Modeling Quality Assurance Project Plan for the Lower Grande Ronde, Wallowa, and Imnaha Subbasins Temperature TMDL

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Abbreviations

7DADM	7-Day Average of the Daily Maximums
AWQMS	Ambient Water Quality Monitoring System
CFS	Cubic Feet Per Second
DEQ	Oregon Department of Environmental Quality
DMR	Discharge Monitoring Report
EQC	Oregon Environmental Quality Commission
MGD	Million Gallons Per Day
NCDC	National Climatic Data Center
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rule
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department
QAPP	Quality Assurance Project Plan
RAWS	Remote Automatic Weather Stations
STP	Sewage Treatment Plant
SWCD	Soil and Water Conservation District
TIR	Thermal Infrared Radiometry
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
WRIS	Water Rights Information System
WWTP	Waste Water Treatment Plant

1 Introduction

This Quality Assurance Project Plan summarizes the modeling approach to be used for the temperature Total Maximum Daily Load, or TMDL, replacement applicable within the Lower Grande Ronde Subbasin (17060106), Imnaha Subbasin (17060102), Wallowa Subbasin (17060105), Lower Snake-Asotin Subbasin (17060103), and Hells Canyon Subbasin (17060101) (Figure 1-1). This temperature TMDL will replace the Lower Grande Ronde Subbasins temperature TMDL approved by EPA on December 17, 2010.

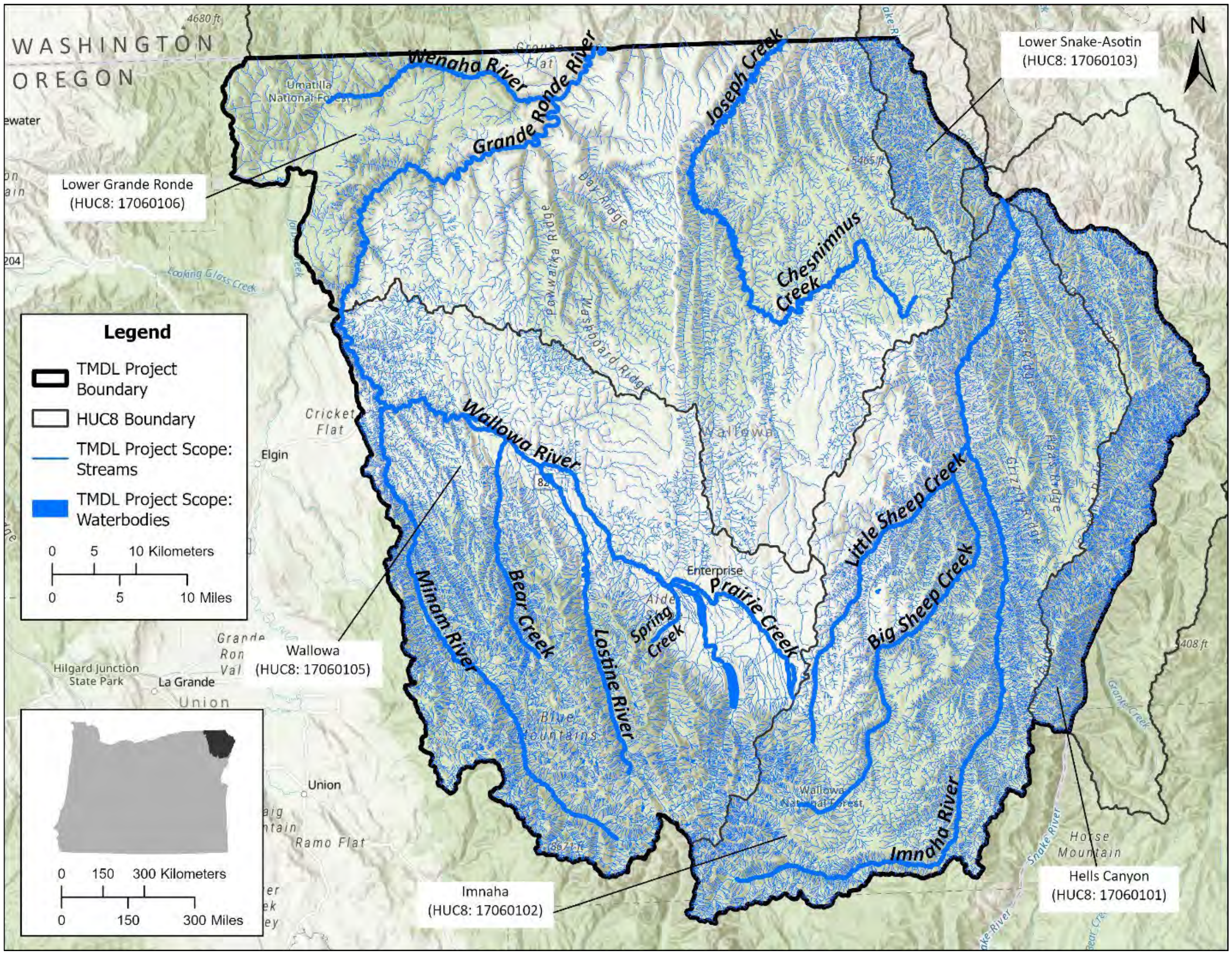

Figure 1-1. Lower Grande Ronde Subbasins temperature TMDL project area overview.

A TMDL is a water quality restoration plan and the calculation of the maximum amount of a pollutant that a waterbody can receive while still meeting water quality standards for that particular pollutant. The maximum amount of loading a waterbody can receive is called the loading capacity. Loading from all pollutant sources must not exceed the loading capacity (TMDL) of a waterbody, including an appropriate margin of safety.

Load allocations are portions of the loading capacity that are allocated to background sources or non-point sources, such as urban, rural agriculture, or forestry activities. Wasteload allocations are portions of the total load, which are allocated to NPDES permitted sources, such as wastewater treatment plants or industries. Wasteload allocations are used to establish effluent limits in NPDES discharge permits. Allocations may also be reserved for future uses, called reserve capacity. Allocations are quantified measures that assure water quality standards will be met and may distribute the pollutant loads between nonpoint and point sources. This general TMDL concept is represented by Equation 1.

$$TMDL = \sum WLA + \sum LA + \textit{Reserve Capacity} + MOS \qquad \text{Equation 1}$$

Where $\sum WLA$ is the sum of wasteload allocations (NPDES permitted sources), $\sum LA$ is the sum of load allocations (nonpoint sources and background), *Reserve Capacity* is allocations reserved for future uses, and *MOS* is a margin-of-safety to account for uncertainty. For a temperature TMDL, these elements establish the maximum thermal loads that a waterbody may receive without exceeding applicable water quality standards for temperature designed to protect aquatic life and other beneficial uses.

The Clean Water Act requires TMDLs be developed for waterbodies that do not meet water quality standards and are listed as water quality impaired on the State's 303(d) list. The Lower Grande Ronde, Imnaha, and Wallowa Subbasins contain several waterbodies listed on the Oregon 2022 Section 303(d) Category 5 list as water quality limited for temperature (Table 1). A TMDL that was previously developed for the Lower Grande Ronde, Imnaha, and Wallowa Subbasins (DEQ, 2010) must be replaced due to recent litigation.

In 2013, the United States Environmental Protection Agency (USEPA) disapproved the Natural Conditions Criterion contained in Oregon's water quality standard for temperature due to the 2012 U.S. District Court decision for NWEA v. EPA, 855 F. Supp. 2d 1199 (D. Or., 2012). This portion of the temperature water quality standard was used in most temperature TMDLs issued from 2003 through 2012. On October 4, 2019, the U.S. District Court issued a judgment for NWEA v. EPA, No. 3:12-cv-01751-HZ (D. Or., Oct. 4, 2019) and required DEQ and USEPA to replace 15 Oregon temperature TMDLs that were based on the Natural Conditions Criterion and to reissue the temperature TMDLs based on the remaining elements of the temperature water quality standard.

This QAPP is consistent with DEQ's and USEPA's modeling QAPP guidance (DEQ, 2017; EPA, 2016) and documents the analysis and numerical modeling approach that will support the updated Lower Grande Ronde, Imnaha, and Wallowa Subbasins temperature TMDLs as well as providing other project details. In particular this QAPP details the following:

- Definition of the issue and objectives, including the spatial and temporal extents of the water quality impairments (section 2);
- A high-level description of the key processes and variables for temperature (Section 3);
- The overarching technical approach, including the appropriate modeling and analytical tools to be used (Section 4);
- The data sources for defining and creating inputs to the model, including data that were used in the modeling for the original TMDLs. Examples of these inputs include meteorological data, stream flow and temperature, point sources and vegetation characteristics (Sections 5 and 6);
- How the analysis and modeling will be evaluated for acceptability (Sections 7 and 9);

- Scenarios for evaluating management strategies for reducing anthropogenic thermal loads (Section 10);
- Various aspects for managing the replacement TMDLs development project, including documentation (Section 8), the project team (Section 11), data and records management (Sections 12 and 13); and
- Aspects relating to this QAPP and its role in the project (Sections 14 and 15).

2 Problem definition and management objectives

Multiple waterbodies in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins do not meet the water quality standards for temperature and are listed as Category 5, water quality limited on Oregon's 2022 Section 303(d) list (Table 1). The temperature water quality standards are set at a level to protect the most sensitive beneficial uses. The beneficial uses most sensitive to warm water temperatures are fish and aquatic life. The temperature water quality standards in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins include the numeric criteria identified below. The numeric temperature criteria are based on a seven-day average daily maximum (7DADM) continuous measurement of temperature.

- Bull Trout Spawning and Juvenile Rearing: 12.0 ºC (OAR 340-041-0028(4)(f))
- Salmon and Steelhead Spawning: 13.0 ºC (OAR 340-041-0028(4)(a))
- Core Cold Water Habitat: 16.0 ºC (OAR 340-041-0028(4)(b))
- Salmon and Trout Rearing and Migration: 18.0 ºC (OAR 340-041-0028(4)(c))

Where and when the applicable criteria apply are based on the designated fish uses maps in OAR 340-041-0151 Figure 151A and Figure 151B. The maps from the rule have been reproduced and are shown below. Figure 2-1 shows various designated fish uses and applicable criteria, while Figure 2-2 shows salmon and steelhead spawning use designations, based on the NHD.

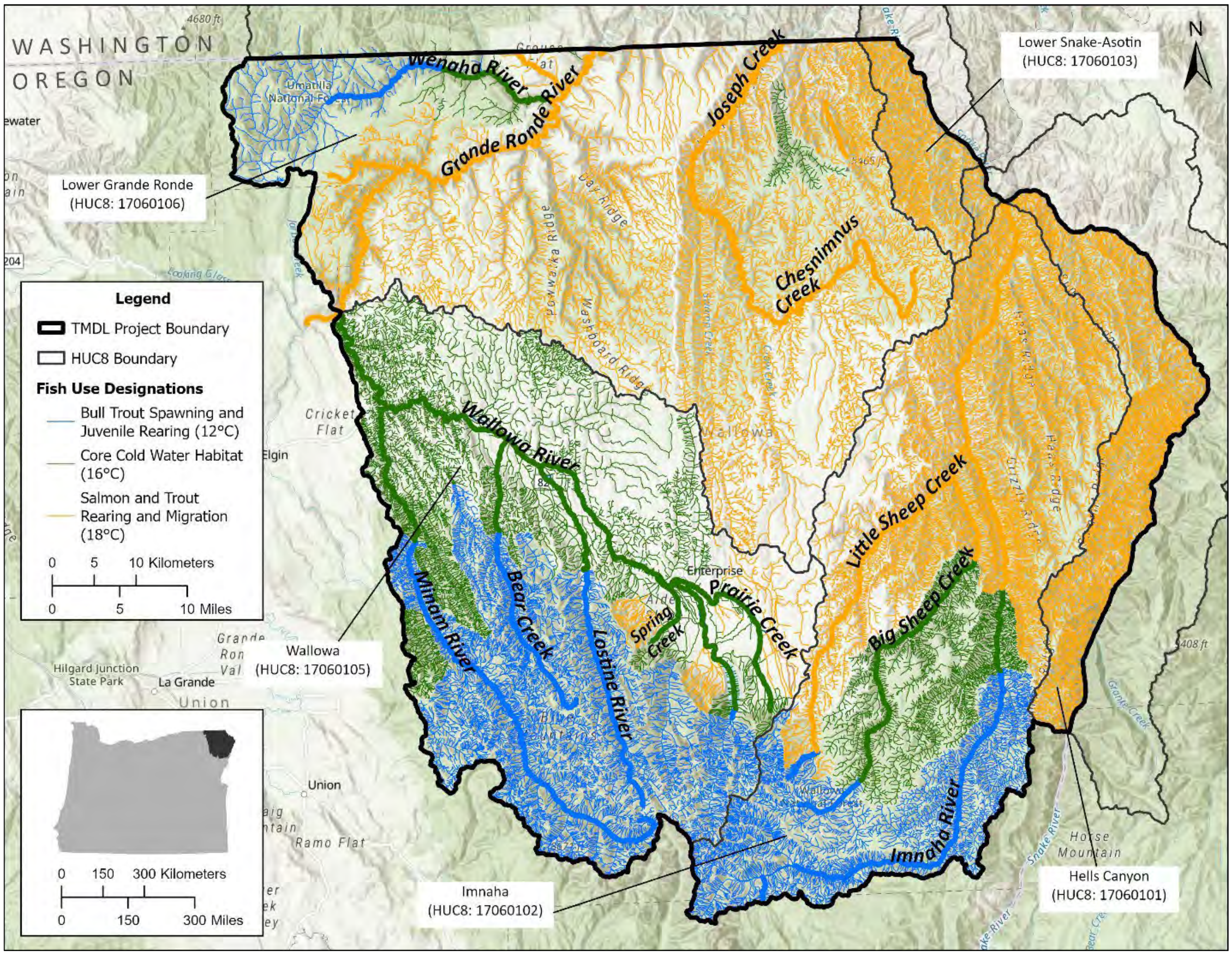

Figure 2-1: Fish use designations and applicable year-round temperature criteria in the TMDL project area.

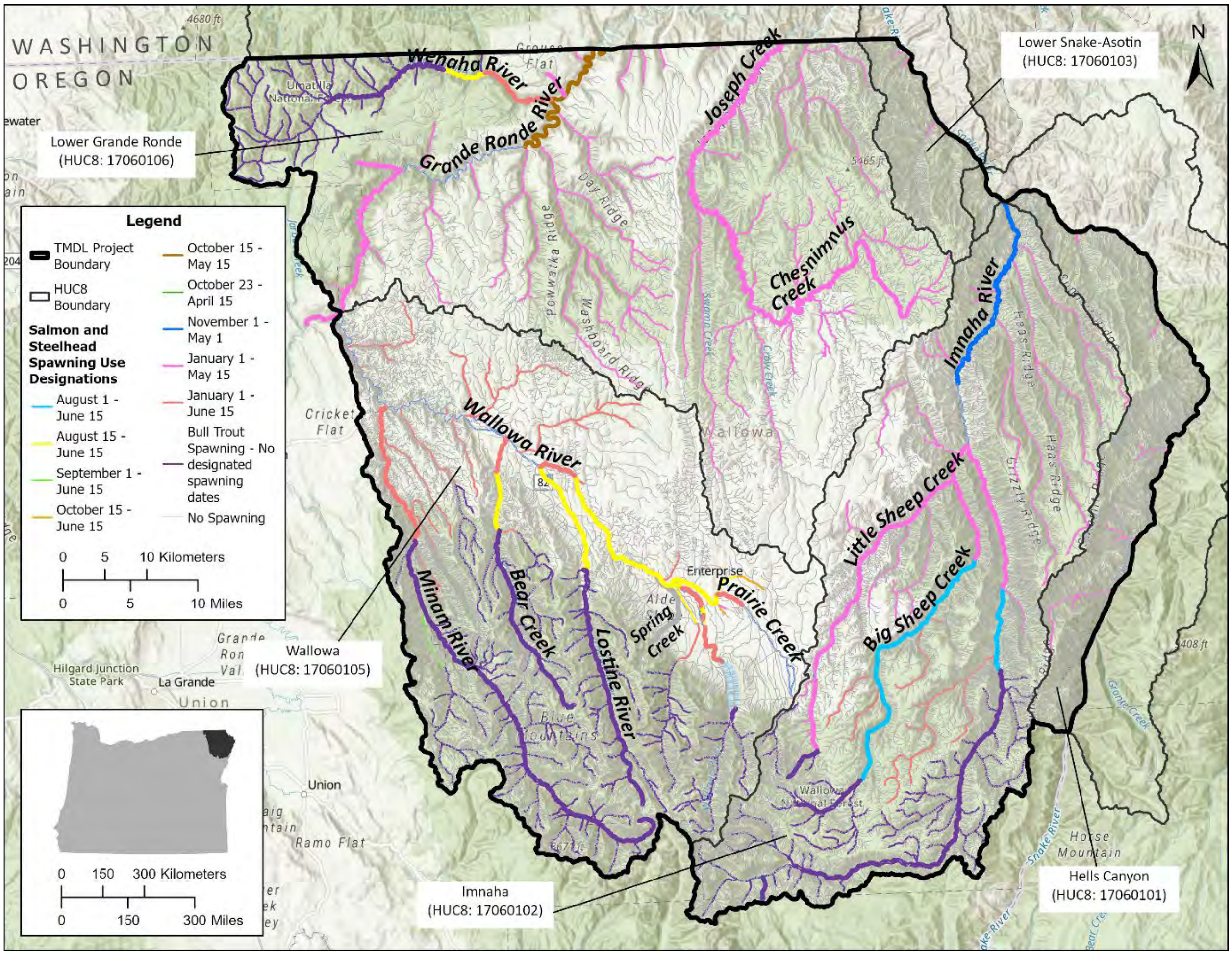

Figure 2-2: Salmon and steelhead spawning use designations in the TMDL project area.

The temperature standard authorizes insignificant additions of heat from human sources in waters that exceed the applicable temperature criteria as follows: Following a temperature TMDL or other cumulative effects analysis, the human use allowance (HUA) will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 ^{o}C (OAR 340-041-0028(12)(b)).

As described in Section 1, the U.S. Environmental Protection Agency (USEPA) and State of Oregon (OR) are required to revise the water temperature TMDLs for the Lower Grande Ronde, Imnaha, and Wallowa Subbasins. In revising the TMDLs, all of the allocations will be updated to target the applicable biologically-based numeric criteria (BBNC) and HUA water quality temperature standards.

Since the issuance of the original TMDLs, the extent and number of waterbodies that are identified as water quality limited for temperature has changed. As part of the TMDL update, DEQ will address all current temperature listings based on the most recent integrated report list. The current listings, as they pertain to the Lower Grande Ronde, Imnaha, and Wallowa Subbasins QAPP project area, were obtained from Oregon's 2022 Integrated Report and are summarized in Table 2-1 and Figure 2-3.

To the extent existing data and information allow, the primary analysis and modeling objectives for this TMDL include:

1) Complete a source assessment and cumulative effects analysis to characterize or identify:

    a. Anthropogenic sources of stream temperature warming;
    b. How much warming comes from background sources;
    c. How much warming comes from each anthropogenic source or source category;
    d. The cumulative warming from all anthropogenic sources combined;
    e. Where along the stream anthropogenic warming occurs;
    f. Where the point of maximum stream warming is located; and
    g. The amount of stream warming that exceeds the human use allowance and applicable water quality standards.

2) Determine TMDL elements and allocations that attain the applicable temperature criteria by identifying:

    a. The thermal loading capacity for each temperature listed waterbody;
    b. The excess thermal load exceeding the loading capacity for each temperature listed waterbody;
    c. The thermal load and wasteload allocations necessary to meet the applicable water quality standards for each listed waterbody;
    d. Any surrogate measures;
    e. Any reserve capacity;
    f. Any margin of safety; and
    g. The seasonal variation and critical conditions corresponding to the time period when the applicable temperature criteria are exceeded.

3) Support development of the TMDL Water Quality Management Plan and evaluate implementation options.

    a. Evaluate existing land management plans, TMDL implementation plans, or rules for sufficiency in minimizing anthropogenic warming to the level established by the TMDL allocations.
    b. Identify additional management strategies or surrogate measures.
    c. Identify under what timeline and where management strategies need to be implemented.

The effort currently described in the QAPP includes use of existing models and the development of new models or new model scenarios.

Table 2-1: Lower Grande Ronde, Imnaha, and Wallowa Subbasins assessment units that are classified as category 5 impaired for temperature based on the Section 303(d) 2022 Integrated Report.

Assessment Unit Name	Assessment Unit ID	Use Period (Year Listed)
Bear Creek	OR_SR_1706010504_02_103353	Year-round (2010), Spawning (2010)

Bear Creek	OR_SR_1706010504_02_103354	Year-round (2010), Spawning (2010)
Big Sheep Creek	OR_SR_1706010203_02_103293	Year-round (2010), Spawning (2018)
Big Sheep Creek	OR_SR_1706010204_02_103296	Year-round (2010)
Chesnimnus Creek	OR_SR_1706010604_02_103371	Year-round (2010)
Chesnimnus Creek	OR_SR_1706010604_02_103373	Year-round (2022)
Cottonwood Creek	OR_SR_1706010606_02_103380	Year-round (2018)
Devils Run Creek	OR_SR_1706010604_02_103372	Year-round (2018)
Dry Creek	OR_SR_1706010201_02_103285	Year-round (2010)
Elk Creek	OR_SR_1706010605_02_103376	Year-round (2010)
Freezeout Creek	OR_SR_1706010202_02_103289	Year-round (2010)
Grande Ronde River	OR_SR_1706010601_02_103366	Year-round (2010)
Grande Ronde River	OR_SR_1706010602_02_103367	Year-round (2010)
Grande Ronde River	OR_SR_1706010607_02_103583	Year-round (2010)
Grouse Creek	OR_SR_1706010202_02_103292	Year-round (2018), Spawning (2010)
Gumboot Creek	OR_SR_1706010201_02_103284	Year-round (2010)
Howard Creek	OR_SR_1706010506_02_103363	Spawning (2010)
HUC12 Name: Buck Creek	OR_WS_170601060206_02_103525	Year-round (2018)
HUC12 Name: Deer Creek	OR_WS_170601050603_02_103513	Year-round (2010)
HUC12 Name: Dry Creek-Imnaha River	OR_WS_170601020104_02_103388	Year-round (2010)
HUC12 Name: Fisher Creek-Wallowa River	OR_WS_170601050606_02_103589	Spawning (2010)
HUC12 Name: Horse Creek	OR_WS_170601060605_02_103569	Year-round (2018)
HUC12 Name: Lick Creek	OR_WS_170601020302_02_103398	Year-round (2018)
HUC12 Name: Lower Bear Creek	OR_WS_170601050402_02_103503	Year-round (2010)
HUC12 Name: Lower Crow Creek	OR_WS_170601060503_02_103543	Year-round (2018)
HUC12 Name: Peavine Creek	OR_WS_170601060407_02_103539	Year-round (2010)
HUC12 Name: Salmon Creek	OR_WS_170601060404_02_103536	Year-round (2010)

HUC12 Name: Upper Cottonwood Creek	OR_WS_170601060603_02_103551	Year-round (2018)
HUC12 Name: Upper Grouse Creek	OR_WS_170601020202_02_103392	Year-round (2018), Spawning (2010)
HUC12 Name: Upper Lightning Creek	OR_WS_170601020505_02_103414	Year-round (2010)
HUC12 Name: Upper Mud Creek	OR_WS_170601060203_02_103522	Year-round (2018)
Imnaha River	OR_SR_1706010201_02_103288	Year-round (2010)
Imnaha River	OR_SR_1706010202_02_103290	Year-round (2010), Spawning (2010)
Imnaha River	OR_SR_1706010205_02_103302	Year-round (2010)
Grouse Creek	OR_SR_1706010202_02_103292	Spawning (2010)
Joseph Creek	OR_SR_1706010605_02_103375	Year-round (2010)
Joseph Creek	OR_SR_1706010606_02_103381	Year-round (2010)
Lightning Creek	OR_SR_1706010205_02_103298	Year-round (2010)
Little Bear Creek	OR_SR_1706010504_02_103352	Year-round (2010)
Little Minam River	OR_SR_1706010505_02_103359	Year-round (2022), Spawning (2022)
Lostine River	OR_SR_1706010502_02_103348	Year-round (2018)
Minam River	OR_SR_1706010505_02_103361	Year-round (2010)
Salmon Creek	OR_SR_1706010604_02_103374	Year-round (2010)
Summit Creek	OR_SR_1706010202_02_103291	Year-round (2018)
Swamp Creek	OR_SR_1706010605_02_103377	Year-round (2018)
Wallowa Lake	OR_LK_1706010501_02_100618	Year-round (2010)
Wallowa River	OR_SR_1706010501_02_103342	Year-round (2010)
Wallowa River	OR_SR_1706010503_02_103351	Year-round (2010)
Wallowa River	OR_SR_1706010506_02_103362	Year-round (2010)
Wenaha River	OR_SR_1706010603_02_103369	Spawning (2010)
Wildcat Creek	OR_SR_1706010602_02_103365	Year-round (2010)

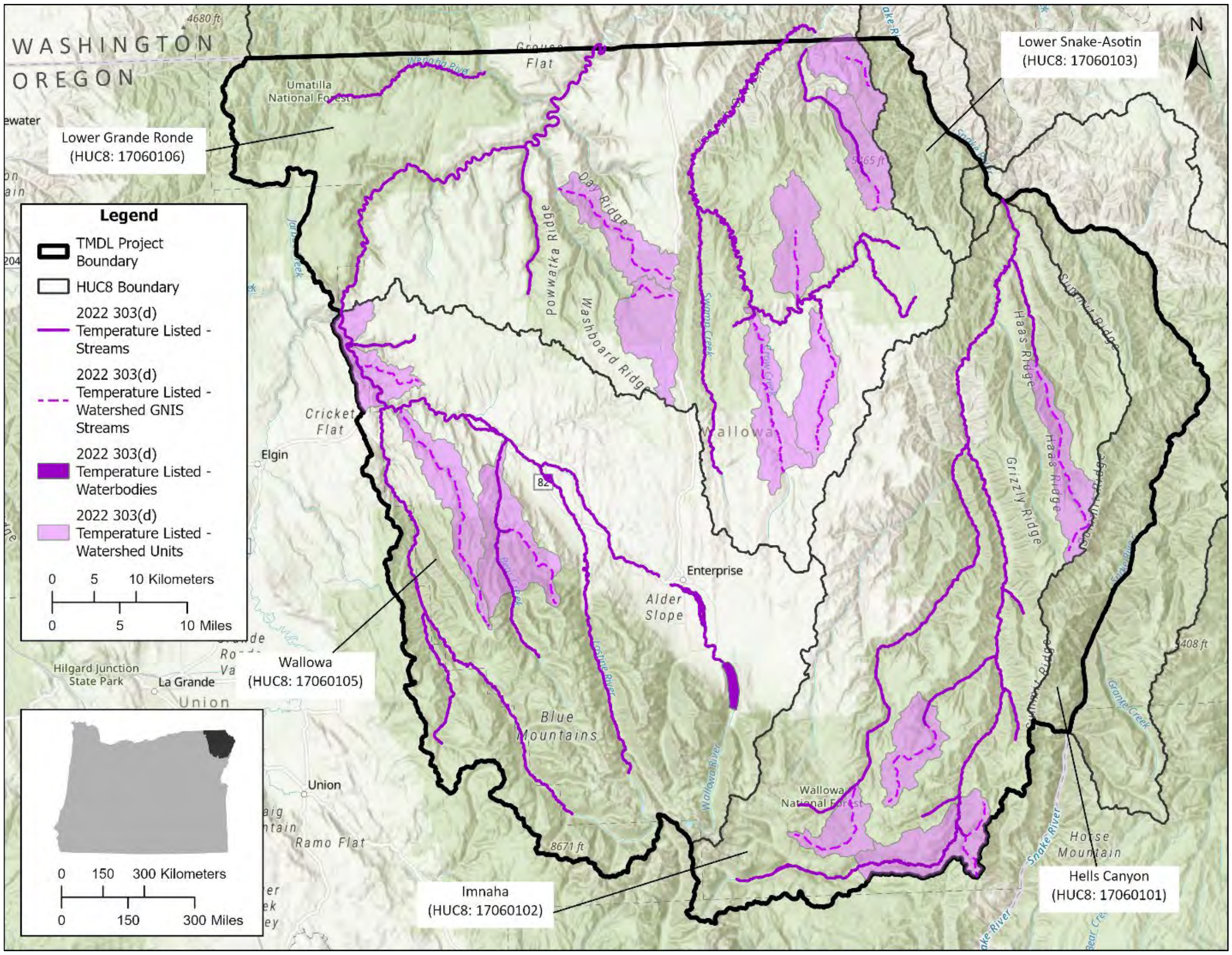

Figure 2-3: Lower Grande Ronde Subbasins Category 5 temperature impairments on the 2022 Integrated Report.

Table 2-2: Assessment units evaluated as not meeting temperature criteria and proposed to be added to the 303(d) list and classified as category 5 impaired for temperature in the draft 2024 Integrated Report.

Assessment Unit Name	Assessment Unit ID	Use Period
Howard Creek	OR_SR_1706010506_02_103363	Year-round
HUC12 Name: Wallupa Creek	OR_WS_170601060201_02_103520	Year-round
HUC12 Name: Lower Courtney Creek	OR_WS_170601060209_02_103528	Year-round
HUC12 Name: Grouse Creek	OR_WS_170601060702_02_103561	Year-round

3 Conceptual model: key processes and variables

The current theory to explain the nature of heat is called the kinetic-molecular theory. The modern version of this theory was developed in the mid-19th century by Rudolf Clausis, James Clerk Maxwell, and Ludwig Boltzmann. The theory is based on the assumption that all matter is composed of a tiny population of molecules that are always in motion. The molecules in hot objects are moving faster and hence have greater kinetic energy than the molecules in cold objects. Individual molecules have a certain amount of kinetic energy based on their mass and velocity. The thermal energy of an object is determined by adding up the kinetic energy of all the molecules in that object. When a hot and cold object come into contact with each other, the molecules collide and the kinetic energy flows from the molecules with more kinetic energy to molecules with less kinetic energy. This type of flow of kinetic energy is called heat.

Temperature is an intensive property and much like concentration measures the “strength” rather than “quantity” of kinetic energy. The temperature of an object is the measure of the average kinetic energy of all the molecules in that object. Hot water has greater average kinetic energy than cold water but may not have greater total kinetic energy. For example, a small pot of water with a temperature near the boiling point has a higher average kinetic energy than a swimming pool at room temperature. The swimming pool has a much larger quantity of molecules and therefore a higher total kinetic energy than the pot of water.

Temperature is the water quality parameter of concern, but heat, in particular heat from human activities or anthropogenic sources, is the pollutant of concern. Water temperature change (ΔTw) 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 result in water temperature change for a defined amount of heat exchange. With this basic conceptual framework of water temperature change, it is possible to discuss stream temperature change as a function of two variables: heat and mass transfer.

Water Temperature Change as a Function of Heat Exchange and Volume,

$$\Delta Tw = \frac{\Delta Heat}{Density \times \text{Specific Heat} \times \Delta Volume} \qquad \text{Equation 2}$$

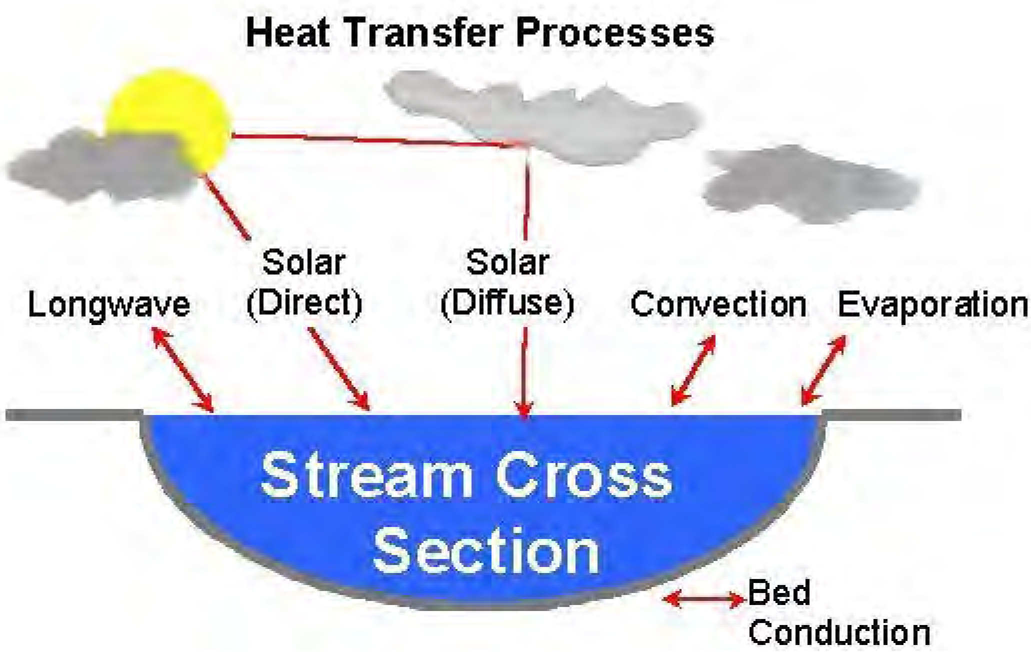

Figure 3-1: Major heat transfer processes.

Heat transfer relates to processes that change heat in a defined water volume. There are several thermodynamic pathways that can introduce or remove heat from a stream. These different processes are shown in Figure 3-1. For any given stream reach heat exchange is closely related to the season, time of day and the surrounding environment and the stream characteristics. Heat transfer can be dynamic and change over relatively small distances and time periods. Equation 3 describes the several heat transfer processes that change stream temperature (Wunderlich, 1972; Jobson and Keefer, 1979; Beschta and Weatherred, 1984; Sinokrot and Stefan, 1993; Boyd, 1996; Johnson, 2004; Hannah et al., 2008; Benyahya et al., 2012).

$$\Phi_{total} = \Phi_{solar} + \Phi_{longwave} + \Phi_{streambed} + \Phi_{convection} + \Phi_{evaporation} \qquad \text{Equation 3}$$

Where,
Φ_{total} = Net heat energy flux (+/-)
Φ_{solar} = Shortwave direct and diffuse solar radiation (+ only)
$\Phi_{longwave}$ = Longwave (thermal) radiation (+/-)
$\Phi_{streambed}$ = Streambed conduction (+/-)
$\Phi_{convection}$ = Stream/air convection[1] (+/-)
$\Phi_{evaporation}$ = Evaporation (+/-)

[1]Air/Water convection includes both turbulent and free surface conduction.

Mass transfer relates to transport of flow volume downstream, instream mixing and the introduction or removal of water from a stream. For instance, flow from a tributary will cause a temperature change if the temperature is different from the receiving water. Mass transfer commonly occurs in stream systems as a result of:

- Advection,
- Dispersion,
- Groundwater exchange,
- Hyporheic flows,
- Surface water exchange (e.g. tributary input, precipitation), and
- Other human related activities that alter stream flow volume.

