Final –
White Pine Creek Temperature TMDL

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Steve Bullock, Governor
Tracy Stone-Manning, Director DEQ

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Prepared by:
Water Quality Planning Bureau
Watershed Management Section

Contributors:
Water Quality Planning Bureau
Watershed Management Section
Eric Sivers, Temperature Project Manager

Montana Department of Environmental Quality
Water Quality Planning Bureau
1520 E. Sixth Avenue
P.O. Box 200901
Helena, MT 59620-0901

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ACRONYM LIST

Acronym	Definition
ARM	Administrative Rules of Montana
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practices
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
DOI	Department of the Interior (federal)
DOR	Department of Revenue (Montana)
EPA	Environmental Protection Agency (U.S.)
FLU	Final Land Unit
FWP	Fish, Wildlife & Parks (Montana)
GIS	Geographic Information System
HUC	Hydrologic Unit Code
IR	Integrated Report
LA	Load Allocation
MCA	Montana Code Annotated
MFISH	Montana Fisheries Information System
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NRCS	Natural Resources Conservation Service
QAPP	Quality Assurance Project Plan
RAWS	Remote Automatic Weather Station
RM	River Mile
SAP	Sampling and Analysis Plan
SSURGO	Soil Survey Geographic database
TMDL	Total Maximum Daily Load
USFS	United States Forest Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
UUILT	Ultimate Upper Incipient Lethal Temperature
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan

DOCUMENT SUMMARY

This document presents a total maximum daily load (TMDL) for White Pine Creek, an impaired stream in the Lower Clark Fork River Tributaries TMDL Planning Area (see **Figure 2-1** found in **Section 2.1**).

The Montana Department of Environmental Quality (DEQ) develops TMDLs and submits them to the U.S. Environmental Protection Agency (EPA) for approval. The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. TMDLs provide an approach to improve water quality so that streams and lakes can support and maintain their state-designated beneficial uses.

The project area is limited to the watershed of White Pine Creek, which is a stream included within the Lower Clark Fork River Tributaries TMDL Planning Area. The project area encompasses approximately 28.5 square miles (19,970 acres) in western Montana. The project area is entirely located within Sanders County.

DEQ determined that this waterbody does not meet the applicable temperature water quality standard (**Table DS-1**). A sediment TMDL was provided for White Pine Creek in 2010, along with sediment TMDLs for other streams in the Lower Clark Fork River Tributaries TMDL Planning Area (Montana Department of Environmental Quality, 2010).

TEMPERATURE

Temperature was identified as impairing aquatic life in White Pine Creek, and a TMDL was developed. Historic removal of riparian vegetation, which is important for regulating stream temperature by providing shade, is the primary cause of impairment. Water quality improvement goals focus on improving riparian shade, however, maintaining stable stream channel morphology and instream flow conditions during the hottest months of the summer are also important for meeting the TMDL. DEQ believes that once these water quality goals are met, all water uses currently affected by temperature will be restored given all reasonable land, soil, and water conservation practices.

White Pine Creek exceeds naturally occurring maximum daily water temperatures by 4%. The example TMDL, provided in **Section 5.6**, shows necessary percent reduction of 4%. General strategies for achieving the instream water temperature reduction goals are also presented in this plan.

WATER QUALITY IMPROVEMENT MEASURES

Implementation of most water quality improvement measures described in this document is based on voluntary actions of watershed stakeholders. Ideally, local watershed groups and/or other watershed stakeholders will use this TMDL document, and associated information, as a tool to guide local water quality improvement activities. Such activities can be documented within a watershed restoration plan consistent with DEQ and EPA recommendations.

An adaptive approach to most nonpoint source TMDL implementation activities may be necessary as more knowledge is gained through implementation and future monitoring. This document includes a monitoring strategy designed to track progress in meeting TMDL objectives and goals and to help refine the plan during its implementation.

Although most water quality improvement measures are based on voluntary measures, federal law specifies permit requirements developed to protect narrative water quality criterion, a numeric water quality criterion, or both, to be consistent with the assumptions and requirements of wasteload allocations (WLAs) on streams were TMDLs have been developed and approved by EPA.

Table DS-1. Impairment cause, associated impaired use, and TMDL contained in this document

Waterbody and Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
White Pine Creek, headwaters to mouth (Clark Fork River)	Temperature	Temperature	Aquatic Life

1.0 Project Overview

This document presents an analysis of water quality information and establishes a total maximum daily load (TMDL) for temperature problems in White Pine Creek. This document also presents a general framework for resolving these problems. **Figure 2-1**, found in **Section 2.1**, shows a map of White Pine Creek and the surrounding area.

1.1 Why We Write TMDLs

In 1972, the U.S. Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act (CWA). The CWA's goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The CWA requires each state to designate uses of their waters and to develop water quality standards to protect those uses.

Montana's water quality designated use classification system includes the following:

- fish and aquatic life
- wildlife
- recreation
- agriculture
- industry
- drinking water

Each waterbody in Montana has a set of designated uses from the list above. Montana has established water quality standards to protect these uses, and a waterbody that does not meet one or more standards is called an impaired water. Each state must monitor their waters to track if they are supporting their designated uses, and every two years the Montana Department of Environmental Quality (DEQ) prepares a Water Quality Integrated Report (IR) which lists all impaired waterbodies and their identified impairment causes. Impairment causes fall within two main categories: pollutant and non-pollutant.

Montana's biennial IR identifies all the state's impaired waterbody segments. The 303(d) list portion of the IR includes all of those waterbody segments impaired by a pollutant, which require a TMDL, whereas TMDLs are not required for non-pollutant causes of impairments. **Table 1-1** identifies all impairments for White Pine Creek, including non-pollutant impairment causes, included in Montana's "2014 Water Quality Integrated Report" (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014a). **Table 1-1** provides the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal CWA require the development of total maximum daily loads for all impaired waterbodies when water quality is impaired by a pollutant. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

Developing TMDLs and water quality improvement strategies includes the following components, which are further defined in **Section 4.0**:

- Determining measurable target values to help evaluate the waterbody's condition in relation to the applicable water quality standards

- Quantifying the magnitude of pollutant contribution from their sources
- Determining the TMDL for each pollutant based on the allowable loading limits for each waterbody-pollutant combination
- Allocating the total allowable load (TMDL) into individual loads for each source

In Montana, restoration strategies and monitoring recommendations are also commonly incorporated in TMDL documents to help facilitate TMDL implementation (see **Section 6.0** of this document). The White Pine Creek watershed is already included within an Environmental Protection Agency (EPA) approved TMDL document that provides a general restoration framework (Montana Department of Environmental Quality, 2010), as well as a DEQ-approved watershed restoration plan, prepared in 2010 for the Lower Clark Fork Watershed (Miller, 2010).

Basically, developing a TMDL for an impaired waterbody is a problem-solving exercise: The problem is excess pollutant loading that impairs a designated use. The solution is developed by identifying the total acceptable pollutant load (the TMDL), identifying all the significant pollutant-contributing sources, and identifying where pollutant loading reductions should be applied to achieve the acceptable load.

1.2 Water Quality Impairments and TMDLs Addressed by this Document

Table 1-1 below lists all of the impairment causes from the “2014 Water Quality Integrated Report” (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014a) that are addressed in this document (also see **Figure 2-1** in **Section 2.1**). Each pollutant impairment falls within a TMDL pollutant category (e.g., sediment, nutrients, and temperature). This document addresses only temperature impairment. A sediment TMDL was developed in 2010 to address the other impairment causes.

TMDLs are completed for each waterbody – pollutant combination, and this document contains one TMDL (**Table 1-1**).

Table 1-1. Water quality impairment causes for the White Pine Creek TMDL Project Area addressed within this document

Waterbody and Location Description[1]	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status
White Pine Creek, headwaters to mouth (Beaver Creek)	MT76N003_120	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a TMDL in a previous document (Montana Department of Environmental Quality, 2010)
		Sedimentation/Siltation	Sediment	Sediment TMDL provided in previous document (Montana Department of Environmental Quality, 2010)
		Temperature, water	Temperature	Temperature TMDL provided in this document

[1] All waterbody segments within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset (NHD)

1.3 WHAT THIS DOCUMENT CONTAINS

This document addresses all of the required components of a TMDL and includes an implementation and monitoring strategy. The TMDL components are summarized within the main body of the document. Additional technical details are contained in the appendices. In addition to this introductory section, this document includes:

Section 2.0 White Pine Creek Project Area Description:
Describes the physical characteristics and social profile of the project area.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to White Pine Creek.

Section 4.0 Defining TMDLs and Their Components
Defines the components of TMDLs and how each is developed.

Sections 5.0 Temperature TMDL Components:
This section includes (a) a discussion of the affected waterbody and the pollutant's effect on designated beneficial uses, (b) the information sources and assessment methods used to evaluate stream health and pollutant source contributions, (c) water quality targets and existing water quality conditions, (d) the quantified pollutant loading from the identified sources, (e) the determined TMDL, (f) the allocations of the allowable pollutant load to the identified sources.

Section 6.0 Monitoring Strategy and Adaptive Management:
Describes methods for future monitoring of temperature-influencing variables, as well as a strategy for adaptive management to respond to changing conditions or improved source assessment.

Section 7.0 Public Participation & Public Comments:
Describes other agencies and stakeholder groups who were involved with the development of this plan and the public participation process used to review the draft document. Addresses comments received during the public review period.

2.0 Project Area Description

This section describes the physical, ecological, and social characteristics of the White Pine Creek watershed ("project area"). These descriptions provide a context for the more detailed pollutant source assessments presented in following chapters.

2.1 Physical Characteristics

The following information describes the physical geography of the project area. This includes location, topography, climate, hydrology, and geology.

2.1.1 Location

The project area is the White Pine Creek watershed, which occupies 28.48 square miles (19,970 acres) in western Montana, near the town of Trout Creek. The location is mapped below in **Figure 2-1**.

