain this allocation (see TSD Appendix C, Section 9.0). The percent consumptive use is the percent of the natural surface flow that does not return to surface water after it has been withdrawn for a water use activity. Modeling indicates that a consumptive use flow rate reduction of 1.90% at USGS gage 14142500 – Sandy River below Bull Run will maintain warming from water withdrawal activities at or less than 0.05°C. The natural flow rate was based on the monthly median natural flow.

Table 9-5: Target percent consumptive use flow rate at USGS 14142500 relative to the monthly median natural flow rate at USGS 14142500.

Maximum percent consumptive use	Reference flow monitoring site
1.90	USGS 14142500 – Sandy River below Bull Run

9.4 Allocation summary

Table 9-6 through **Table 9-10** present examples of allocation calculations for sources or source categories on select temperature-impaired AUs. The allocations to background sources were calculated using **Equation 9-8** and were based on the applicable year-round criterion and the spawning criterion in the respective AU. In cases when there was more than one year-round criterion applicable in the AU, the minimum criterion was used. The allocations to NPDES point sources were calculated using **Equation 9-1**. The allocations to nonpoint sources were calculated using **Equation 9-9**. All allocations presented in **Table 9-6** through **Table 9-10** were calculated using the annual 7Q10 river flow rate. As summarized in the TMDL, allocations may be dynamic and calculated using the relevant equations when river flow rates are greater than 7Q10.

The HUA assignments to anthropogenic sources or source categories are equal to 0.30°C. WLAs to point sources and LAs to nonpoint sources are based on loads equivalent to the allowed 0.30°C increase. For some NPDES-permitted point sources and nonpoint sources, the maximum cumulative impact at the POMI in an AU is less than the sum of the individual HUA assignments at their respective points of discharge or activity due to heat dissipation within the AU.

Table 9-6: Allocation for the Sandy River from Bull Run River to the confluence with the Columbia River (AU: OR_SR_1708000107_02_103616) based on an annual 7Q10 of 278 cfs, a year-round criterion of 18.0°C, and a spawning criterion of 13.0°C. The allocation period is May 1 through October 31.

Source or source category	Assigned HUA (°C)	7Q10 allocation year-round (kilocalories/day)	7Q10 allocation spawning (kilocalories/day)
Background	0.0	12,243.11E+6	8,842.25E+6
NPDES point sources	0.12	81.62E+6	81.62E+6
City of Portland nonpoint source dam and reservoir operations	0.02	13.6E+6	13.6E+6
Water management activities and water withdrawals	0.05	34.01E+6	34.01E+6
Solar loading from existing transportation corridors and utility infrastructure	0.05	34.01E+6	34.01E+6
Solar loading from other nonpoint source sectors	0.0	0	0
Reserve capacity	0.06	40.81E+6	40.81E+6
Total allocated load:		12,447.16E+6	9,046.3E+6
Loading capacity:		12,447.16E+6	9,046.3E+6

Table 9-7: Allocation for the Bull Run River from Reservoir Number Two to the confluence with the Sandy River (AU: OR_SR_1708000105_11_103611) based on an annual 7Q10 of 20 cfs, a year-round criterion of 16.0°C, and a spawning criterion of 13.0°C. The allocation period is May 1 through October 31.

Source or source category	Assigned HUA (°C)	7Q10 allocation year-round (kilocalories/day)	7Q10 allocation spawning (kilocalories/day)
Background	0.0	782.93E+6	636.13E+6
NPDES point sources	0.0	0	0
City of Portland nonpoint source dam and reservoir operations	0.30	14.68E+6	14.68E+6
Water management activities and water withdrawals	0.0	0	0
Solar loading from existing transportation corridors and utility infrastructure	0.0	0	0
Solar loading from other nonpoint source sectors	0.0	0	0
Reserve capacity	0.0	0	0
Total allocated load:		797.61E+6	650.81E+6
Loading capacity:		797.61E+6	650.81E+6

Table 9-8: Allocation for the Salmon River from the South Fork Salmon River to confluence with Sandy River (AU: OR_SR_1708000103_02_103606) based on an annual 7Q10 of 174 cfs, a year-round criterion of 16.0°C, and a spawning criterion of 13.0°C. The allocation period is May 1 through October 31.

Source or source category	Assigned HUA (°C)	7Q10 allocation year-round (kilocalories/day)	7Q10 allocation spawning (kilocalories/day)
Background	0.0	6,811.52E+6	5,534.36E+6
NPDES point sources	0.0	0	0
Nonpoint source dam and reservoir operations	0.0	0	0
Water management activities and water withdrawals	0.05	21.29E+6	21.29E+6
Solar loading from existing transportation corridors and utility infrastructure	0.06	25.54E+6	25.54E+6
Solar loading from other nonpoint source sectors	0.0	0	0
Reserve capacity	0.19	80.89E+6	80.89E+6
Total allocated load:		6,939.23E+6	5,662.07E+6
Loading capacity:		6,939.23E+6	5,662.07E+6

Table 9-9: Allocation for the Little Sandy River from Bow Creek to the confluence with Bull Run River (AU: OR_SR_1708000105_11_103609) based on an annual 7Q10 of 11 cfs, a year-round criterion of 16.0°C, and a spawning criterion of 13.0°C. The allocation period is May 1 through November 15.