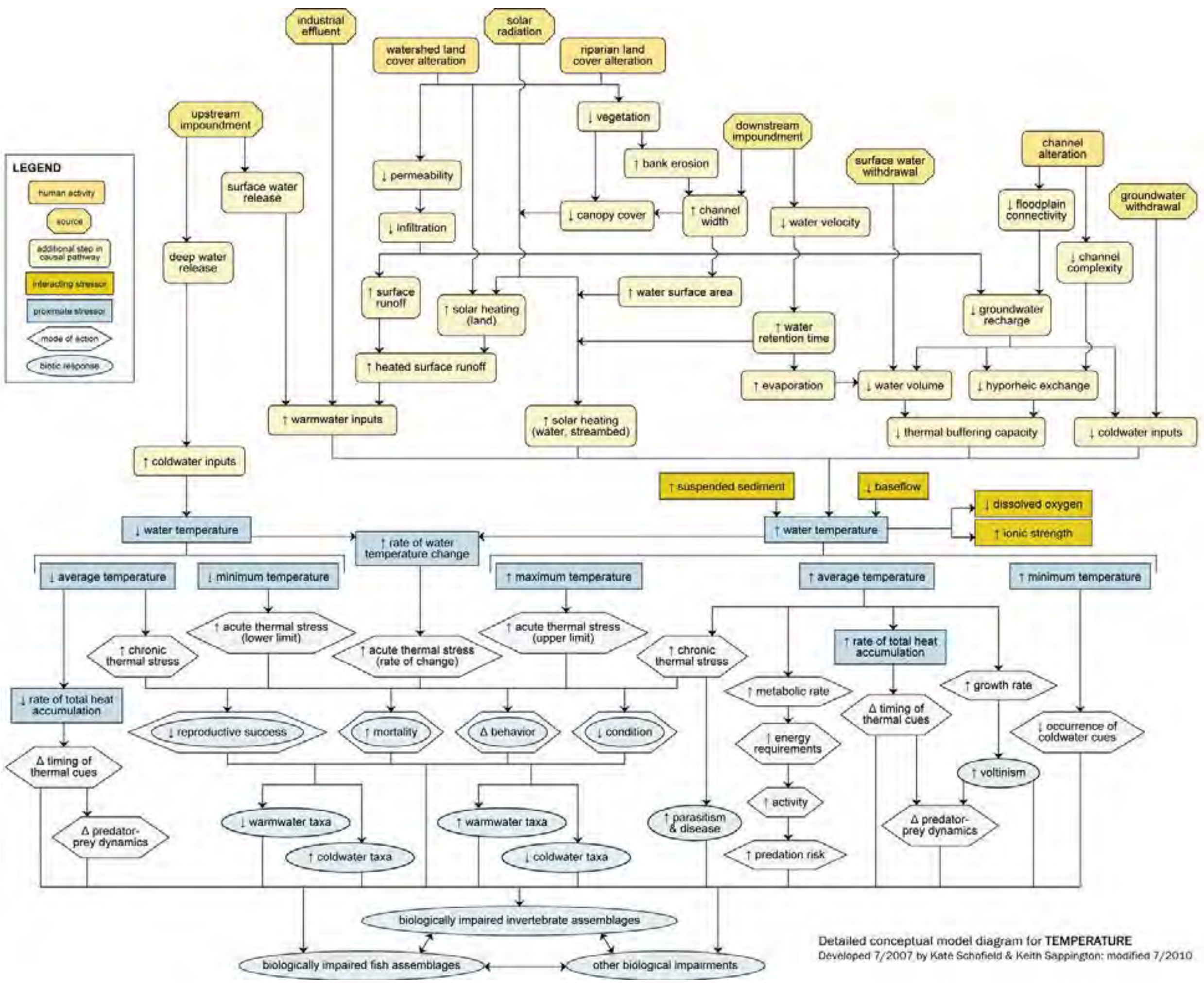

Figure 3-2: Conceptual diagram that identifies the key processes and variables that drive stream temperature changes and the biological responses (Schofield and Sappington, 2010).

Stream temperature is influenced by both human and natural factors. Figure 3-2 is a conceptual diagram that identifies the key process and variables that drive stream temperature. Human sources and natural sources are identified. Near the bottom of the diagram the biological responses are identified.

Anthropogenic Point Sources: Temperature increases from point sources are those caused by warm water discharges from NPDES permitted facilities, such as industrial outfalls, municipal WWTPs, and other point sources.

Anthropogenic Nonpoint Sources: Temperature increases from human-caused nonpoint sources are caused by increases in solar radiation loading to the stream network from the disturbance or removal of near-stream vegetation, channel modification and widening, reductions to the stream flow rate or volume, changes in hyporheic flows and channel connectivity, reductions in cold groundwater inflows, and changes to meteorological conditions, such as those caused by climate change.

Background Sources: Background sources include all sources of pollution or pollutants not originating from human activities. In the context of a TMDL, 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 (OAR 340-042-0030(1)).

4 Technical approach

4.1 Overview

Stream temperature TMDLs are generally scaled to a subbasin or basin scale since stream temperatures are affected by cumulative interactions between upstream and local sources. For this reason the TMDL considers all surface waters that affect the temperatures of 303(d) listed waterbodies. For example, the Imnaha River is water quality limited for temperature. To address this listing in the TMDL, all upstream waters are considered in the TMDL analysis, TMDL allocations are typically applied throughout the entire stream network and include all waters of the state.

An important step in the TMDL is to perform a source assessment which quantifies the background and anthropogenic contributions to stream heating. Models provide a way to evaluate potential sources of stream warming and, to the extent existing data allow, the amount of pollutant loading from these sources. The model that is selected for the TMDL analysis should support the needs of the project. Section 4.2 describes the model framework needs for this project and the models that will be used to support the TMDL.

TMDLs also require identification of seasonal variation and critical conditions. The TMDL analysis will determine seasonal variation by including a statistical summary and visual plots summarizing the instream temperatures and flow rates observed at various monitoring locations. The time period when the applicable temperature criteria are exceeded will be described in relation to the critical conditions.

The TMDL will establish a loading capacity that specifies the amount of a pollutant or pollutants that a waterbody can receive and still meet water quality standards. The pollutant addressed in the temperature TMDL is heat. The TMDL will divide the loading capacity into thermal wasteload allocations for NPDES permittees and load allocations for background and nonpoint sources of heat to ensure that the applicable temperature standards are achieved. Anthropogenic nonpoint and NPDES permitted point sources are not permitted to heat a waterbody more than 0.3°C above the applicable criteria, cumulatively at the point of maximum impact. The portion of the HUA allocated to each source will be determined in the TMDL with the modeling approach supporting assessment of different allocation options. The modeling approach may also be used to support development of TMDL surrogate measures such as effective shade targets. Nonpoint source allocations can be translated into surrogate measures when a pollutant is difficult to measure, highly variable, or difficult to monitor (OAR 340-042-0040(5)(b)). Thermal load allocations for nonpoint sources can be difficult to measure and monitor. Attainment of the surrogate measures ensures compliance with the nonpoint source allocations.

4.2 Model selection

The modeling framework needs for this project include:

1) Prediction of hourly stream temperatures over a period of days months and at a no greater than 500 meter longitudinal resolution.
2) Prediction of hourly solar radiation flux and daily effective shade at a no greater than 100 meter longitudinal resolution.
3) Ability to evaluate hourly stream temperature response from changes in streamside vegetation.
4) Ability to evaluate hourly stream temperature response from changes in water withdrawals and tributary stream flow within the upstream catchment.
5) Ability to evaluate hourly stream temperature response from changes in channel morphology within the upstream catchment.
6) Ability to evaluate hourly stream temperature response from changes in effluent temperature and flow discharge from NPDES permitted facilities.

The Heat Source stream thermodynamics model (Boyd and Kasper, 2003) was used to model several streams for the 2010 TMDL (DEQ, 2010). Because these models already exist and meet all the model framework needs, Heat Source was selected for stream temperature simulation in the project area. The Heat Source model was originally developed at Oregon State University as a master’s thesis where it was evaluated and approved by an academic committee (Boyd, 1996). Development of the model continued and in 1999 DEQ submitted the model equations and methodology for peer review (DEQ, 1999) and again in 2004 to the Independent Multidisciplinary Science Team (IMST, 2004) where the model was found to be scientifically sound.

The Heat Source model has been used in numerous stream temperature related studies including Loheide and Gorelick (2006), Diabat et al. (2013), Holzapfel et al. (2013), Lawrence et al. (2014), Bond et al. (2015), Woltemade and Hawkins (2016), Justice et al. (2017), and Wondzell et al. (2019). Heat Source has also been used in numerous Oregon TMDLs (DEQ, 2001, 2002, 2003, 2005, 2006, 2007, 2008, 2010, 2018, 2019).

4.3 Software Development Quality Assessment

We do not anticipate any new software development or model code changes as part of this project.

5 Model development and calibration

Waterbodies where model development was initiated for the Lower Grande Ronde Subbasins TMDL (DEQ, 2010) are listed in Table 5-1 and Table 5-2. The models identified in Table 5-2 were developed between 2005 and 2009 by DEQ but not used in the final 2010 TMDL. DEQ has reviewed these models and determined minimal effort is needed to complete their development. The remaining work is summarized in each model subsection. The extent and location of these models is shown in Figure 5-1.

Table 5-1: Waterbodies where a calibrated model has already been developed.

Model Version	Model Waterbody
Heat Source version 7 temperature and shade model	Grande Ronde and Wallowa Rivers

The setup and calibration for the Grande Ronde and Wallowa River model was completed by DEQ and documented in the Lower Grande Ronde Subbasins TMDL (DEQ, 2010). Adjustments to the existing calibrated model are unlikely to occur as part of this project. However, if it is determined that the model calibration needs to be updated, the model inputs that are expected to be modified are described in Section 6.1. DEQ will follow the model acceptance criteria and model fit statistics described in Section 7.2.

Table 5-2: Waterbodies where additional work is needed to complete development of a calibrated model.

Model Version	Model Waterbody
Heat Source version 7 solar model	Big Sheep Creek, Joseph Creek and Chesnimnus Creek, Little Sheep Creek, Prairie Creek, Spring Creek, Wenaha River
Heat Source version 7 temperature and shade model	Bear Creek, Imnaha River, Lostine River, Minam River

DEQ will develop effective shade curves for all other waterbodies that were not specifically listed in Table 5-1 and Table 5-2. Effective shade curves represent the maximum possible effective shade for different vegetation types, stream widths, and stream aspect. Every combination of these conditions are modeled in Heat Source to develop the estimated effective shade. The results are summarized in a shade curve plot. The results can also be summarized in a lookup table with additional combinations of vegetation height, density, and buffer width included. Effective shade curves were developed for the original Lower Grande Ronde Subbasins TMDL (DEQ, 2010). Adjustments to the existing shade curve models are unlikely to occur as part of this project. However, if it is determined that the models need to be updated DEQ will follow the procedures outlined in this QAPP.

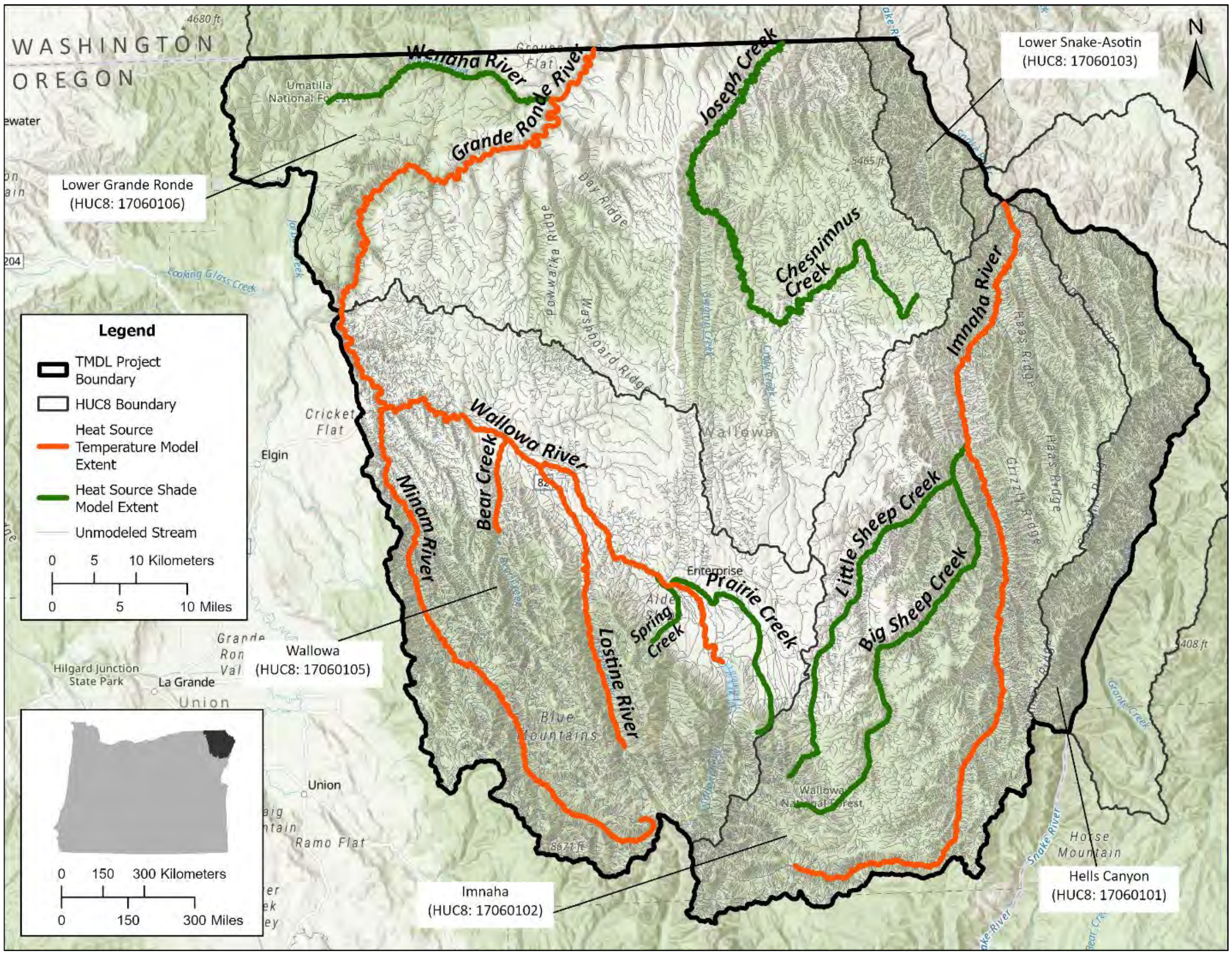

Figure 5-1: Heat Source temperature and shade model extents within the TMDL project area.

5.1 Data availability and quality

This section describes the data that is available to support the TMDL project and the quality assurance procedures used when collecting or reviewing the available data.

5.1.1 Meteorological data

Hourly meteorological data inputs into the model include air temperature, relative humidity, cloudiness, and wind speed. The data sources for these parameters used to support model development are listed in Table 5-3. Figure 5-2 shows the locations of climate stations used to establish meteorological conditions for model simulations.

Table 5-3: Meteorological monitoring sites supporting model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Measurement Parameters
Roberts Butte Oregon	Roberts Butte Oregon	RAWS	45.6817	-117.2064	Air Temperature, Wind Speed, Relative Humidity
Firegone near Joseph, Oregon	Joesph, Oregon	Firegone, Ltd	45.3887	-117.2324	Air Temperature, Wind Speed, Relative Humidity

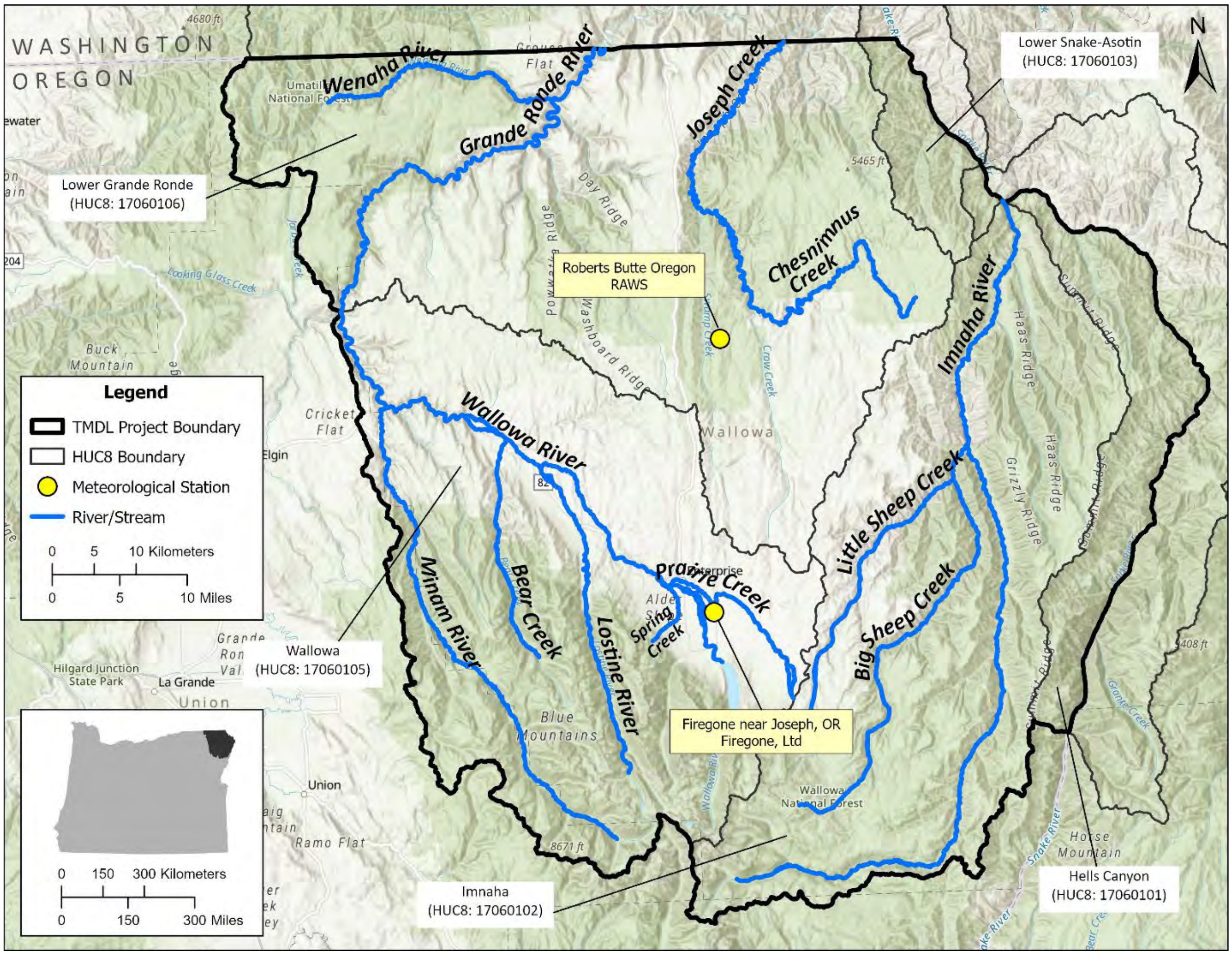

Figure 5-2: Location of climate stations providing meteorological data for model simulations.

Available meteorological data includes air temperature, sky conditions, cloudiness, relative humidity, and wind speed from the National Interagency Fire Center's Remote Automatic Weather Stations (RAWS), and a private weather station operated near Joesph, Oregon by a fire management business named Firegone Ltd. The Firegone weather station is no longer in operation.

The quality control procedures for the RAWS meteorological data is documented in NWCG (2019). The Firegone quality control procedures are unknown, although due to the lack of weather data in the Joseph area the National Weather Service took interest in the station with an employee visiting to check the equipment and ensure proper calibration (Dickenson, 2003).

5.1.2 Continuous stream temperature data

All available continuous stream temperature data were retrieved from DEQ's Ambient Water Quality Monitoring System (AWQMS), USGS's National Water Information System (NWIS), or were obtained during the data solicitation for DEQ's temperature TMDL replacement project. Some temperature data presented in this QAPP were retrieved from DEQ's files and were not available in AWQMS or USGS's database.

The data retrieval period for continuous stream temperature data is from January 1, 1999 to December 31, 2024. Data retrieved from the AWQMS database has a Data Quality Level (DQL) of A, B or E and a result status of "Final", "Validated", or "Provisional". The data quality level criteria are outlined in **DEQ's Data Quality Matrix for Field Parameters** (DEQ, 2013). The TMDL program uses waterbody results with a data quality level of A, B, or E (DEQ, 2021). Data of unknown quality are used after careful review.

A summary of available temperature data is presented in Appendix A. This data will be used to develop temperature models, characterize stream temperature across the TMDL project area, determine seasonal variation, critical conditions, and excess load.

5.1.3 Thermal Infrared Radiometry (TIR) data

DEQ contracted with Watershed Sciences, Inc. to provide airborne Thermal Infrared Radiometry (TIR) imagery of spatial temperature patterns within the Lower Grande Ronde, Imnaha, and Wallowa Subbasins (Watershed Sciences, 2000). TIR data is used to characterize the thermal regime of the streams and habitat quality. For modeled streams, it is used to develop tributary temperature input, as part of the mass balance for derivation of tributary inflow rate, and for model calibration. All streams and the TIR collection dates are summarized in Table 5-4.

Table 5-4: Streams and the TIR collection dates in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins.

Stream	Survey Extent	Date	Time	Survey Distance
Bear Creek	Mouth to headwaters	1999-08-23	16:05-16:26	19.6 mi
Chesnimnus Creek	Mouth to headwaters	1999-08-22	15:14-15:37	25.6 mi
Joseph Creek	Mouth to confluence of Chesimnus Creek and Crow Creek	1999-08-22	14:31-15:12	48.2 mi
Lostine River	Mouth to upstream of East Lostine Creek	1999-08-23	15:24-15:50	25.6 mi
Lower Grande Ronde River	Mouth to Rondowa	1999-08-19	14:33-15:38	79.8 mi
Minam River	Mouth to headwaters	1999-08-21	15:59-16:35	45.3 mi
Wallowa River	Mouth to Wallowa Lake	1999-08-23	13:35-14:23	50.1 mi

5.1.4 Stream flow data and channel measurements

DEQ retrieved continuous flow rate measurements from various United States Geological Survey (USGS) and Oregon Water Resources Department (OWRD) monitoring sites. DEQ measured instantaneous flow rate at multiple stream survey sites during the model period in the summers of 1999 and 2000. In addition to instantaneous flow rate, the surveys included measurements of flow velocity, wetted width, wetted depth, and cross-sectional area. These instream measurements were used to develop flow inputs into the model, support flow mass balance analysis, and calibrate the temperature models. DEQ relies upon the quality control checks implemented by USGS and OWRD. DEQ-collected stream flow measurements utilize field and quality control methods outlined in DEQ's Mode of Operations Manual **V3** & **V4** (DEQ, 2024).

Appendix B summarizes locations of available continuous and instantaneous flow rate measurements in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins. This data will be used to develop temperature models, calculate 7Q10 low flows statistics, determine seasonal variation, and critical conditions.

5.1.5 Water rights/surface water diversions

Data on surface water diversion rates (usage) and the points of diversion (location) are available from the Oregon Water Resources Department (OWRD). OWRD regulates all commercial, industrial, domestic, and agricultural water use in the state of Oregon through water rights.

Estimates of water diversion rates and location of points of diversion can be derived from the following OWRD sources:

- **Water Rights Information System** (WRIS) – the WRIS database contains all permitted or certificated water rights. Data in the WRIS corresponding to quantities of water for use are expressed as maximum use allowable, generally as monthly, seasonal or annual rates or volumes. These maximum values may not correspond to actual usage, which will likely vary based on factors such as irrigation application rate or household consumer demand. DEQ may choose to incorporate the maximum amount allowable or some lesser quantity provided sufficient information is available to support those rates in the modeling. Water rights information can also be accessed using their online mapping application (**https://apps.wrd.state.or.us/apps/gis/wr/Default.aspx**).

- **Water Use Reports** – some, but not all, water rights holders must monitor and report the water they use to the state, typically on a monthly or yearly basis, as a requirement of their water rights. These water use reports will be used to develop withdrawal time series based on available information.

5.1.6 Point source discharges

Table 5-5 identifies all the active individual NPDES permittees in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins as of the date of this QAPP. Table 5-6 lists the registrants covered under the general NPDES 300-J permit. This group of general permits are highlighted because the permits require temperature monitoring at a frequency of at least one grab sample per month. The location of these NPDES permittees is shown in Figure 5-3. Many of these permittees submit Discharge Monitoring Reports (DMRs) as a condition of their permit. Depending on the monitoring requirements in the permit, some permittees are required to report effluent temperature and effluent flow rates in the DMR. The frequency and type of reporting varies by permit and permit type. Some permits only require monthly, weekly, or daily grab samples while others require summary statistics such as daily maximum, daily mean, or seven-day average daily maximum. The NPDES permits require data be collected and reported on the DMR using appropriate methods based on a quality assurance and quality control plan. Where possible, DEQ will utilize any continuous effluent data that has been provided to DEQ. When continuous data is not available, DMR data will be utilized to characterize point source discharges. Table 5-7 lists the current number of registrants for all the other general NPDES permits in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins that are not listed in Table 5-6.

Table 5-5: Summary of individual NPDES permitted discharges in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins.

Facility Name (File Number : EPA Number)	Latitude	Longitude	Permit Type and Description	Stream River Mile
Enterprise STP (27514 : OR0020567)	45.4265	-117.3112	NPDES-DOM-Da: Sewage - less than 1 MGD	Wallowa River RM 40.7
Joseph STP (44329 : OR0020605)	45.3977	-117.2321	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Prairie Creek RM 4
Wallowa STP (93617 : OR0020028)	45.5769	-117.5291	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Wallowa River RM 23

Table 5-6: Summary of current registrants under the general NPDES 300-J permit in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins.

Facility Name (File Number : EPA Number)	Latitude	Longitude	Permit Type and Description	Stream River Mile
ODFW - Wallowa River Hatchery 64580 : ORG137003	45.4176	-117.3021	300-J: Industrial Wastewater; NPDES fish hatcheries	Spring Creek RM 1.6

Table 5-7: Summary of the current number of registrants for all the other general NPDES permits in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins that are not listed in Table 5-6.

Permit Type and Description	Current Number of Registrants
1200-C: Stormwater; NPDES construction more than 1 acre disturbed ground	3

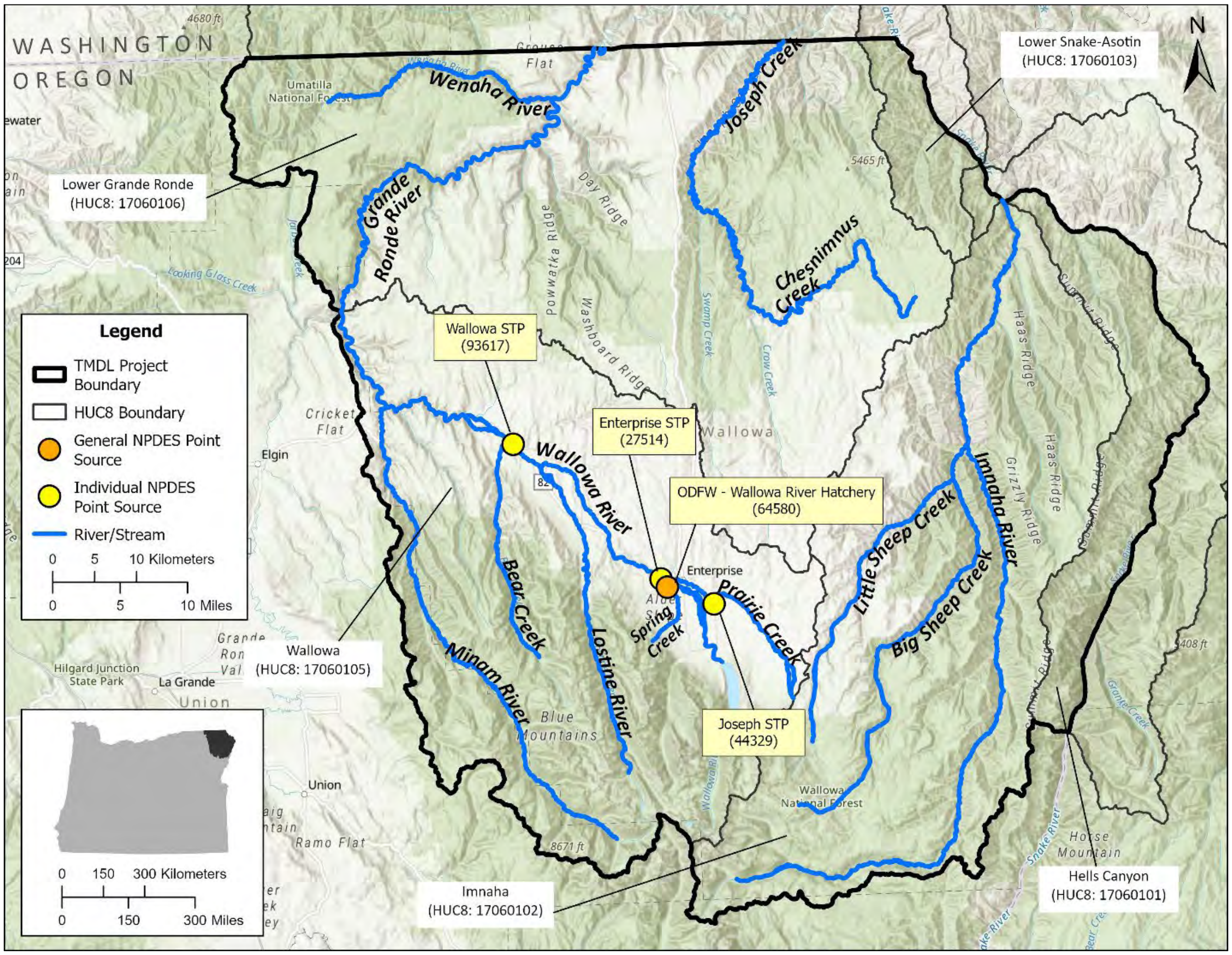

Figure 5-3: Individual and general NPDES permittees located within the Lower Grande Ronde Subbasins TMDL project area.

5.1.7 Stream habitat surveys

During the summers of 1999 and 2000, Oregon DEQ collected ground-level habitat data at several locations focusing on the Wallowa River and Imnaha River Subbasins. Stream survey data focused on near stream vegetation classification, vegetation height, and effective shade measurements.

Effective shade is the percent of potential daily solar radiation flux that is blocked by vegetation and topography. DEQ and/or partner agency staff used an instrument called a solar pathfinder to collect effective shade measurements in the field. The effective shade measurement methods and quality control procedures used are outlined in the Water Quality Monitoring Technical Guide Book (OWEB, 1999) and the solar pathfinder manual (Solar Pathfinder, 2016). Table 5-8 lists the locations where effective shade measurements were collected and the effective shade value for August 1999. Figure 5-4 displays the effective shade measurement locations.

In addition, ODFW has completed numerous habitat surveys in the project area (Figure 5-5). Their data sets focus on measurements of channel morphology, sediment size class distribution, riparian and bank condition, and wood. These data are useful for parameterizing channel morphology inputs in the model. The methodology and quality controls used in these surveys is a modified version of methods developed by Bisson, et al. (1982), and Hankin and Reeves (1988). These methods are summarized in ODFW's aquatic inventory program field survey methods manual (ODFW, 2025). ODFW provides an interpretation guide for the habitat survey data in Foster et al (2001).

Table 5-8: Effective shade data collected in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Effective Shade (%)	Data Source
Field Site #16	Little Sheep Creek at Bear Gulch	45.4979	-116.8994	44	DEQ
Field Site #3	Big Sheep Creek downstream Camp Creek	45.5457	-116.8469	4	DEQ
Field Site #9	Imnaha River downstream of Imnaha, OR	45.5756	-116.8391	12	DEQ
Field Site #12	Imnaha River upstream of Imnaha, OR	45.5100	-116.8131	5	DEQ
Field Site #8	Imnaha River downstream Freezeout Creek	45.4054	-116.7898	39	DEQ
Field Site #5	Freezeout Creek at ODFW Fish Screen	45.3998	-116.7797	59	DEQ
Field Site #6	Imnaha River at Grouse Creek	45.3304	-116.7988	3	DEQ
Field Site #4	Big Sheep Creek upstream Lick Creek	45.1950	-117.0323	22	DEQ
Field Site #14	Lick Creek upstream Lick Creek Campground	45.1646	-117.0323	23	DEQ
Field Site #17	Little Sheep Creek below Cabin Creek	45.2337	-117.0866	14	DEQ
Field Site #13	Imnaha River downstream Weir	45.3417	-116.8053	9	DEQ

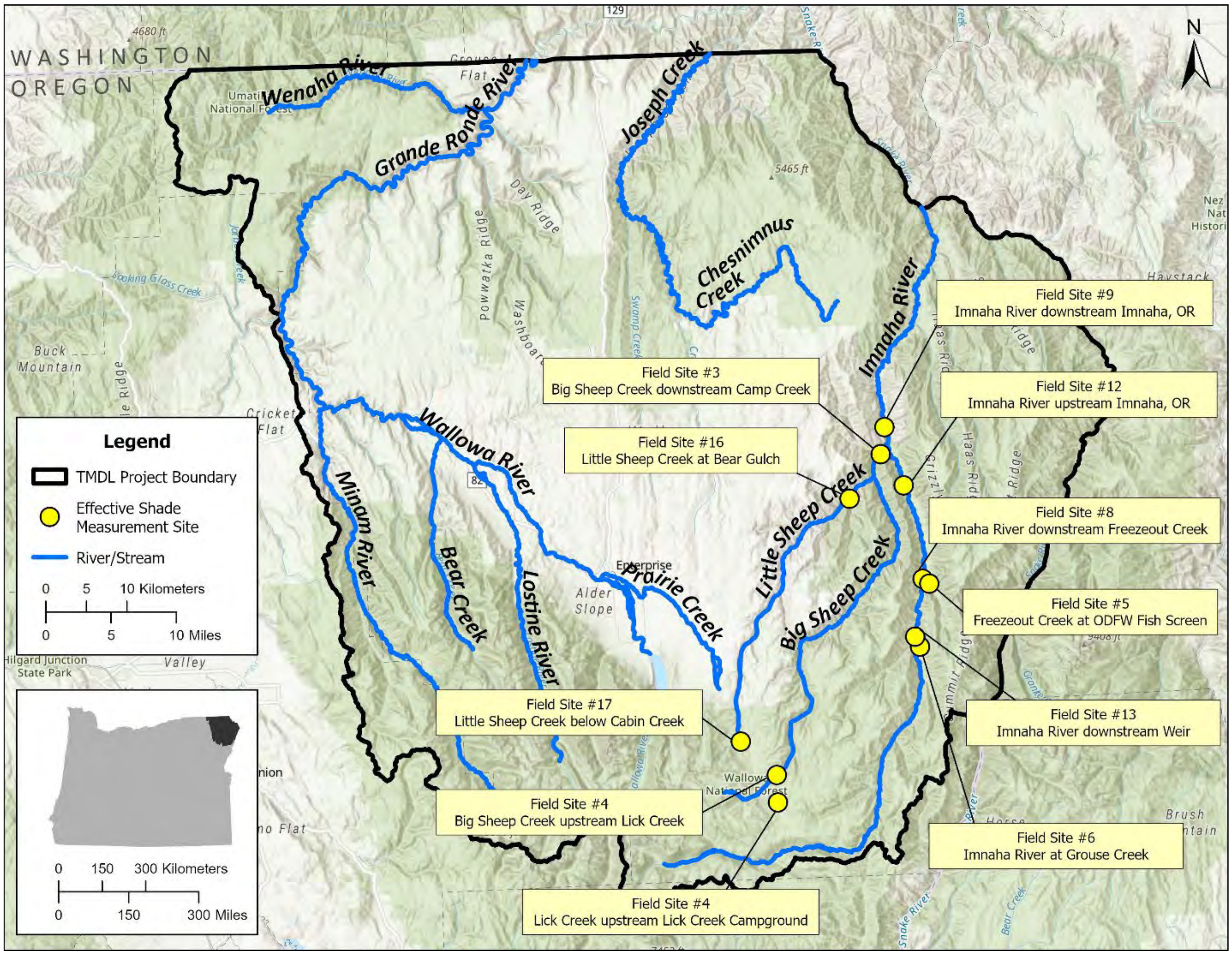

Figure 5-4: Effective shade measurement locations in the TMDL project area.