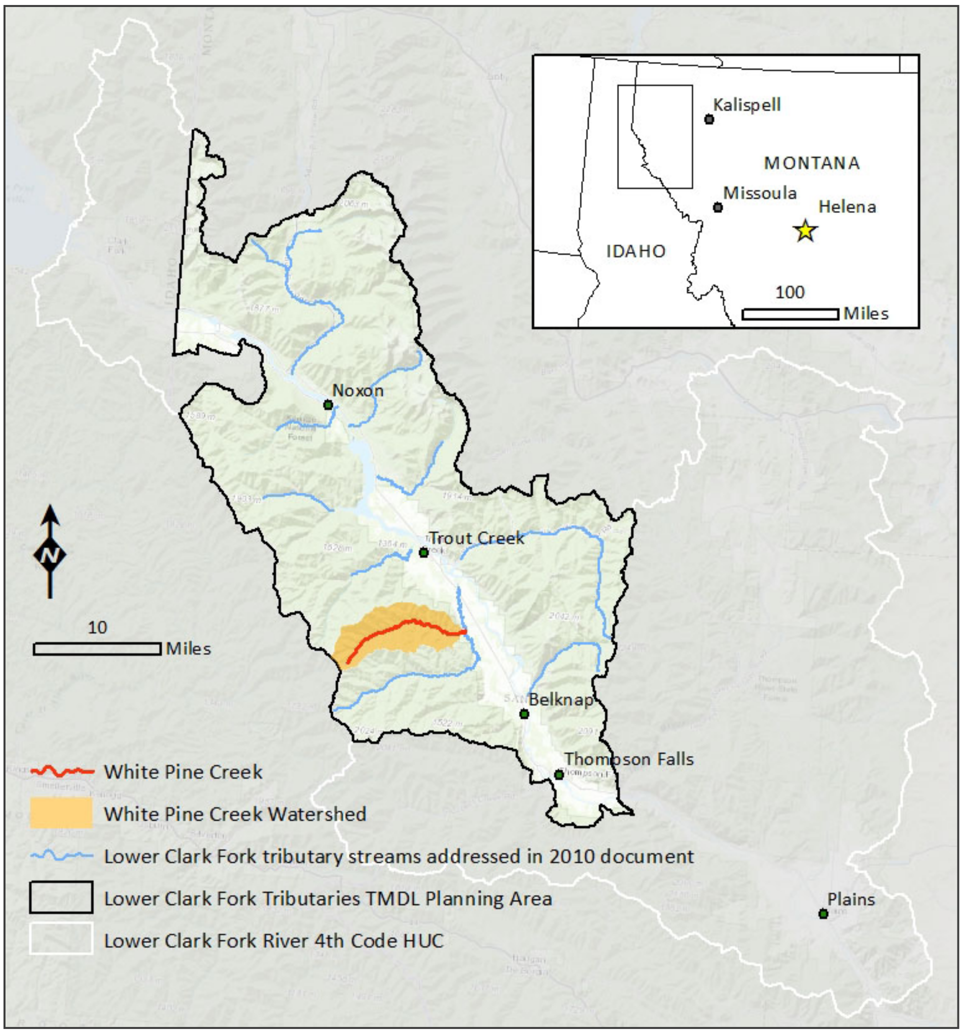


Figure 2-1. Location of White Pine Creek

2.1.2 Topography

The topography is mapped below in **Figure 2-2**. Elevation ranges from 6,538 feet in the headwaters to 2,460 feet at the confluence with Beaver Creek.

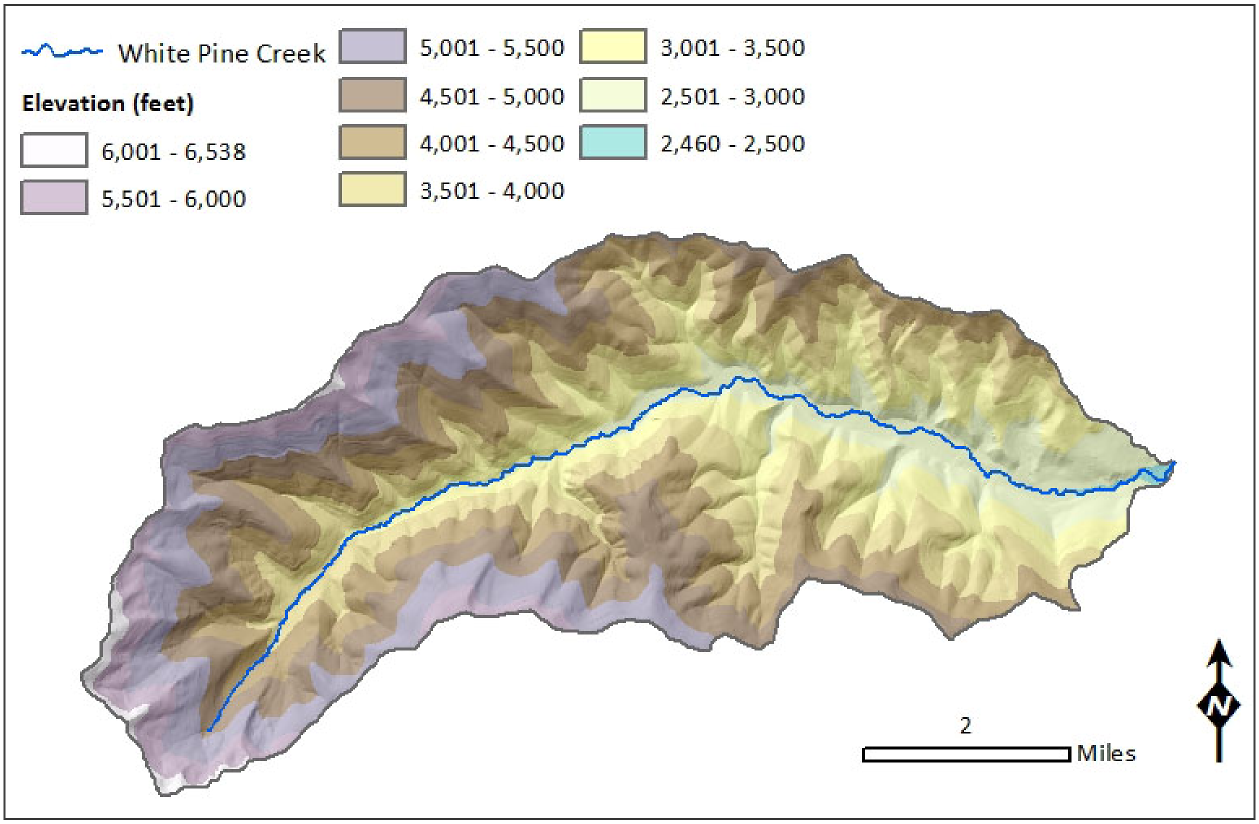


Figure 2-2. Topography of the White Pine Creek watershed

2.1.3 Climate

Average precipitation in the White Pine Creek watershed ranges from just over 27 inches per year near the mouth to just under 55 inches per year at the headwaters, according to climate summaries provided by the Western Regional Climate Center (http://www.wrcc.dri.edu/summary/Climsmnidwmt.html). May and June are consistently the wettest months of the year and winter precipitation is dominated by snowfall. Average annual precipitation is mapped below in **Figure 2-3**.

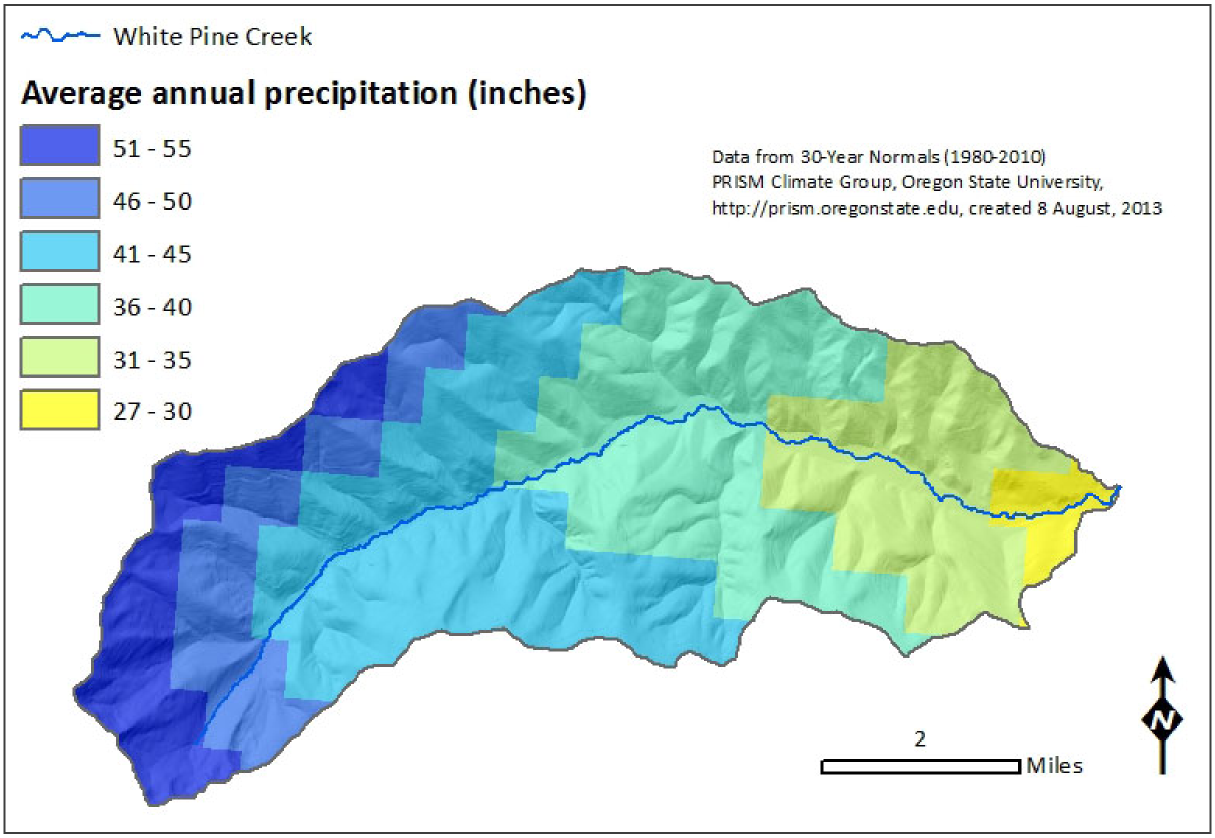


Figure 2-3. Average annual precipitation of the White Pine Creek watershed

A map of average annual temperatures is provided below (**Figure 2-4**). The climate is similar to the Plains Valley, a lower elevation intermontane basin typical of the Northern Rockies with warm summers and cool, humid winters (Kendy and Tresch, 1996).