Source or source category	Assigned HUA (°C)	7Q10 allocation year-round (kilocalories/day)	7Q10 allocation spawning (kilocalories/day)
Background	0.0	430.61E+6	349.87E+6
NPDES point sources	0.0	0	0
Nonpoint source dam and reservoir operations	0.0	0	0
Water management activities and water withdrawals	0.05	1.35E+6	1.35E+6
Solar loading from existing transportation corridors and utility infrastructure	0.02	0.54E+6	0.54E+6
Solar loading from other nonpoint source sectors	0.0	0	0
Reserve capacity	0.23	6.19E+6	6.19E+6
Total allocated load:		438.69E+6	357.95E+6
Loading capacity:		438.69E+6	357.95E+6

Table 9-10: Allocation for the Zigzag River from Still Creek to the confluence with the Sandy River (AU: OR_SR_1708000102_02_103600) based on an annual 7Q10 of 48 cfs, a year-round criterion of 16.0°C, and a spawning criterion of 13.0°C. The allocation period is May 1 through October 31.

Source or source category	Assigned HUA (°C)	7Q10 allocation year-round (kilocalories/day)	7Q10 allocation spawning (kilocalories/day)
Background	0.0	1,879.04E+6	1,526.72E+6
NPDES point sources	0.09	10.57E+6	10.57E+6
Nonpoint source dam and reservoir operations	0.0	0	0
Water management activities and water withdrawals	0.05	5.87E+6	5.87E+6
Solar loading from existing transportation corridors and utility infrastructure	0.03	3.52E+6	3.52E+6
Solar loading from other nonpoint source sectors	0.0	0	0
Reserve capacity	0.13	15.27E+6	15.27E+6
Total allocated load:		1,914.27E+6	1,561.95E+6
Loading capacity:		1,914.27E+6	1,561.95E+6

10 Water quality standards attainment

DEQ conducted modeling to determine if and demonstrate that implementation of the various proposed individual HUAs and LAs on the Sandy River and its tributaries will attain applicable water quality standards in the Sandy River. Numerous models were developed that variously assessed individual TMDL components separately (e.g., separate models for WLAs, LAs, etc.) and comprehensively (e.g., a single model including all proposed WLAs, LAs, MOS, etc.). This section reports on the results of the various models. See TSD Appendices A, C, and D for details.

10.1 Comprehensive wasteload and load allocations assessment

To determine if the combined attainment of the various proposed individual WLA and LAs would be sufficient to meet the cumulative HUA (0.30°C) and attain applicable water quality standards in the Sandy River, DEQ completed modeling that incorporated all such allocations in a "Comprehensive Wasteload and Load Allocations Attainment" scenario. Two versions of this scenario were modeled; "Comprehensive Attainment_A" represented WLAs with the ODFW Sandy River Fish Hatchery discharging to Cedar Creek, and "Comprehensive Attainment_B" represented WLAs with the ODFW Sandy River Fish Hatchery discharging to the Sandy River. Results of these scenarios were compared to those of a baseline scenario to determine temperature effects and standards attainment in the Sandy River for the 2016 model period.

Briefly, the Baseline scenario assumptions included: no point source discharges, restored vegetation "A", Salmon River tributary inputs at modeled background temperatures, Bull Run River inputs at modeled Bull Run River Background (no dams and restored vegetation) scenario output, Cedar River inputs equal to those in the Sandy River No Point Sources scenario, and all other tributaries' inputs equal to current conditions model inputs.

Comprehensive Wasteload and Load Allocations Attainment scenarios (A and B) assumptions included:

- Point sources reflected proposed WLAs (WLA_A and WLA_B, respectively),
- Restored vegetation, except for infrastructure (i.e., roads, buildings, utilities, bridges),
- Tributaries at Baseline temperatures +0.07°C, except:
    - Salmon River temperatures were equal to the outputs from Restored Vegetation B scenario +0.05°C,
    - Cedar River inputs were defined as:
        - Version A: the WLA_A scenario values (including fish hatchery discharge to the Cedar River) +0.07°C, and
        - Version B: the WLA_B scenario values, (diversion of fish hatchery discharge to the Sandy River) +0.07°C,
- Upstream boundary condition temperatures at current conditions values +0.03°C.