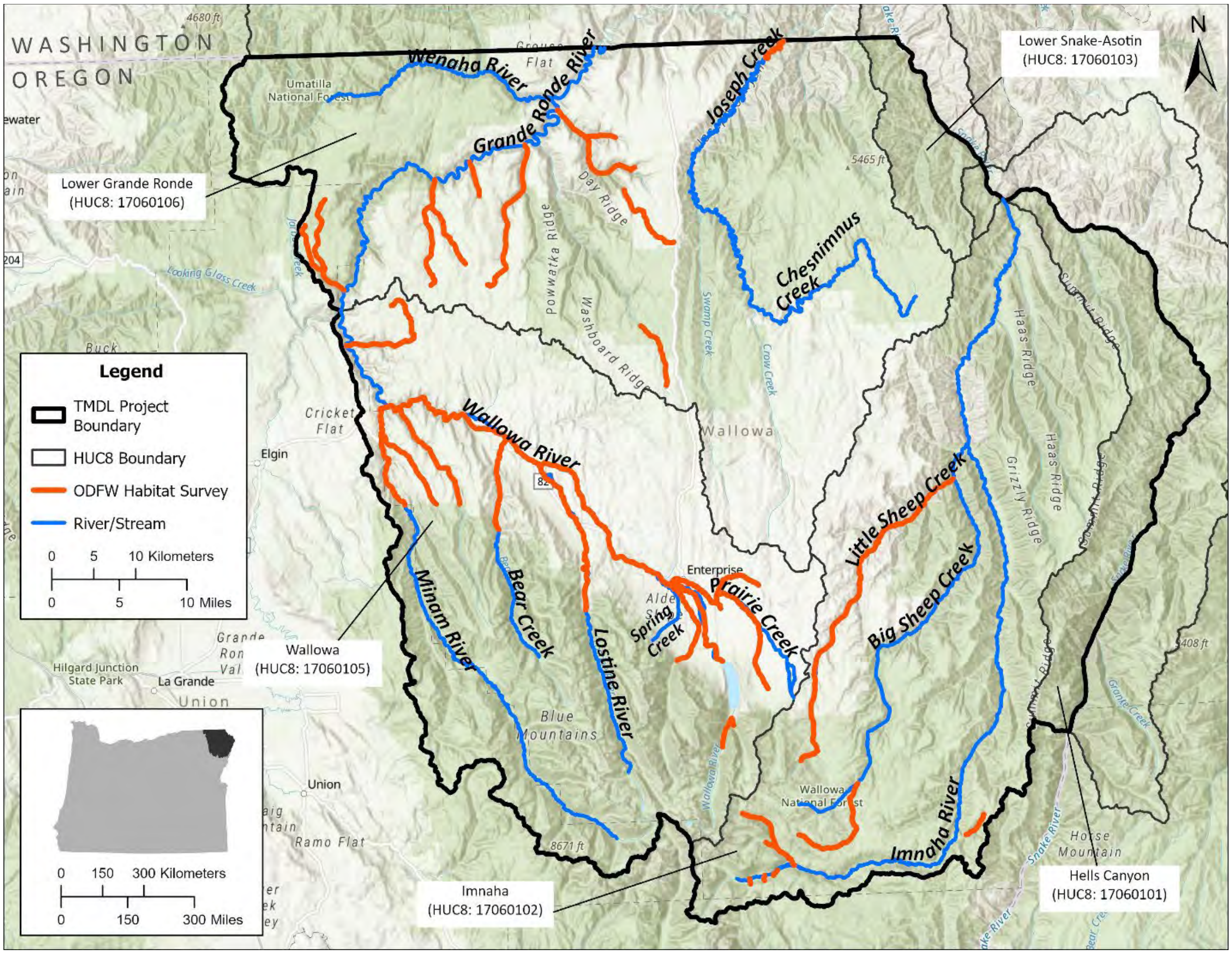

Figure 5-5: ODFW habitat survey locations in the TMDL project area.

5.1.8 Spatial data

Multiple spatial GIS datasets will be used to support model setup and configuration. Table 5-9 identifies the GIS datasets expected to be used for model setup and a brief summary of the application or derived data.

Table 5-9: Spatial data used to support model setup and configuration.

Spatial Data	Source	Application
10-Meter Digital Elevation Model (DEM)	USGS	Measure land surface elevation and stream gradient. Measure valley shape and landform Measure topographic shade angles
LiDAR Bare Earth (DEM)	DOGAMI	The LiDAR bare earth DEM is used to estimate topographic shading angles and land surface elevation.
Digital Aerial Photogrammetry (DAP)	OSIP 2022, ODF 2024	Digital photogrammetry methods can be used to develop a digital surface model (DSM) from stereoscopic aerial imagery. The difference between the LiDAR bare earth DEM and DSM is used to derive vegetation canopy height.

Digital Orthophoto Quarter Quadrangles (DOQQ)	NRCS	One-meter resolution black-and-white digital orthophotos covering a USGS quarter quadrangle were used to map stream position, channel location, and landcover for the exiting models developed for the 2010 TMDL. The images were collected in May through July of 1994, 1995, and 1996, and were provided through the Natural Resources Conservation Service National Cartography and Geospatial Center. These images were used to digitize vegetation classification for the existing models.
Digital Orthophoto Quarter Quadrangles (DOQQ)	OSIP 2024	One-foot resolution color Digital Orthophoto Quarter Quadrangles are available for the entire state for years 2022 and 2024. This aerial imagery will be used to map stream position, channel location, and identify landcover.

5.2 Data gaps

Non-steady state stream models typically require a significant amount of data because of the large spatial and temporal extents the models typically encompass. As the model size or modeling period increase, the amount of information needed to parameterize it also increases. Often it is not possible to parameterize a model entirely from field data because it can be resource intensive or impractical to collect everything that is needed. In general, these data gaps may be considered and addressed in a number of ways. Table 5-10 summarizes methods that are used to derive the data needed to parameterize the model.

To the greatest extent possible, the method used to derive the model parameters for the existing TMDL models have been summarized in the specific sub-section for each model (Sections 5.7 through 5.17).

Table 5-10: Methods to derive model parameters for data gaps.

Method	Possible Parameters	Description
Direct surrogate	Tributary temperatures, meteorological inputs, sediment	Often, neighboring or nearby tributary watersheds share climatological and landscape features. Model parameters that have an incomplete record or no data may be parameterized using data from a neighboring or nearby location where data is available.
Calibration adjustment	All inputs	In some instances, a significant input may be required for appropriate representation in the modeling, however little may be known about the nature of that input. An example of this is groundwater influx and temperature. Datasets for these inputs can be estimated by adjusting the necessary values within acceptable ranges during the calibration process.

Method	Possible Parameters	Description
Literature-based values	All inputs	Literature values are often used for model parameters or unquantified model inputs when little is known about the site-specific nature of those inputs. Examples of these types of parameters include stream bed heat transfer properties, hyporheic characteristics or substrate porosity (Bencala and Walters, 1983; Hart, 1995; Pelletier et al., 2006; Sinokrot and Stefan, 1993).
Mass balance	Tributary temperature and flow	On main stem modeled reaches, tributary stream flow or temperature can be estimated using a mass balance approach assuming either flow or temperature data for the tributary are known. If estimating temperature, flow is required, and if estimating flow, temperature is required. Often TIR data are used to estimate tributary flow because upstream, downstream and tributary temperatures are known, and upstream and tributary flows are known (or estimated).
Simple linear regression	Tributary temperature and flow	Parameters such as flow and temperature in neighboring or nearby tributaries often demonstrate similar diurnal patterns or hydrographs which allow for the development of suitable mathematical relationships (simple linear regression) in order to fill the data gaps for those inputs. This method requires at least some data exist for the incomplete dataset in order to develop the relationship.
Drainage area ratio	Tributary flow	For ungaged tributaries, flows can be estimated using the ratio between the watershed drainage areas of the ungaged location and from a nearby gaged tributary (Ries et al., 2017; Risley, 2009; Gianfagna, 2015). For example, if the watershed area upstream of a gaged tributary is 10 square kilometers, and the watershed area of an ungaged tributary is 5, the flows in the ungaged tributary are estimated to be half of those in the gaged tributary. The method is typically used to calculate low flow or flood frequency statistics. In that context a weighting factor is recommended when the drainage area ratio of the two sites is between 0.5 and 1.5. Weighting factors can be evaluated if instantaneous observed flows are available at the ungaged location.
Flow-probability-probability-flow (QPPQ)	Tributary flow	The flow-probability-probability-flow (QPPQ) method makes use of relating flow duration curves between a gaged tributary and an ungaged tributary (Lorenz and Ziegeweid, 2016). The flow duration curve at ungaged sites is estimated using regression approaches (Risley et al., 2008) and the online USGS tool StreamStats (Ries et al., 2017).
Adiabatic adjustment	Air temperature	Air temperature can vary significantly throughout a watershed, particularly with large differences in elevation from headwaters to the mouth of the drainage. To account for these differences, air temperatures can be adjusted using an equation that relates air temperature measured at a meteorological station to a location of a given elevation using the dry adiabatic lapse rate of 9.8 °C/km and the differences in elevation.

Method	Possible Parameters	Description
GIS Data	Channel position, Channel width, Landcover, Gradient, Elevation, Topographic shade angles	Several landscape scale GIS data sets can be used to derive a number of model parameters. Digital orthophotos quads (DOQs) are used to classify landcover and estimate vegetation type, height, density, and overhang. DOQs can also be used to determine stream position, stream aspect, and channel width. A digital elevation model (DEM) consists of digital information that provides a uniform matrix of terrain elevation values. It provides basic quantitative data for deriving surface elevation, stream gradient, and maximum topographic shade angles.

5.3 Important assumptions

The effort currently described in the QAPP includes use of existing models developed during the original Lower Grande Ronde Subbasins TMDL (DEQ, 2010). Model setup and configuration assumptions used for that effort will be relied upon for new model scenarios included in this QAPP (see Section 9). The calibrated models are not expected to be modified; however multiple new scenarios will be developed (Section 9) that will utilize many of the parameter and configuration aspects of the calibrated models. It is assumed the parameters used in the calibrations are appropriate for the new model scenarios. The updated TMDL will document model setup assumptions and any changes to the calibrations. Assumptions related to the model theory and underlying model equations can be found in the model user guide (Boyd and Kasper, 2003).

5.4 Model calibration

Calibration is the process of adjusting model inputs and parameters to best represent environmental conditions and field measurements in the waterbody or watershed under study. Model calibration is an iterative process that takes into account multiple lines of evidence so specific sub-tasks are difficult to predict in the planning phase. Generally a model is calibrated through a sequential process beginning with the flow balance and hydrology, followed by effective shade, and water temperature. The temperature field measurements include both the TIR data (Section 5.1.3), which represents the longitudinal temperatures at single point in time, and continuous temporal temperature measurements (Section 5.1.2) at various location on the study stream. The two datasets are used together to calibrate the temperature models over the two week simulation period.

The model inputs and parameters that are expected to be modified to improve model fit are described in Table 5-11. It is unlikely all of these parameters will be adjusted; rather this list identifies the candidate model inputs that will be considered for adjustment through the calibration process. Adjustments are only made to parameters that have not been measured directly for the waterbody being modeled. Typically measured data is only adjusted when the measurements are from another location and are used to approximate model input for an unmonitored location. Adjustments should be global in nature and within literature values. The model simulation results will endeavor to match field measured water temperature and stream flow rates.

Table 5-11: Summary of candidate model inputs that might be adjusted to improve model fit.

Input Type	Input/Parameter	Units
Meteorological Data	Cloudiness	proportion (0-1)
Meteorological Data	Wind Speed	meters/second
Meteorological Data	Air Temperature	degrees Celsius
Accretion	Accretion Inflow Rate	cubic meters/second
Accretion	Water Temperature	degrees Celsius
Accretion	Withdrawal Flow Rate	cubic meters/second
Tributary	Tributary Inflow Rate	cubic meters/second
Tributary	Water Temperature	degrees Celsius
Land Cover Codes	Landcover Height	meters
Land Cover Codes	Canopy Density	proportion (0-1)
Land Cover Codes	Landcover Overhang	meters
Morphology Data	Channel Gradient	meters/meters
Morphology Data	Channel Angle z	meters/meters
Morphology Data	Manning’s Roughness Coefficient, n	seconds/meter
Morphology Data	Bed Particle Size	millimeters
Morphology Data	Percent Embeddedness	proportion (0-1)
Morphology Data	Width to Depth (W:D) Ratio	unitless

5.5 Model parameters

Table 5-12 summarizes all of the user entered model inputs and parameters required to run Heat Source version 7. The following subsections briefly summarize the model parameter categories and why the parameters are candidates for adjustment during calibration.

5.5.1 Morphology

The morphology inputs that could be used as calibration parameters fall into two categories: channel hydraulics and bed conduction.

5.5.1.1 Channel hydraulics

These inputs include stream gradient, width to depth ratio, channel angle-z, and Manning’s *n*. Channel hydraulics are important for predicting stream temperatures because they govern the surface area of water that could be exposed to solar radiation, the residence time for exposure, and the degree of light penetration into the water column. Field data for these inputs are often difficult to collect over large spatial scales, and values can vary significantly on a small scale. Heat Source is a one-dimensional model and complex channel configurations are represented as a trapezoidal pattern. Adjustments to inputs that affect channel hydraulics are often necessary to calibrate the model. Starting point values for these inputs come from the measured channel dimensions at locations of instantaneous flow rate measurements or ODFW stream habitat surveys.

5.5.1.2 Bed conduction

These inputs include percent embeddedness and porosity. channel width and side slope angle also affect these inputs by controlling the wetted perimeter of the channel (i.e., the portion or lateral length of the channel bed in direct contact with the stream). These stream morphological characteristics largely govern heat and mass transfer across the stream bed. Typically, habitat surveys and information on the waterbody sediment size class (e.g. bedrock, gravel, sand, silt) is used as the basis for selecting literature values for these inputs.

5.5.2 Meteorology

The two meteorological inputs typically modified in calibration are percent cloudiness and wind speed. Both cloudiness and wind speed can vary significantly on a small geographic scale and the distance to the source of the meteorological data is often much greater than the small-scale localized weather. Hence, adjusting wind and cloudiness is an appropriate calibration method to account for more site-specific weather patterns. Air temperature data is modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location.

5.5.3 Inflows and outflows

Mass and thermal inflows and outflows are inputs often adjusted during the calibration process. These inflows of heat and water consist of tributary and groundwater inflows as well as diversions (i.e., water rights withdrawals) and groundwater losses. The temporal and geographic extents of flow gaging and temperature monitoring on tributaries or groundwater are generally sparse. An effective way of improving the calibration is to complete a flow mass balance with available data, and then add, subtract, or adjust flows either globally or in specific locations within the bounds of the flow mass balance and available measurements, and the temperature response predicted by the model.

5.5.4 Vegetation

Vegetation characteristics input into the model are often derived from aerial imagery or LiDAR. The vegetation characteristics determine the degree to which near-stream vegetation has the capacity to block incidental solar radiation on the surface of the modeled waterbody. Three vegetation inputs incorporated into the model calibration process are the vegetation density, overhang, and height. Field measurements offer a general understanding of vegetation characteristics within the watershed, however variability in these parameters can be significant on smaller geographic scales. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort (DEQ, 2010). The vegetation classes will be applied to all the temperature and shade models.

Table 5-12: Summary of model inputs required for Heat Source version 7.

Input Type	Input/Parameter	Units
General	Stream Length	kilometers
General	Modeling Start Date	date (mm/dd/yyyy)
General	Simulation Period	days
General	Flush Initial Condition	days
General	Time Zone	-
General	Model Time Step	minutes

Input Type	Input/Parameter	Units
General	Model Distance Step	meters
General	Longitudinal Stream Sample Distance	meters
General	Number Of Tributary Inflow Sites	-
General	Number Of Meteorological Data Sites	-
General	Include Evaporation Losses from Flow (True/False)	-
General	Evaporation Method (Mass Transfer/Penman)	-
General	Wind Function Coefficient a	unitless
General	Wind Function Coefficient b	unitless
General	Include Deep Alluvium Temperature (True/False)	-
General	Deep Alluvium Temperature	degrees Celsius
General	Distance Between Transect Samples	meters
Meteorological Data	Meteorological Data Model Kilometers	kilometers
Meteorological Data	Cloudiness	proportion (0-1)
Meteorological Data	Wind Speed	meters/second
Meteorological Data	Relative Humidity	proportion (0-1)
Meteorological Data	Air Temperature	degrees Celsius
Accretion	Stream Kilometers	kilometers
Accretion	Accretion Inflow Rate	cubic meters/second
Accretion	Water Temperature	degrees Celsius
Accretion	Withdrawal Flow Rate	cubic meters/second
Boundary Condition	Boundary Condition Inflow Rate	cubic meters/second
Boundary Condition	Water Temperature	degrees Celsius
Tributary	Tributary Inflow Model Kilometers	kilometers
Tributary	Tributary Inflow Rate	cubic meters/second
Tributary	Water Temperature	degrees Celsius
Land Cover	Node Longitude	decimal degrees
Land Cover	Node Latitude	decimal degrees
Land Cover	Topographic Shade Angle - West	degrees
Land Cover	Topographic Shade Angle - South	degrees
Land Cover	Topographic Shade Angle - East	degrees
Land Cover	Landcover Ground Elevation	meters
Land Cover	Landcover Height	meters
Land Cover	Canopy Density	proportion (0-1)
Land Cover	Landcover Overhang	meters
Morphology Data	Stream Kilometer	kilometers
Morphology Data	Channel Bed Elevation	meters
Morphology Data	Channel Gradient	meters/meters
Morphology Data	Channel Angle z	meters/meters

Input Type	Input/Parameter	Units
Morphology Data	Manning's Roughness Coefficient, n	seconds/meter
Morphology Data	Horizontal Bed Conductivity	Millimeters/second
Morphology Data	Bed Particle Size	millimeters
Morphology Data	Percent Embeddedness	proportion (0-1)
Morphology Data	Rosgen Level I Stream Type (Optional)	-
Morphology Data	Width to Depth (W:D) Ratio	unitless
Morphology Data	Bankfull Width	meters
Morphology Data	X Factor	unitless
Morphology Data	Stream Aspect	degrees

5.6 Effective shade curves and lookup tables

Heat Source shade models estimate the solar flux and effective shade at any given location using internally calculated solar angles based on inputs of latitude and longitude, vegetation height, vegetation density, vegetation overhang, and vegetation buffer width, elevation, stream aspect, and channel width. The outputs of the shade models are used to produce effective shade curves.

Effective shade curves are plots that present the maximum possible effective shade as a function of different types of natural near-stream vegetation, active channel widths, and stream aspect. Channel width is plotted on the x-axis, effective shade is on the y-axis, and a separate symbol and/or line color is used for each stream aspect. Separate plots are produced for each type of natural vegetation that is expected in the TMDL project area. The plots are called effective shade curves because the pattern on the plot resembles a gentle downward sloping curve. As channel width increases effective shade gets smaller. The plots are produced from the output of Heat Source version 6 shade models that have been parameterized with every combination of the previously mentioned conditions. The effective shade curve approach can be used almost anywhere to quantify the amount of background solar radiation loading and the effective shade necessary to eliminate temperature increases from anthropogenic disturbance or removal of near-stream vegetation.

This model approach can also be used to develop a lookup table to determine the effective shade resulting from other combinations of vegetation height, vegetation density, vegetation overhang, and vegetation buffer widths that are different from background conditions. The lookup table provides a convenient way for readers of the TMDL to estimate the effective shade for current conditions without using the model. The lookup table can also be used as a reverse lookup to determine what vegetation height, buffer width, or vegetation density would achieve a certain effective shade.

5.6.1 Model boundaries

Effective shade models used to develop shade curves are not specific to any single waterbody but will be parameterized using a latitude and longitude located in the TMDL watershed to ensure that the modeled solar altitude and sun angles are appropriate for the area. There is minimal difference in solar altitude and sun angle at any given location within the TMDL project area. The differences are not large enough to affect shade results.

5.6.2 Spatial and temporal resolution

Vegetation in the model is parameterized along a transect perpendicular to the stream aspect on both the right and left sides. The transect includes nine vegetation samples with each sample being 4.6 meters apart. The total transect sample distance is 36.8 meters with the first sample being on the edge of the stream channel. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

5.6.3 Source characteristics

The effective shade curve approach can be used almost anywhere in the watershed to quantify the amount of background solar radiation loading and the effective shade necessary to eliminate temperature increases from anthropogenic disturbance or removal of near-stream vegetation.

The lookup tables can be used to estimate existing shade or current solar loading. Other potential sources of thermal loading and the temperature response will not be evaluated by this model.

5.6.4 Time frame of simulation

The model period is a single day in late July or early August. This time frame was chosen to characterize the solar loading when maximum stream temperatures are observed, the sun altitude angle is highest, and the period of solar exposure is longest. This period is considered the critical condition. If shade targets are attained during this period, they will be attained in other times of the year, including the spawning period.

5.6.5 Important assumptions

Models used to develop effective shade curves assume no cloud cover and no topographic shade. The modeled terrain is flat so there is no difference in ground elevation between the stream and the adjacent vegetation buffer area. The vegetation density, vegetation height, vegetation overhang, and vegetation buffer width are assumed to be equal on both sides of the stream. The width of the active channel is assumed to be equal to the distance between near-stream vegetation on either side of the stream. The models also use the same latitude and longitude located in the TMDL project area. There is minimal difference in solar altitude and sun angle at any given location within the TMDL project area. The differences are not large enough to affect shade results.

Effective shade curves were developed for the original Lower Grande Ronde Subbasins TMDL (DEQ, 2010). Adjustments to the existing shade curve models are unlikely to occur as part of this project. However, if it is determined that the models need to be updated DEQ will follow the procedures outlined in this QAPP.

5.6.6 Model parameters

There are two categories of models, each with different sets of inputs:

- Effective shade curves: Model input values for vegetation height, vegetation density, vegetation overhang, and vegetation buffer width correspond to the restored streamside vegetation types expected in areas that are currently lacking streamside vegetation because of anthropogenic disturbance. The specific values will be determined during the TMDL process and will likely be the same or similar to the values presented in the Lower Grande Ronde Subbasins TMDL (DEQ, 2010). The other model inputs are the same as what is described in Table 5-13.
- Effective shade lookup tables: Model input values to be used for the lookup tables are described in Table 5-13.

Table 5-13: Range of model inputs to be used for effective shade lookup tables.

Model Input	Value Range
Vegetation height (meters)	0 - 90 (or expected maximum)
Vegetation density (percent)	0 -100
Vegetation overhang (meters)	0 - 3 (or expected maximum)
Vegetation buffer width (meters)	0 - 45
Active channel width (meters)	0 - 100 (or expected maximum)
Stream aspect (degrees)	North/South (0/180); Northeast/Southwest (45/225); East/West (90/270); Southeast/Northwest (135/315)
Topographic shade angles (degrees)	0
Cloudiness	0

5.7 Bear Creek

The Bear Creek model is a temperature and solar model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not completed or used in the final 2010 TMDL. The primary tasks remaining include adjusting the location of the upstream model boundary, review of the model goodness of fit, and making adjustments as necessary to improve the calibration.

5.7.1 Model boundaries

The upstream extent of the Bear Creek model begins upstream of Little Bear Creek and ends at the confluence of Bear Creek and Wallowa Rivers (Figure 5-6).

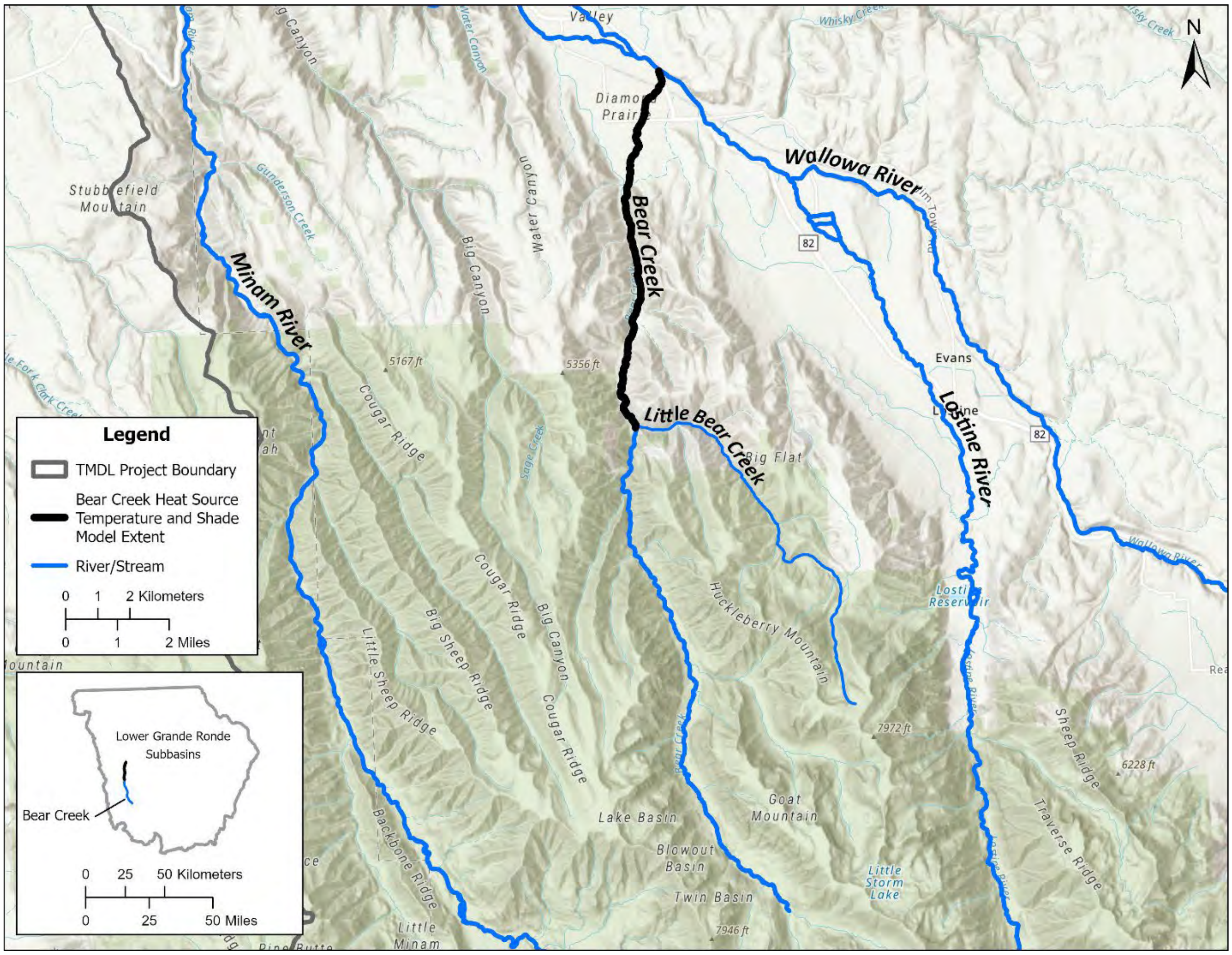

Figure 5-6: Bear Creek temperature and shade model extent.

5.7.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.7.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in Bear Creek may include increases in solar radiation loading from the disturbance or removal of near-stream vegetation, reductions to the stream flow rate or volume, and background sources. Other potential sources include channel modification and widening and warming caused by climate change.

There are no permitted individual NPDES point sources discharging within the model extent.

The majority land use along Bear Creek is forestry accounting for about 85 percent of the near-stream area. Table 5-14 summarizes all the land uses within 100 meters of the digitized Bear Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-14: Summary of land uses along the model extent within 100 meters of the digitized Bear Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	1321.0	84.2
Hay/Pasture	125.0	8
Developed, Open Space	39.1	2.5
Herbaceous	37.8	2.4
Shrub/Scrub	20.5	1.3
Mixed Forest	8.5	0.5
Woody Wetlands	8.2	0.5
Cultivated Crops	3.3	0.2
Developed, Low Intensity	2.7	0.2
Emergent Herbaceous Wetlands	2.0	0.1

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-15).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 5-15 summarizes the potential designated management agencies and responsible persons along Bear Creek model extent.

Table 5-15: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Bear Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Forest Service	954.3	59.6

Oregon Department of Forestry - Private Forestland	395.2	24.7
Wallowa County	150.6	9.4
Oregon Department of Agriculture	89.1	5.6
Oregon Department of Transportation	10	0.6
Wallowa Union Railroad	1.3	0.1

5.7.4 Time frame of simulation

The model period is August 14, 1999 to September 02, 1999.

5.7.5 Model calibration

The Bear Creek model will be calibrated through a sequential process beginning with the flow balance and hydrology followed by water temperature. The temperature field measurements include both the TIR data (Section 5.1.3), which represents the longitudinal temperatures at single point in time, and continuous temporal temperature measurements (Section 5.1.2) at two locations on the study stream. The TIR data will be used for longitudinal temperature calibration while the continuous temperature data are relied upon for calibration over the two week simulation period.

The expected model calibration sites and data sources for temperature and flow model inputs are summarized in Table 5-16 through Table 5-18, with locations of temperature and flow monitoring sites shown in Figure 5-7 and Figure 5-8, respectively. TIR data (Watershed Sciences, 2000) was collected on Augst 23, 1999 and is available for the entire model extent.

Field measured effective shade data are not available for Bear Creek so the model will rely upon the final land cover class attributes from the other calibrated models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort If time and resources allow, DEQ will collect field effective shade measurements on Bear Creek.

5.7.6 Model parameters

The model inputs and parameters that are expected to be modified to improve model fit are described in Section 5.3.

There are 2 tributary inflow locations included in the model domain:

- Little Bear Creek
- Hays Canyon

Little Bear Creek inflow will be based on field measured data. Hays Canyon will be derived from TIR measurements at the mouth. Other flow inputs are derived using a flow mass balance.

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed. These data are derived from the RAWS Roberts Butte monitoring station. Air temperature data may be modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds may be adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see Section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements collected as part of the stream habitat surveys (DEQ, 2010). Ground elevations, stream gradient, and topographic shade angles are derived from a DEM.

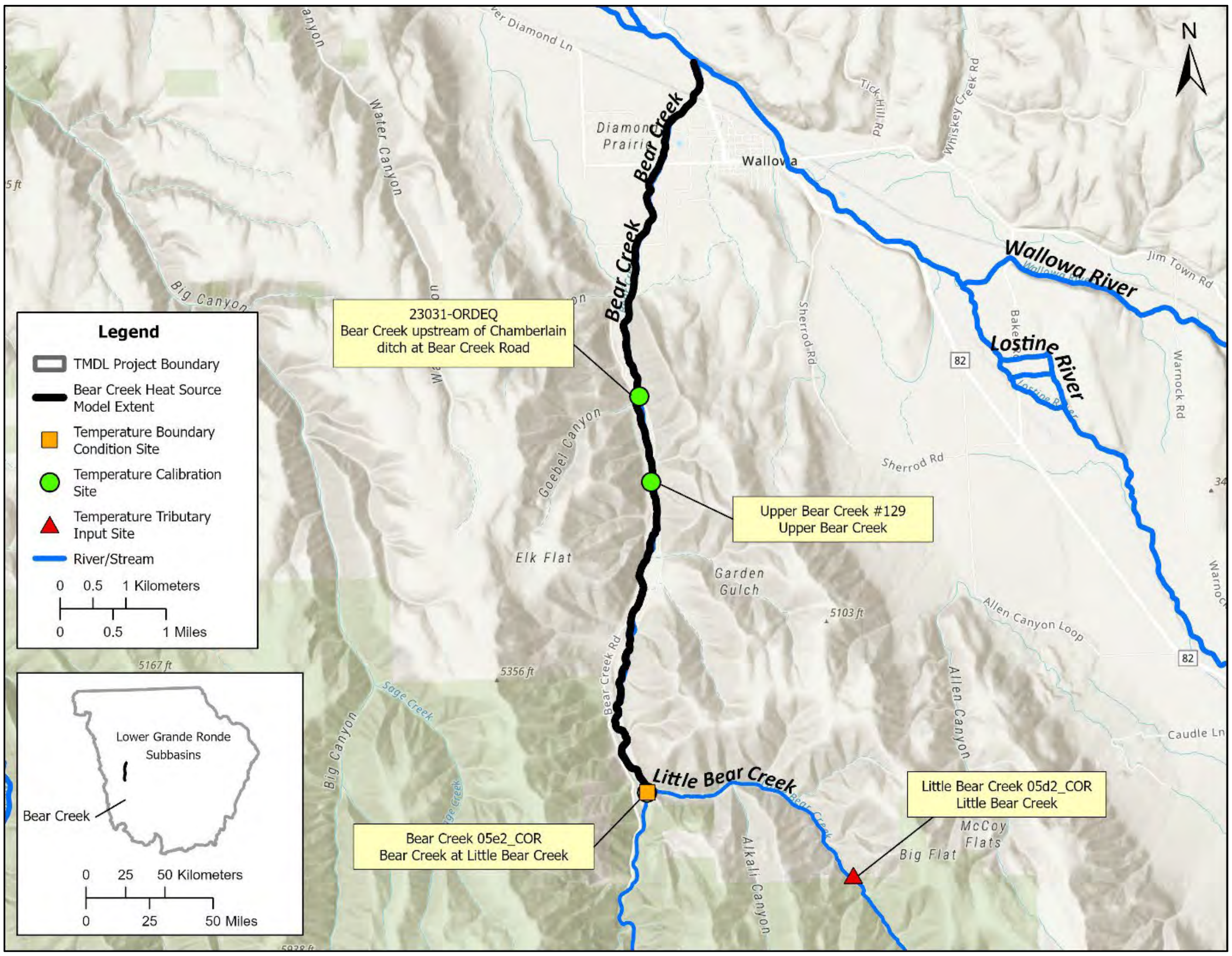

Figure 5-7: Temperature monitoring locations used for Bear Creek model setup and calibration.