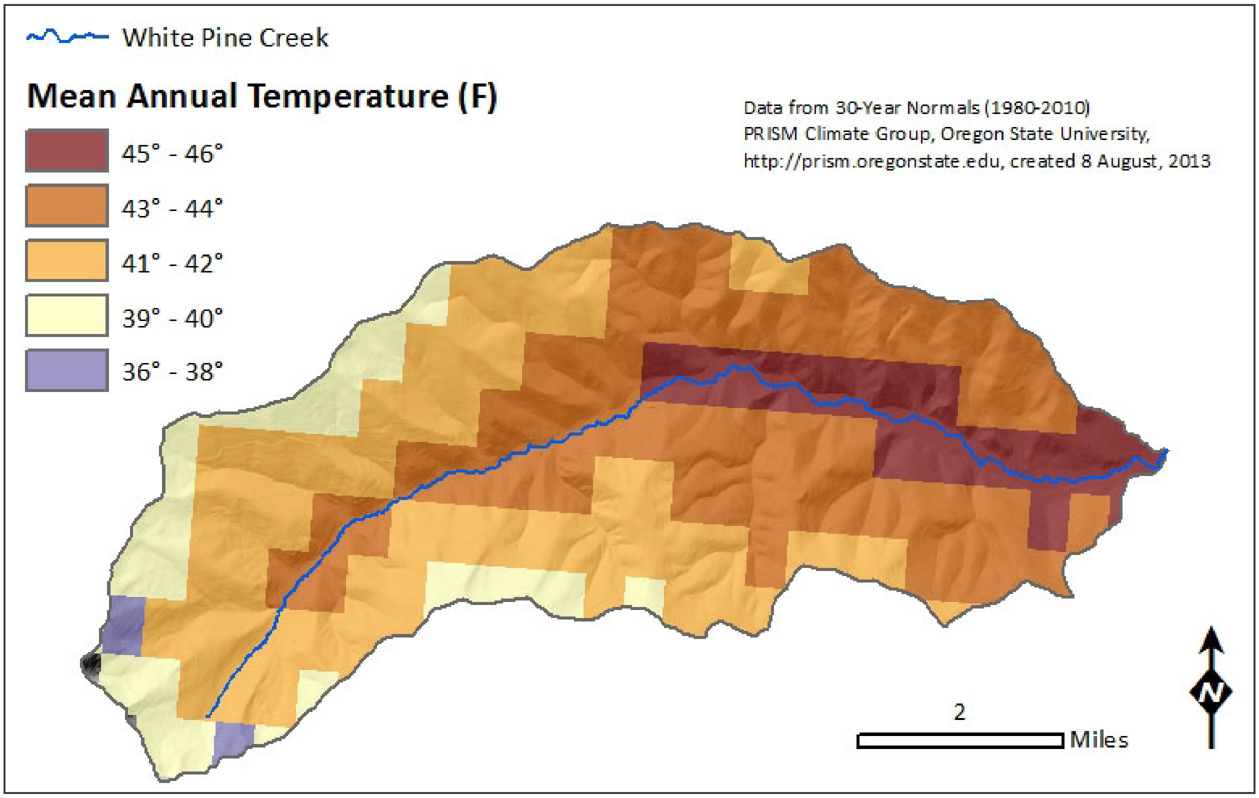


Figure 2-4. Average annual temperatures of the White Pine Creek watershed

2.1.4 Hydrology

White Pine Creek is a first- and second-order stream, with several first-order tributaries. The drainage is mapped below in **Figure 2-5**. White Pine Creek flows into Beaver Creek, a tributary to the Clark Fork River. The White Pine Creek watershed is a 6th Code HUC (Hydrologic Unit Code) (170102130703), located within the Lower Clark Fork 4th Code HUC (17010213). The Lower Clark Fork 4th Code HUC also includes the Thompson River drainage, and extends into Idaho, ending at Lake Pend Oreille.

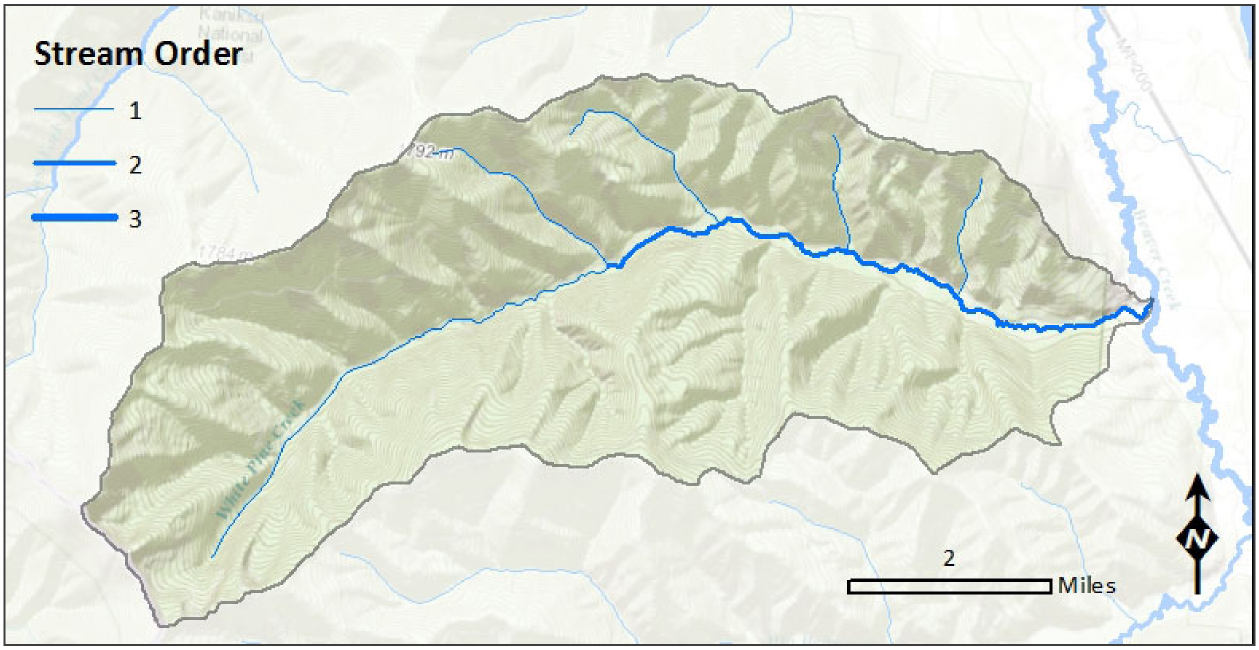


Figure 2-5. Hydrography of the White Pine Creek watershed

White Pine Creek is not monitored by any United States Geological Survey (USGS) gaging stations. Streamflow generally follows a hydrograph typical for the region, highest in May and June. These are the months with the greatest amount of precipitation and snowmelt runoff. Streamflow begins to decline in late June or early July, reaching minimum flow levels in September. Streamflow begins to rebound in October and November when fall storms supplement the base-flow levels. White Pine Creek typically goes dry in its middle reach, where the substrate is composed of cobble-boulder bed material deposited in the wake of massive fires and timber cutting in the early 20th Century.

2.1.5 Geology and Soils

Bedrock in the White Pine Creek watershed is dominated by Precambrian Belt Series metasedimentary rocks. Minor Quaternary deposits of glacial sediments and alluvium are mapped near the valley mouth and bottom, respectively. The project area geology is mapped below in **Figure 2-6,** based on work mapping by Harrison et al. (2000).

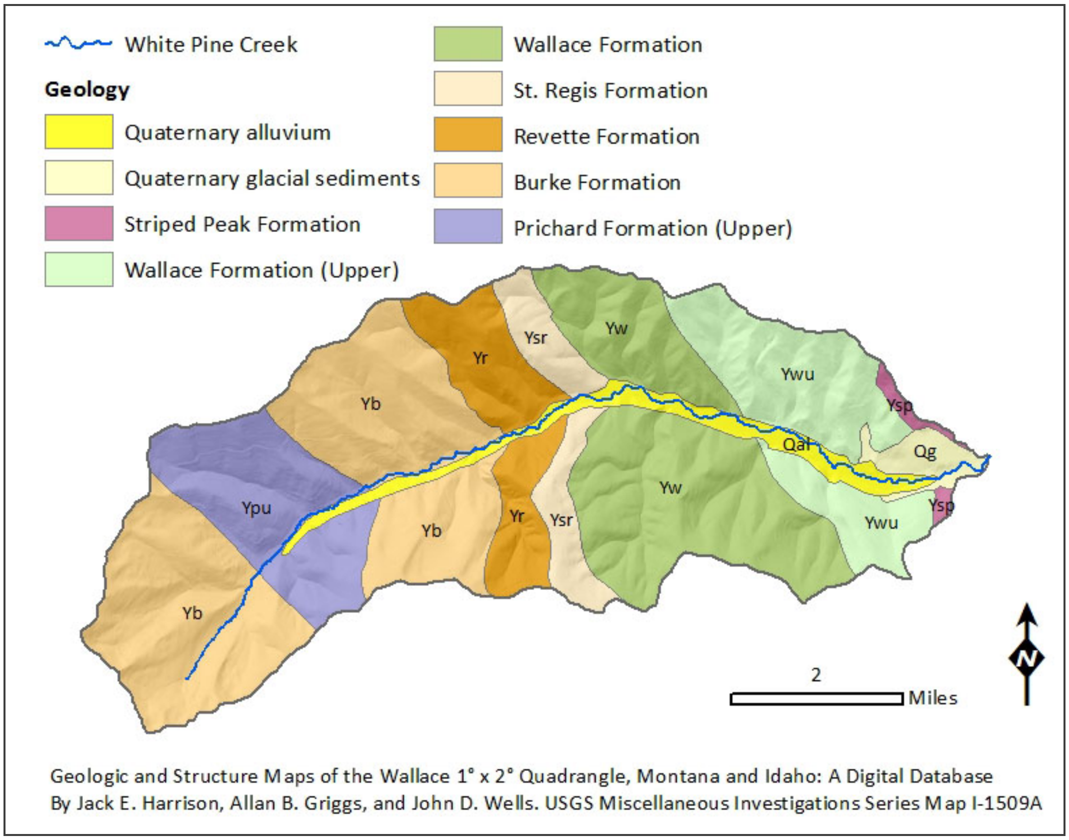


Figure 2-6. Generalized geology of the White Pine Creek watershed

The USGS Water Resources Division (Schwarz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the United States Department of Agriculture, Natural Resources Conservation Service (NRCS) STATSGO soil database. The STATSGO data are intended for small-scale (watershed or larger) mapping, and is too general to be used at scales larger than 1:250,000. It is important to realize, therefore, that each soil unit in the STATSGO data may include up to 21 soil components. Soil analysis at a larger scale should use NRCS SSURGO (Soil Survey Geographic database) data.

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier and Smith, 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped below in **Figure 2-7**, with soil units assigned to the following ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of >0.4 are considered highly susceptible to erosion. Despite the steep and rugged topography, the majority of the project area is mapped with soils rated as having low and moderate-low erodibility. No values greater than 0.34 are mapped in the project area. The moderate-high erodibility soils are mapped in the lower part of the valley, generally coinciding with areas of bank instability (Montana Department of Environmental Quality, 2010).