All other parameters were identical between the Comprehensive Wasteload and Load Allocations Attainment and Baseline scenarios. See TSD Appendix C, Section 15.0 for details.

Comparing Comprehensive Wasteload and Load Allocations Attainment version A to the Baseline scenario (**Figure 10-1**), the maximum 7DADM temperature change was 0.15°C at the POMI (river km 3.10, September 4, 2016) and 0.14°C at the mouth (July 21, 2016). Results for Comprehensive Wasteload and Load Allocations Attainment version B were nearly identical (**Figure 10-2**): again, the maximum 7DADM temperature change was 0.15°C at the POMI (river km 3.10, September 4, 2016) and 0.14°C at the mouth (July 21, 2016). Thus, under attainment of all WLAs and LAs under either WLA_A or WLA_B specifications on the mainstem and tributaries, the cumulative 0.30°C HUA on the Sandy River is not exceeded during the model period.

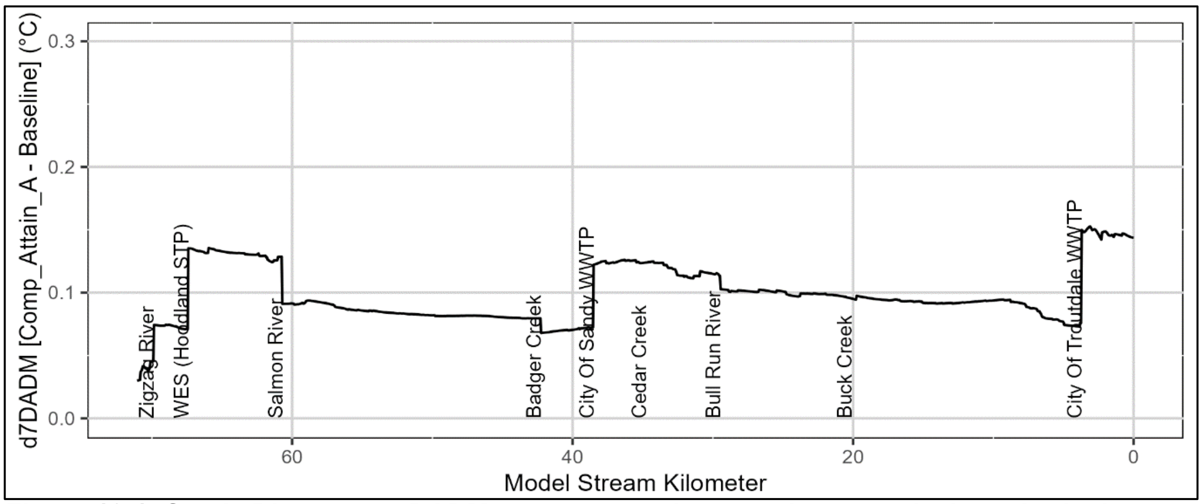

Figure 10-1: Sandy River max. 7DADM temperature changes above applicable criteria due to implementation of all HUAs in the mainstem and tributaries, with wasteload allocations set to WLA_A parameters.

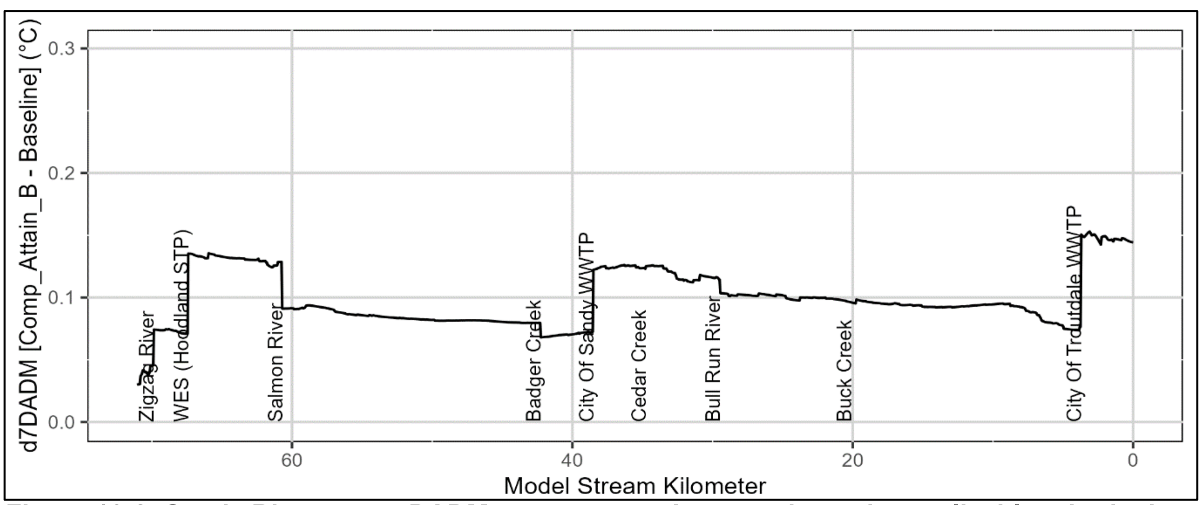

Figure 10-2: Sandy River max. 7DADM temperature changes above the applicable criteria due to implementation of all HUAs in the mainstem and tributaries, with wasteload allocations set to WLA_B parameters.