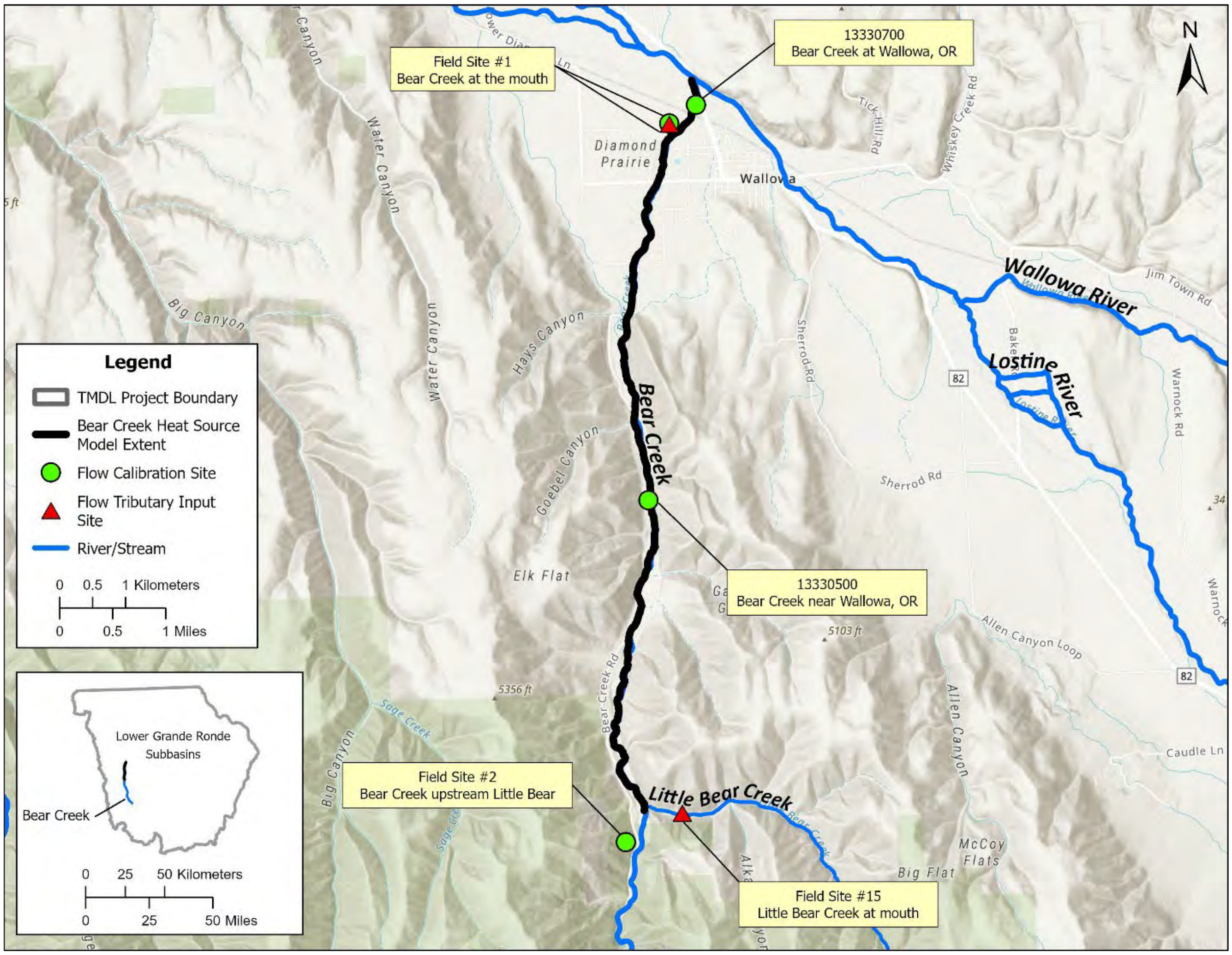

Figure 5-8: Flow monitoring locations used for the Bear Creek model setup and calibration.

Table 5-16: Stream temperature monitoring sites supporting Bear Creek model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
23031-ORDEQ	Bear Creek upstream of Chamberlain ditch at Bear Creek Road	DEQ	45.5386	-117.5539	Calibration
Bear Creek 05e2_COR	Bear Creek at Little Bear Creek	USFS	45.4844	-117.5551	Boundary Condition
Upper_Bear_Creek_#129	Upper Bear Creek	Wallowa SWCD	45.5268	-117.5522	Calibration
Little Bear Creek 05d2_COR	Little Bear Creek	USFS	45.4722	-117.5156	Tributary Input

Table 5-17: Continuous flow rate measurement sites supporting Bear Creek model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
13330700	Bear Creek at Wallowa, OR	USGS	45.5806	-117.5403	Calibration

13330500	Bear Creek near Wallowa, OR	USGS	45.5268	-117.5523	Calibration

Table 5-18: Instantaneous flow rate measurement sites supporting Bear Creek model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
Field Site #1	Bear Creek at the mouth	DEQ	45.5782	-117.5456	Calibration
Field Site #2	Bear Creek upstream Little Bear	DEQ	45.4802	-117.5591	Boundary Condition
Field Site #15	Little Bear Creek at Mouth	DEQ	45.4840	-117.5479	Tributary Input

5.8 Big Sheep Creek

The Big Sheep Creek model is a shade model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.8.1 Model boundaries

The upstream extent of the model begins at the confluence of North Fork Big Sheep Creek and Middle Fork Big Sheep Creek and ends downstream at the Big Sheep Creek mouth at the confluence with the Imnaha River (Figure 5-9).

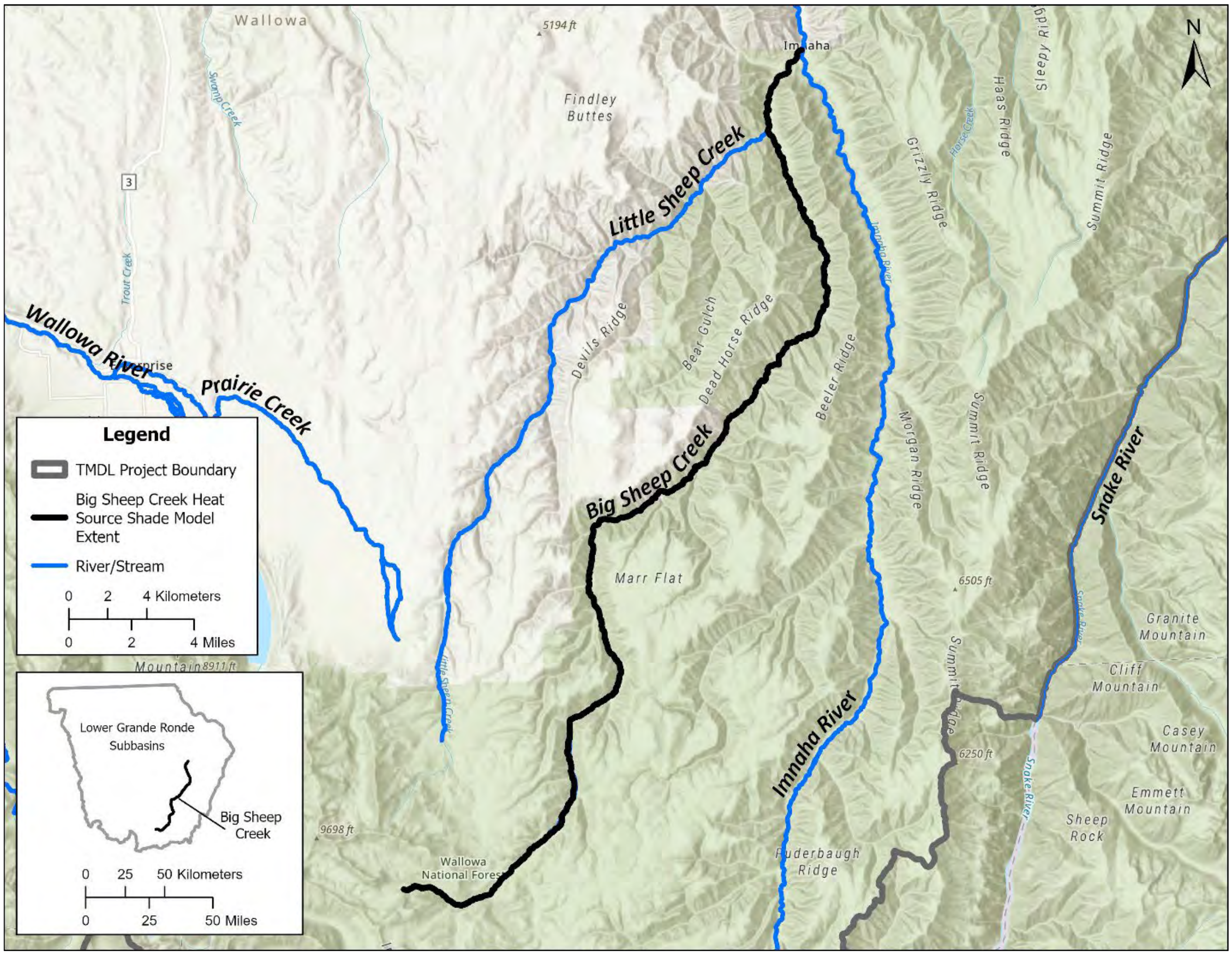

Figure 5-9: Big Sheep Creek shade model extent.

5.8.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.8.3 Source characteristics

The primary purpose of the Big Sheep Creek solar model is to characterize effective shade. Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. Other potential sources of thermal loading will not be evaluated by this model.

The majority land uses along Big Sheep Creek are forestry and rangeland accounting for about 94 percent of the near-stream area. Table 5-19 summarizes all the land uses within 100 meters of the digitized Big Sheep Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-19: Summary of land uses along the model extent within 100 meters of the digitized Big Sheep Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	1645.1	52.1
Shrub/Scrub	844.9	26.8
Herbaceous	427.2	13.5
Developed, Open Space	137.9	4.4
Emergent Herbaceous Wetlands	51.8	1.6
Woody Wetlands	39.6	1.3
Developed, Low Intensity	7.8	0.2
Cultivated Crops	1.8	0.1
Hay/Pasture	1.1	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-20).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 17 summarizes the potential designated management agencies and responsible persons along Big Sheep Creek model extent.

Table 5-20: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Big Sheep Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Forest Service	1610	49.7
Oregon Department of Agriculture	1137	35.1
Oregon Department of Forestry - Private Forestland	365.7	11.3
U.S. Government	79	2.4
Oregon Department of Transportation	21.8	0.7
Wallowa County	19	0.6

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Bureau of Land Management	4.9	0.2

5.8.4 Time frame of simulation

The model period is for a single day: August 01, 1999.

5.8.5 Model calibration

The model is calibrated primarily by comparing measured vegetation heights to those in the model as well as the model effective shade predictions to the field measured effective shade values (Table 5-21). To improve the calibration results global changes can be made to land cover class attributes which include canopy cover, height, and overhang. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort (DEQ, 2010).

The model calibration sites include all the effective shade data presented in Table 5-21. The model location in the table below describes the distance of each input from the most downstream model node.

Table 5-21: Calibration sites and parameters used in the Big Sheep Creek Heat Source model.

Model Location Name (Station ID)	Model Location (kilometers)	Calibration Parameter	Data Source
Big Sheep Creek upstream Lick Creek (Field Site #4)	55.35	Effective Shade	DEQ
Big Sheep Creek downstream Camp Creek (Field Site #3)	1.75	Effective Shade	DEQ

5.8.6 Model parameters

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see Section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations and topographic shade angles are derived from a DEM. The model will be setup to assume no cloud cover. This is done to isolate the solar radiation flux blocked by vegetation and topography only.

5.9 Imnaha River

The Imnaha River model is a temperature and solar model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.9.1 Model boundaries

The upstream model extent begins at the Imnaha River headwaters in the Eagle Cap Wilderness to the Imnaha River month at the confluence of the Imnaha River and Snake River. (Figure 5-10).

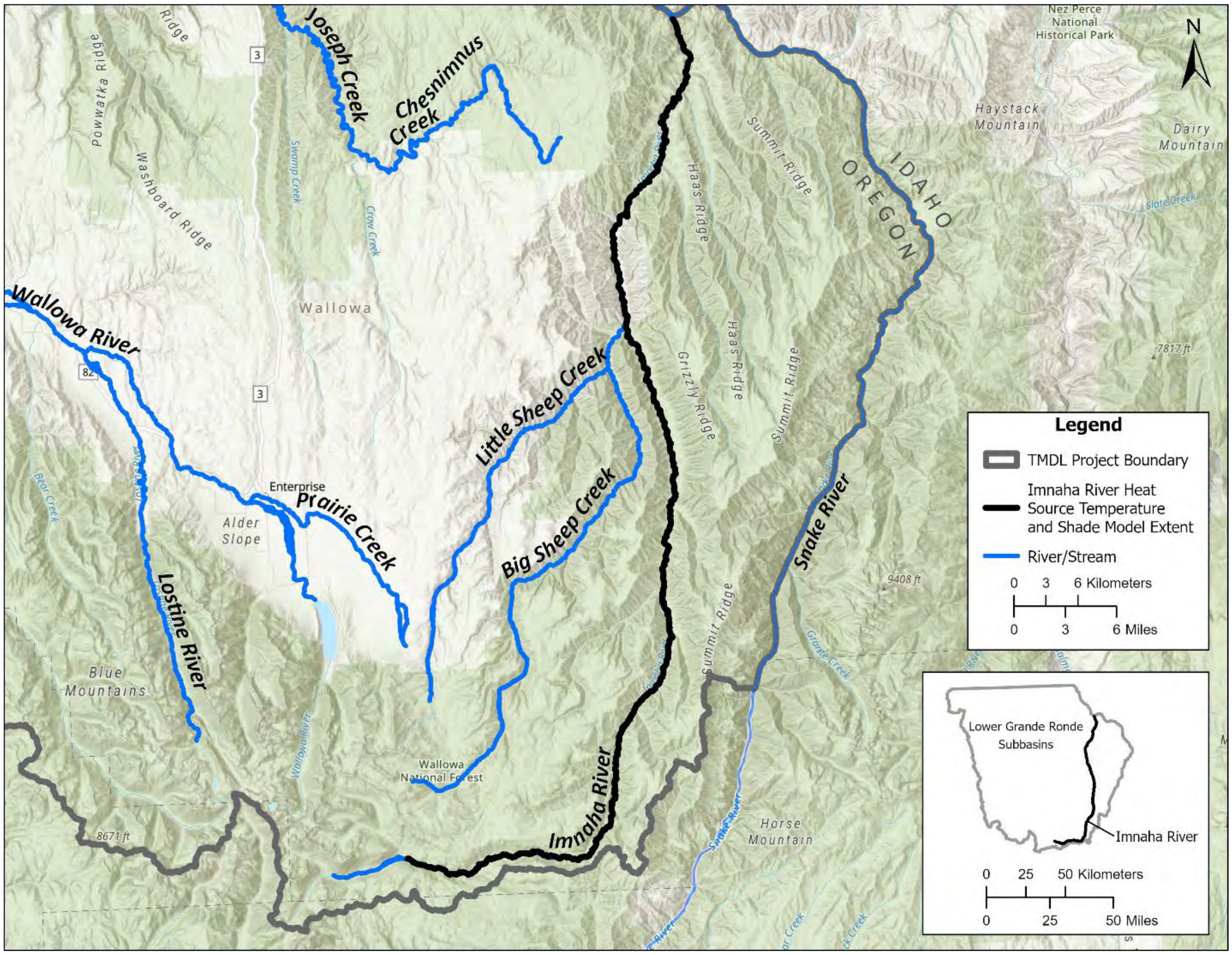

Figure 5-10: Imnaha River temperature and shade model extent.

5.9.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.9.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in the Imnaha River may include increases in solar radiation loading from the disturbance or removal of near-stream vegetation, reductions to the stream flow rate or volume, and background sources. Other potential sources include channel modification and widening and warming caused by climate change.

There are no permitted individual NPDES point sources discharging within the model extent.

The majority land uses along the Imnaha River are forestry and rangeland accounting for about 96 percent of the near-stream area. Table 5-22 summarizes all the land uses within 100 meters of the digitized Imnaha River centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-22: Summary of land uses along the model extent within 100 meters of the digitized Imnaha River centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	2587.6	45.2
Herbaceous	1525.2	26.7
Shrub/Scrub	1003.4	17.5
Woody Wetlands	397.9	7
Emergent Herbaceous Wetlands	142.3	2.5
Developed, Open Space	48.0	0.8
Developed, Low Intensity	6.9	0.1
Hay/Pasture	2.7	<0.05
Open Water	2.4	<0.05
Cultivated Crops	2.0	<0.05
Mixed Forest	0.4	<0.05
Developed, Medium Intensity	0.2	<0.05
Deciduous Forest	0.2	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-23).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 25 summarizes the potential designated management agencies and responsible persons along the Imnaha River model extent.

Table 5-23: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Imnaha River centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Forest Service	2397.2	40.8
Oregon Department of Agriculture	2140.5	36.5
Oregon Department of Forestry - Private Forestland	462.2	7.9
U.S. Government	419.8	7.2
Wallowa County	419.4	7.1
U.S. Department of Agriculture	25.3	0.4
Oregon Department of Transportation	2.9	<0.05
U.S. Bureau of Land Management	1.6	<0.05
Curry County	<0.05	<0.05

5.9.4 Time frame of simulation

The model period is August 14, 2000 to September 02, 2000.

5.9.5 Model calibration

The Imnaha River model will be calibrated through a sequential process beginning with the flow balance and hydrology followed by effective shade and water temperature. The expected model calibration sites and data sources for model inputs are summarized in Table 5-24 through Table 5-26, with locations of temperature and flow monitoring sites shown in Figure 5-11 and Figure 5-12, respectively. TIR data is not available on the Imnaha River, however there are 13 continuous temperature monitoring sites that are sufficient to support temperature calibration. Effective shade model calibration sites are summarized in Table 5-8.

5.9.6 Model parameters

The model inputs and parameters that are expected to be modified to improve model fit are described in Section 5.3.

There are nine tributary inflow locations included in the model domain:

- Dry Creek
- Gumboot Creek
- Crazyman Creek
- Grouse Creek
- Freezeout Creek
- Big Sheep Creek
- Horse Creek
- Lightning Creek
- Cow Creek

Five tributary inputs and the Imnaha River boundary condition temperatures will be based on measured data. Big Sheep Creek (24096-ORDEQ) may be used as a surrogate for nearby tributaries without temperature data (Cow Creek, Lightning Creek, and Horse Creek). Similarly, Gumboot Creek temperature data (23602-ORDEQ) may be used for Dry Creek. This is based on proximity and may be revised following closer review. Flows will be derived using a flow balance from the available field measurements.

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed. These data are derived from the RAWS Roberts Butte monitoring station. Air temperature data may be modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds may be adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see Section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations, stream gradient, and topographic shade angles are derived from a DEM.

Table 5-24: Stream temperature monitoring sites supporting Imnaha River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
23234-ORDEQ	Imnaha River at mouth	DEQ	45.5386	-117.5539	Calibration
12661-ORDEQ	Imnaha River downstream of Imnaha	USFS	45.4844	-117.5551	Calibration
23042-ORDEQ	Imnaha River 4.8 miles upstream of Imnaha, Oregon	Wallowa SWCD	45.5268	-117.5522	Calibration
24095-ORDEQ	Imnaha River at Thorn Creek Guard Station	DEQ	45.8166	-116.7639	Calibration
24098-ORDEQ	Imnaha River upstream of Freezeout Creek	DEQ	45.6312	-116.8458	Calibration
23032-ORDEQ	Imnaha River upstream of Grouse Creek	DEQ	45.5024	-116.8084	Calibration
23600-ORDEQ	Imnaha River upstream of Crazyman Creek	DEQ	45.7353	-116.7744	Calibration
23601-ORDEQ	Imnaha River near Ninepoint Creek	DEQ	45.4000	-116.7910	Calibration
24099-ORDEQ	Imnaha River downstream Mahogany Creek	DEQ	45.3263	-116.8052	Calibration
23603-ORDEQ	Imnaha River upstream of Gumboot Creek	DEQ	45.2306	-116.8468	Calibration
24389-ORDEQ	Imnaha River downstream of Dry Creek near Ollokot Campground	DEQ	45.2117	-116.8636	Calibration
12662-ORDEQ	Imnaha River at Coverdale Campground	DEQ	45.2054	-116.8655	Calibration
23236-ORDEQ	Imnaha River downstream of North & South Fork Imnaha Rivers at Indian Crossing Campground	DEQ	45.1804	-116.8723	Calibration

24390-ORDEQ	Imnaha River 4.8 miles upstream of Imnaha, Oregon	DEQ	45.1070	-117.1048	Boundary Condition
24096-ORDEQ	Big Sheep Creek downstream of Camp Creek	DEQ	45.5470	-116.8450	Tributary Input
23595-ORDEQ	Freezeout Creek at mouth	DEQ	45.4005	-116.7907	Tributary Input
23596-ORDEQ	Grouse Creek at mouth	DEQ	45.3281	-116.8065	Tributary Input
23599-ORDEQ	Crazyman Creek at mouth	DEQ	45.2305	-116.8461	Tributary Input
23602-ORDEQ	Gumboot Creek at mouth	DEQ	45.1840	-116.8733	Tributary Input

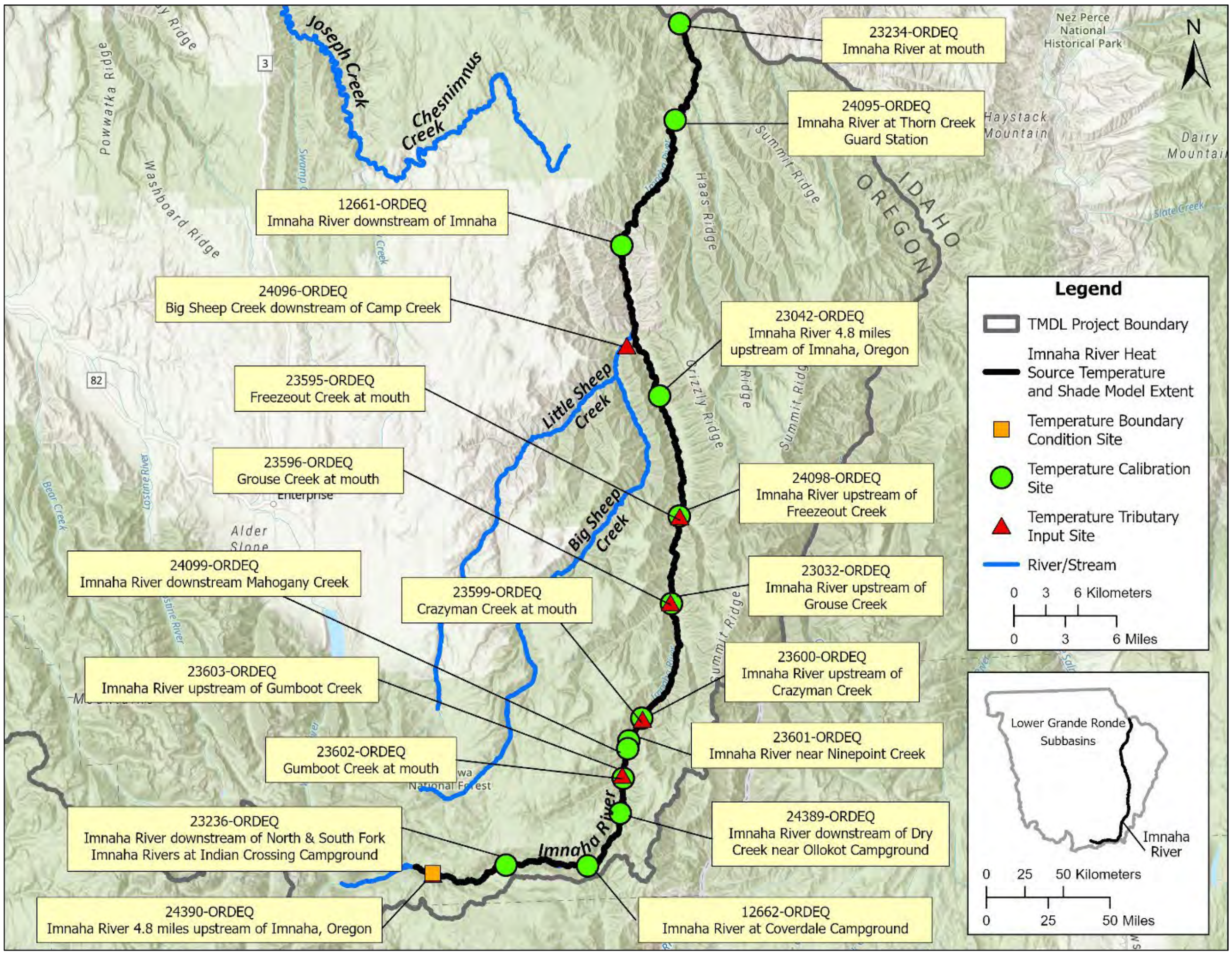

Figure 5-11: Temperature monitoring locations used for Imnaha River model setup and calibration.

Table 5-25: Continuous flow rate measurement sites supporting Imnaha River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
13292000	Imnaha River at Imnaha, OR	USGS	45.5624	-116.8338	Calibration

Table 5-26: Instantaneous flow rate measurement sites supporting Imnaha River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
12661-ORDEQ	Imnaha River downstream of Imnaha	DEQ	45.6312	-116.8458	Calibration
23042-ORDEQ	Imnaha River 4.8 miles upstream of Imnaha, Oregon	DEQ	45.5024	-116.8084	Calibration
24098-ORDEQ	Imnaha River upstream of Freezeout Creek	DEQ	45.4000	-116.7910	Calibration
24099-ORDEQ	Imnaha River downstream Mahogany Creek	DEQ	45.2054	-116.8655	Calibration
24096-ORDEQ	Big Sheep Creek downstream of Camp Creek	DEQ	45.5470	-116.8450	Tributary Input
23595-ORDEQ	Freezeout Creek at mouth	DEQ	45.4005	-116.7907	Tributary Input

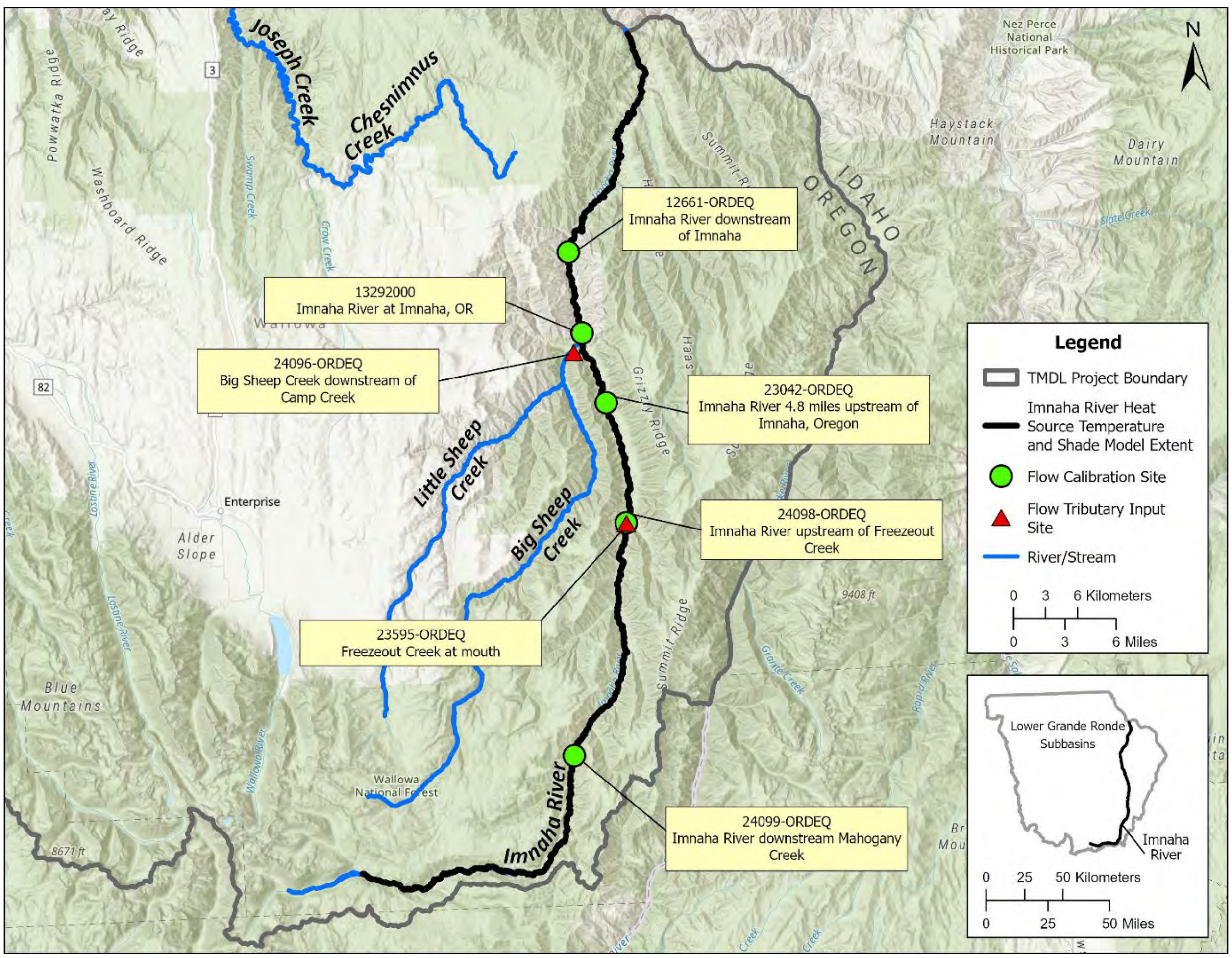

Figure 5-12: Flow monitoring locations used for Imnaha River model setup and calibration.

5.10 Joseph Creek and Chesnimnus Creek

The Joseph Creek and Chesnimnus Creek model is a shade model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.10.1 Model boundaries

The model extent includes Joseph Creek, Chesnimnus Creek, and a short reach of South Fork Chesnimnus Creek. The upstream end of the model begins about 600 meters upstream of the confluence of South Fork Chesnimnus Creek and Chesnimnus Creek. On Chesnimnus Creek, the model extent is from the South Fork to the Chesnimnus Creek mouth at the confluence with Joseph Creek. On Joseph Creek, the model extent is from Chesnimus Creek to the Oregon/Washington Stateline (Figure 5-13).

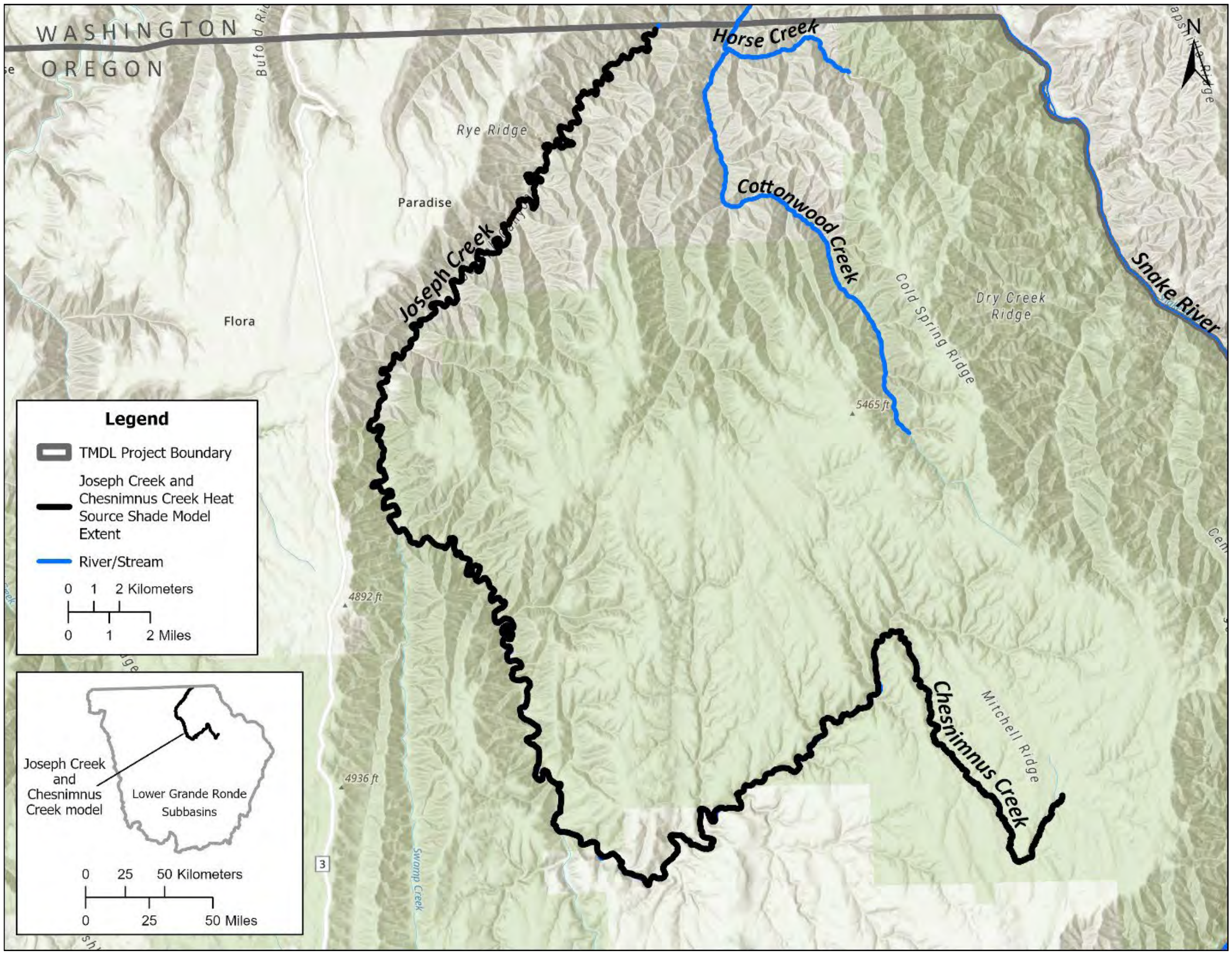

Figure 5-13: Joseph Creek and Chesnimnus Creek shade model extent.

5.10.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.10.3 Source characteristics

The primary purpose of the Joseph Creek and Chesnimnus Creek solar model is to characterize effective shade. Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. Other potential sources of thermal loading will not be evaluated by this model.

The majority land uses along Joseph Creek and Chesnimnus Creek are forestry and rangeland accounting for about 96 percent of the near-stream area. Table 5-27 summarizes all the land uses within 100 meters of the digitized Joseph Creek and Chesnimnus Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-27: Summary of land uses along the model extent within 100 meters of the digitized Joseph Creek and Chesnimnus Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	2731.9	50.9
Shrub/Scrub	1402.4	26.1
Herbaceous	981.6	18.3
Emergent Herbaceous Wetlands	190.8	3.6
Open Water	51.6	1
Woody Wetlands	11.1	0.2

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-28).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 29 summarizes the potential designated management agencies and responsible persons along Joseph Creek and Chesnimnus Creek model extent.

Table 5-28: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Joseph Creek and Chesnimnus Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Oregon Department of Agriculture	2099.4	38.7
U.S. Forest Service	2073.3	38.2
Oregon Department of Forestry - Private Forestland	607	11.2
U.S. Bureau of Land Management	463.3	8.5
State of Oregon	121	2.2
U.S. Department of Agriculture	42.2	0.8
Wallowa County	24.6	0.5

5.10.4 Time frame of simulation

The model period is for a single day: August 01, 1999.