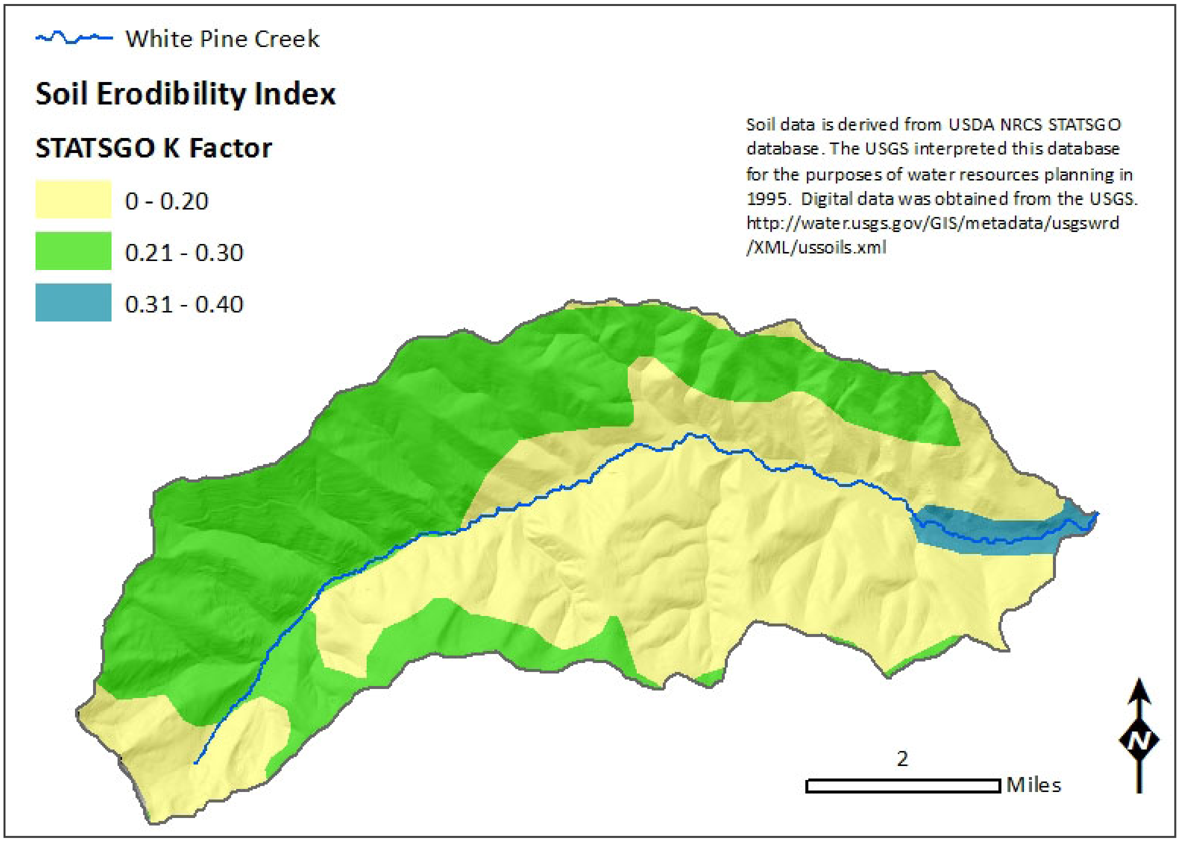


Figure 2-7. Soil erodibility of the White Pine Creek watershed

2.2 Ecological Profile

This section describes the ecology of the project area, including the ecoregions mapped within it, land cover, fire history, and fish species of concern.

2.2.1 Ecoregions

The White Pine Creek watershed is located within the Northern Rockies Level III Ecoregion (Woods et al., 2002). Three Level IV Ecoregions are mapped within the White Pine Creek watershed, as shown below in **Figure 2-8**. More detailed information about the ecoregions is available on the Internet at: http://www.epa.gov/wed/pages/ecoregions/mt_eco.htm.

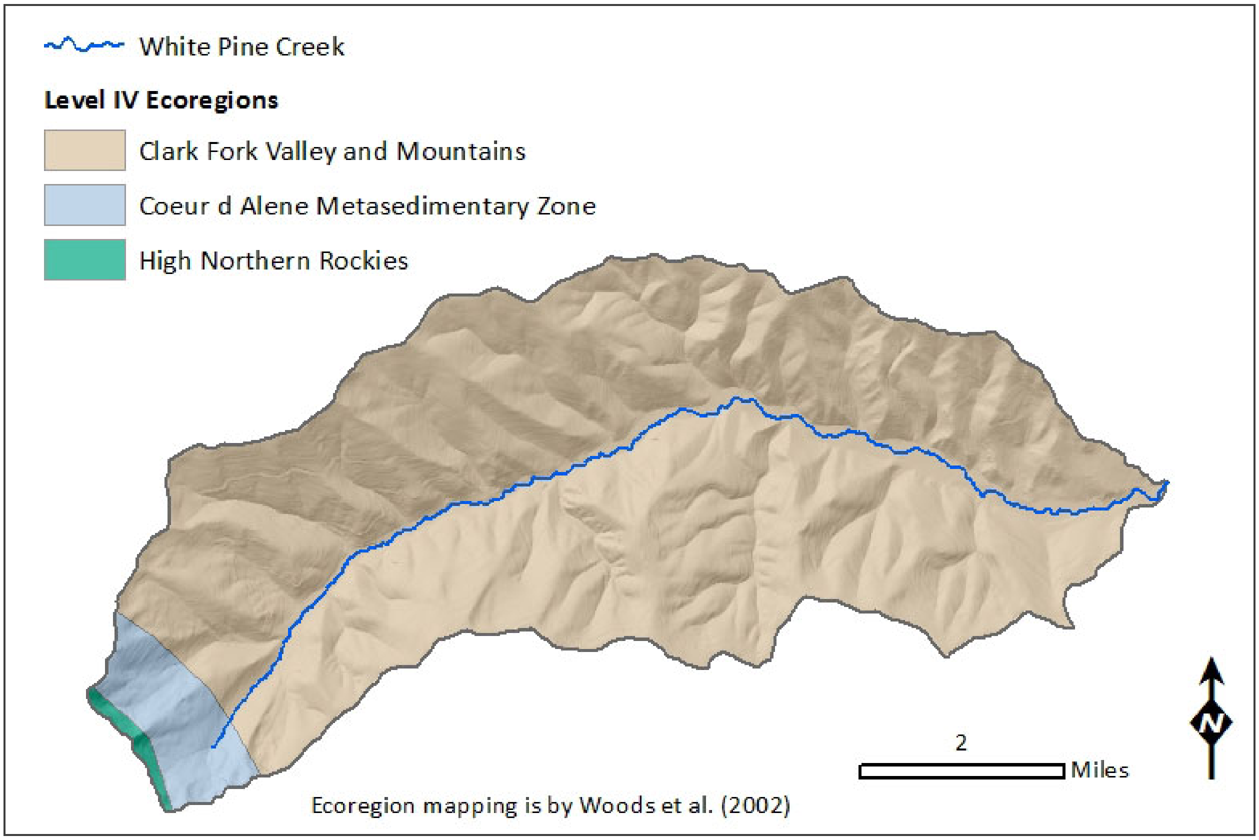


Figure 2-8. Level IV ecoregions in the White Pine Creek watershed

2.2.2 Land Cover

Land cover is mapped below in **Figure 2-9**, based on the USGS National Land Cover Dataset (NLCD) (Fry et al., 2011). As apparent in this figure, the project area is dominated by evergreen forest in the uplands, and woody/emergent wetlands in the lowlands. Hay/pasture and cultivated crops are present in isolated areas.

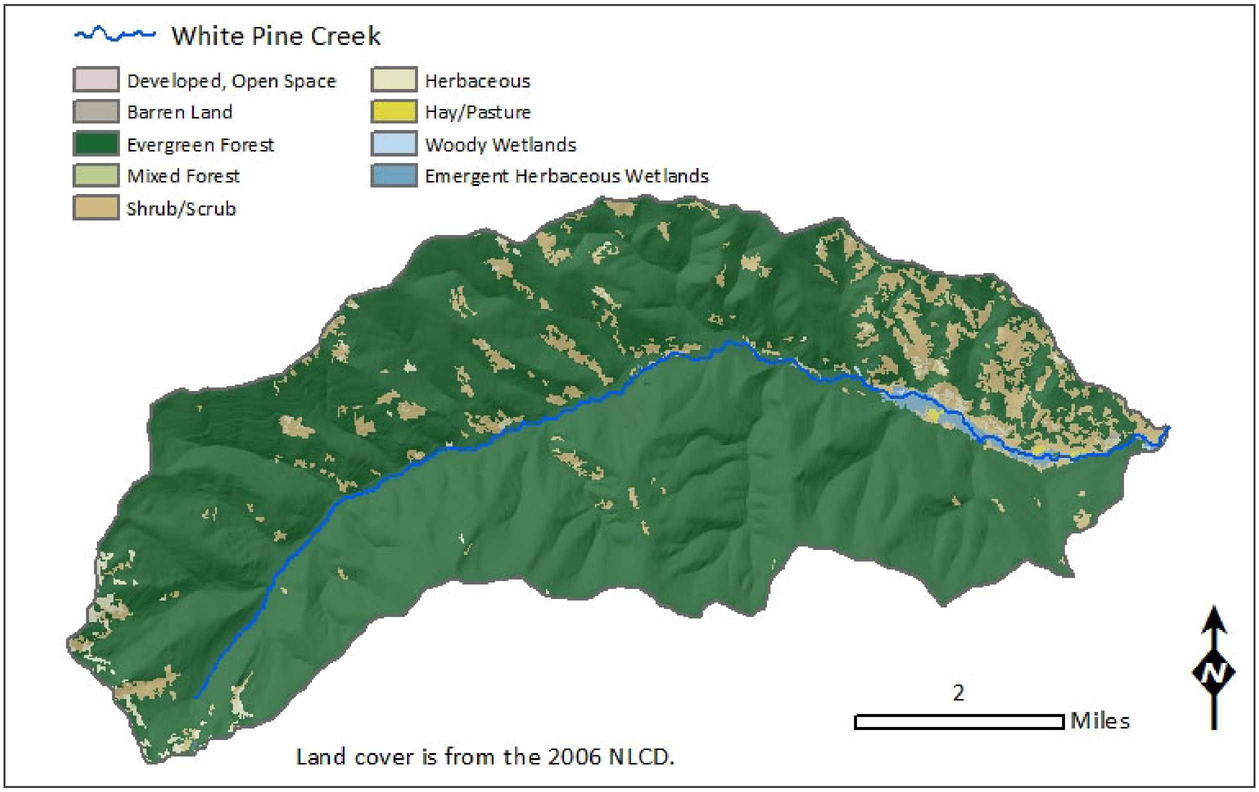


Figure 2-9. Land cover in the White Pine Creek watershed

2.2.3 Fire History

Fire history (1889-2013) is mapped below in **Figure 2-10**. Large regions of the project area burned in the late 19th and early 20th Centuries.