10.2 Wasteload allocation attainment results

Current NPDES-permitted point source discharges were associated with a maximum cumulative 7DADM water temperature increase of 0.02°C (river km 1.60, September 5, 2016) based on 2016 modeling (**Figure 10-3**). This assessment excluded the potential new discharge from the City of Sandy WWTP. With this new discharge included, the maximum cumulative 7DADM increase was 0.03°C (river km 1.60, September 5, 2016).

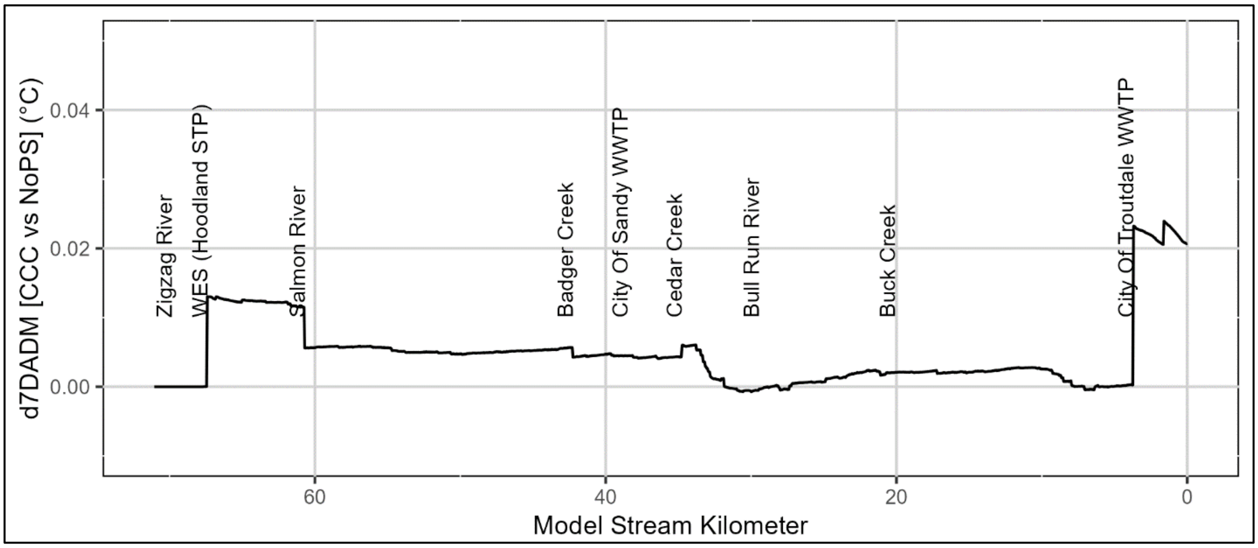

Figure 10-3: Longitudinal maximum 7DADM temperature differences, CCC minus NoPS scenarios, Sandy River.

The mass balance analysis, which evaluated temperature increases from point sources across multiple years of effluent and river discharge data, indicated a maximum increase of 0.05°C in the Sandy River among individual sources at their respective points of discharge (**Table 7-1**).

Attainment of the WLAs in the Sandy River was assessed via two different WLA scenarios: scenario WLA_A included the ODFW fish hatchery discharge at its current (Cedar Creek) location, while scenario WLA_B included the ODFW fish hatchery discharge relocated to the Sandy River (kilometer 34.80). The allocated portion of the HUA expressed as maximum allowable 7DADM water temperature increases are:

- 0.12°C cumulatively for all permittees at the POMI under both WLA_A and WLA_B scenarios.
- 0.06°C, 0.05°C, and 0.09°C respectively for the Hoodland STP, City of Sandy WWTP, and City of Troutdale WPCF at their points of discharge under both WLA_A and WLA_B scenarios.
- 0.20°C for Government Camp STP discharges to Camp Creek under both WLA_A and WLA_B scenarios.
- 0.30°C for the ODFW Sandy River Fish Hatchery at the Cedar Creek point of discharge (scenario WLA_A), and 0.08°C to the potential future Sandy River point of discharge (scenario WLA_B).