5.10.5 Model calibration

The model is calibrated primarily by comparing measured vegetation heights to those in the model. To improve the calibration results global changes can be made to land cover class attributes which include canopy cover, height, and overhang. Field measured effective shade data are not available for Joseph and Chesnimnus Creeks so the model will rely upon the final land cover class attributes from all the other calibrated models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort. If time and resources allow, DEQ will collect field effective shade measurements on Joseph and Chesnimnus Creeks.

5.10.6 Model parameters

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see Section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations and topographic shade angles are derived from a DEM. The model will be setup to assume no cloud cover. This is done to isolate the solar radiation flux blocked by vegetation and topography only.

5.11 Little Sheep Creek

The Little Sheep Creek model is a shade model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.11.1 Model boundaries

The Little Sheep Creek model extent begins at the headwaters downstream to Little Sheep Creek mouth at the confluence of Little Sheep Creek and Big Sheep Creek (Figure 5-14).

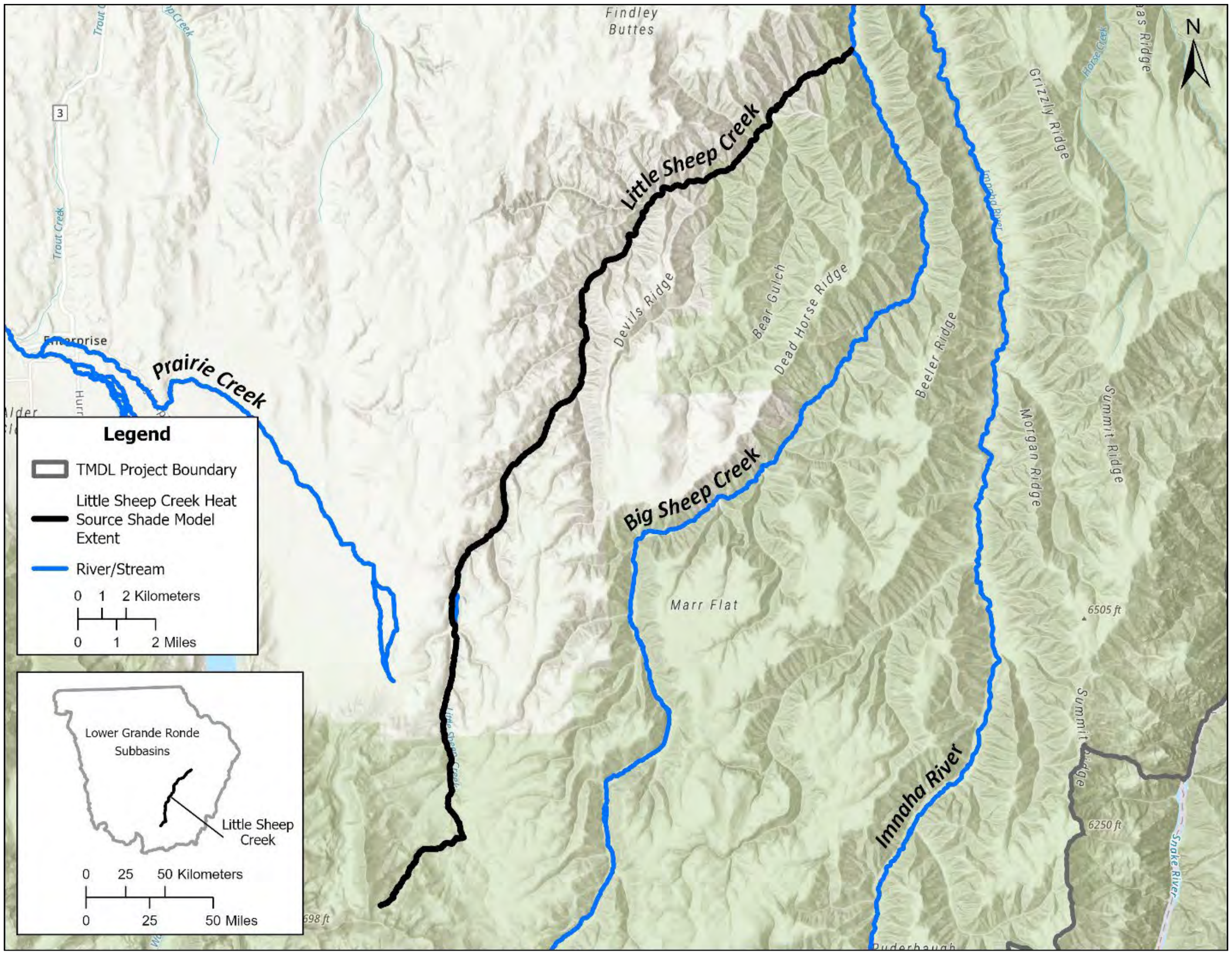

Figure 5-14: Little Sheep Creek shade model extent.

5.11.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.11.3 Source characteristics

The primary purpose of the Little Sheep Creek solar model is to characterize effective shade. Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. Other potential sources of thermal loading will not be evaluated by this model.

The majority land uses along Little Sheep Creek are forestry and rangeland accounting for about 83 percent of the near-stream area. Table 5-29 summarizes all the land uses within 100 meters of the digitized Little Sheep Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-29: Summary of land uses along the model extent within 100 meters of the digitized Little Sheep Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	1207.2	49.7
Herbaceous	594.5	24.5
Developed, Open Space	369.4	15.2
Shrub/Scrub	194.2	8
Developed, Low Intensity	26.0	1.1
Hay/Pasture	14.9	0.6
Woody Wetlands	9.3	0.4
Emergent Herbaceous Wetlands	6.0	0.2
Barren Land	5.6	0.2
Developed, Medium Intensity	0.4	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-30).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 31 summarizes the potential designated management agencies and responsible persons along Little Sheep Creek model extent.

Table 5-30: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Little Sheep Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Oregon Department of Forestry - Private Forestland	861.7	34.5
Oregon Department of Agriculture	822.1	32.9
U.S. Forest Service	563	22.6
Oregon Department of Transportation	138.4	5.5
Wallowa County	84.1	3.4
Oregon Department of Fish and Wildlife	22.6	0.9
U.S. Bureau of Land Management	3.6	0.1
U.S. Government	0.4	<0.05

5.11.4 Time frame of simulation

The model period is for a single day: August 01, 1999.

5.11.5 Model calibration

The model is calibrated primarily by comparing measured vegetation heights to those in the model as well as the model effective shade predictions to the field measured effective shade values (Table 5-31). To improve the calibration results global changes can be made to land cover class attributes which include canopy cover, height, and overhang. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort (DEQ, 2010).

The model calibration sites include all the effective shade data presented in Table 5-31. The model location in the table below describes the distance of each input from the most downstream model node.

Table 5-31: Calibration sites and parameters used in the Little Sheep Creek Heat Source model.

Model Location Name (Station ID)	Model Location (kilometers)	Calibration Parameter	Data Source
Little Sheep Creek below Cabin Creek (Field Site #17)	44.39	Effective Shade	DEQ
Little Sheep Creek at Bear Gulch (Field Site #16)	4.80	Effective Shade	DEQ

5.11.6 Model parameters

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see Section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations and topographic shade angles are derived from a DEM. The model will be setup to assume no cloud cover. This is done to isolate the solar radiation flux blocked by vegetation and topography only.

5.12 Lostine River

The Lostine River model is a temperature and solar model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.12.1 Model boundaries

The upstream end of the model begins on the Lostine River just downstream from the confluence of the Lostine River and East Lostine River and ends at the Lostine River mouth at the confluence of the Lostine and Wallowa Rivers (Figure 5-15).

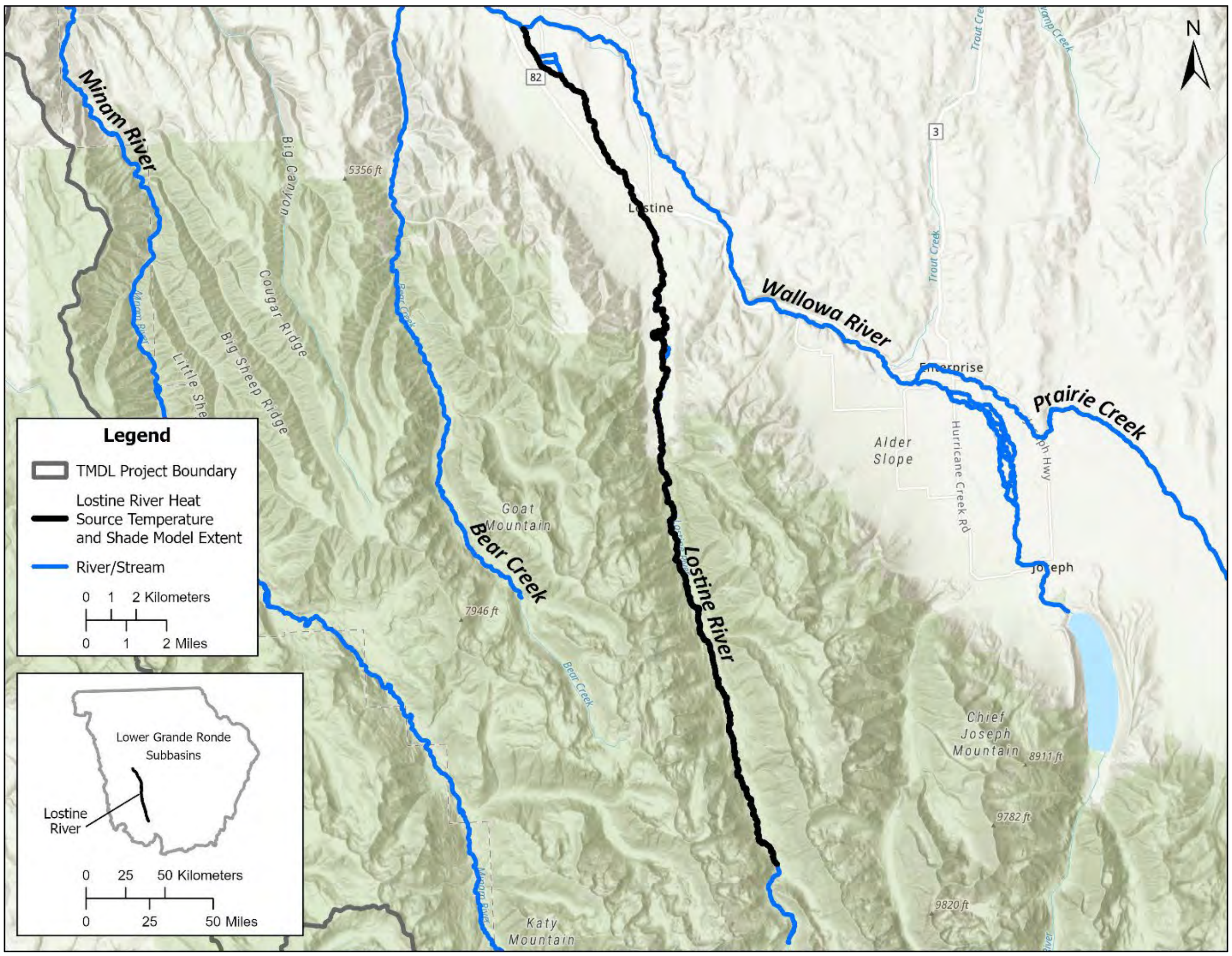

Figure 5-15: Lostine River temperature and shade model extent.

5.12.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center.

Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.12.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in the Lostine River may include increases in solar radiation loading from the disturbance or removal of near-stream vegetation, reductions to the stream flow rate or volume, and background sources. Other potential sources include channel modification and widening, and warming caused by climate change.

There are no permitted individual NPDES point sources discharging within the model extent.

The majority land use along the Lostine River is forestry accounting for about 72 percent of the near-stream area. Table 5-32 summarizes all the land uses within 100 meters of the digitized Lostine River centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-32: Summary of land uses along the model extent within 100 meters of the digitized Lostine River centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	1335.9	65.1
Hay/Pasture	325.1	15.9
Woody Wetlands	138.6	6.8
Herbaceous	82.3	4
Emergent Herbaceous Wetlands	54.0	2.6
Developed, Open Space	40.9	2
Shrub/Scrub	33.1	1.6
Cultivated Crops	29.1	1.4
Developed, Low Intensity	7.6	0.4
Mixed Forest	2.0	0.1
Developed, Medium Intensity	1.8	0.1
Developed, High Intensity	0.4	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-33).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 34 summarizes the potential designated management agencies and responsible persons along the Lostine River model extent.

Table 5-33: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Lostine River centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Forest Service	971.6	45.9
Oregon Department of Agriculture	819.8	38.7
Oregon Department of Forestry - Private Forestland	144.1	6.8
Wallowa County	142.7	6.7
City of Lostine	33.9	1.6
Oregon Department of Transportation	4.7	0.2
Oregon Department of Fish and Wildlife	0.4	<0.05

5.12.4 Time frame of simulation

The model period is August 14, 1999 to September 02, 1999.

5.12.5 Model calibration

The Lostine River model will be calibrated through a sequential process beginning with the flow balance and hydrology followed by water temperature. The temperature field measurements include both the TIR data (Section 5.1.3), which represents the longitudinal temperatures at single point in time, and one continuous temporal temperature measurement near the midpoint of the model. The TIR data will be used for longitudinal temperature calibration while the continuous temperature data are relied upon for calibration over the two week simulation period.

The expected model calibration sites and data sources for temperature and flow model inputs are summarized in Table 5-34 through Table 5-36, with locations of temperature and flow monitoring sites shown in Figure 5-16 and Figure 5-17, respectively. TIR data (Watershed Sciences, 2000) was collected on Augst 23, 1999 and is available for the entire model extent.

Field measured effective shade data are not available on the Lostine River so the model will rely upon the final land cover class attributes from the other calibrated models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort. If time and resources allow, DEQ will collect additional field effective shade measurements on the Lostine River.

5.12.6 Model parameters

The model inputs and parameters that are expected to be modified to improve model fit are described in Section 5.3.

There are 23 tributary, groundwater, canal, or spring inflow locations included in the model domain:

- Unnamed tributary at model km 40.24
- Unnamed tributary at model km 38.54
- Spring on RB at model km 38.14
- Unnamed tributary at model km 37.64
- Recharge at bar at model km 37.09
- Bowman Creek
- Unnamed tributary and spring at model km 29.44
- Wood Lake tributary
- Unnamed tributary on LB at model km 31.24
- Lake Creek
- Unnamed tributary on LB at model km 29.44
- Spring on RB
- Storm Creek
- Silver Creek
- Lostine Reservoir return flow
- Spring on LB at model km 12.39
- Spring on LB at model km 11.79
- Return flow from Poley-Allen ditch
- Recharge from side channel at model km 7.54
- Recharge at bar at model km 6.24
- Recharge from canal

All inflow temperatures are derived from TIR measurements at the tributary mouth. Flow inputs are derived using a flow balance from the available field measurements and TIR data.

The model boundary condition temperature data is measured and based on monitoring at 21444-ORDEQ, Lostine River downstream East Lostine River at Two Pan Campground. The temperature data at this site were assigned a DQL of C from 7/25/1999 - 9/29/1999. This time period overlaps with the model period. A DQL of C was assigned due to the last audit on 9/29/1999 being measured many hours after the last result available from the logger. It is unclear why there was a long delay. The audit result on 7/25/1999 has a DQL of A+ and is consistent with the probe measured temperatures. The temperatures after 7/25/1999 were reviewed carefully and it appears the probe was fully out of the water about 7 hours before the September audit and maybe intermittently throughout September. All of the August data is consistent with temperatures observed at other monitoring stations and does not appear to be out of the water. Based on this review, the data in August is acceptable for use even though it was assigned a DQL of C.

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed. These data are derived from the RAWS Roberts Butte monitoring station. Air temperature data may be modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds may be adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements collected as part of the stream habitat surveys (DEQ, 2010). Ground elevations, stream gradient, and topographic shade angles are derived from a DEM.

Table 5-34: Stream temperature monitoring sites supporting Lostine River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
Lostine_River_#144	Lostine River #144	Wallowa SWCD	45.4389	-117.4264	Calibration
21444-ORDEQ	Lostine River downstream East Lostine River at Two Pan Campground	DEQ	45.2507	-117.3775	Boundary Condition

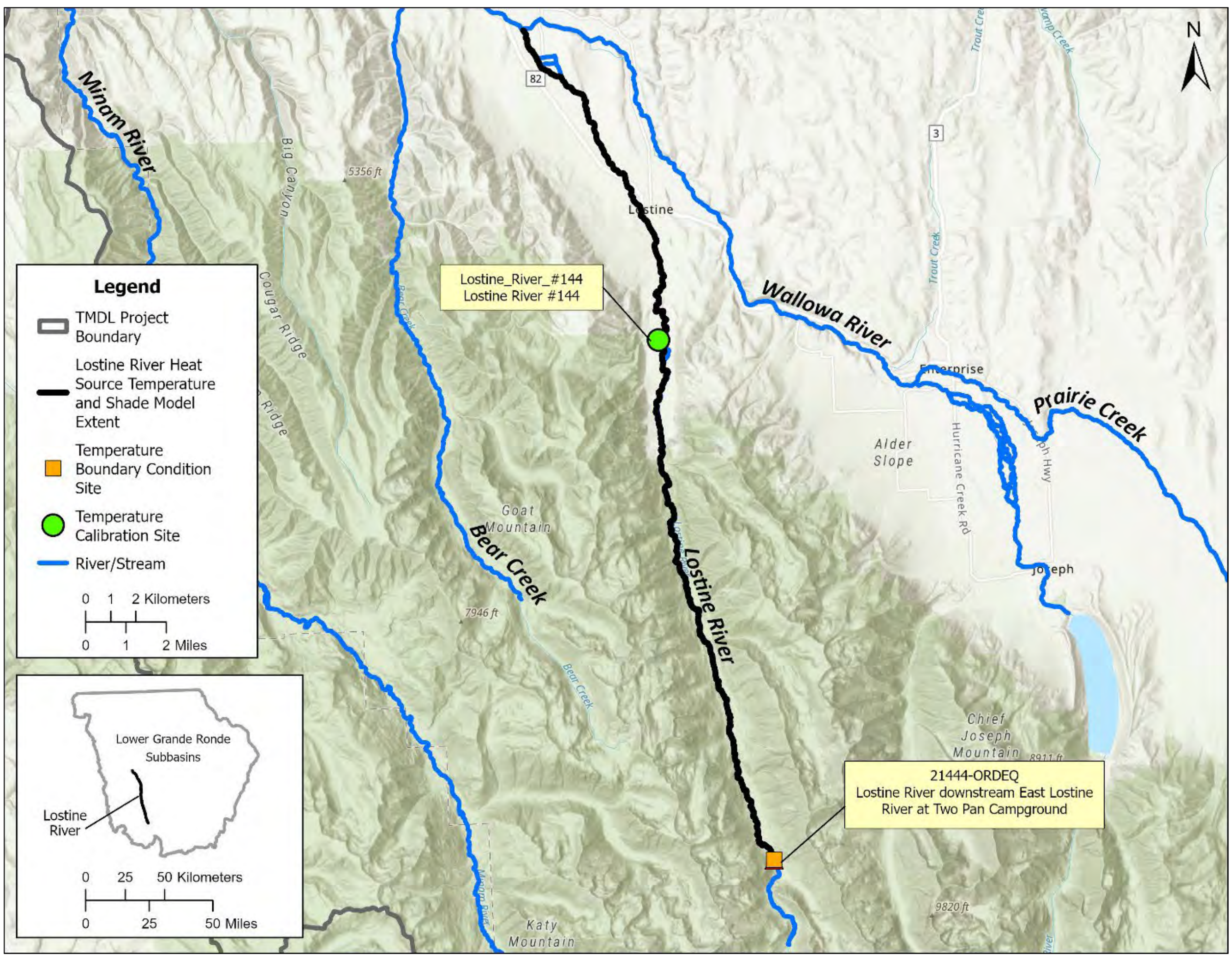

Figure 5-16: Temperature monitoring locations used for Lostine River model setup and calibration.

Table 5-35: Continuous flow rate measurement sites supporting Lostine River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
13330300	Lostine River at Baker Road near Lostine	OWRD	45.4391	-117.4266	Calibration
13330000	Lostine River near Lostine, OR	USGS	45.4388	-117.4274	Calibration
13330050	Lostine River at Caudle Lane at Lostine, OR	OWRD	45.4897	-117.4366	Calibration

Table 5-36: Instantaneous flow rate measurement sites supporting Lostine River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
Field Site #20	Lostine River at mouth	DEQ	45.5500	-117.4882	Calibration
Field Site #18	Lostine River at 1st Bridge on Lostine Road	DEQ	45.4083	-117.4277	Calibration
Field Site #19	Lostine River (Lake Creek Campground US Williamson)	DEQ	45.3463	-117.4160	Calibration
Field Site #21	Lostine River upstream of French Camp	DEQ	45.2683	-117.3870	Calibration

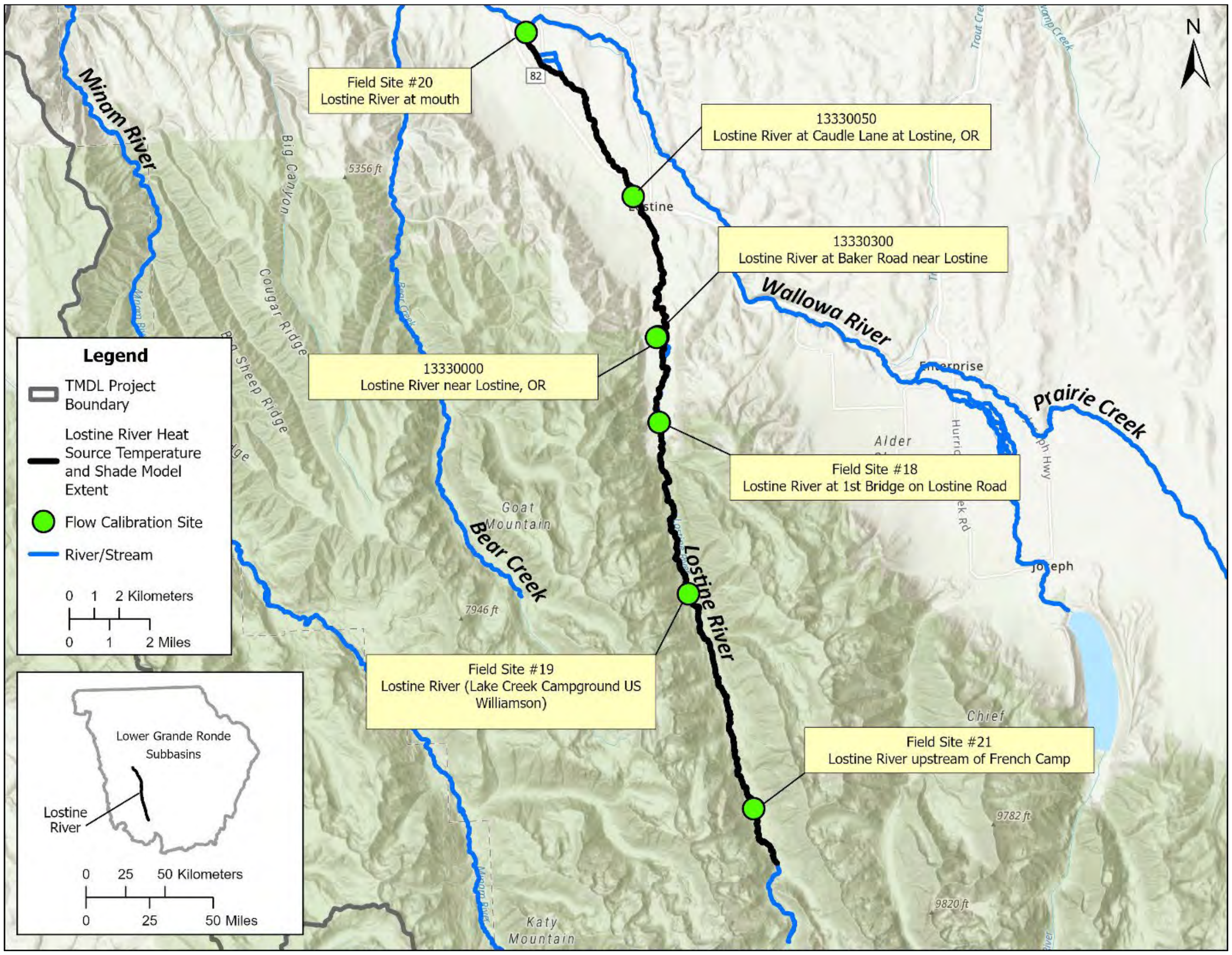

Figure 5-17: Flow monitoring locations used for Lostine River model setup and calibration.

5.13 Minam River

The Minam River model is a temperature and solar model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ. The model was not completed or used in the final 2010 TMDL. The primary tasks remaining include adjustment to the location of the upstream model boundary, review the model goodness of fit, and make adjustments as necessary to improve the calibration.

5.13.1 Model boundaries

The upstream model extent is expected to begin on the Minam River near Blue Lake. The downstream extent of the model ends at the Minam River mouth at the confluence of the Minam and Wallowa Rivers at Highway 82 (Figure 5-18).

The existing model nodes and stream centerline are setup to follow the Minam River channel flowing from Minam Lake, but the available temperature data used for the model boundary condition is located on the Minam River channel flowing from Blue Lake (23045-ORDEQ). The scope of work includes adjusting about 800 meters of model extent, so the model boundary condition is properly aligned with the temperature monitoring location. This will require updating the vegetation, channel dimensions, and ground elevations in that reach.

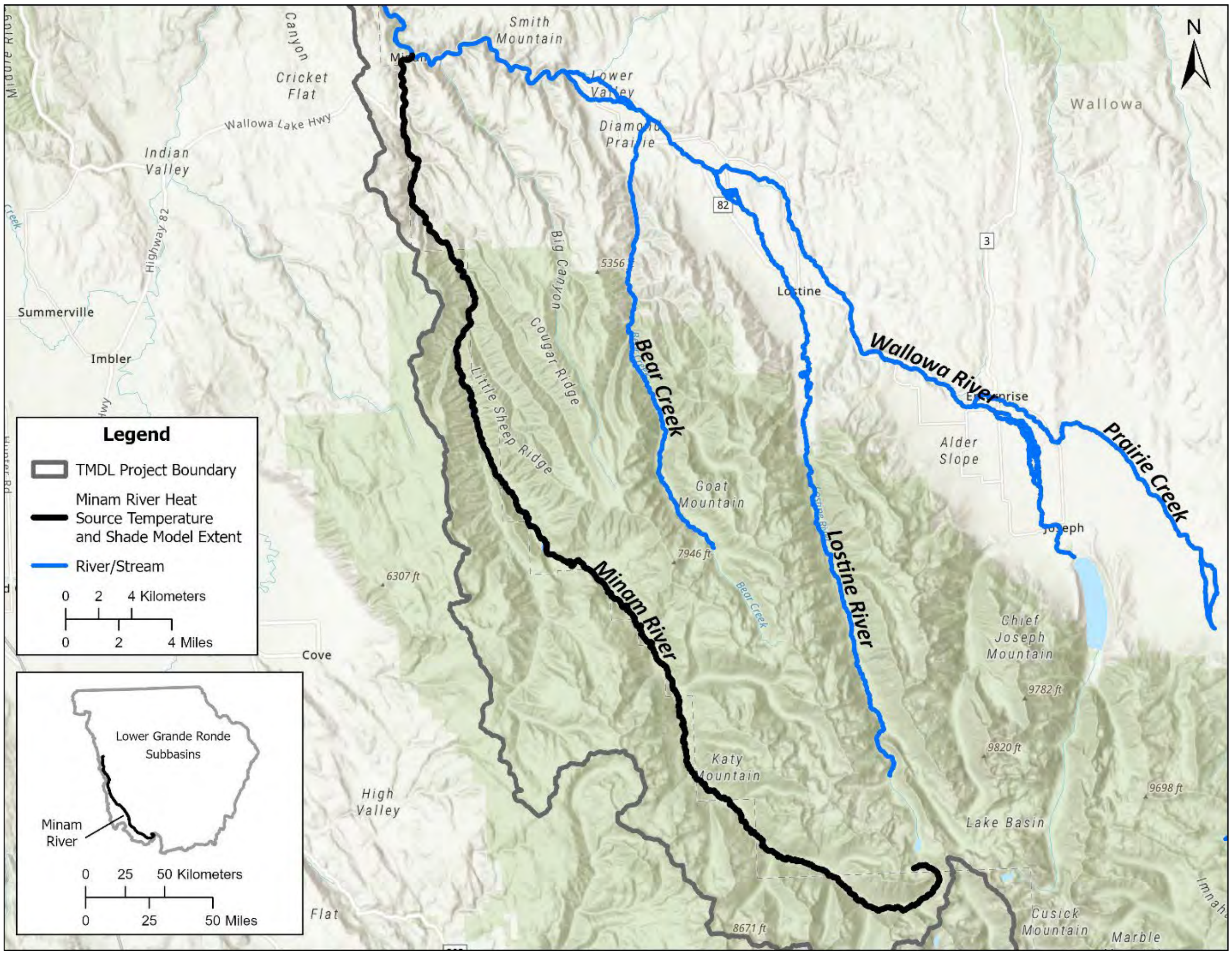

Figure 5-18: Minam River temperature and shade model extent.

5.13.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.13.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in the Minam River may include increases in solar radiation loading from the disturbance or removal of near-stream vegetation, reductions to the stream flow rate or volume, and background sources. Other potential sources include channel modification and widening, and warming caused by climate change.

There are no permitted individual NPDES point sources discharging within the model extent.

The majority land use along the Minam River is forestry accounting for about 96 percent of the near-stream area. Table 5-37 summarizes all the land uses within 100 meters of the digitized Minam River centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-37: Summary of land uses along the model extent within 100 meters of the digitized Minam River centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	3783.6	96
Shrub/Scrub	85.0	2.2
Herbaceous	29.1	0.7
Developed, Open Space	23.1	0.6
Developed, Low Intensity	11.8	0.3
Hay/Pasture	4.2	0.1
Mixed Forest	1.8	<0.05
Woody Wetlands	1.8	<0.05
Developed, Medium Intensity	0.2	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-38).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 38 summarizes the potential designated management agencies and responsible persons along the Minam River model extent.

Table 5-38: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Minam River centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Forest Service	3196.7	79.3
Oregon Department of Forestry - Private Forestland	563.3	14
Oregon Department of Fish and Wildlife	204.1	5.1
Oregon Parks and Recreation Department	34.5	0.9
Oregon Department of Transportation	24.2	0.6

DMA or Responsible Person	Acres	Percent of Total Acres
Wallowa County	6.6	0.2
State of Oregon	0.1	<0.05
Idaho Northern & Pacific Railroad	<0.05	<0.05
Pacific Power and Light	<0.05	<0.05
U.S. Bureau of Land Management	<0.05	<0.05
Union County	<0.05	<0.05
Wallowa Union Railroad	<0.05	<0.05

5.13.4 Time frame of simulation

The model period is August 14, 1999 to September 02, 1999.

5.13.5 Model calibration

The Minam River model will be calibrated through a sequential process beginning with the flow balance and hydrology followed by water temperature. The temperature field measurements include both the TIR data (Section 5.1.3), which represents the longitudinal temperatures at single point in time, and one continuous temporal temperature measurement near the mouth of the Lostine River. The TIR data will be used for longitudinal temperature calibration while the continuous temperature data are relied upon for calibration over the two week simulation period. There isn't continuous temperature data available in the middle of the model extent making it more difficult to evaluate model performance outside of the TIR data period. One approach to address this data gap is to shorten the model simulation period. This may be considered after reviewing the calibration results.

The expected model calibration sites and data sources for temperature and flow model inputs and summarized in Table 5-39 through Table 5-41, with locations of temperature and flow monitoring sites shown in Figure 5-19 and Figure 5-20, respectively. TIR data (Watershed Sciences, 2000) was collected on Augst 21, 1999 and is available for the entire model extent.

5.13.6 Model parameters

The model inputs and parameters that are expected to be modified to improve model fit are described in section 5.3.

There are 15 tributary inflow locations included in the model domain:

- Trail Creek
- Lowry Gulch
- Unnamed tributary at model km 69.43
- Elk Creek
- Last Chance Creek
- China Cap Creek
- Rock Creek
- Unnamed tributary at model km 53.39
- North Minam River
- Unnamed spring/tributary at model km 50.64
- Spring at model km 48.74

- Chaparral Creek
- Little Minam River
- Murphy Creek
- Trout Creek

All inflow temperatures are derived from TIR measurements at the tributary mouth. Flows inputs are derived using a flow balance from the available field measurements and TIR data.

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed. These data are derived from the RAWS Roberts Butte monitoring station. Air temperature data may be modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds may be adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements collected as part of the stream habitat surveys (DEQ, 2010). Ground elevations, stream gradient, and topographic shade angles are derived from a DEM.

Table 5-39: Stream temperature monitoring sites supporting Minam River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
11457-ORDEQ	Minam River at Minam	DEQ	45.6197	-117.7279	Calibration
23045-ORDEQ	Minam River downstream of Blue Lake (headwaters)	DEQ	45.1685	-117.3558	Boundary Condition

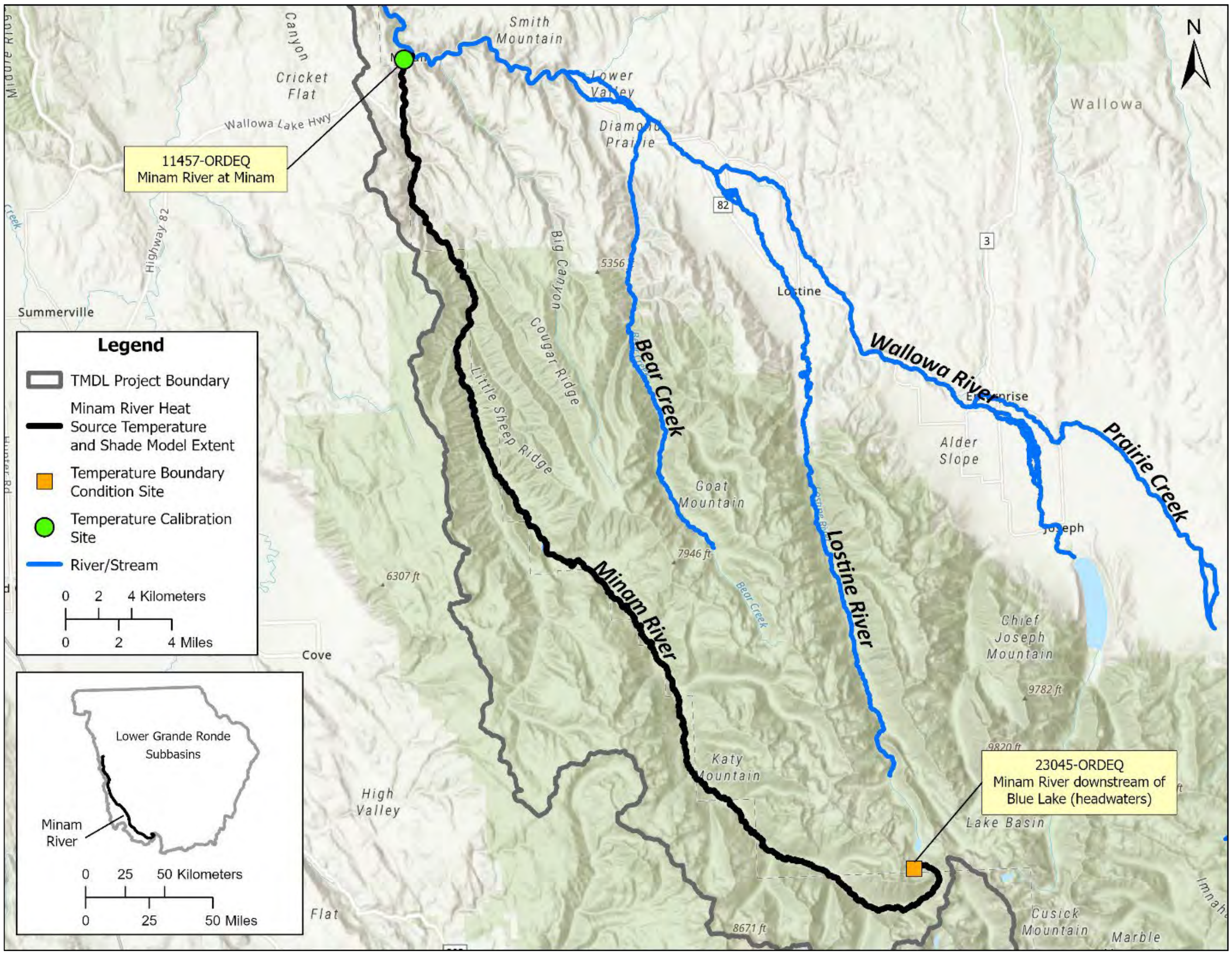

Figure 5-19: Temperature monitoring locations used for Minam River model setup and calibration.