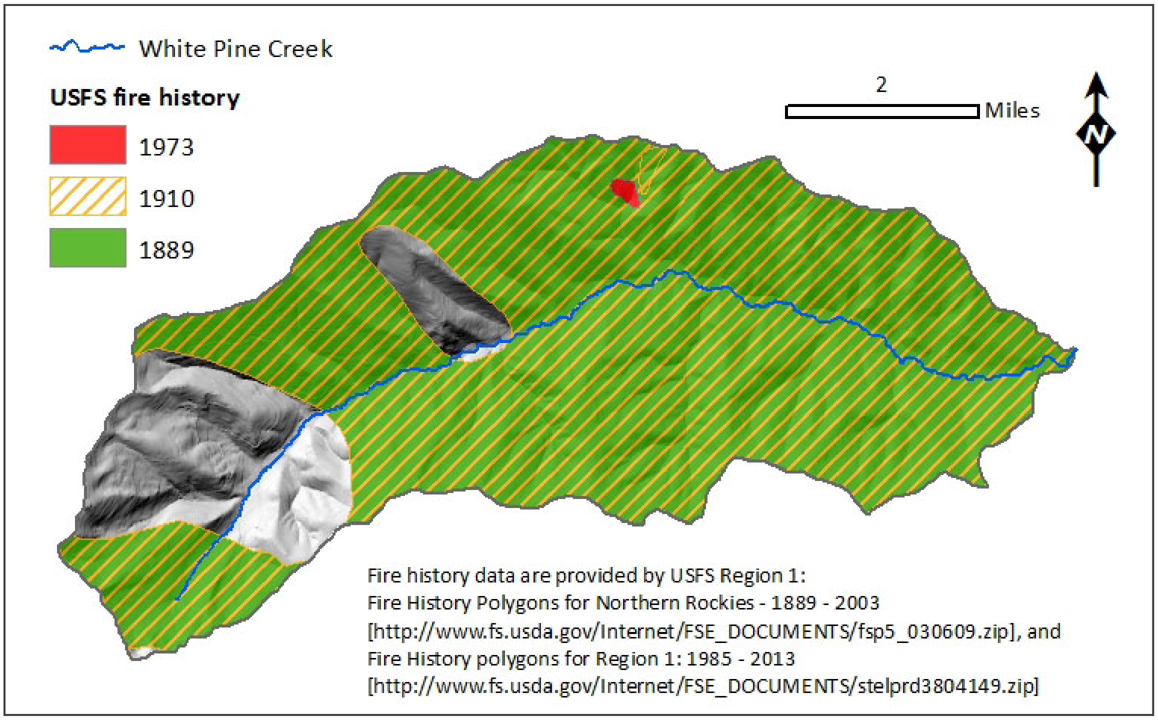


Figure 2-10. Fire history (1889–2013) of White Pine Creek watershed

2.2.4 Fish Distribution

The fishery is dominated by brook trout, although both bull trout, which is considered a threatened species by the US Fish and Wildlife Service, and westslope cutthroat trout, a Montana Species of Concern have been recorded. The mapped distribution of both these species is shown below in **Figure 2-11**, based on data provided by Montana Fish, Wildlife, and Parks (2014).

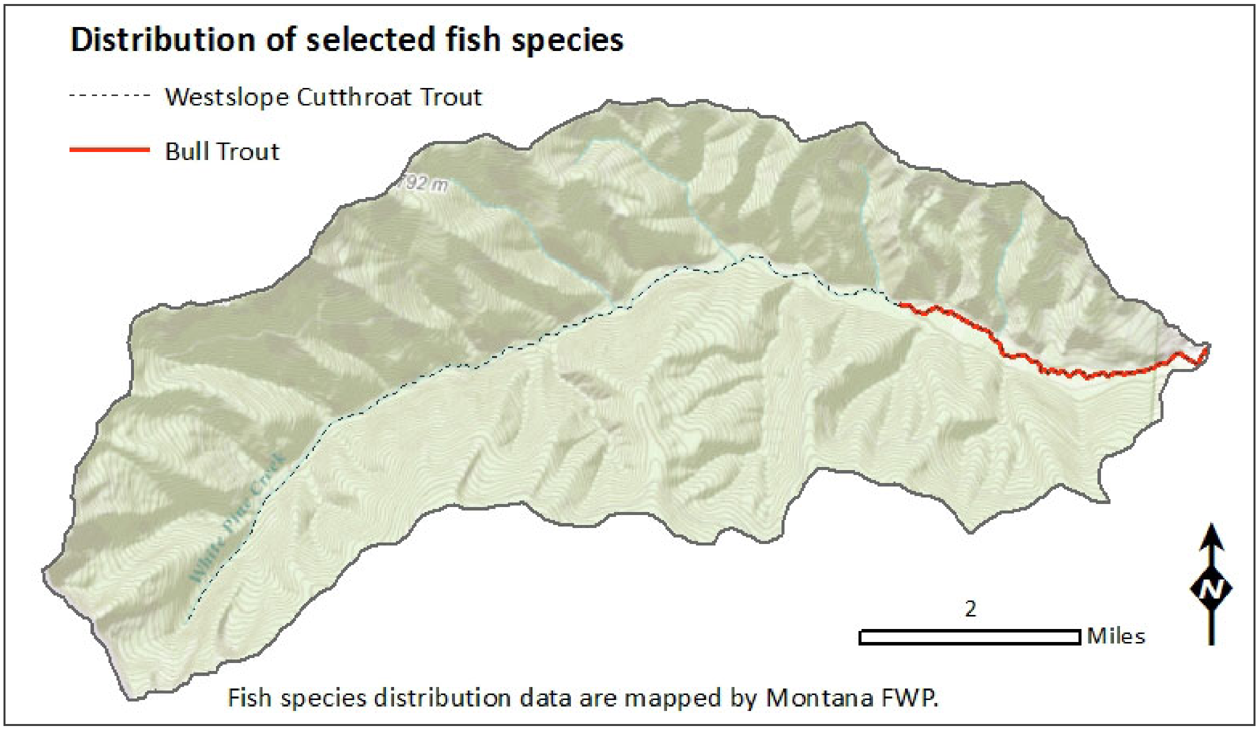


Figure 2-11. Westslope Cutthroat Trout and Bull Trout distribution in White Pine Creek

2.3 Social Profile

The following section describes the human geography of the project area. This includes population distribution, land ownership, and land management.

2.3.1 Population Density

There are no census geometries that exactly correspond to the project area, but the resident population is low, based on 2010 census Geographic Information System (GIS) files. Large areas of United States Forest Service (USFS) land are uninhabited, although there are isolated inholdings. Population density is mapped below in **Figure 2-12**.

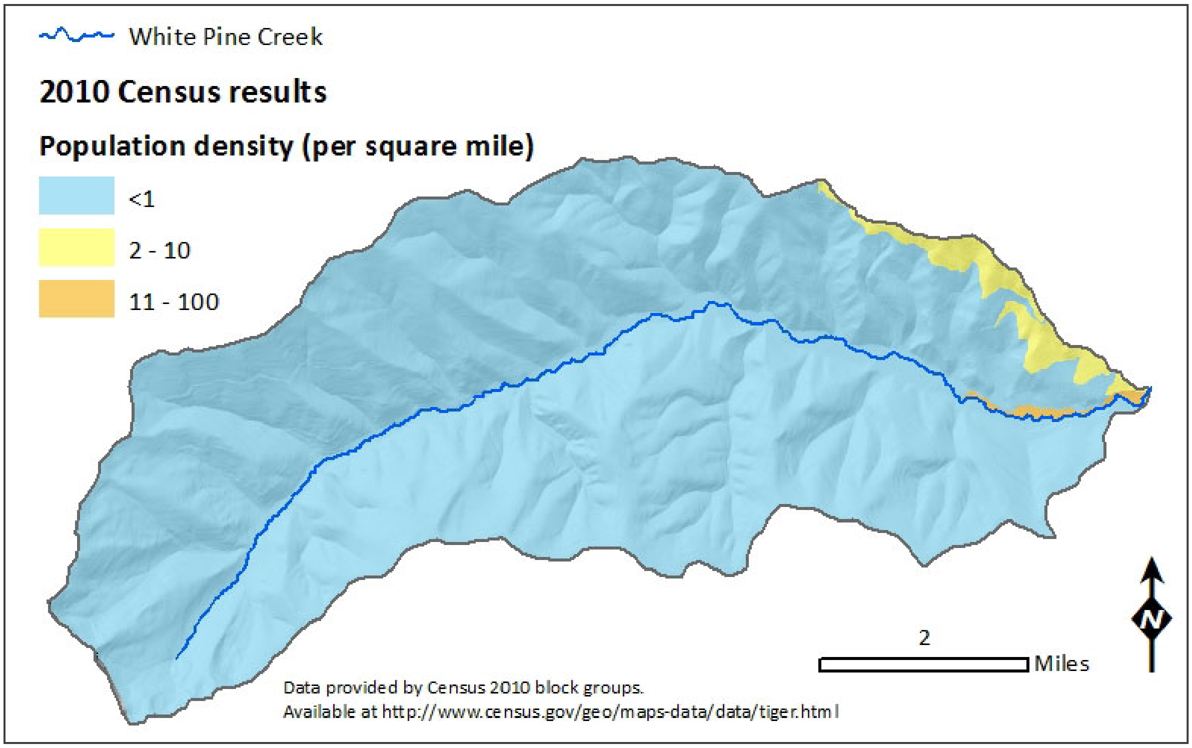


Figure 2-12. Population density of the White Pine Creek watershed

2.3.2 Land Management

Federal lands managed by the U.S. Forest Service (USFS) dominate the project area. Smaller tracts of private land are located in the valley bottom, along White Pine Creek and around the valley mouth. Land management is mapped below in **Figure 2-13**.