With NPDES permittees assigned individual WLAs as per scenario WLA_A, NPDES point sources accounted for a cumulative maximum 7DADM temperature increase of 0.12°C at the

POMI (river km 3.70, July 23, 2016) (**Figure 10-4**). The results were nearly identical with NPDES permittees assigned individual WLAs as per scenario WLA_B: NPDES sources again accounted for a cumulative maximum 7DADM water temperature increase of 0.12°C at the POMI (river km 3.65, July 23, 2016) (**Figure 10-5**). Thus, both WLA scenarios met the 0.12°C cumulative HUA proposed for point sources (**Table 10-2**).

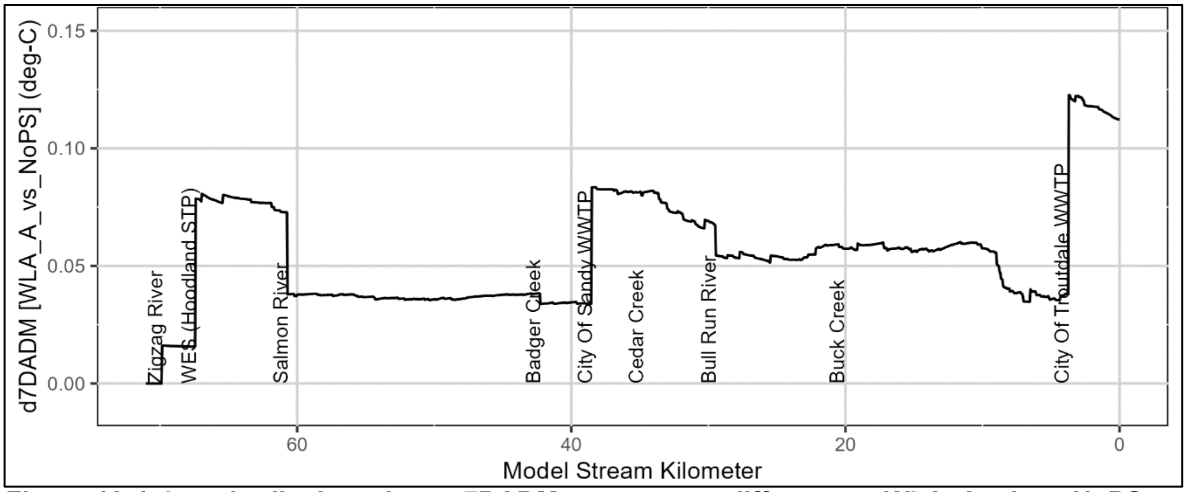

Figure 10-4: Longitudinal maximum 7DADM temperature differences, WLA_A minus NoPS scenarios, Sandy River.

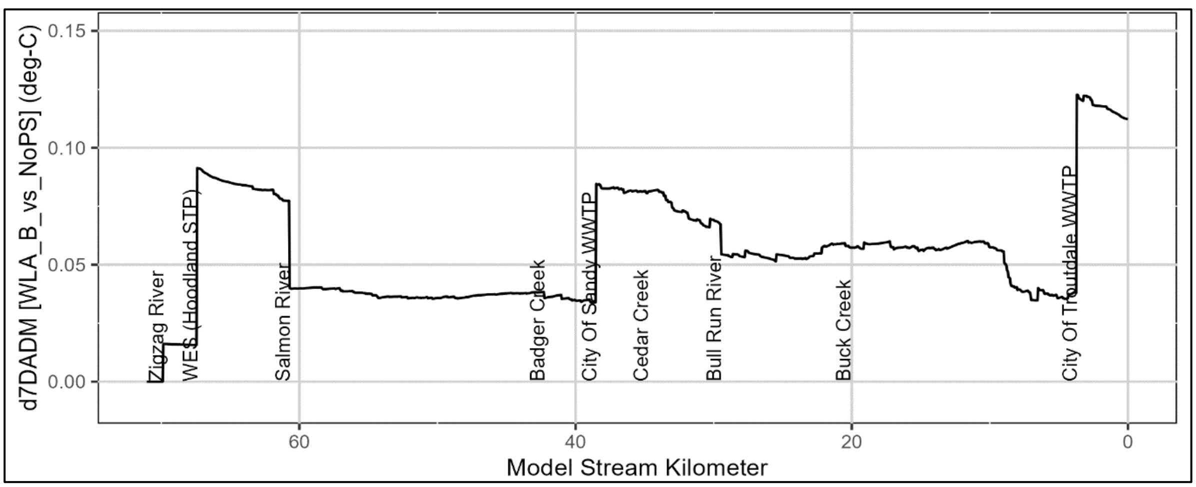

Figure 10-5: Longitudinal maximum 7DADM temperature differences, WLA_B minus NoPS scenarios, Sandy River.

10.3 Bull Run Dam and reservoir attainment

To assess the temperature changes on the Bull Run River due to the Bull Run River dams and reservoirs with discharges reflecting the proposed 0.30°C dam and reservoir HUA, DEQ compared the Bull Run River Background scenario to the Bull Run River Dam Surrogate Measure Attainment scenario (see TSD Appendix A Sections 4.6.3 and 4.6.4 for details).