Table 5-40: Continuous flow rate measurement sites supporting Minam River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
13331500	Minam River at Minam, OR	USGS	45.6199	-117.7266	Calibration

Table 5-41: Instantaneous flow rate measurement sites supporting Minam River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
Field Site #22	Minam River at Landing Strip	DEQ	45.3513	-117.6301	Calibration
Field Site #23	Minam River at mouth	DEQ	45.6203	-117.7224	Calibration

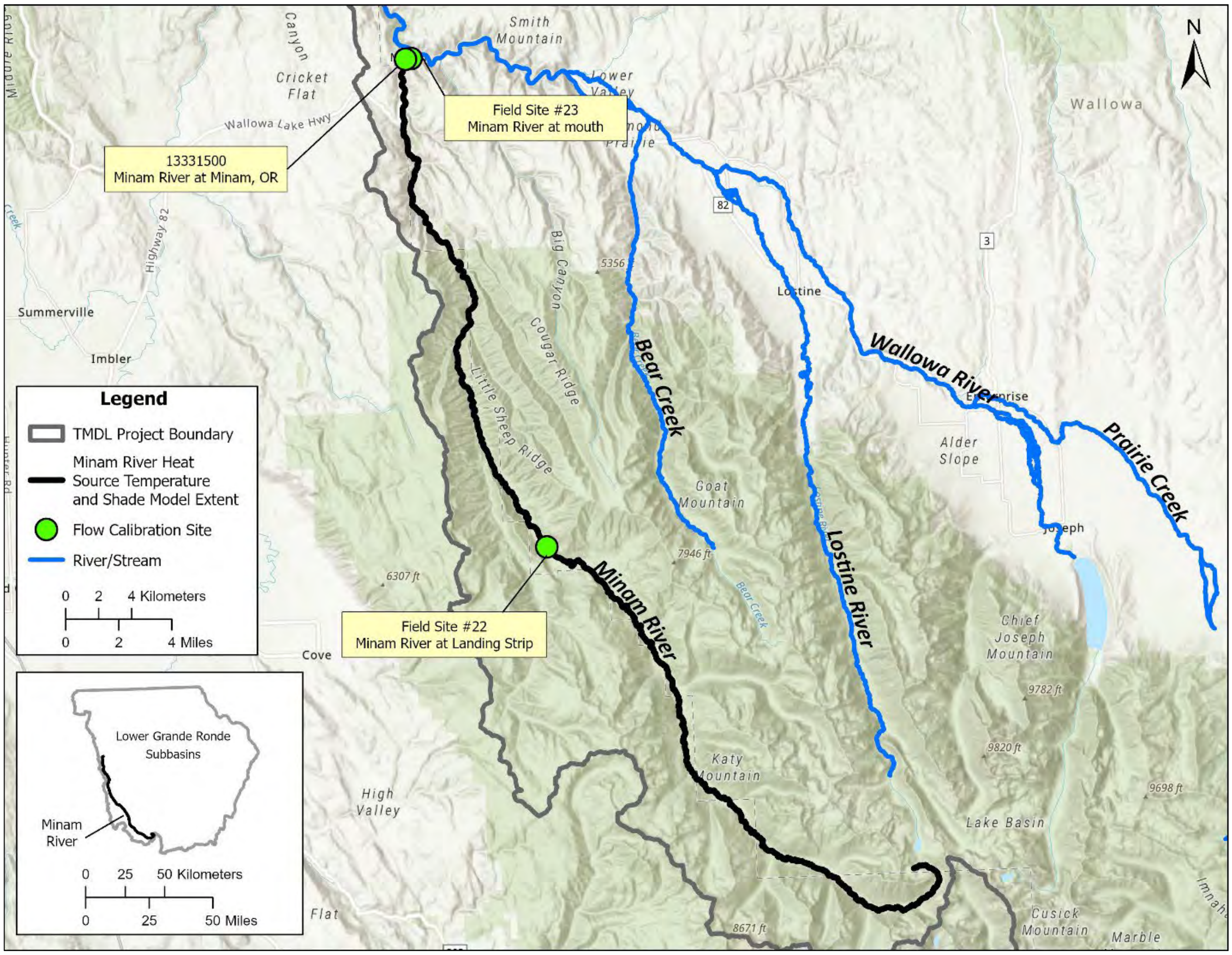

Figure 5-20: Flow monitoring locations used for Minam River model setup and calibration.

5.14 Prairie Creek

The Prairie Creek model is a shade model developed using Heat Source 7.0. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.14.1 Model boundaries

The model extent is Prairie Creek from headwaters to the mouth at the confluence of Prairie Creek and Wallowa River (Figure 5-21).

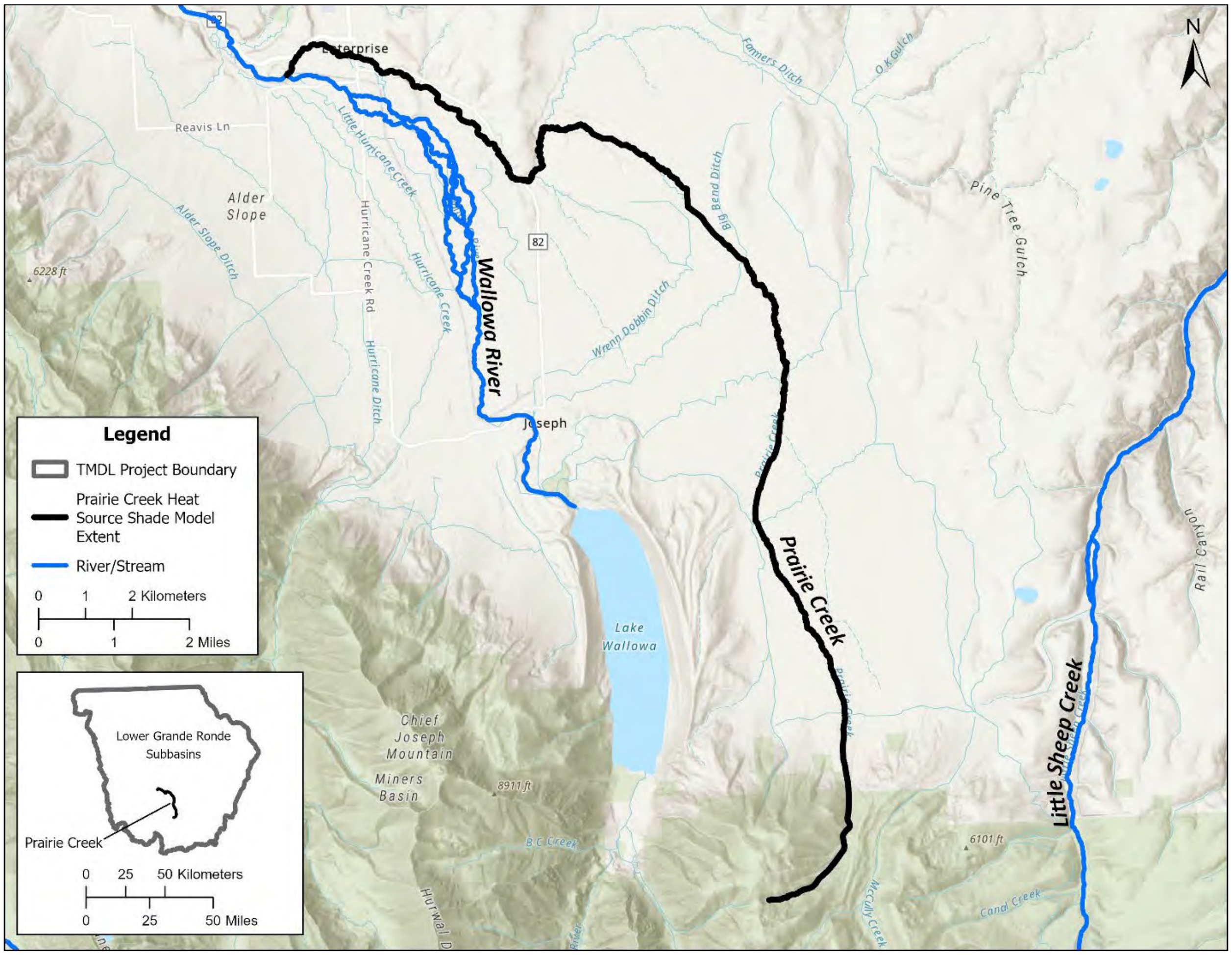

Figure 5-21: Prairie Creek shade model extent.

5.14.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.14.3 Source characteristics

The primary purpose of the Prairie Creek solar model is to characterize effective shade. Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. Other potential sources of thermal loading will not be evaluated by this model.

The majority land use along Prairie Creek is agriculture accounting for about 51 percent of the near-stream area. Table 5-42 summarizes all the land uses within 100 meters of the digitized Prairie Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-42: Summary of land uses along the model extent within 100 meters of the digitized Prairie Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Cultivated Crops	415.9	27.3
Hay/Pasture	362.7	23.8
Evergreen Forest	270.4	17.7
Herbaceous	268.9	17.6
Developed, Open Space	97.9	6.4
Developed, Low Intensity	68.1	4.5
Shrub/Scrub	24.2	1.6
Developed, Medium Intensity	9.3	0.6
Woody Wetlands	3.8	0.2
Emergent Herbaceous Wetlands	2.2	0.1
Developed, High Intensity	0.2	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-43).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 42 summarizes the potential designated management agencies and responsible persons along Prairie Creek model extent.

Table 5-43: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Prairie Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Oregon Department of Agriculture	1035.1	65.8
City of Enterprise	191.6	12.2
U.S. Forest Service	189.1	12
Oregon Department of Forestry - Private Forestland	88.8	5.6

DMA or Responsible Person	Acres	Percent of Total Acres
Wallowa County	30.9	2
Oregon Department of Transportation	28.2	1.8
Oregon Department of Fish and Wildlife	9	0.6

5.14.4 Time frame of simulation

The model period is for a single day: August 01, 1999.

5.14.5 Model calibration

The model is calibrated primarily by comparing measured vegetation heights to those in the model. To improve the calibration results global changes can be made to land cover class attributes which include canopy cover, height, and overhang. Field measured effective shade data are not available for Prairie Creek so the model will rely upon the final land cover class attributes from the other calibrated shade models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort. If time and resources allow, DEQ will collect field effective shade measurements on Prairie Creek for improved assessment of model performance.

5.14.6 Model parameters

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations and topographic shade angles are derived from a DEM. The model will be setup to assume no cloud cover. This is done to isolate the solar radiation flux blocked by vegetation and topography only.

5.15 Spring Creek

The Spring Creek model is a shade model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ and the USFS. The model was not used in the final 2010 TMDL. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.15.1 Model boundaries

The model extent is from Spring Creek headwaters to the mouth at the confluence with Spring Creek and Wallowa River (Figure 5-22).

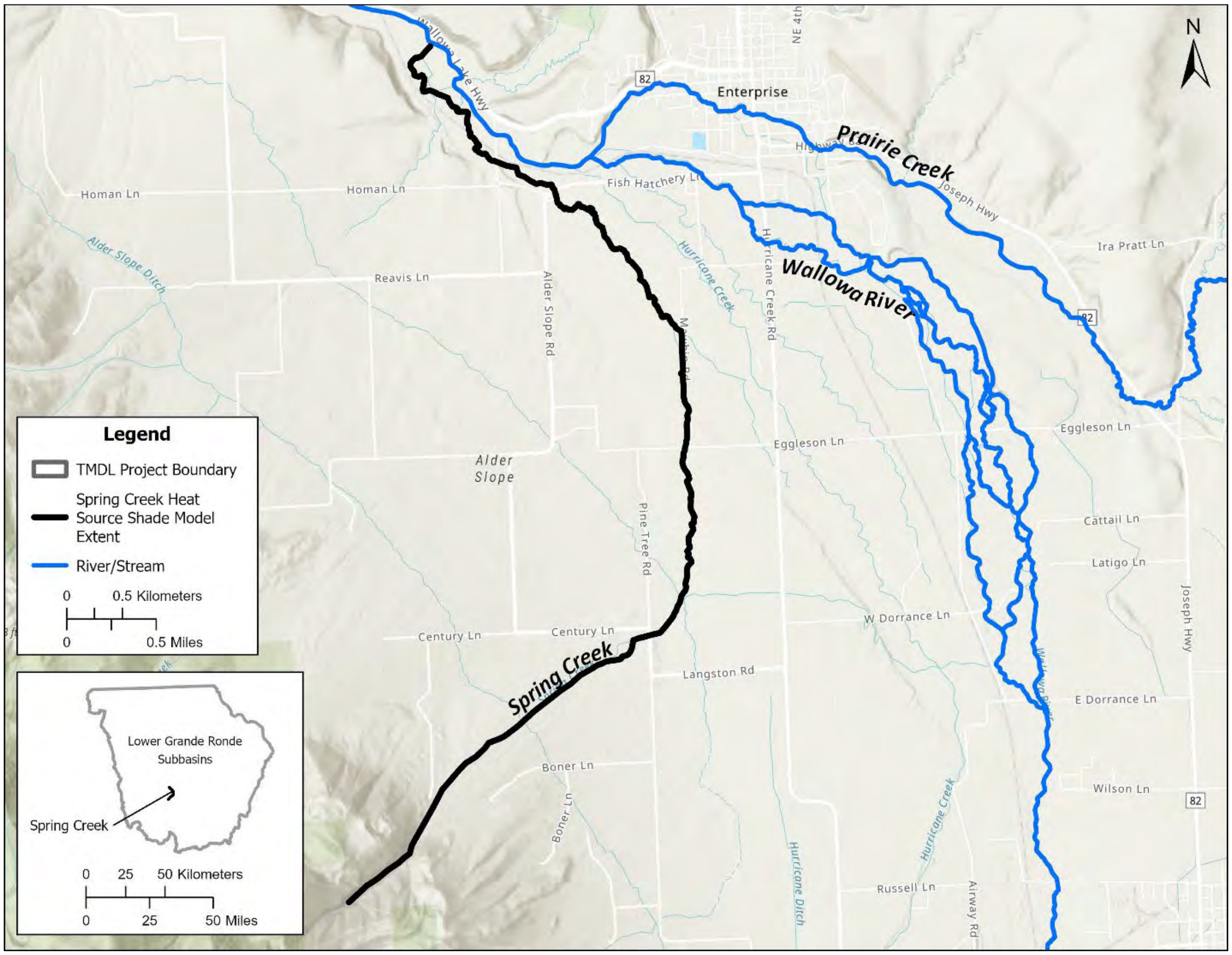

Figure 5-22: Spring Creek shade model extent.

5.15.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.15.3 Source characteristics

The primary purpose of the Spring Creek solar model is to characterize effective shade. Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. Other potential sources of thermal loading will not be evaluated by this model.

The majority land uses along Spring Creek are agriculture and forestry accounting for about 87 percent of the near-stream area. Table 5-44 summarizes all the land uses within 100 meters of the digitized Spring Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-44: Summary of land uses along the model extent within 100 meters of the digitized Spring Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Hay/Pasture	217.5	39.8
Evergreen Forest	150.6	27.5
Cultivated Crops	87.2	15.9
Herbaceous	31.1	5.7
Developed, Open Space	22.0	4
Emergent Herbaceous Wetlands	13.3	2.4
Woody Wetlands	10.5	1.9
Mixed Forest	7.8	1.4
Developed, Low Intensity	4.0	0.7
Shrub/Scrub	2.2	0.4
Developed, Medium Intensity	0.4	0.1
Developed, High Intensity	0.2	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-45).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 44 summarizes the potential designated management agencies and responsible persons along Spring Creek model extent.

Table 5-45: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Spring Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Oregon Department of Agriculture	387.5	69.5
Oregon Department of Forestry - Private Forestland	91.6	16.4
Wallowa County	64.2	11.5

DMA or Responsible Person	Acres	Percent of Total Acres
Wallowa Union Railroad	11.4	2
Oregon Department of Transportation	2.9	0.5

5.15.4 Time frame of simulation

The model period is for a single day: August 01, 1999.

5.15.5 Model calibration

The model is calibrated primarily by comparing measured vegetation heights to those in the model. To improve the calibration results global changes can be made to land cover class attributes which include canopy cover, height, and overhang. Field measured effective shade data are not available for Spring Creek so the model will rely upon the final land cover class attributes from the other calibrated shade models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort. If time and resources allow, DEQ will collect field effective shade measurements on Spring Creek for improved assessment of model performance.

5.15.6 Model parameters

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations and topographic shade angles are derived from a DEM. The model will be setup to assume no cloud cover. This is done to isolate the solar radiation flux blocked by vegetation and topography only.

5.16 Wenaha River

The Wenaha River model is a shade model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ for the 2010 TMDL but was not completed. The primary task remaining is to review the goodness of fit and make adjustments as necessary to improve the calibration.

5.16.1 Model boundaries

The upstream model extent begins at the confluence of the North Fork and South Fork Wenaha Rivers downstream to the Wenaha River mouth at the confluence of the Wenaha and Grande Ronde Rivers (Figure 5-23).

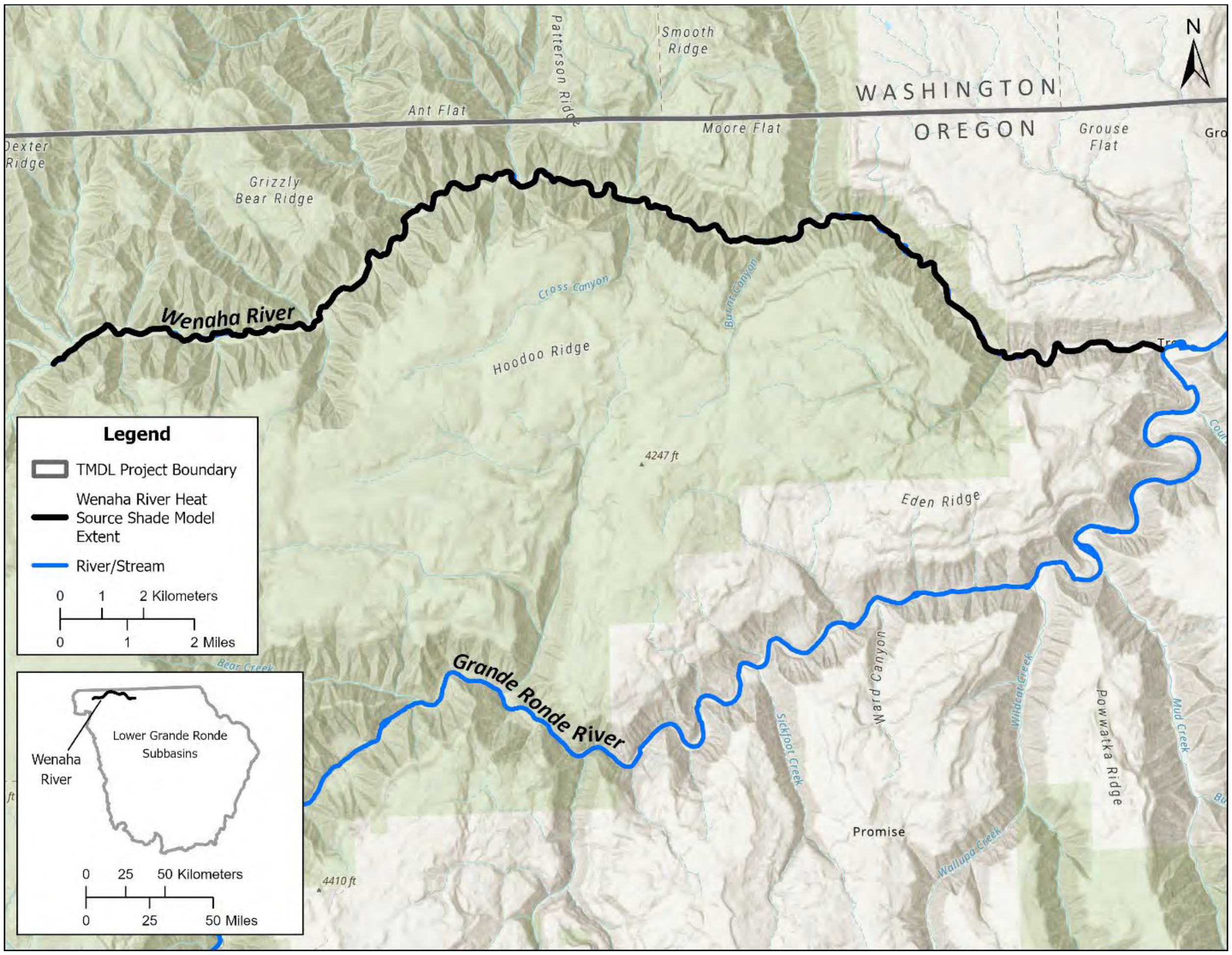

Figure 5-23: Wenaha River shade model extent.

5.16.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.16.3 Source characteristics

The primary purpose of the Wenaha River solar model is to characterize effective shade. Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. Other potential sources of thermal loading will not be evaluated by this model.

The majority land uses along the Wenaha River are rangeland and forestry accounting for about 100 percent of the near-stream area. Table 5-46 summarizes all the land uses within 100 meters of the digitized Wenaha River centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-46: Summary of land uses along the model extent within 100 meters of the digitized Wenaha River centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Herbaceous	1009.7	58.1
Evergreen Forest	648.3	37.3
Shrub/Scrub	67.2	3.9
Woody Wetlands	11.1	0.6
Hay/Pasture	1.6	0.1

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-47).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 46 summarizes the potential designated management agencies and responsible persons along the Wenaha River model extent.

Table 5-47: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Wenaha River centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Forest Service	1454.9	82.8
State of Oregon	84.3	4.8
U.S. Government	71.7	4.1
U.S. Bureau of Land Management	70.4	4
Oregon Department of Agriculture	65.5	3.7
Wallowa County	9.2	0.5
Oregon Department of Forestry - Private Forestland	2	0.1

5.16.4 Time frame of simulation

The model period is for a single day: August 01, 1999.

5.16.5 Model calibration

The model is calibrated primarily by comparing measured vegetation heights to those in the model. To improve the calibration results global changes can be made to land cover class attributes which include canopy cover, height, and overhang. Field measured effective shade data are not available for Wenaha River so the model will rely upon the final land cover class attributes from the other calibrated shade models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort. If time and resources allow, DEQ will collect field effective shade measurements on Wenaha River for improved assessment of model performance.

5.16.6 Model parameters

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations and topographic shade angles are derived from a DEM. The model will be setup to assume no cloud cover. This is done to isolate the solar radiation flux blocked by vegetation and topography only.

5.17 Wallowa River and Grande Ronde River

The Wallowa River and Grande Ronde model is a temperature and solar model developed using Heat Source 7.0. The model was originally developed between 2005 and 2009 by DEQ for the 2010 TMDL. The calibrated model is not expected to be modified; however multiple new scenarios will be developed (section 9) that will utilize many parameter and configuration aspects of the calibrated model.

5.17.1 Model boundaries

The model extent includes both the Wallowa River and the lower portion of the Grande Ronde River downstream of the Wallowa River to the Oregon/Washington Stateline. The upstream extent of the model begins at Wallowa Lake. (Figure 5-24).

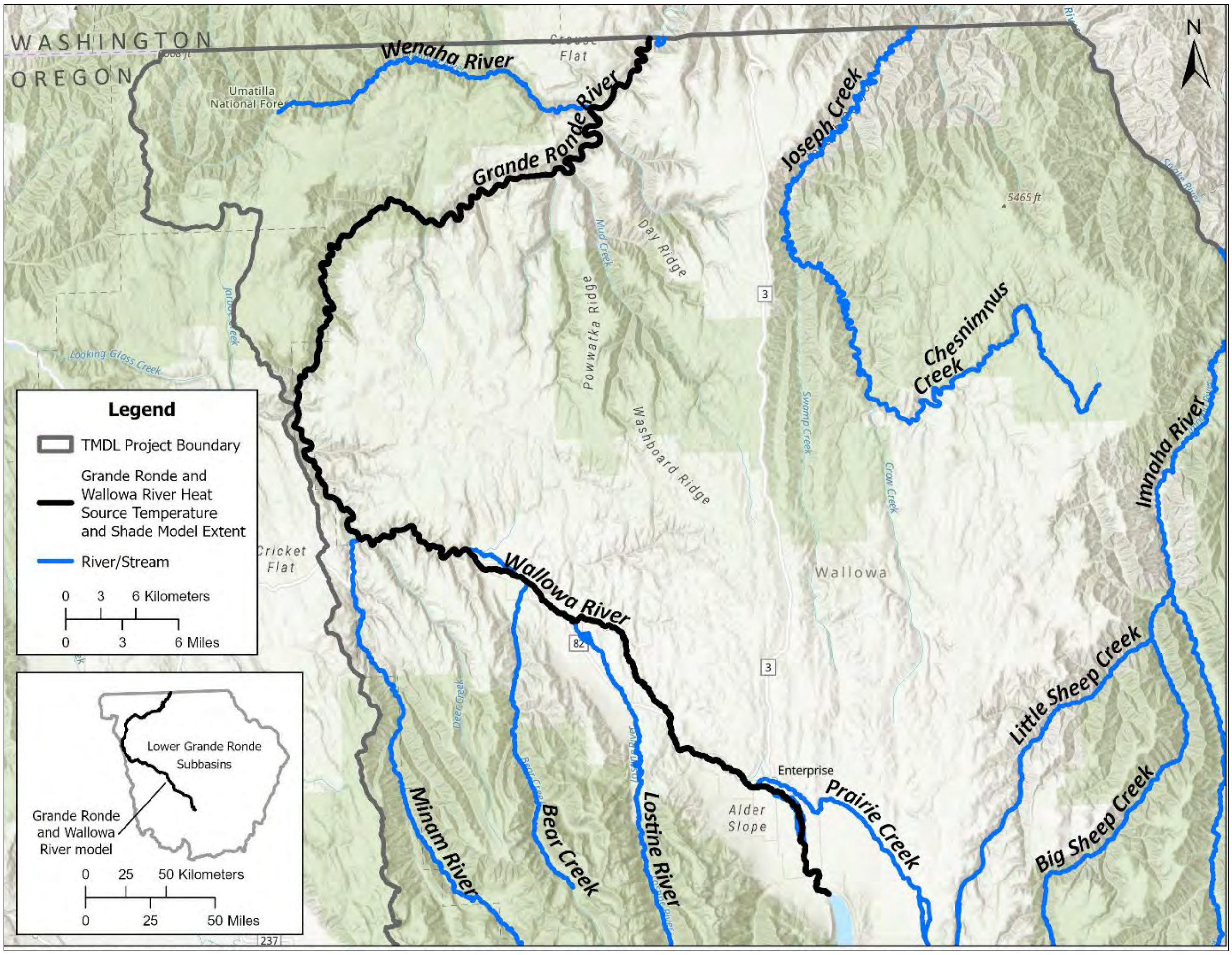

Figure 5-24: Wallowa River and Grande Ronde River temperature and shade model extent.

5.17.2 Spatial and temporal resolution

The longitudinal model node spacing (*dx*) is 50 meters. At each model node, vegetation input is parameterized along 7 transects radiating outward from the stream center in a star pattern. There is one sample at the stream center and four samples on each transect with each sample being 15 meters apart. The first transect sample begins 7.5 meters from the stream center. Longitudinal model outputs are generated every 100 meters. The internal model time step (*dt*) is 1 minute and outputs are generated every hour.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency.

5.17.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in the Grande Ronde and Wallowa River include increases in solar radiation loading from the disturbance or removal of near-stream vegetation, point source discharges, reductions to the stream flow rate or volume, and background sources (DEQ, 2010). Other potential sources include channel modification and widening and warming caused by climate change.

There are two permitted individual NPDES point sources discharging within the model extent. Detail about each point source is summarized in Table 5-48.

Table 5-48: Summary of individual NPDES permitted discharges in the Grande Ronde and Wallowa River.

Facility Name (Facility Number)	Latitude/Longitude	Permit Type and Description	Stream/River Mile
Enterprise STP (27514)	45.437/-117.289	NPDES-DOM-Da: Sewage - less than 1 MGD	Wallowa River RM 40.7
Wallowa STP (93617)	45.5722/-117.528	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Wallowa River RM 23

The majority land uses along the Grande Ronde and Wallowa River are forestry and rangeland accounting for about 81 percent of the near-stream area. Table 5-49 summarizes all the land uses within 100 meters of the digitized Grande Ronde and Wallowa River centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that the removal of riparian vegetation is a major source of stream temperature warming, and typically occurs in developed or cultivated land uses. In some instances following vegetation removal, the land may cease to be actively managed and may enter the early stages of forest regrowth. For instance, Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 5-49: Summary of land uses along the model extent within 100 meters of the digitized Grande Ronde and Wallowa River centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	3457.3	53.1
Herbaceous	980.8	15.1
Hay/Pasture	759.7	11.7
Shrub/Scrub	749.5	11.5
Developed, Open Space	218.4	3.4
Developed, Low Intensity	123.4	1.9
Cultivated Crops	105.0	1.6
Woody Wetlands	60.0	0.9
Emergent Herbaceous Wetlands	41.1	0.6
Developed, Medium Intensity	8.2	0.1
Mixed Forest	4.9	0.1
Open Water	3.3	0.1
Barren Land	0.7	<0.05
Developed, High Intensity	0.2	<0.05
Deciduous Forest	0.2	<0.05

Anthropogenic related stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 5-50).

A designated management agency is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. Table 21 summarizes the potential designated management agencies and responsible persons along the Grande Ronde and Wallowa River model extent.

Table 5-50: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Grande Ronde and Wallowa River centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Oregon Department of Agriculture	2375.2	31.1
U.S. Forest Service	1569.4	20.6
U.S. Bureau of Land Management	966.7	12.7
Oregon Department of Forestry - Private Forestland	812.7	10.6
Wallowa County	587.8	7.7
Oregon Department of Transportation	290.4	3.8
Oregon Parks and Recreation Department	275	3.6
Oregon Department of Fish and Wildlife	228.4	3
State of Oregon	199.8	2.6
Wallowa Union Railroad	171.4	2.2
City of Wallowa	70.5	0.9
City of Joseph	52.1	0.7
City of Enterprise	24.6	0.3
U.S. Government	3.9	0.1
Pacific Power and Light	3.3	<0.05
Idaho Northern & Pacific Railroad	1.6	<0.05
Curry County	0.4	<0.05

5.17.4 Time frame of simulation

The model period is August 14, 1999 to September 02, 1999. This period covers the critical summer period exceedances to the temperature criteria and the August 15 - June 15 spawning period use criteria on the Wallowa River.

5.17.5 Model calibration

The Wallowa River and Grande Ronde River model will be calibrated through a sequential process beginning with the flow balance and hydrology followed by water temperature. The temperature field measurements include both the TIR data (Section 5.1.3), which represents the longitudinal temperatures at single point in time, and three continuous temporal temperature measurement near the mouth of the Lostine River. The TIR data will be used for longitudinal temperature calibration while the continuous temperature data are relied upon for calibration over the two week simulation period.

The expected model calibration sites and data sources for model inputs are summarized in Table 5-51 through Table 5-53, with locations of temperature and flow monitoring sites shown in Figure 5-25 and Figure 5-26, respectively. TIR data (Watershed Sciences, 2000) is available for the entire model extent and was collected on Augst 23, 1999 on the Wallowa River and August 19, 1999 on the Grande Ronde River.

Field measured effective shade data are not available on the Wallowa River and Grande Ronde River so the model will rely upon the final land cover class attributes from the other calibrated models. It is expected that these parameters will be set globally for different vegetation classes within the bounds of available data based on the previously digitized near stream vegetation and landcover classification effort. If time and resources allow, DEQ will collect additional field effective shade measurements.

5.17.6 Model parameters

The model inputs and parameters that are expected to be modified to improve model fit are described in section 5.3.

There are 14 major tributary inflow locations and numerous small springs, or agriculture return flows included in the model domain. The Wallowa River boundary condition and three tributary inputs (Wenaha River, and the Grande Ronde River upstream of Wallowa River) will be based on measured data. There is also measured data for Bear Creek, Lostine River, and Minam River however the flow and temperature inputs will reflect the model outputs for those rivers. All other tributary temperatures are derived from TIR measurements at the tributary mouth. Flow inputs for unmonitored tributaries are derived using a flow mass balance from the available measurements and TIR data.

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed. These data are derived from the RAWS Roberts Butte monitoring station and the Firgone weather station near Joseph. Air temperature data may be modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds may be adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Stream position (latitude and longitude), channel width, vegetation height and cover classes for the calibrated model are derived from heads-up digitization of near-stream land cover at a 1:5000 scale using black and white digital orthophoto quads (DOQs) from 1994-1996. Note updated vegetation will be incorporated as a new model scenario (see section 9.1). Values for the vegetation height and canopy density classes are derived from field measurements (DEQ, 2010). Ground elevations, stream gradient, and topographic shade angles are derived from a DEM. Channel morphology inputs are developed from data collected during ODFW's stream habitat surveys summarized in section 5.1.7.