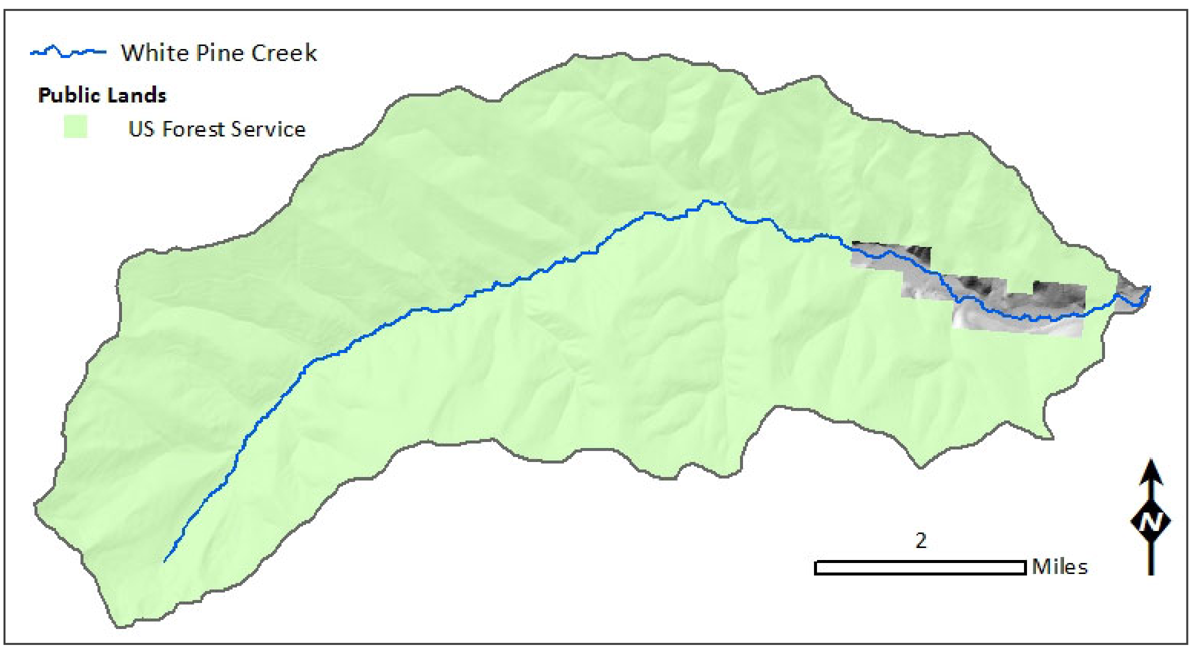


Figure 2-13. Land management of the White Pine Creek watershed

2.3.3 Agricultural Land Use

Montana Department of Revenue (DOR) assesses agricultural land for taxation. The resulting dataset is known as the Final Land Unit (FLU) classification. The agricultural uses were determined by DOR GIS specialists, and confirmed by maps sent to private landholders for verification. The FLU data are available at: ftp://ftp.geoinfo.msl.mt.gov/Data/Spatial/NonMSDI/Geodatabases/revenue_flu.zip. Agricultural uses as determined in the FLU are mapped below in **Figure 2-14**. The only agricultural uses identified are forest land and grazing. No USFS grazing allotments are identified. As evident in the land cover map above (**Figure 2-9**), forest dominates the project area.

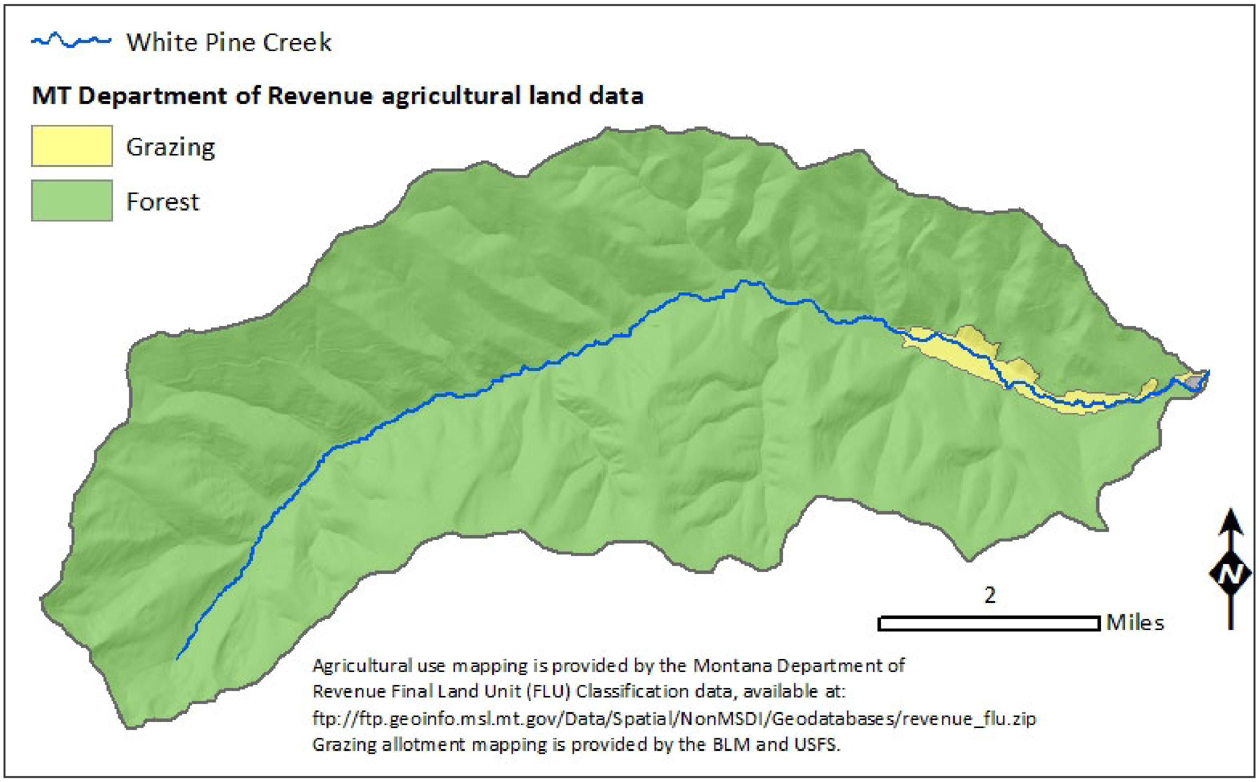


Figure 2-14. Agricultural use and grazing allotments in the White Pine Creek watershed

3.0 MONTANA WATER QUALITY STANDARDS

The federal Clean Water Act provides for the restoration and maintenance of the chemical, physical, and biological integrity of the nation's surface waters so that they support all designated uses. Water quality standards are used to determine impairment, establish water quality targets, and to formulate the total maximum daily loads (TMDLs) and allocations.

Montana's water quality standards and water quality standards in general include three main parts:

1. Stream classifications and designated uses
2. Numeric and narrative water quality criteria designed to protect designated uses
3. Nondegradation provisions for existing high-quality waters

Montana's water quality standards also incorporate prohibitions against water quality degradation as well as point source permitting and other water quality protection requirements.

Nondegradation provisions are not applicable to the TMDLs developed within this document because of the impaired nature of the streams addressed. Those water quality standards that apply to this document are reviewed briefly below. More detailed descriptions of Montana's water quality standards may be found in the Montana Water Quality Act (75-5-301,302 Montana Code Annotated (MCA)), and Montana's Surface Water Quality Standards and Procedures (Administrative Rules of Montana (ARM) 17.30.601-670) and Circular DEQ-7 (Montana Department of Environmental Quality, 2012).

3.1 STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Waterbodies are classified based on their designated uses. All Montana waters are classified for multiple uses. White Pine Creek is classified as B-1. Waters classified as B-1 are to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. While some of the waterbodies might not actually be used for a designated use (e.g., drinking water supply), their water quality still must be maintained suitable for that designated use. More detailed descriptions of Montana's surface water classifications and designated uses are provided in **Appendix A**. Department of Environmental Quality's (DEQ) water quality assessment methods are designed to evaluate the most sensitive uses for each pollutant group addressed within this document, thus ensuring protection of all designated uses (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011). For streams in Western Montana, the most sensitive use assessed for sediment and turbidity is aquatic life and for temperature is aquatic life. DEQ determined that White Pine Creek does not meet the temperature water quality standard (**Table 3-1**).

Table 3-1. White Pine Creek's impaired use and associated impairment causes

Waterbody and Location Description	Waterbody ID	Impairment Cause	Impaired Use(s)
White Pine Creek, headwaters to mouth (Beaver Creek	MT76N003_120	Alteration in streamside or littoral vegetative covers	Aquatic Life
		Sedimentation/Siltation	Aquatic Life
		Temperature, water	Aquatic Life

3.2 Numeric and Narrative Water Quality Standards

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria that protect the designated uses. Numeric criteria define the allowable concentrations, frequency, and duration of specific pollutants so as not to impair designated uses.

Numeric standards apply to pollutants that are known to have adverse effects on human health or aquatic life (e.g., metals, organic chemicals, and other toxic constituents). These include human health standards and aquatic life standards. Numeric standards for aquatic life include chronic and acute values. Numeric standards also apply to other designated uses such as protecting irrigation and stock water quality for agriculture.

Narrative standards are developed when there is insufficient information to develop numeric standards and/or the natural variability makes it impractical to develop numeric standards. Narrative standards describe the allowable or desired condition. This condition is often defined as an allowable increase above "naturally occurring." DEQ often uses the naturally occurring condition, called a "reference condition," to help determine whether or not narrative standards are being met (see **Appendix A**).

For the White Pine Creek temperature TMDL project, a narrative standard applies. Because stream temperatures change throughout the course of a day, the temperature TMDL is expressed as the instantaneous thermal load associated with the stream temperature when in compliance with Montana's water quality standards. The temperature standard is defined as follows: The maximum allowable increase over the naturally occurring temperature is 1°F, when the naturally occurring temperature is less than 66°F. Within the naturally occurring temperature range of 66–66.5°F, the allowable increase cannot exceed 67°F. If the naturally occurring temperature is greater than 66.5°F, the maximum allowable increase is 0.5°F. Montana's temperature standard is depicted in **Figure 3-1**.