Results (**Figure 10-6**) indicated that at the Bull Run River mouth, the maximum 7DADM temperature increase was 0.07°C. Then, to assess temperature changes on the Sandy River due to the Bull Run River dams and reservoirs with discharges reflecting their 0.30°C dam and reservoir HUA on the Bull Run River, DEQ compared the Baseline scenario (Section 10.1) to a “Dam-Only” scenario. The “Dam-Only” scenario and Baseline scenario were identical except that in the former, the Bull Run River tributary temperature inputs were increased by 0.07°C compared to the latter (see TSD Appendix C Section 13.0 for details).

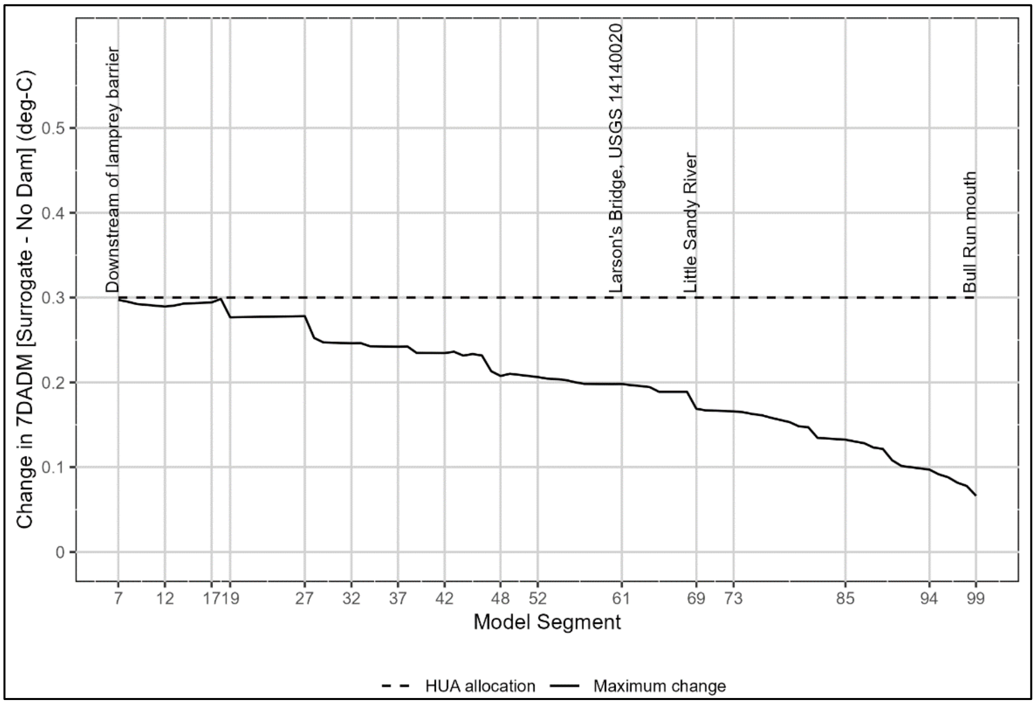

Figure 10-6: Longitudinal maximum 7DADM temperature changes above the applicable criteria due to presence of dams and reservoirs, Bull Run River.