Table 5-51: Stream temperature monitoring sites supporting the Wallowa River and Grande Ronde River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use

11561-ORDEQ	Wallowa River at Baker Road (upstream of Lostine River)	DEQ	45.5549	-117.4794	Calibration
23028-ORDEQ	Grande Ronde River upstream of Wenaha River near Troy	DEQ	45.9421	-117.4497	Calibration
23029-ORDEQ	Grande Ronde River at OR/WA State Line	DEQ	46.0003	-117.3796	Calibration
10722-ORDEQ	Wallowa River downstream of dam (Wallowa Street Park)	DEQ	45.3354	-117.2221	Boundary Condition
23027-ORDEQ	Grande Ronde River upstream of Wallowa River at Palmer Junction	DEQ	45.7169	-117.8378	Tributary Input
21521-ORDEQ	Wenaha River at mouth at Troy	DEQ	45.9453	-117.4513	Tributary Input

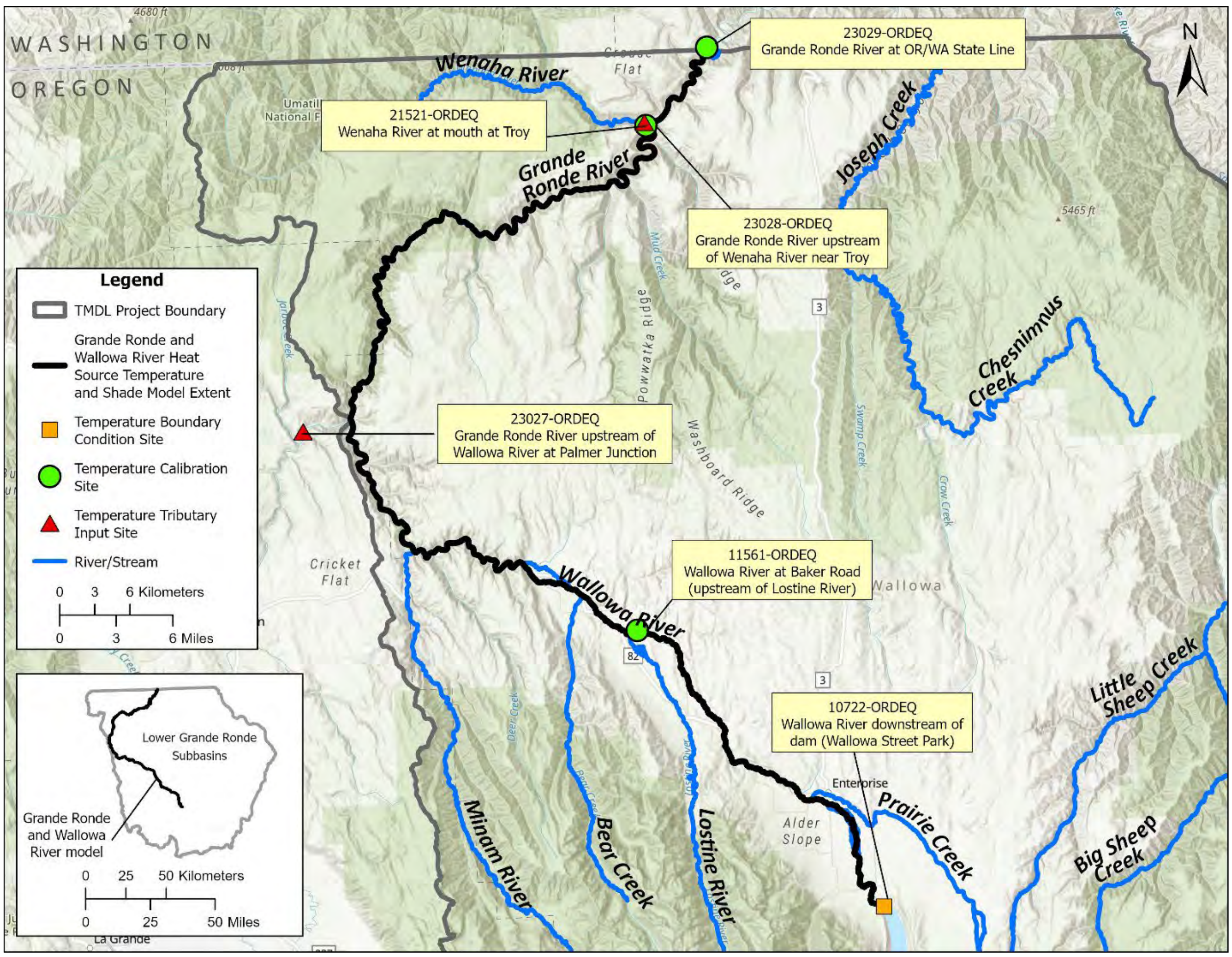

Figure 5-25: Temperature monitoring locations used for Wallowa River and Grande Ronde River model setup and calibration.

Table 5-52: Continuous flow rate measurement sites supporting Wallowa River and Grande Ronde River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use

13333000	Grande Ronde River at Troy, OR	OWRD	45.9457	-117.4511	Calibration
13329770	Wallowa River above Cross Country Canal near Enterprise, OR	OWRD	45.4882	-117.4038	Calibration
13331450	Wallowa River below Water Canyon near Wallowa	OWRD	45.6089	-117.6161	Calibration

Table 5-53: Instantaneous flow rate measurement sites supporting Wallowa River and Grande Ronde River model development.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Model Use
Field Site #25	Wallowa River upstream Minam River	DEQ	45.6220	-117.7131	Calibration
Field Site #24	Wallowa River at Evens Rd	DEQ	45.4957	-117.4119	Calibration
Field Site #20	Lostine River at mouth	DEQ	45.5500	-117.4882	Tributary Input
Field Site #1	Bear Creek at the mouth	DEQ	45.5782	-117.5456	Tributary Input
Field Site #23	Minam River at mouth	DEQ	45.6203	-117.7224	Tributary Input

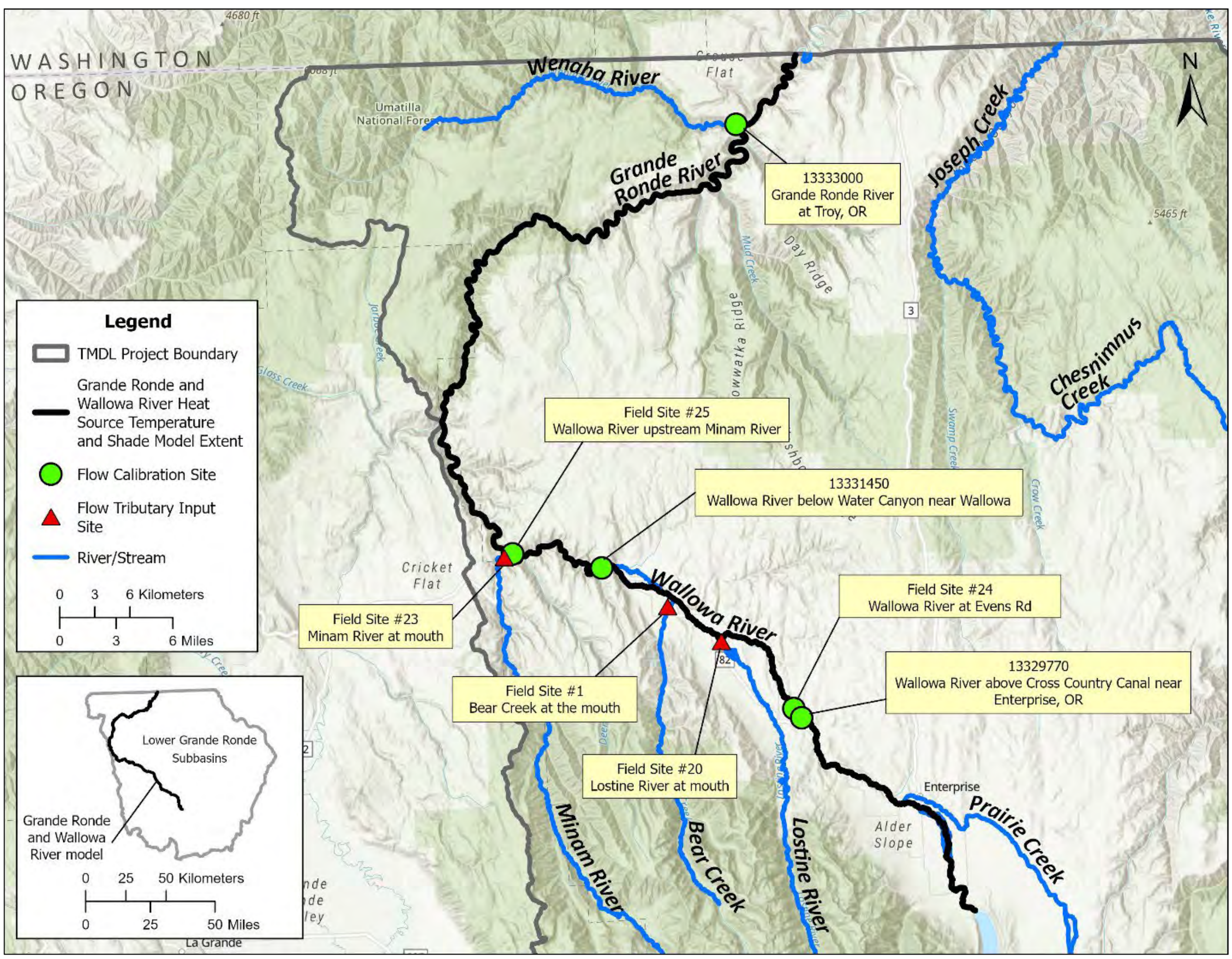

Figure 5-26: Flow monitoring locations used for Wallowa River and Grande Ronde River model setup and calibration.

6 Model evaluation and acceptance

6.1 Model uncertainty and sensitivity

Model uncertainty can arise from a number of sources including error associated with measuring field parameters used for model input or calibration, lack of knowledge on the appropriate value to use for model parameters or constants, or an imperfect mathematical formulation in the model of real world physical processes. A model's sensitivity is the degree to which predictions are affected by changes in a single or multiple input parameters.

In many cases, the major source of uncertainty is due to uncertainty in spatial representation of the river channel and adjacent landcover (e.g., bathymetry, vegetation height and density) from lack of data or simplification, configuration of the boundary conditions (e.g., uncertainty in estimation of ungaged tributary flows or temperatures), and uncertainty from limited amount or spatial distribution of observed data used for calibration. These sources of uncertainty are largely unavoidable, but do not invalidate the use of the model for decision purposes.

During the calibration process, it is good practice to evaluate and minimize uncertainty associated with the model parameters to the greatest extent practical (Beck, 1987; EPA, 2009). During the model calibration process, the responsiveness of the model predictions to various assumptions and rate constants should be evaluated. The model setup should include parameters based on literature recommendations and best professional judgment.

Reducing uncertainty in measured field parameters used for model input and calibration is accomplished in the following ways:

- Data used for the TMDL must have been collected based on a project plan with quality assurance and quality control protocols for collecting and analyzing samples.
- The sampling and laboratory analysis must follow widely accepted scientific methods and protocols. These may include DEQ's Mode of Operations Manual (DEQ, 2024), USEPA's methods (EPA, 1983), USGS's published techniques of water-resources investigations, the USGS National Field Manual, or Standard Methods for the Examination of Water and Wastewater. All acceptable methods include applicable precision and accuracy checks.
- When possible, accuracy and precision should be evaluated using DEQ's data validation criteria as outlined in DEQ Data Quality Matrix for Field Parameters (DEQ, 2013). The TMDL program uses waterbody results that demonstrate a data quality level of A, B, or E with careful review (DEQ, 2021). For continuous temperature data a data quality of A or B corresponds to an absolute accuracy 1.0 ºC and absolute precision 2.0 ºC. Data of unknown quality lacking audit and pre and post accuracy checks may also be used following a careful review where it is determined the results appear reasonable and free of issues based on professional judgment.

Uncertainties in the mathematical formulation are addressed by using open source models that allow free and transparent inspection of model code, and models that have had their methodologies peer reviewed and evaluated.

It is not anticipated that additional uncertainty or sensitivity analyses will be performed beyond the sensitivity analysis involved in the calibration process.

6.2 Model acceptance

This section identifies the model acceptance criteria. Model acceptance relies on satisfying seven (7) conditions:

1) Incorporation of all available field observations of the system (e.g., geometry, flow, boundary inputs/withdrawals, and meteorology) for the time period simulated.
2) Model parameters and unmeasured boundary conditions that are within literature-supported and physically defensible ranges.
3) Model predicted results have been compared with the associated observed measurements using graphical presentations. Visual comparisons are useful in evaluating model performance over the appropriate temporal or spatial scales.
4) Goodness of fit statistics have been calculated comparing the model predicted results to the associated observed measurements. The calibration goodness of fit statistics are shown in Equation 4 through Equation 8.
5) Goodness of fit statistics have been used to inform the appropriate use of the model. Where a model achieves an excellent or good fit it can generally assume a strong role in decision making about appropriate management options. Conversely, where a model achieves only a fair or poor fit it should assume a much less prominent role in decision making about appropriate management options. If a desired level of quality is not achieved on some or all measures, the model might still be useful; however, a detailed description of its potential range of applicability will be provided.
6) Written documentation of all important elements in the model, including model setup, model parameterization, key assumptions, and known areas of uncertainty.
7) Peer review as described in section 8.

Equation 5 through Equation 8 are the goodness of fit statistics to be calculated for each calibrated temperature model. Equation 4 through Equation 7 are the goodness of fit statistics to be calculated for each calibrated shade model.

Coefficient of Determination – R squared (R^2): A coefficient of determination, or R^2, of one indicates a perfect fit. R^2 is a measure of how well predicted values fit the observed data. It compares the variations in the residuals to the variation of the observed data.

$$R^2 = 1 - \frac{\sum(X_{obs} - X_{mod})^2}{\sum\left(X_{obs} - \overline{X_{obs}}\right)^2} \qquad \text{Equation 4}$$

Mean Error (ME): A mean error of zero indicates a perfect fit. A positive value indicates on average the model predicted values are less than the observed data. A negative value indicates on average the model predicted values are greater than the observed data. The mean error statistic may give a false ideal value of zero (or near zero) if the average of the positive deviations between predictions and observations is about equal to the average of the negative deviations in a data set. Because of this, the mean absolute error (MAE) statistic should be used in conjunction with mean error to evaluate model performance.

$$ME = \frac{1}{n}\sum(X_{mod} - X_{obs}) \qquad \text{Equation 5}$$

Mean Absolute Error (MAE): A mean absolute error of zero indicates a perfect fit. The magnitude of the mean absolute error indicates the average deviation between model predicted values and observed data. The mean absolute error cannot give a false zero.

$$MAE = \frac{1}{n}\sum|X_{mod} - X_{obs}| \qquad \text{Equation 6}$$

Root Mean Square Error (RMSE): A root mean square error of zero indicates a perfect fit. Root mean square error is a measure of the magnitude of the difference between model predicted values and observed data.

$$RMSE = \sqrt{\frac{1}{n}\sum(X_{mod} - X_{obs})^2} \qquad \text{Equation 7}$$

Nash-Sutcliffe efficiency coefficient (NS): Nash-Sutcliffe efficiencies can range from -∞ to 1. An efficiency of 1 corresponds to a perfect match of modeled predicted values to the observed data. An efficiency of 0 indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero occurs when the observed mean is a better predictor than the model.

$$NS = 1 - \frac{\sum(X_{obs} - X_{mod})^2}{\sum\left(X_{obs} - \overline{X_{obs}}\right)^2} \qquad \text{Equation 8}$$

where,
X_{mod} = The model predicted results;
X_{obs} = The observed or measured results;
$\overline{X}_{obs}$ = The mean of the observed or measured temperature;
n = The sample size.

7 Documentation in model reports

Model documentation will consist of a series of TMDL technical appendices describing the model setup, model calibration results, model scenario setup, and model scenario results.

The model setup and calibration documentation will include details on the calibrated model domain and layout; spatial and temporal resolution; timeframe of simulation; summary of data used for model inputs; summary of methods used to fill data gaps; summary of data used for calibration; time series plots comparing observed and model predicted temperatures and other parameters as appropriate; goodness-of-fit statistics, and plots and tables summarizing temperature and effective shade model results.

The model scenario setup and scenario results documentation will include a description of the scenario, what model elements were modified for the scenario; tables, plots, or narrative summarizing the final values for any modified inputs or parameters; methods or data sources used to setup the scenario; and plots and tables that summarize the scenario results.

When no changes or minor changes are made to the existing TMDL models, the existing TMDL technical appendices will be amended as necessary to document any changes to the existing calibration or management scenarios. For more extensive changes or entirely new models new technical appendices may need to be developed to document the models and results.

8 Peer review

Peer review of the models and model results will be conducted in the following ways:

DEQ will conduct internal peer review during the modeling process with input from USEPA Region 10 as needed. For models being developed by USEPA's contractor, Tetra Tech, USEPA and DEQ will peer review all contractor developed models and model documentation.

DEQ will consider feedback on model scenarios and results from the TMDL advisory group and make changes as appropriate.

DEQ will review and respond to any public comments received on the model and model results and make changes as appropriate.

9 Management scenarios

Management scenarios described in this section summarize the means by which sources of stream warming and different management alternatives will be evaluated. Some of these model scenarios may not be developed due to lack of sufficient data and information, because the management scenario is not applicable to the specific waterbody, or because it is determined the scenario will require an effort and timeline that does not align with the project schedule or available resources. In some cases, the management scenario has already been developed as part of the previous TMDL and does not need further adjustment. DEQ will review all available data and information during model development and document final model scenario decisions, setup, and results in the TMDL technical appendix.

9.1 Vegetation conditions 2024

This scenario evaluates the stream temperature or shade response based on 2024 vegetation conditions. This scenario is similar to the calibrated model except that the vegetation landcover will be updated to reflect vegetation heights and cover in 2024.

This scenario will be developed for all modeled rivers in the project area. Elements of this scenario or scenarios include:

- Updating the landcover classification and vegetation heights, density, and overhang using recently collected LiDAR, Digital Aerial Photogrammetry (DAP), arial imagery, or other remote sensing data.

9.2 Restored vegetation A

This scenario evaluates the stream temperature response with streamside vegetation at restored conditions. The stream temperature warming or cooling contributed by removal of streamside vegetation is evaluated by comparing this scenario to the current condition model.

This model scenario will be developed for all modeled rivers in the project area. Elements of this scenario or scenarios may include:

- Streamside vegetation will be set to restored conditions in areas along the model extent that are currently characterized as lacking streamside vegetation because of anthropogenic disturbance. The restored vegetation type, height, density, and overhang values will be determined during the TMDL process and will likely be the same or similar to the values presented in the Lower Grande Ronde Subbasins TMDL (DEQ, 2010).
- Model inputs for land cover height, canopy density, and overhang will be modified to reflect the restored conditions.
- All other model inputs will be the same as the current condition model.

9.3 Restored vegetation B

This scenario evaluates the stream temperature response with streamside vegetation at restored conditions, except in areas with existing infrastructure (i.e., buildings and roads).

Restored vegetation scenario “B” (RV_B) is setup identical to restored vegetation scenario “A” (RV_A) except that areas associated with buildings, roads, and bridges are left unchanged and retain the same landcover heights and densities as the current condition model. RV_A and RV_B results are compared to quantify shade and instream temperature effects of existing infrastructure.

This model scenario will be developed for all modeled rivers in the project area.

9.4 Topography

This scenario evaluates the portion of effective shade contributed by topographic features only. The effective shade results of this scenario are compared with the current condition and restored vegetation scenarios to quantify the portion of effective shade associated with current and restored vegetation only.

This model scenario will be developed for all modeled rivers in the project area. Elements of this scenario or scenarios may include:

- Model inputs for land cover height, canopy density, and overhang will be set to zero.
- All other model inputs will be the same as the current condition model.

9.5 Natural stream flow

This scenario evaluates stream temperature response at natural flow rates. The model is setup so permitted water withdrawals are kept as instream flow. The stream temperature warming or cooling from keeping permitted water withdrawals as instream flow is evaluated by comparing this scenario to the current condition model scenario. Assumptions and methods used to estimate natural stream flow will be documented in the TMDL.

This model scenario will be developed for Bear Creek, Grande Ronde River, Wallowa River, Imnaha River, and Lostine River only. Elements of this scenario or scenarios may include:

- Maintaining all currently permitted water withdrawals as instream flow in order to increase the thermal loading capacity and reduce stream warming.
- Model boundary and tributary flows will be set to reflect the additional instream flows.
- All other model inputs will be the same as the current condition model.

9.6 Consumptive use

These scenarios evaluate the stream temperature response to different amounts of consumptive use water withdrawals. They are identical to the natural stream flow model setup except that all points of withdrawal and boundary and tributary inflows are modified iteratively to reflect various rates of consumptive water withdrawals. The purpose of these scenarios is to determine the consumptive withdrawal rates (as a percentage of natural flow) that will attain both the TMDL load allocation, and any HUA assigned for permitted withdrawals. Other scenarios may include the percent consumptive withdrawal rate that attains the overall HUA (0.30°C) or a target consumptive use rates recommended by OWRD the TMDL advisory committee. Results of this scenario will be compared to the natural stream flow scenario to quantify the instream temperature effects of water withdrawals at the reference gage.

This model scenario will be developed for Bear Creek, Grande Ronde River, Wallowa River, Imnaha River, and Lostine River only. Elements of this scenario or scenarios may include:

- Adjusting all currently permitted water withdrawals to reflect various rates of consumptive use as measured at the reference location.
- Model boundary and tributary flows will be set to reflect the rate of consumptive water use as measured at the reference location.
- All other model inputs will be the same as the current condition model.

9.7 Tributary temperatures A

This scenario evaluates the stream temperature response when the temperature of tributaries that exceed applicable temperature standards are set to temperatures that attain those temperature standards. This scenario will be compared to the current condition model to quantify the stream temperature impact of tributary temperature standard exceedances. Assumptions and methods used to estimate tributary temperatures that attain the applicable temperature standard will be documented in the TMDL.

This model scenario will be developed for Bear Creek, Grande Ronde River, Wallowa River, Imnaha River, Lostine River, and Minam River only. Elements of this scenario or scenarios may include:

- Tributary temperature inputs set so they attain the applicable temperature standards.
- All other model inputs, including tributary flow, will be the same as the current condition model.

9.8 Tributary temperatures B

This scenario evaluates stream temperature warming or cooling from sources on upstream tributaries attaining their HUA assignment. This scenario will be compared to the current condition model.

This model scenario will be developed for Bear Creek, Grande Ronde River, Wallowa River, Imnaha River, Lostine River, and Minam River only. Elements of this scenario or scenarios may include:

- Tributary temperatures are increased by the portion of the HUA assigned to point or nonpoint sources on that tributary. HUA held as reserve capacity is not included.
- All other model inputs, including tributary flow, will be the same as the current condition model.

9.9 Background

This scenario evaluates the stream temperature response from background sources only. 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 (OAR 340-042-0030(1)). This scenario essentially combines the following model scenarios: restored vegetation A and natural stream flow. The background scenario will be compared to the current condition model scenario to determine the point of maximum impact, and the amount of cumulative warming originating from human activities. The background scenario will also be used to determine the portion of temperature increases above the temperature criteria that are attributable to background sources. This model scenario will be developed for Bear Creek, Grande Ronde River, Wallowa River, Imnaha River, Lostine River, and Minam River only.

9.10 No point sources

This scenario evaluates the stream temperature response from removing point source heat load. The stream temperature warming or cooling from permitted NPDES point sources is evaluated by comparing this scenario to the current condition model scenario.

This model scenario will be developed for the Grande Ronde and Wallowa Rivers only. Elements of this scenario include:

- Removal of all point sources from the model.
- All other model inputs will be the same as the current condition model.

9.11 TMDL wasteload allocations

This scenario evaluates stream temperature warming or cooling from the TMDL wasteload allocations. These scenarios will be compared to the no point source model scenario to evaluate attainment of the HUA allocations. Numeric wasteload allocations will be developed for all individual NPDES permittees but some of the permittees may not be included in this model scenario due to availability of effluent data, lack of discharge, or because the discharge is not a significant source of thermal loading.

This model scenario will be developed for Grande Ronde and Wallowa Rivers only. Elements of this scenario or scenarios may include:

- Modifying point source discharges to reflect proposed or existing TMDL wasteload allocations.
- All other model inputs will be the same as the current condition model.

9.12 Attainment

The attainment scenario evaluates attainment of the cumulative HUA (0.3°C) based on point and nonpoint sources being set at their respective allocations. This scenario will be compared to the background or similar scenario that excludes the sources receiving a TMDL allocation.

This model scenario will be developed for Bear Creek, Grande Ronde River, Wallowa River, Imnaha River, Lostine River, and Minam River. Elements of this scenario may include:

- Point source discharges are set to reflect individual proposed wasteload allocation flows and temperatures (Wallowa River only).
- Tributary temperatures are increased by the portion of the HUA assigned to point or nonpoint sources on that tributary. HUA held as reserve capacity is not included.
- Model inputs for land cover height, canopy density, and overhang will be modified to reflect the streamside vegetation that achieve TMDL effective shade targets. The vegetation type, height, density, and overhang values will be determined during the TMDL process and will likely be the same or similar to the values presented in the Lower Grande Ronde Subbasins TMDL (DEQ, 2010).

10 Project organization

10.1 Project team/roles

Project roles and responsibilities are described in Table 10-1.

Table 10-1: The roles and responsibilities of each team member involved in the temperature TMDL replacement project.

Name	Position	Role and Responsibilities
Jennifer Wigal	Water Quality Administrator, Oregon DEQ	**Sponsor** 1. Provide guidance to team and project manager 2. Approve project plan and changes to the project, scope, budget, and schedule (pending manager elevation as necessary) 3. Sustain support of decision makers at their level, all stakeholders 4. Remove roadblocks 5. Communicate progress to other managers and Water Quality Director 6. Review project status 7. Manage resistance 8. Ensure communication with employees affected by changes 9. Provide forum to listen to concerns
Steve Mrazik	Manager, Watershed Management, Oregon DEQ	**Manager** 1. Review and approve teamwork products 2. Communicate progress to other managers 3. Approve project plan, changes to the project, and any changes that affect scope and schedule 4. Approve development and finalization of solutions to issues that occur during the project 5. Decide measures of project success
Michele Martin	Project Manager, Water Quality, Oregon DEQ	**Project Manager** 1. Facilitate meetings, effective meeting management 2. Provide feedback and leadership in the development of meeting agendas, activities during meetings, and tasks

Name	Position	Role and Responsibilities
		3. Provide feedback on project planning and design 4. Keep sponsor informed 5. Develop project charter 6. Develop project plan (including major tasks, milestones, project schedule, communication plan, risk analysis, etc.) 7. Develop team meeting agendas 8. Keep track of meeting decisions and notes (very brief), and team ideas 9. Ensure team's work drives towards outcomes and deliverables 10. Sustain engagement of team members and team performance 11. Control project scope (with Technical Lead) 12. Coordinate team communication: emails, SharePoint, shared drives 13. Closeout project and document lessons learned
Ryan Michie	Senior Water Quality Analyst, Watershed Management, Oregon DEQ	**Project Technical Lead** 1. Lead, oversee, and direct development of the project QAPP 2. Lead, oversee, and direct the public data solicitation process 3. Coordination with EPA and Contractor 4. Lead, oversee, and direct DEQ technical staff 5. Perform model calibration/evaluation 6. Run model scenarios 7. Analyze and interpret model results 8. Lead, oversee, and direct TMDL document writing 9. Participate and present at TMDL public meetings 10. Respond to public comments
Trea Nance	Basin Coordinator, Oregon DEQ	1. Review QAPP and TMDL 2. Write WQMP 3. TMDL rulemaking advisory committee coordinator 4. Participate and present at TMDL public meetings 5. Respond to public comments
Ben Hamilton	Agency QA Officer, Oregon DEQ	Review QAPP
Dianne Lloyd	Oregon Department of Justice	**Legal Counsel**

Name	Position	Role and Responsibilities
Phillip Sprague	Water Quality Specialist, Oregon DEQ	1. Project team point of contact to NPDES permit program and permittees 2. Review wasteload allocations
Rebecca Veiga Nascimento	EPA Region 10 Oregon TMDL Program Manager	**EPA TMDL Lead** 1. Review and direct EPA Contractor work products 2. Technical TMDL reviewer 3. Regulatory/Policy TMDL reviewer
Ben Cope	EPA Region 10 QAPP Officer for Modeling Projects	**EPA Modeling Lead** 1. Review QAPPs 2. Review EPA Contractor work products
TMDL rulemaking advisory committee	This TMDL will have a rulemaking advisory committee	1. Participate in TMDL rulemaking advisory committee meetings 2. Provide input to DEQ on TMDL and WQMP elements 3. Advise DEQ on economic and fiscal impacts of the proposed rules for entities impacted by the proposed TMDL and potential impacts on small businesses

10.2 Expertise and special training requirements

Additional expertise or special training is not necessary at this time.

DEQ staff involved in developing and configuring models, performing model calibration, running model scenarios, and analyzing and interpreting model results have experience in these tasks from numerous other modeling projects. The Project Manager has extensive experience managing large complex projects and will ensure strict adherence to the project protocols.

10.3 Reports to management

The DEQ Project Manager (or designee) will provide progress reports to DEQ Management and USEPA as needed based on new project information. As appropriate, these reports will provide information on the following:

- Adherence to project schedule and/or budget.
- Deviations from approved QAPP, as determined from project assessment and oversight activities.
- The impact of any deviations on model application quality and uncertainty.
- The need for and results of response actions to correct any deviations.

- Potential uncertainties in decisions based on model predictions and data.
- Data quality assessment findings regarding model input data and model outputs.

10.4 Project schedule

The estimated project schedule for the Lower Grande Ronde, Imnaha, and Wallowa Subbasins TMDL is summarized below. This schedule is subject to change based on TMDL development progress and available resources.

Aug 2025 – Feb 2027: Organization and review of existing models, relevant river temperature, stream flow, habitat, and other data. Completion of TMDL analysis, models, and other technical work described in this modeling QAPP. Early draft TMDL and WQMP documents will be written.

Mar 2027 – Nov 2027: TMDL rule advisory committee meetings to discuss the draft TMDL, WQMP, and fiscal impacts.

Nov 2027: Draft TMDL and WQMP posted for public comment. DEQ will respond to all public comments received, revise the TMDL and WQMP as necessary.

Dec 4, 2028: Deadline for USEPA's final agency action approving or disapproving of the TMDL.

11 Data management

DEQ does not anticipate collecting additional field samples. Water quality data gathered and used for this project will be managed in DEQ's AWQMS database or the project files.

The modeling software to be used for this project is available on DEQ's TMDL program website.

Model-generated data resulting from testing, calibration, and scenarios will be stored in spreadsheets and text files by DEQ in the TMDL project directory. Metadata describing the content, date, and personnel involved in modeling will be documented alongside raw and summarized data.

Secondary data developed as part of this task will be maintained as hardcopy only, both hardcopy and electronic, or electronic only, depending on their nature.

All electronic data will be maintained on DEQ's computers and servers. DEQ's computers are serviced by in-house specialists. When a problem with DEQ's computers and servers occurs, in-house computer specialists diagnose the problem and correct it if possible. When outside assistance is necessary, the computer specialists call the appropriate vendor. For other computer equipment requiring outside repair and not covered by a service contract, local computer service companies are used on a time-and-materials basis.

Routine maintenance of DEQ's computers and servers is performed by in-house computer specialists. Electric power to each computer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. All computer users have been instructed on the importance of routinely archiving work assignment data files from hard drive to server storage. The office network server is backed up on tape nightly during the week.

Screening for viruses on electronic files loaded on DEQ's computers or the network is standard policy. Automated screening systems have been placed on all computer systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

12 Recordkeeping and archiving

All data and documents generated during the course of the TMDL project will be archived according to the current Oregon State Archives Records Retention Schedules. Generally TMDL documents will be retained until 15 years after the TMDL is no longer operational.

Records that are stored in electronic format will be located in either the TMDL project folder or Master TMDL folder located on DEQ's TMDL server. The TMDL project folder will contain at minimum the following subfolders: "Project Plans", "Data", "NPDES", "Models", and "Meetings". Alternative names and additional subfolders can be used as appropriate. The Master TMDL folder will contain the final written TMDL documents (Word, PDF) along with supporting written documents that support the public comment period and TMDL issuance. The contents and organization of these subfolders is described below.

Project Plans: All documents related to project planning, project proposals, project schedules, and the modeling QAPPs. Each will reside in their relevant subfolders. The final versions of documents will be clearly identified from drafts and ideally located in separate folders.

Data: All field data organized or collected in support of the TMDL project. This may include water quality samples, field sheets, photos, monitoring metadata, third party sampling project plans, or other documentation. The data should be organized by parameter and data source if possible.

NPDES: All available NPDES effluent data, discharge monitoring reports, copies of NPDES permits, and related information. Data and permit information will be organized for each permittee and located in separate subfolders.

Models: All models used for the TMDL project including calibration and scenario models. The models should be organized into subfolders for each model domain and model scenario. Draft models and the final TMDL models will be clearly identified and ideally saved in separate folders. The model folders should include:

- The model with all input and output files and any executable code used;
- Copy of all raw and summarized data (including GIS files) used for model input with data source and location metadata included;
- Scripts or spreadsheets used to transform raw data or used to derive model inputs;
- Key assumptions and documentation for the model setup and parameterization;
- Documentation of newly developed model code or modifications to the existing model; and

- Identification of staff that completed the model.

Meetings: All documents produced for external meetings including agendas, presentations, and meeting materials. Material for each meeting will be saved in a subfolder organized by meeting type. Draft documents and final documents will be clearly identified.

TMDL documents: At each key stage of TMDL and WQMP development copies of the following documents will be saved in separate subfolders within the project folder on the Master TMDL directory. The final versions of documents will be clearly identified from drafts and ideally saved in separate folders.

- Public Comment Draft:
  - Briefing memo to DEQ Water Quality Division Administrator or Director on public comment draft
  - Draft TMDL and WQMP Report (Both Word and PDF)
  - Draft TMDL Appendices (Both Word and PDF)
  - Public Notice document
  - TMDL Summary Fact Sheet
  - News release
  - GovDelivery Notice and email
  - Other public notification emails
  - Mailing List (if used)
  - Public Comments Errata
- Public Comments Received: Copy of all public comments received
- Final TMDL and WQMP documents:
  - Briefing memo to DEQ Water Quality Division Administrator or Director on final TMDL
  - Signed TMDL order (both Word and PDF)
  - TMDL issuance letter to USEPA (both Word and PDF)
  - USEPA approval letter (USEPA)
  - Response to Comment Document (both Word and PDF)
  - TMDL and WQMP Report (both Word and PDF)
  - TMDL Appendices (both Word and PDF)
  - TMDL Summary Fact Sheet
  - News release
  - GovDelivery Notice and email
  - Other public notification emails
  - Relevant EQC agenda documents
  - Designated Management Agency/Responsible Person notification letters (both Word and PDF)
  - Addendums
  - Errata

- ATTAINS upload files

13 QAPP review and approval

The DEQ Project Technical Lead will distribute the draft QAPP to the respective DEQ and USEPA project team members for review. Comments will be provided to the Project Technical Lead for further discussion. When possible, revision and submittal of the final plan will be made within 10 business days of receipt of comments. Following approval, the Project Technical Lead will distribute the final, signed copy to the respective DEQ and USEPA project team members.

USEPA approval is necessary for USEPA contractors to begin any modeling work.

Official copies of the final, approved QAPP will be retained in DEQ's document control system. If any change(s) to the QAPP are required during the project, they must be described in a memorandum and approved by the signatories to this QAPP and attached to the QAPP.

14 Implementation and adaptive management

DEQ plans to develop a Risk Management Plan to identify project constraints, the risks that may arise during project implementation, and potential solutions. Identified project constraints include the abbreviated project schedule with hard deadlines established via court order, limited resources, uncertain funding from USEPA, and a complex TMDL technical effort which may require additional time and public process. Projects risks from these constraints and proposed solutions are described in Table 14-1.