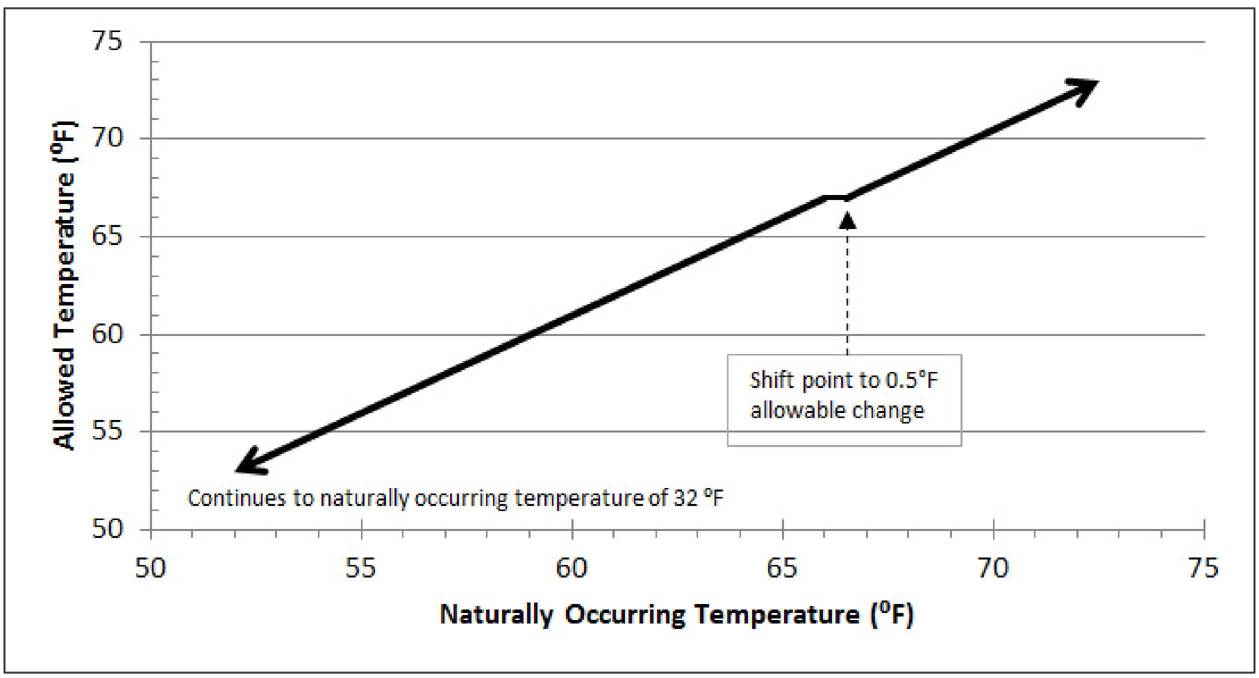


Figure 3-1. Line graph of the temperature standard that applies to White Pine Creek

4.0 Defining TMDLs and Their Components

A total maximum daily load (TMDL) is a tool for implementing water quality standards and is based on the relationship between pollutant sources and water quality conditions. More specifically, a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive from all sources and still meet water quality standards.

Pollutant sources are generally defined as two categories: point sources and nonpoint sources. Point sources are discernible, confined and discrete conveyances, such as pipes, ditches, wells, containers, or concentrated animal feeding operations, from which pollutants are being, or may be, discharged. Some sources such as return flows from irrigated agriculture are not included in this definition. All other pollutant loading sources are considered nonpoint sources. Nonpoint sources are diffuse and are typically associated with runoff, streambank erosion, most agricultural activities, atmospheric deposition, and groundwater seepage. Natural background loading is a type of nonpoint source.

As part of TMDL development, the allowable load is divided among all significant contributing point and nonpoint sources. For point sources, the allocated loads are called “wasteload allocations” (WLAs). For nonpoint sources, the allocated loads are called “load allocations” (LAs).

A TMDL is expressed by the equation: TMDL = ΣWLA + ΣLA, where:

ΣWLA is the sum of the wasteload allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)

TMDL development must include a margin of safety (MOS), which can be explicitly incorporated into the above equation. Alternatively, the MOS can be implicit in the TMDL. A TMDL must also ensure that the waterbody will be able to meet and maintain water quality standards for all applicable seasonal variations (e.g., pollutant loading or use protection).

Development of each TMDL has four major components:

- Determining water quality targets
- Quantifying pollutant sources
- Establishing the total allowable pollutant load
- Allocating the total allowable pollutant load to their sources

Although the way a TMDL is expressed can vary by pollutant, these four components are common to all TMDLs, regardless of pollutant. Each component is described in further detail in the following subsections.

Figure 4-1 illustrates how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

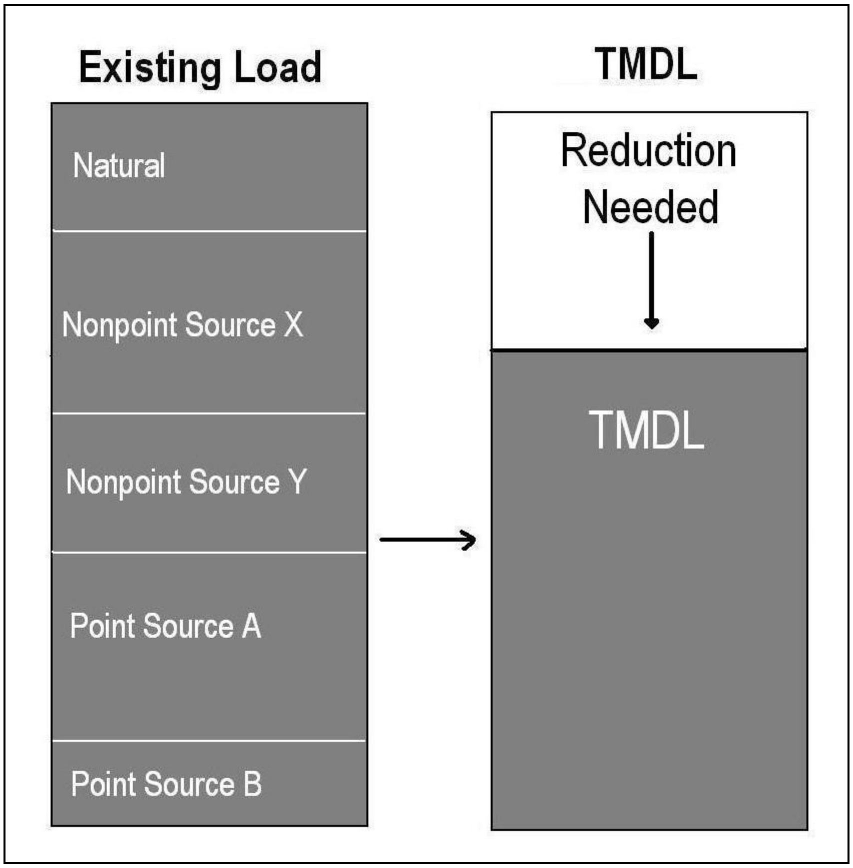


Figure 4-1. Schematic example of TMDL development

4.1 Developing Water Quality Targets

TMDL water quality targets are a translation of the applicable numeric or narrative water quality standard(s) for each pollutant. For pollutants with established numeric water quality standards, the numeric value(s) are used as the TMDL targets. For pollutants with narrative water quality standard(s), the targets provide a waterbody-specific interpretation of the narrative standard(s).

Water quality targets are typically developed for multiple parameters that link directly to the impaired beneficial use(s) and applicable water quality standard(s). Therefore, the targets provide a benchmark by which to evaluate attainment of water quality standards. Furthermore, comparing existing stream conditions to target values allows for a better understanding of the extent and severity of the problem.

4.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Because the effects of pollutants on water quality can vary throughout the year, assessing pollutant sources must include an evaluation of the seasonal variability of the pollutant loading. The source assessment helps to define the extent of the problem by linking the pollutant load to specific sources in the watershed.

A pollutant load is usually quantified for each point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) program (none of which are present in this watershed, or addressed in this document). Nonpoint sources are quantified by source categories (e.g., unpaved roads) and/or by land uses (e.g., crop production or forestry). These source categories and land uses can be divided further by ownership, such as federal, state, or private. Alternatively, most, or all, pollutant sources in a sub-watershed or source area can be combined for quantification purposes.

Because all potentially significant sources of the water quality problems must be evaluated, source assessments are conducted on a watershed scale. The source quantification approach may produce reasonably accurate estimates or gross allotments, depending on the data available and the techniques used for predicting the loading (40 Code of Federal Regulations (CFR), Section 130.2(I)). Montana TMDL development often includes a combination of approaches, depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 Establishing the Total Allowable Load

Identifying the TMDL requires a determination of the total allowable load over the appropriate time period necessary to comply with the applicable water quality standard(s). Although a "TMDL" is specifically defined as a "daily load," determining a daily loading may not be consistent with the applicable water quality standard(s), or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading during a time period that is appropriate for applying the water quality standard(s) and which is consistent with established approaches to properly characterize, quantify, and manage pollutant sources in a given watershed. For example, temperature TMDLs may be expressed in terms of kilocalories per second.

If a stream is impaired by a pollutant for which numeric water quality criteria exist, the TMDL, or allowable load, is typically calculated as a function of streamflow and the numeric criteria. This same approach can be applied when a numeric target is developed to interpret a narrative standard.

Some narrative standards, such as those for temperature, often have a suite of targets. In many of these situations it is difficult to link the desired target values to highly variable, and often episodic, instream loading conditions. In such cases the TMDL is often expressed as a percent reduction in total loading based on source quantification results and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the federal Clean Water Act. When this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period, as noted above.

4.4 Determining Pollutant Allocations

Once the allowable load (the TMDL) is determined, that total must be divided among the contributing sources. The allocations are often determined by quantifying feasible and achievable load reductions through application of a variety of best management practices and other reasonable conservation practices.

Under the current regulatory framework (40 CFR 130.2) for developing TMDLs, flexibility is allowed in allocations in that "TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure (e.g., a percent increase in canopy density for temperature TMDLs).

Figure 4-2 illustrates how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the waterbody.