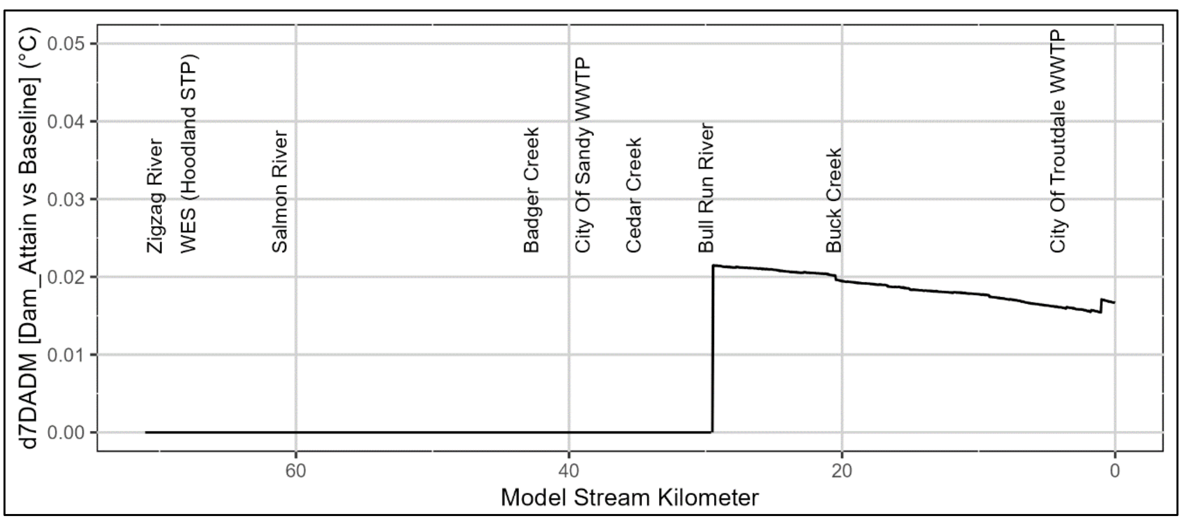

Figure 10-7: Sandy River maximum 7DADM temperature changes above the applicable criteria due to Bull Run River dam and reservoir operations reflecting the assigned human use allowance portion.

Comparing the Dam-Only scenario to the Baseline scenario (**Figure 10-7**) indicated maximum 7DADM Sandy River temperature changes of 0.02°C at the POMI (river km 29.45, July 29, 2016) and the mouth (July 19, 2016). Thus, under the dam-specific attainment scenario, the proposed dam and reservoir HUA (0.02°C) on the Sandy River is not exceeded during the model period.

10.4 Tributary temperature assessment

DEQ modeled a "Tributary Temperatures Attainment" scenario that represented background conditions except that most tributaries' temperatures were set to CCC +0.07°C throughout the modeling period (except that the Bull Run River was set at Background scenario temperatures +0.07°C, the Salmon River was set at Background scenario temperatures +0.05°C, and the upstream boundary condition was set at CCC temperatures +0.03°C). This Tributary Temperatures Attainment scenario was compared to the Baseline scenario (see Section 10.1) to model the effects of tributaries discharging at their assigned HUAs on the Sandy River temperatures, which excludes any reserve capacity.

Comparison of the Tributary Temperatures Attainment scenario to the Baseline scenario (**Figure 10-8)** indicated a maximum 7DADM temperature change of 0.05°C at the POMI (river km 29.45, August 15, 2016) and 0.04°C at the mouth (river km 0.00, July 19, 2016).

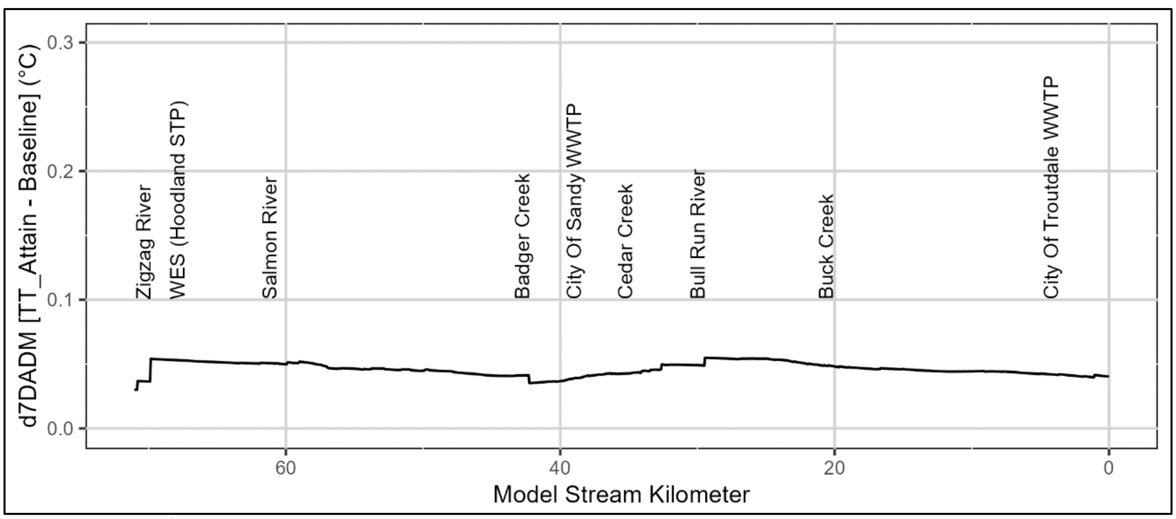

Figure 10-8: Sandy River maximum 7DADM temperature changes above applicable criteria due to tributary discharges reflecting their proposed load allocations.

10.5 Sandy River assessment for Columbia River Temperature TMDL

10.5.1 Background

EPA's Columbia and Lower Snake Rivers temperature TMDL (EPA, 2021) allocated 0.1°C of warming in the Columbia River to anthropogenic sources in Columbia River tributaries. EPA determined that to achieve this allocation, tributary temperatures must be ≤0.5°C above the natural condition at their mouths. Per consultation with EPA, the 0.5°C increase is measured above the daily mean. This is due to the daily timestep of the model simulation. DEQ evaluated

Sandy River temperatures for this purpose via comparisons of various model scenarios to determine if temperature changes associated with allocations to anthropogenic sources attain the Columbia River allocation.