Table 14-1: Projects risks and proposed solutions.

Risk Description	Solution
Extended public process for complex TMDLs	Communication to DEQ manager and external contacts as deemed necessary by the manager
Team member availability: Inadequate resources to effectively produce the TMDL	Dedicate additional resources to support the effort from internal staff
Delivery commitment	Designate the projects as priority and dedicate additional resources to support the effort from internal staff or contractor (depending on contractor funding)
Scope creep: Working on the TMDLs could be an opportunity for attempts to add additional technical work that are outside the project scope	Sponsor and Manager to address scope creep with stakeholders as necessary
In scope – no time e.g., technical work may take longer than expected. Prioritizing the in-scope work for only absolute requirements	Request court extensions or allocate more resources to meet deadlines, if more resources are available, or reduce the in-scope requirements to the absolute minimum for a scientifically defensible and EPA approvable TMDL

Should a situation arise that requires a significant change in the technical approach, the project team will update the QAPP as needed through revisions or addenda.

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16 Revision history

Table 16-1: QAPP revision history.

Revision	Date	Changes	Editor
1.0	10/22/2025	New QAPP	R. Michie

A. Appendix A Continuous stream temperature data summary

The data retrieval period for continuous stream temperature data summarized in this section is from January 1, 1999 to December 31, 2024. Table A-1 through Table A-4 are organized by HUC8 subbasin. The result count reflects the number of available 7DADM results. A handful of monitoring locations did not have 7DADM calculated so the result count represents the number of daily maximum results. Some monitoring locations have more results relative to the period of record due to multiple probes being deployed at the same location.

Table A-1: Summary of continuous temperature data available in public databases in the Lower Grande Ronde Subbasin. Result count indicates the number of 7DADM temperature results during the period or record. Data from DEQ files not in the databases were not summarized in the table.

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
WWNF-021	Broady.02D.3_LTWT	Broady Creek	45.8841	-117.0861	07/13/11 - 09/30/19	1076
WWNF-022	Buck.24J.2_LTWT	Buck Creek	45.7802	-117.3352	07/13/10 - 07/10/17	289
WWNF-025	Burnt.24J.1_LTWT	Burnt Creek	45.7812	-117.3321	07/14/10 - 08/20/19	822
34263-ORDEQ	Butte Creek at mouth (Chesnimnus, Joseph, Grande Ronde)	Butte Creek	45.7022	-117.1014	07/08/99 - 11/22/99	138
23044-ORDEQ	Chesimnus Creek at mouth	Chesnimnus Creek	45.7130	-117.1505	06/17/02 - 10/27/02	133
34271-ORDEQ	Chesnimnus Creek at RM 10.4 (Joseph, Grande Ronde)	Chesnimnus Creek	45.7336	-117.0349	06/17/02 - 10/27/02	133
WWNF-031	Chesnimnus.26E.2_LTWT	Chesnimnus Creek	45.7142	-117.1557	06/17/02 - 10/07/08	649
WWNF-032	Chesnimnus.26I.2_LTWT	Chesnimnus Creek	45.7342	-117.0347	07/14/04 - 10/15/20	1833
WWNF-210	Chesnimnus.26J.1	Chesnimnus Creek	45.7291	-116.9502	06/21/00 - 08/31/01	141
WWNF-283	Chesnimnus.26I.4_WT	Chesnimnus Creek	45.7550	-116.9980	06/08/19 - 10/06/20	243
WWNF-284	Chesnimnus.26J.3_WT	Chesnimnus Creek	45.7270	-116.9500	06/08/19 - 09/07/20	203
WWNF-285	Chesnimnus.26J.4_WT	Chesnimnus Creek	45.7800	-116.9850	06/08/19 - 08/04/20	132
WWNF-286	Chesnimnus.26J.6_WT	Chesnimnus Creek	45.7510	-116.9670	06/09/19 - 09/03/20	198

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
WWNF-287	Chesnimnus.26J.7_WT	Chesnimnus Creek	45.7070	-116.9150	05/29/19 - 08/31/20	151
WWNF-042	Cottonwood.02F.1_WT	Cottonwood Creek	45.8866	-116.9869	05/28/15 - 10/17/18	485
WWNF-043	Cottonwood.02F.2_WT	Cottonwood Creek	45.8319	-116.9547	06/23/17 - 09/30/19	324
WWNF-044	Cougar.02O.1_WT	Cougar Creek	45.7917	-117.1749	07/23/09 - 10/03/10	178
203110-BLM	Courtney Creek at RM 0.37	Courtney Creek	45.9286	-117.4376	07/18/19 - 10/06/20	215
27796-ORDEQ	Courtney Creek #2	Courtney Creek	45.9005	-117.3987	06/19/01 - 09/25/01	99
23033-ORDEQ	Crow Creek at mouth	Crow Creek	45.7050	-117.1526	07/29/99 - 10/27/02	188
34272-ORDEQ	Crow Creek at rivermile 3.2 (Joseph, Grande Ronde)	Crow Creek	45.6763	-117.1411	06/17/02 - 10/27/02	133
WWNF-047	Crow.26A.2_LTWT	Crow Creek	45.7136	-117.1556	06/15/05 - 10/07/08	362
WWNF-048	Crow.26A.3_LTWT	Crow Creek	45.6764	-117.1407	06/15/05 - 10/07/08	362
WWNF-049	Davis.02L.2_WT	Davis Creek	45.6922	-117.2617	06/22/10 - 08/25/17	523
WWNF-050	Davis.02L.3_WT	Davis Creek	45.6611	-117.2596	06/22/10 - 08/04/11	86
WWNF-058	DevilsRun.26K.1_LTWT	Devils Run Creek	45.7823	-116.9859	07/14/04 - 10/06/20	1692
WWNF-290	DevilsRun.26K.5_WT	Devils Run Creek	45.7690	-116.8980	06/08/19 - 10/06/20	253
WWNF-074	EFBroady.02D.1_WT	East Fork Broady Creek	45.8746	-117.0680	06/08/16 - 10/04/17	250
34274-ORDEQ	Elk Creek at bridge at RM 3.8 (Crow, Joseph, Grande Ronde)	Elk Creek	45.6699	-117.1906	06/17/02 - 10/27/02	133
WWNF-080	Elk.26B.2_LTWT	Elk Creek	45.6707	-117.1907	07/21/08 - 09/22/17	1177
34264-ORDEQ	Gooseberry Creek at mouth (Chesnimnus, Joseph, Grande Ronde)	Gooseberry Creek	45.6977	-117.1022	07/08/99 - 11/22/99	138
13333000	GRANDE RONDE RIVER AT TROY, OR	Grande Ronde River	45.9457	-117.4510	04/02/24 - 12/31/24	199
186461-BLM	Grouse Creek at RM 0.13	Grouse Creek	45.9868	-117.3993	07/18/19 - 10/27/19	102
203119-BLM	Grouse Creek at RM 0.13	Grouse Creek	45.9867	-117.3993	06/18/20 - 10/06/20	111
27797-ORDEQ	Grouse Creek	Grouse Creek	45.9868	-117.3990	05/29/01 - 09/23/02	229
27802-ORDEQ	Wenaha River #2	Grouse Creek	45.9867	-117.3991	05/29/01 - 10/08/01	133
WWNF-098	Horse.02G.1_WT	Horse Creek	45.9760	-116.9881	06/15/15 - 10/04/18	467
WWNF-104	Joseph.02P.1_WT	Joseph Creek	45.7679	-117.1695	07/23/09 - 09/26/17	859

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
27783-ORDEQ	Mud Creek	Mud Creek	45.8963	-117.4707	06/15/00 - 09/24/01	251
WWNF-131	Mud.24I.1_WT	Mud Creek	45.7213	-117.3428	07/04/11 - 10/19/20	1114
34275-ORDEQ	Peavine Creek below McCrty Gulch (Chesnimnus, Joseph, Grande Ronde)	Peavine Creek	45.7344	-117.0846	06/17/02 - 10/27/02	133
WWNF-155	Peavine.26M.2_LTWT	Peavine Creek	45.7364	-117.0847	07/14/04 - 10/07/08	423
UmatNF-108	SheepMTG_LTWT	Sheep Creek	45.7480	-117.7790	06/25/04 - 10/17/07	376
27786-ORDEQ	Sickfoot Creek	Sickfoot Creek	45.8785	-117.5790	06/15/00 - 10/09/02	250
WWNF-171	Sled.24I.1_WT	Sled Creek	45.7403	-117.3186	07/04/11 - 10/19/20	1022
WWNF-292	SFChesnimnus.26J.1_WT	South Fork Chesnimnus Creek	45.7270	-116.8970	05/29/19 - 08/26/20	164
WWNF-178	Swamp.02K.2_LTWT	Swamp Creek	45.6193	-117.2228	07/17/08 - 10/05/16	427
WWNF-179	Swamp.02K.3_WT	Swamp Creek	45.6781	-117.2313	05/21/04 - 10/06/08	332
WWNF-180	Swamp.02K.4_LTWT	Swamp Creek	45.7041	-117.2315	07/17/08 - 09/26/17	860
203131-BLM	Wallupa Creek at RM 2.49	Wallupa Creek	45.8235	-117.5302	07/17/19 - 10/06/20	224
27800-ORDEQ	Wallupa Creek #1	Wallupa Creek	45.8439	-117.5045	05/31/01 - 09/24/02	215
27801-ORDEQ	Wallupa Creek #2	Wallupa Creek	45.8306	-117.5283	05/31/01 - 09/24/02	215
27789-ORDEQ	Wenaha River	Wenaha River	45.9458	-117.4772	06/28/00 - 10/04/00	99
203133-BLM	Wildcat Creek at RM 3.5	Wildcat Creek	45.8485	-117.4990	07/18/19 - 10/06/20	223
203134-BLM	Wildcat Creek at RM 1.65	Wildcat Creek	45.8746	-117.4971	07/18/19 - 10/06/20	215
27790-ORDEQ	Wildcat Creek #2	Wildcat Creek	45.8728	-117.4979	06/27/00 - 09/24/01	216
27791-ORDEQ	Wildcat Creek #4	Wildcat Creek	45.8475	-117.4976	07/05/00 - 10/02/00	90
27803-ORDEQ	Wildcat Creek #3	Wildcat Creek	45.8543	-117.4987	05/30/01 - 09/24/01	118
34273-ORDEQ	Poison Creek at mouth (Chesnimnus, Joseph, Grande Ronde)	Grouse Creek	45.7806	-116.9851	06/17/02 - 10/27/02	133
WWNF-288	Chesnimnus.26J.8_WT	Chesnimnus Creek	45.7350	-116.9010	05/29/19 - 07/23/20	96

Table A-2: Summary of continuous temperature data available in public databases in the Wallowa Subbasin. Result count indicates the number of 7DADM temperature results during the period or record. Data from DEQ files not in the databases were not summarized in the table.

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
34238-ORDEQ	Bear Creek at Frontage Road (Wallowa, Grande Ronde)	Bear Creek	45.5803	-117.5399	04/26/00 - 11/01/04	591
34239-ORDEQ	Bear Creek at Getchel Meadows at RM 6.1 (Wallowa, Grande Ronde)	Bear Creek	45.5027	-117.5581	04/27/00 - 10/10/01	300
34240-ORDEQ	Bear Creek above Boundary Campground at RM 8.5 (Wallowa, Grande Ronde)	Bear Creek	45.4706	-117.5607	04/27/00 - 10/10/01	308
34261-ORDEQ	Bear Creek DS Garden Gulch (Wallowa, Grande Ronde)	Bear Creek	45.5268	-117.5518	05/25/23 - 10/08/23	137
34261-ORDEQ	Bear Creek DS Garden Gulch (Wallowa, Grande Ronde)	Bear Creek	45.5268	-117.5518	07/06/99 - 11/15/05	831
42056-ORDEQ	Bear Creek at River Mile 0.23	Bear Creek	45.5812	-117.5399	05/25/23 - 10/08/23	123
WWNF-215	Deer.05A.1	Deer Creek	45.5814	-117.6683	07/05/99 - 10/08/01	285
WWNF-216	Deer.05B.1	Deer Creek	45.5000	-117.6076	07/03/99 - 10/04/20	498
42055-ORDEQ	Dry Creek at River Mile 0.11	Dry Creek	45.6099	-117.5999	05/25/23 - 10/08/23	137
27779-ORDEQ	Fisher Creek	Fisher Creek	45.6654	-117.7569	06/13/00 - 10/23/00	112
203120-BLM	Howard Creek at RM 0.06	Howard Creek	45.6877	-117.7768	07/17/19 - 10/27/20	218
27780-ORDEQ	Howard Creek	Howard Creek	45.6878	-117.7769	06/14/00 - 09/19/01	247
42060-ORDEQ	Hurricane Creek at River Mile 0.23	Hurricane Creek	45.4187	-117.2976	07/28/23 - 10/08/23	73
42061-ORDEQ	Hurricane Creek at River Mile 9.06	Hurricane Creek	45.3203	-117.3045	08/26/23 - 10/08/23	44
34268-ORDEQ	Little Bear Creek RM 2.5 (Bear, Wallowa, Grande Ronde)	Little Bear Creek	45.4707	-117.5142	04/27/00 - 10/10/01	308
WWNF-291	LittleBear.05D.2_WT	Little Bear Creek	45.4710	-117.5150	06/26/19 - 10/04/20	211
35825-ORDEQ	LITTLE MINAM R AT RM 1.3	Little Minam River	45.3840	-117.6719	10/01/19 - 07/25/22	521
MNM00001-000081	Little Minam River	Little Minam River	45.3462	-117.6534	08/12/10 - 08/11/20	2900

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
MNM00001-000197	Little Minam River	Little Minam River	45.3985	-117.6739	07/10/13 - 07/31/14	373
MNM00001-000209	Little Minam River	Little Minam River	45.3799	-117.6734	10/05/16 - 08/10/20	371
MNM00001-000369	Little Minam River	Little Minam River	45.3639	-117.6646	08/02/13 - 08/10/20	2300
MNM00001-000397	Little Minam River	Little Minam River	45.3442	-117.6523	09/06/15 - 08/10/20	1723
MNM00001-000445	Little Minam River	Little Minam River	45.3700	-117.6708	08/08/14 - 08/10/20	2093
11727-ORDEQ	Lostine River at Baker Road (Wallowa)	Lostine River	45.5375	-117.4791	04/26/00 - 10/08/23	862
21444-ORDEQ	Lostine River downstream East Lostine River at Two Pan Ca	Lostine River	45.2507	-117.3775	06/13/00 - 11/15/00	156
34266-ORDEQ	Lostine River near Lostine at RM 10.2 (Wallowa, Grande Ronde)	Lostine River	45.4365	-117.4237	07/06/99 - 11/15/05	899
34267-ORDEQ	Lostine River at Caudle Lane (Wallowa, Grande Ronde)	Lostine River	45.4888	-117.4360	04/26/00 - 11/01/04	623
34269-ORDEQ	Lostine River at RM 13.6 above Silver Creek (Wallowa, Grande Ronde)	Lostine River	45.3903	-117.4255	05/22/00 - 10/10/01	213
34291-ORDEQ	Tailflow ditch connected to the Clearwater Ditch (Lostine, Wallowa, Grande Ronde)	Lostine River	45.5377	-117.4795	07/09/03 - 11/15/05	355
42058-ORDEQ	Lostine River at River Mile 13.65	Lostine River	45.3931	-117.4273	05/25/23 - 10/08/23	137
WWNF-121	Lostine.05I.3_LTWT	Lostine River	45.2560	-117.3816	07/21/05 - 10/07/08	323
13331500	MINAM RIVER AT MINAM, OR	Minam River	45.6199	-117.7266	11/11/11 - 12/31/24	4653
CBW05583-113834	Minam River	Minam River	45.2627	-117.5324	09/06/14 - 09/13/16	711
CBW05583-344746	Minam River	Minam River	45.2113	-117.5001	08/12/13 - 09/13/16	1087
CBW05583-425130	Minam River	Minam River	45.2264	-117.5244	08/27/14 - 08/11/20	2093

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
MNM00001-000009	Minam River	Minam River	45.3795	-117.6540	09/09/14 - 08/10/19	1727
MNM00001-000096	Minam River	Minam River	45.2422	-117.5301	08/27/14 - 08/11/20	2093
MNM00001-000200	Minam River	Minam River	45.1926	-117.4802	08/20/15 - 09/13/16	377
MNM00001-000229	Minam River	Minam River	45.3690	-117.6445	09/08/14 - 08/11/20	2081
MNM00001-000236	Minam River	Minam River	45.2216	-117.5196	08/12/13 - 09/12/16	1086
MNM00001-000393	Minam River	Minam River	45.4126	-117.6786	08/13/15 - 08/12/20	1757
MNM00001-000444	Minam River	Minam River	45.2675	-117.5332	08/27/14 - 08/03/19	1338
MNM00001-M53240	Minam River	Minam River	45.3439	-117.6181	07/15/10 - 07/27/15	1512
MNM00001-M53247	Minam River	Minam River	45.3400	-117.6021	09/13/13 - 08/20/18	1667
42062-ORDEQ	Prairie Creek at River Mile 1.61	Prairie Creek	45.4201	-117.2708	05/25/23 - 10/08/23	137
WWNF-250	Sage.05B.1	Sage Creek	45.5002	-117.6066	07/02/01 - 10/04/20	310
42059-ORDEQ	Spring Creek at River Mile 0.16	Spring Creek	45.4221	-117.3104	05/26/23 - 10/08/23	136
13008-ORDEQ	Trout Creek at Mouth	Trout Creek	45.4266	-117.3100	05/25/23 - 10/08/23	137
11561-ORDEQ	Wallowa River at Baker Road (upstream of Lostine River)	Wallowa River	45.5549	-117.4794	07/27/99 - 09/19/99	55
187408-BLM	Wallowa River at RM 3.49	Wallowa River	45.6873	-117.7776	07/17/19 - 10/08/19	84
27788-ORDEQ	Wallowa River	Wallowa River	45.6637	-117.7579	06/13/00 - 10/23/00	133
27799-ORDEQ	Wallowa River #2	Wallowa River	45.6509	-117.7430	05/14/01 - 09/19/01	129
34270-ORDEQ	Wallowa River above Cross Country Ditch (Grande Ronde)	Wallowa River	45.4885	-117.4038	04/27/00 - 10/08/23	896
34277-ORDEQ	Wallowa River Below Water Canyon (Grande Ronde)	Wallowa River	45.6087	-117.6159	04/27/00 - 10/08/23	879

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
34278-ORDEQ	Wallowa River below Cross Country Ditch (Grande Ronde)	Wallowa River	45.4969	-117.4105	07/02/03 - 11/15/05	279
34279-ORDEQ	Wallowa River at rivermile 25 (Grande Ronde)	Wallowa River	45.5580	-117.4999	07/22/04 - 11/01/04	103
42064-ORDEQ	Wallowa River at River Mile 48.19	Wallowa River	45.3531	-117.2376	05/26/23 - 10/08/23	136
34276-ORDEQ	Little Bear Creek at mouth (Bear, Wallowa, Grande Ronde)	Little Bear Creek	45.4852	-117.5550	04/27/00 - 10/10/01	298
34290-ORDEQ	Spring Branch at Wallowa Lake HWY (Wallowa, Grande Ronde)	Spring Branch	45.5503	-117.4962	07/09/03 - 11/01/04	210
42057-ORDEQ	Whiskey Creek at River Mile 0.39	Whiskey Creek	45.5687	-117.5154	05/25/23 - 09/15/23	106
42063-ORDEQ	Cross Country Canal at River Mile 5.28	Cross Country Canal	45.4950	-117.4369	05/25/23 - 10/07/23	126
MNM00001-000269	Minam River	Minam River	45.3557	-117.6322	09/03/15 - 09/26/16	376
10410-ORDEQ	Wallowa River at Minam	Wallowa River	45.6208	-117.7197	08/03/99 - 08/06/99	4
10722-ORDEQ	Wallowa River downstream of dam (Wallowa Street Park)	Wallowa River	45.3354	-117.2221	08/04/99 - 08/06/99	3
11457-ORDEQ	Minam River at Minam	Minam River	45.6197	-117.7279	08/01/99 - 08/06/99	6
11582-ORDEQ	Spring Creek upstream of ODFW hatchery settling pond (at entrance of hatchery)	Spring Creek	45.4170	-117.3004	08/04/99 - 08/06/99	3

Table A-3: Summary of continuous temperature data available in public databases in the Imnaha Subbasin. Result count indicates the number of 7DADM temperature results during the period or record. Data from DEQ files not in the databases were not summarized in the table.

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
21446-ORDEQ	Big Sheep Creek downstream of Little Sheep Creek	Big Sheep Creek	45.5222	-116.8590	06/30/99 - 09/20/99	83
34262-ORDEQ	Big Sheep Creek DS Lost Basin Creek (Imnaha)	Big Sheep Creek	45.5029	-116.8496	07/05/99 - 10/14/01	461
42038-ORDEQ	42038-ORDEQ	Big Sheep Creek	45.5202	-116.8600	05/22/22 - 11/13/23	323

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
42040-ORDEQ	42040-ORDEQ	Big Sheep Creek	45.1817	-117.0535	09/28/22 - 10/15/23	151
WWNF-012	BigSheep.07K.1_WT	Big Sheep Creek	45.4106	-116.8670	07/13/17 - 10/17/17	97
WWNF-013	BigSheep.07P.1_LTWT	Big Sheep Creek	45.2259	-117.0052	06/06/17 - 10/16/17	133
WWNF-014	BigSheep.07P.2_WT	Big Sheep Creek	45.2490	-117.0071	06/06/17 - 10/16/17	133
WWNF-015	BigSheep.07P.3_WT	Big Sheep Creek	45.2725	-116.9721	07/06/17 - 10/05/17	92
WWNF-016	BigSheep.07R.1_LTWT	Big Sheep Creek	45.1964	-117.0297	07/06/10 - 10/03/16	765
WWNF-017	BigSheep.07R.5_WT	Big Sheep Creek	45.1815	-117.0541	07/04/17 - 10/05/17	94
WWNF-207	BigSheep.07R.12	Big Sheep Creek	45.1781	-117.1054	06/07/00 - 09/15/00	101
25382-ORDEQ	Dry Creek at Road 39 crossing	Dry Creek	45.1171	-116.8617	05/15/01 - 09/17/01	94
WWNF-094	Grouse.09D.1_WT	Grouse Creek	45.3124	-116.8399	07/20/11 - 10/02/12	177
WWNF-095	Grouse.09D.2_WT	Grouse Creek	45.2963	-116.8748	07/02/15 - 10/06/19	531
WWNF-096	Grouse.09F.2_WT	Grouse Creek	45.2030	-116.9665	06/28/00 - 10/16/20	1015
WWNF-097	Gumboot.09K.1_LTWT	Gumboot Creek	45.1804	-116.8734	07/24/09 - 10/07/20	889
23234-ORDEQ	Imnaha River at mouth	Imnaha River	45.8165	-116.7649	07/31/99 - 09/20/99	52
42037-ORDEQ	42037-ORDEQ	Imnaha River	45.5558	-116.8357	05/22/22 - 11/13/23	323
Imnaha_River_0.1_RB	Imnaha River at river mile 0.1, right bank	Imnaha River	45.8108	-116.7604	10/09/01 - 03/09/19	5128
Imnaha_River_0.3_LC	Imnaha River at river mile 0.3, left half channel	Imnaha River	45.8145	-116.7632	09/15/15 - 09/17/19	1408
WWNF-230	Imnaha.09J.3	Imnaha River	45.2195	-116.8556	05/12/99 - 10/25/99	167
WWNF-231	Imnaha.09M.1	Imnaha River	45.1112	-117.0185	06/01/99 - 09/19/00	251
WWNF-111	Lick.07Q.1_LTWT	Lick Creek	45.1960	-117.0273	07/05/11 - 10/02/17	491
WWNF-112	Lick.07Q.2_WT	Lick Creek	45.1719	-117.0354	06/06/17 - 10/02/17	119
WWNF-113	Lick.07Q.3_WT	Lick Creek	45.1303	-117.0847	06/19/00 - 10/10/17	191
WWNF-114	Lick.07Q.4_WT	Lick Creek	45.1779	-117.0377	06/27/00 - 10/10/17	308
21447-ORDEQ	Little Sheep Creek upstream of Big Sheep Creek	Little Sheep Creek	45.5200	-116.8608	06/30/99 - 09/20/99	83
34265-ORDEQ	Little Sheep Creek DS Cottonwood Creek (Big Sheep, Imnaha)	Little Sheep Creek	45.5146	-116.8743	07/05/99 - 10/14/01	461

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
42039-ORDEQ	42039-ORDEQ	Little Sheep Creek	45.5170	-116.8677	05/22/22 - 11/13/23	323
WWNF-119	LittleSheep.07J.1_LTWT	Little Sheep Creek	45.2670	-117.0891	07/21/10 - 10/07/20	1168
WWNF-243	NFCarrol.07O.2	North Fork Carrol Creek	45.2960	-116.9917	07/20/00 - 10/16/00	89
WWNF-142	NFDry.09L.1_WT	North Fork Dry Creek	45.1378	-116.8642	06/19/08 - 10/05/09	198
WWNF-160	Salt.07R.2_LTWT	Salt Creek	45.1882	-117.0477	07/15/10 - 10/03/16	814
WWNF-175	Summit.09H.1_WT	Summit Creek	45.2933	-116.7982	06/19/08 - 09/29/10	308

Table A-4: Summary of continuous temperature data available in public databases in the Hells Canyon Subbasin. Result count indicates the number of 7DADM temperature results during the period or record. Data from DEQ files not in the databases were not summarized in the table.

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
Battle_Creek_0.12_MC	Battle Creek at river mile 0.12, mid channel	Battle Creek	45.3120	-116.6765	05/22/03 - 11/08/04	317
Battle_Creek_0.1_MC	Battle Creek at river mile 0.1, mid channel	Battle Creek	45.3120	-116.6764	05/22/03 - 11/08/04	256
Eureka_Creek_0.12_MC	Eureka Creek at river mile 0.12, mid channel	Eureka Creek	45.8230	-116.7756	05/11/04 - 07/12/04	63
Eureka_Creek_0.1_MC	Eureka Creek at river mile 0.1, mid channel	Eureka Creek	45.8230	-116.7755	05/21/03 - 07/12/04	127
Hat_Creek_0.12_MC	Hat Creek at river mile 0.12, mid channel	Hat Creek	45.3957	-116.6210	05/12/04 - 11/08/04	150
Hat_Creek_0.1_MC	Hat Creek at river mile 0.1, mid channel	Hat Creek	45.3957	-116.6210	05/22/03 - 11/08/04	228
Knight_Creek_0.12_MC	Knight Creek at river mile 0.12, mid channel	Knight Creek	45.8280	-116.7854	05/21/03 - 11/08/04	246
Knight_Creek_0.1_MC	Knight Creek at river mile 0.1, mid channel	Knight Creek	45.8280	-116.7854	05/21/03 - 11/08/04	246

Monitoring Location ID	Monitoring Location Name	Stream Name	Latitude	Longitude	Period of Record	Result Count
Pittsburg_Creek_0.12_MC	Pittsburg Creek at river mile 0.12, mid channel	Pittsburg Creek	45.6280	-116.4745	05/21/03 - 07/04/03	45
Pittsburg_Creek_0.1_MC	Pittsburg Creek at river mile 0.1, mid channel	Pittsburg Creek	45.6282	-116.4740	05/21/03 - 07/04/03	45
Rush_Creek_0.12_MC	Rush Creek at river mile 0.12, mid channel	Rush Creek	45.4503	-116.5814	05/22/03 - 11/09/04	320
Rush_Creek_0.1_MC	Rush Creek at river mile 0.1, mid channel	Rush Creek	45.4503	-116.5814	05/22/03 - 10/22/04	249
Saddle_Creek_0.12_MC	Saddle Creek at river mile 0.12, mid channel	Saddle Creek	45.3918	-116.6251	05/22/03 - 11/08/04	326
Saddle_Creek_0.1_MC	Saddle Creek at river mile 0.1, mid channel	Saddle Creek	45.3918	-116.6250	05/22/03 - 11/08/04	326
Salt_Creek_0.12_MC	Salt Creek at river mile 0.12, mid channel	Salt Creek	45.5533	-116.5274	05/13/04 - 11/09/04	174
Salt_Creek_0.1_MC	Salt Creek at river mile 0.1, mid channel	Salt Creek	45.5533	-116.5275	05/23/03 - 11/09/04	325
Sluice_Creek_0.12_MC	Sluice Creek at river mile 0.12, mid channel	Sluice Creek	45.4452	-116.5858	05/22/03 - 11/08/04	235
Sluice_Creek_0.1_MC	Sluice Creek at river mile 0.1, mid channel	Sluice Creek	45.4452	-116.5858	05/22/03 - 11/09/04	261
Somers_Creek_0.12_MC	Somers Creek at river mile 0.12, mid channel	Somers Creek	45.6844	-116.5309	05/23/03 - 11/08/04	326
Somers_Creek_0.1_MC	Somers Creek at river mile 0.1, mid channel	Somers Creek	45.6845	-116.5308	05/23/03 - 11/08/04	326
Temperance_Creek_0.12_MC	Temperance Creek at river mile 0.12, mid channel	Temperance Creek	45.5399	-116.5310	05/23/03 - 11/09/04	326
Temperance_Creek_0.1_MC	Temperance Creek at river mile 0.1, mid channel	Temperance Creek	45.5400	-116.5312	05/23/03 - 11/09/04	310
Tryon_Creek_0.12_MC	Tryon Creek at river mile 0.12, mid channel	Tryon Creek	45.6928	-116.5370	05/21/03 - 08/03/04	113
Tryon_Creek_0.1_MC	Tryon Creek at river mile 0.1, mid channel	Tryon Creek	45.6928	-116.5369	05/21/03 - 08/03/04	121

B. Appendix B Stream flow data summary

Table B-1: Continuous flow measurements stations available from the USGS and OWRD in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Period of Record	Complete Water Years
13292000	Imnaha River at Imnaha, OR	USGS	45.5624	-116.8338	10/01/1928 - 10/22/2013	85
13325000	East Fork Wallowa River Near Joseph, OR	USGS	45.2711	-117.2113	08/01/1924 - 11/20/202	49
13325500	Wallowa R Ab Wallowa Lake Nr Joseph, OR	OWRD	45.2749	-117.2115	02/01/1924 - 09/30/1941	11
13327000	Silver Lake Ditch At Joseph,OR	USGS	45.3332	-117.2204	05/07/1926 - 08/13/1991	52
13327500	Wallowa River At Joseph,OR	USGS	45.3374	-117.2274	11/01/1903 - 09/30/1991	61
13329500	Hurricane Creek near Joesph, OR	OWRD	45.3374	-117.2927	05/01/1915 - 09/30/1978	54
13329765	Wallowa R Nr Enterprise	OWRD	45.4751	-117.3875	10/21/2008 - 09/30/2015	6
13329770	Wallowa River above Cross Country Canal near Enterprise, OR	OWRD	45.4882	-117.4038	04/28/1995 - 06/24/2009	13
13330000	Lostine River near Lostine, OR	USGS	45.4388	-117.4274	09/01/1912 - 09/30/2012	84
13330050	Lostine River at Caudle Lane at Lostine, OR	OWRD	45.4897	-117.4366	08/01/1995 - 09/30/2024	11
13330300	Lostine River at Baker Road near Lostine	OWRD	45.4391	-117.4266	06/01/1995 - 09/30/2015	20

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Period of Record	Complete Water Years
13330500	Bear Creek near Wallowa, OR	USGS	45.5268	-117.5523	04/01/1915 - 10/31/2015	80
13330700	Bear Creek at Wallowa, OR	USGS	45.5806	-117.5403	05/09/1995 - 09/30/2003	8
13331450	Wallowa River below Water Canyon near Wallowa	OWRD	45.6089	-117.6161	08/16/1995 - 09/30/2012	17
13331500	Minam River at Minam, OR	USGS	45.6199	-117.7266	06/01/1912 - 02/11/2024	59
13332500	Grande Ronde R At Rondowa, OR	USGS	45.7265	-117.7841	10/01/1926 - 03/05/1996	68
13333000	Grande Ronde River at Troy, OR	OWRD	45.9457	-117.4511	10/01/1944 - 01/03/2024	79

Table B-2: Instantaneous flow measurements made by DEQ in the Lower Grande Ronde, Imnaha, and Wallowa Subbasins.

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Date	Time	Flow (cfs)
Field Site #1	Bear Creek at the mouth	DEQ	45.5782	-117.5456	1999-08-19	14:20	20
Field Site #2	Bear Creek upstream Little Bear	DEQ	45.4802	-117.5591	1999-08-19	13:40	31
24096-ORDEQ	Big Sheep Creek downstream Camp Creek	DEQ	45.5470	-116.8449	2000-08-29	14:02	42
Field Site #4	Big Sheep Creek upstream Lick Creek	DEQ	45.1950	-117.0323	2000-08-29		6
23595-ORDEQ	Freezeout Creek at Mouth (ODFW Fish Screen)	DEQ	45.4005	-116.7907	2000-08-29	8:40	1
24098-ORDEQ	Imnaha River downstream Freezeout Creek	DEQ	45.4000	-116.7910	2000-08-29	10:29	92
12661-ORDEQ	Imnaha River downstream Imnaha, OR	DEQ	45.6312	-116.8458	2000-08-29	12:15	148
24099-ORDEQ	Imnaha River downstream Mahogany Creek	DEQ	45.2054	-116.8655	1999-08-28		96
23042-ORDEQ	Imnaha River upstream Imnaha	DEQ	45.5024	-116.8084	2000-08-29	10:29	96
Field Site #14	Lick Creek upstream Lick Creek Campground	DEQ	45.1646	-117.0323	2000-08-29		3

Monitoring Location ID	Monitoring Location Name	Data Source	Latitude	Longitude	Date	Time	Flow (cfs)
Field Site #15	Little Bear Creek	DEQ	45.4840	-117.5479	1999-08-19	13:16	4
Field Site #16	Little Sheep Creek at Bear Gulch	DEQ	45.4979	-116.8994	1999-08-29	15:03	13
Field Site #17	Little Sheep Creek downstream Cabin Creek	DEQ	45.2337	-117.0866	2000-08-29		20
Field Site #19	Lostine River (Lake Creek Campground upstream Williamson)	DEQ	45.3463	-117.4160	1999-08-19	16:30	83
Field Site #18	Lostine River at 1st Bridge on Lostine Road	DEQ	45.4083	-117.4277	1999-08-19	15:56	110
Field Site #20	Lostine River at mouth	DEQ	45.5500	-117.4882	1999-08-19	15:14	99
Field Site #21	Lostine River upstream of French Camp	DEQ	45.2683	-117.3870	1999-08-18	10:31	56
Field Site #22	Minam River at Landing Strip	DEQ	45.3513	-117.6301	1999-08-21	17:16	127
Field Site #23	Minam River at mouth	DEQ	45.6203	-117.7224	1999-08-19	11:14	161
Field Site #24	Wallowa River at Evens Rd	DEQ	45.4957	-117.4119	1999-08-19	18:26	263
Field Site #25	Wallowa River upstream Minam River	DEQ	45.6220	-117.7131	1999-08-19	12:22	434

C. Appendix C: Distribution List

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