10.5.2 Methods and assumptions

DEQ provided allocations that are greater than zero to multiple anthropogenic source categories including point sources, dam and reservoir operations, consumptive uses (water withdrawals), solar loading from existing transportation corridors, existing buildings, and existing utility infrastructure, and reserve capacity. Except for point sources and consumptive uses, DEQ did not develop model scenarios that represent the ground conditions, operations, or other management strategies that attain the other nonpoint source TMDL allocations. The models were focused on assessing current loading only.

To estimate the impact of the other nonpoint source categories, a conversion factor was developed to convert increases above the 7DADM to increases above the daily mean temperatures. This provided an estimate using the allocated portion of the HUA. The sum of each sector's increase was evaluated against the Columbia River TMDL allocation of 0.5 °C.

For point sources and consumptive use sectors, the model was used to assess the Sandy River's attainment of its Columbia River TMDL allocation. No single model scenario was developed that reflected both point sources and consumptive use withdrawals attaining their allocations. Thus, DEQ evaluated the results from each source category and assumed that the sum of the results equals the total change above natural conditions. DEQ completed the following scenario comparisons using the model:

1. Consumptive use water withdrawal scenario A vs. natural flow
2. TMDL WLA option "A" vs. no (NPDES-permitted) point sources
3. TMDL WLA option "B" vs. no (NPDES-permitted) point sources

The TSD Appendices A, B, and C provide detailed information on the model scenarios setup and results. The change above the daily mean was computed as follows:

1. Calculate scenario 1 (i.e., natural conditions) daily mean temperatures at each km and day in the model extent.
2. Calculate scenario 2 (i.e., anthropogenically altered conditions) daily mean temperatures at each km and day in the model extent.
3. For each day and model km, subtract step 1 result from step 2 result.
4. From the time-series longitudinal results of step 3, find the maximum difference at the Sandy River mouth (km: 0.00).

10.5.3 Results

Table 10-1 provides the results of these model scenario comparisons at the Sandy River mouth. The maximum cumulative (accounting for point sources and water withdrawals) temperature change from the daily mean is 0.22°C, based on the sum of the maximum changes for the WLA vs. no point sources scenarios (0.15°C) and the consumptive use water withdrawal vs. natural flow scenarios (0.07°C).

For the source categories listed in **Table 10-1**, the maximum model-calculated increases above the daily means are about 1.25 to 1.4 times greater than the equivalent allocated portions of the

HUA measured above the 7DADM. The maximum factor (1.4) was then applied as a precautionary factor (coefficient) to estimate the maximum increases above the daily means for the remaining source categories (**Table 10-2**).

After summing the results (**Table 10-2**), the total estimated increase is 0.40°C and is thus likely to attain the 0.5°C tributary temperature allocation for the Sandy River in the Columbia and Lower Snake Rivers temperature TMDL.

Table 10-1: Maximum differences between daily mean temperature under various scenarios, Sandy River mouth.

Scenario 1	Scenario 2	Related source or source category	Max. difference in daily means (°C), Scenario 2 minus Scenario 1	Max. difference in daily means (°C) / Human use allowance assignment (°C)
Natural flow	Water withdrawals A	Water management activities & withdrawals	0.07	1.40
No point sources	WLA option "A"	NPDES point sources (cumulative)	0.15	1.25
No point sources	WLA option "B"	NPDES point sources (cumulative)	0.15	1.25

Table 10-2: Sandy River human use allowance assignments and the equivalent maximum increase measured above the daily mean temperature.

Source or source category	Allocated portion of human use allowance (°C)	Max. increase above the daily mean (°C)
NPDES point sources (cumulative)	0.12	0.15[a]
City of Portland Bull Run dam and reservoir operations	0.02	0.03[b]
Water management activities and water withdrawals	0.05	0.07[a]
Solar loading from existing transportation corridors, buildings, and utility infrastructure	0.05	0.07[b]
Solar loading from other NPS sectors	0.00	0.00[b]
Reserve capacity	0.06	0.08[b]
Total	**0.30**	**0.40**

[a.] Model calculated.
[b.] Calculated as 1.4 times the source-specific human use allowance.

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12 Appendices

The TSD includes the following list of appendices.

Appendix A: Model Report
Appendix B: Sandy River Model Calibration Report
Appendix C: Sandy River Model Scenario Report
Appendix D: Bull Run Model Report
Appendix E: Bull Run River Surrogate Measure Approach
Appendix F: Climate Change and Stream Temperature in Oregon: A Literature Synthesis
Appendix G: Stream Buffer Width Literature Review
Appendix H: Assessment Units addressed by Temperature TMDLs for the Lower Columbia-Sandy Subbasin