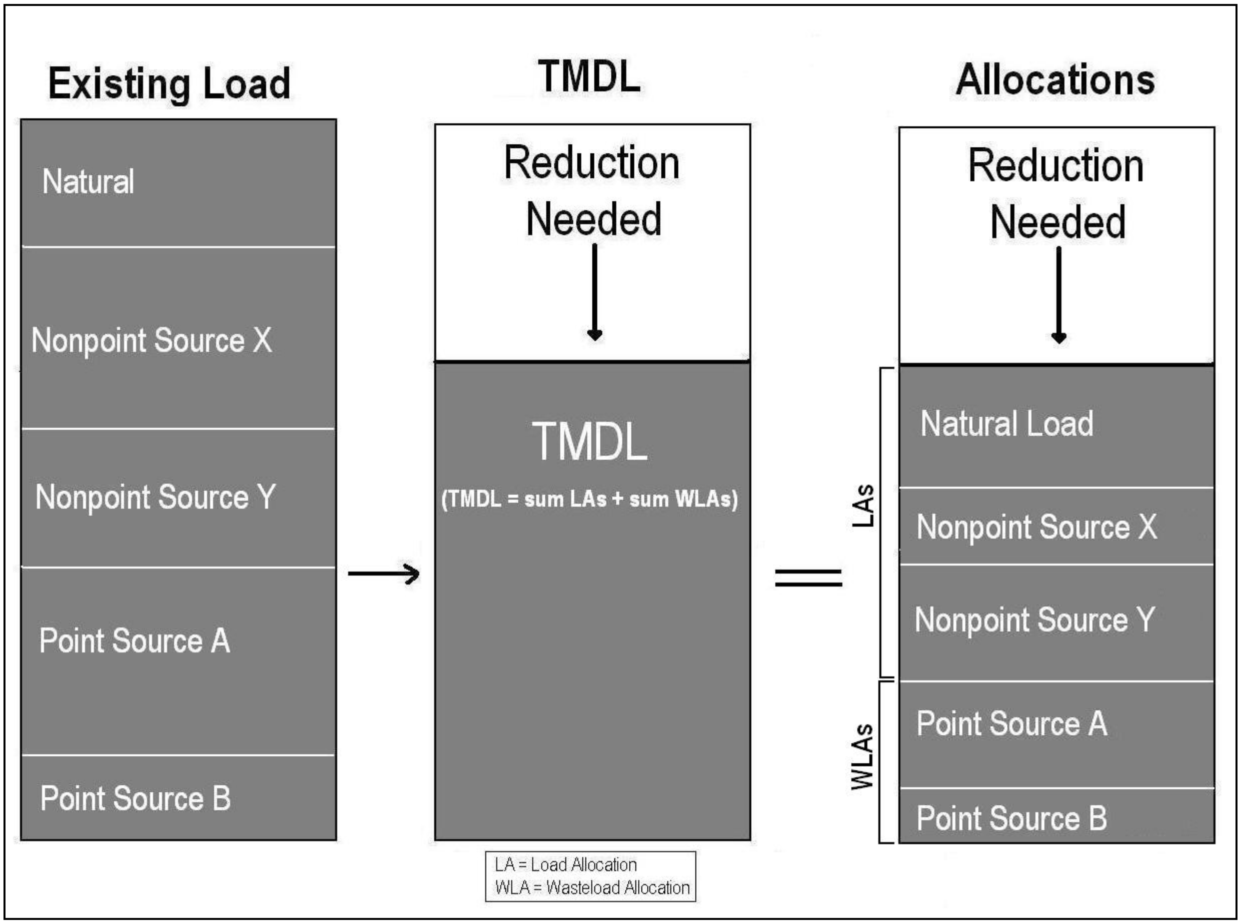


Figure 4-2. Schematic diagram of a TMDL and its allocations

TMDLs must also incorporate a margin of safety. The margin of safety accounts for the uncertainty, or any lack of knowledge, about the relationship between the pollutant loads and the quality of the receiving waterbody. The margin of safety may be applied implicitly by using conservative assumptions in the TMDL development process, or explicitly by setting aside a portion of the allowable loading (i.e., a TMDL = $\sum$WLA + $\sum$LA + MOS) (U.S. Environmental Protection Agency, 1999a; U.S. Environmental Protection Agency, 1999b). The margin of safety is a required component to help ensure that water quality standards will be met when all allocations are achieved. The temperature TMDL in this document uses an implicit margin of safety, discussed further in **Section 5.7**.

4.5 Implementing TMDL Allocations

The Clean Water Act (CWA) and Montana state law (Section 75-5-703 of the Montana Water Quality Act) require wasteload allocations to be incorporated into appropriate discharge permits, thereby providing a regulatory mechanism to achieve load reductions from point sources. Nonpoint source reductions linked to load allocations are not required by the CWA or Montana statute, and are primarily implemented through voluntary measures. White Pine Creek is included within an approved Watershed Restoration Plan (WRP) that has been created for the Lower Clark Fork River Tributaries (Miller, 2010). This document contains several components to assist stakeholders in implementing nonpoint source controls for sediment. Causes of temperature impairment are commonly similar to the causes of sediment impairment, and the recommendations within the WRP can help address both impairments. Department of Environmental Quality's (DEQ) Watershed Protection Section (Nonpoint Source Program) helps to coordinate water quality improvement projects for nonpoint sources of pollution throughout the state and provides resources to stakeholders to assist in nonpoint source best management practices (BMPs). Montana's Nonpoint Source Management Plan further discusses nonpoint source implementation strategies at the state level. (http://www.deq.mt.gov/wqinfo/nonpoint/2012NonpointPlan/NPSPlan_Complete_07162012.pdf)

DEQ uses an adaptive management approach to implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 6.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute (Section 75-5-703 of the Montana Water Quality Act). TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

5.0 Temperature TMDL Components

This portion of the document focuses on temperature as an identified cause of water quality impairment in the Lower Clark Fork Tributaries Planning Area. It describes: (1) the mechanisms by which temperature affects beneficial uses of streams; (2) the stream segments of concern; (3) information sources used for temperature total maximum daily loads (TMDL) development; (4) temperature target development; (5) assessment of sources contributing to excess thermal loading; (6) the temperature TMDL and allocations; (7) seasonality and margin of safety; and (8) uncertainty and adaptive management.

5.1 Temperature (Thermal) Effects on Beneficial Uses

Human influences that reduce stream shade, increase stream channel width, add heated water, or decrease the capacity of the stream to buffer incoming solar radiation all increase stream temperatures. Warmer temperatures can negatively affect aquatic life that depends upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increases metabolism and reduces the amount of available oxygen in the water. Coldwater fish and other aquatic life may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, which can result in fish kills. Also, elevated temperatures can boost the ability of non-native fish to outcompete native fish if the latter are less able to adapt to warmer water conditions (Bear et al., 2007). Although the TMDL will address increased summer temperatures as the most likely to cause detrimental effects on fish and aquatic life, human influences on stream temperature, such as those that reduce shade, can also lead to lower minimum temperatures during the winter (Hewlett and Fortson, 1982). Lower winter temperatures can lead to the formation of anchor and frazil ice which can harm aquatic life by causing changes in movement patterns (Brown, 1999; Jakober et al., 1998), reducing available habitat, and inducing physiological stress (Brown et al., 1993). Addressing the issues associated with increased summer maximum temperatures will also address these potential winter problems. Assessing thermal effects upon a beneficial use is an important initial consideration when interpreting Montana's water quality standard (**Appendix A**) and subsequently developing temperature TMDLs.

5.2 Stream Segments of Concern

One waterbody segment in the Lower Clark Fork Tributaries Planning Area is identified as impaired by temperature in Montana's 2014 Integrated Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014b): White Pine Creek. To help put sampling data into perspective and understand how elevated stream temperatures may affect aquatic life, information on fish presence in these waterbodies and temperature preferences for the most sensitive species are described below.

5.2.1 Fish Presence in White Pine Creek

Based on a query of the Montana Fisheries Information System (MFISH), a species distribution database managed by Montana Fish, Wildlife and Parks (FWP), White Pine Creek is inhabited by brook trout, brown trout, bull trout, longnose dace, mountain whitefish, rainbow trout, redside shiner, slimy sculpin, and westslope cutthroat trout (Montana Department of Fish, Wildlife and Parks, 2014). White Pine Creek is not within a bull trout Core or Nodal area (Montana Department of Fish, Wildlife and Parks, 2014). According to the Montana Fish, Wildlife, and Parks fisheries resource value ratings, White Pine

Creek is considered "Substantial" (rating score 3) (Montana Department of Fish, Wildlife and Parks, 2014).

5.2.2 Temperature Levels of Concern

Special temperature considerations are warranted for the westslope cutthroat trout, which are identified in Montana as species of concern and occur in White Pine Creek. Research by Bear et al. (2007) found that westslope cutthroat maximum growth occurs around 56.5°F, with an optimum growth range (based on 95% confidence intervals) from 50.5–62.6°F. The ultimate upper incipient lethal temperature (UUILT) is the temperature considered to be survivable by 50% of the population over a specified time period. Bear et al. (2007) found the 60-day UUILT for westslope cutthroat trout to be 67.3°F and the 7-day UUILT to be 75.4°F. Considering a higher level of survival, the lethal temperature dose that will kill 10% (LD10) of the population in a 24-hour period for westslope cutthroat is 73.0°F (Liknes and Graham, 1988).

5.3 Information Sources and Data Collection

As discussed in **Appendix A** and **Section 5.4.1**, Montana defines temperature impairment as occurring when human sources cause a certain degree of change over the water temperature that occurs as a result of natural sources and human sources that are implementing all reasonable land, soil, and water conservation practices. Because interpreting the standard is more complex than just comparing measured temperatures to the temperature levels of concern discussed above, a QUAL2K water quality model was needed to determine if human sources are causing the allowable temperature change to be exceeded in White Pine Creek. The QUAL2K model was developed for the lower segments of White Pine Creek from Set Creek, which begins at river mile (RM) 3.7 and just below temperature logger WPC-T4, to the mouth of White Pine Creek on Beaver Creek (**Figure 5-1**). Only the lower segments were modeled because QUAL2K could not simulate the dry reaches in the upper segments of White Pine Creek. Model details for White Pine Creek are presented in **Appendix B**, but the model summary and outcome is provided in **Section 5.5**, **Source Assessment**.

The following information sources were searched and/or used to set up the QUAL2K model and assist with temperature TMDL development.

5.3.1 Department of Environmental Quality Assessment Files

Department of Environmental Quality (DEQ) maintains assessment files that provide a summary of available water quality and other existing condition information, along with a justification for impairment determinations.

5.3.2 Temperature Related Data Collection

In summer 2013, DEQ and Environmental Protection Agency (EPA) collected temperature data, along with measurements of streamflow, riparian shade, and channel geometry from White Pine Creek. EPA collected continuous temperature data at seven locations in White Pine Creek (sites WPC-T1, WPC-T2, WPC-T3, WPC-T4, WPC-T6, WPC-T7, WPC-T8) and at one tributary (Chute Creek, Chute-F1) . One location on White Pine Creek (WPC-T5) was observed to be dry and no temperature logger was deployed. Data loggers recorded temperatures every one-half hour for approximately two months between June 25 and September 10, 2013. Instantaneous temperatures were also monitored by EPA and DEQ in June, August, and September 2013 on White Pine Creek and three of its tributaries: Chute-F1 on Chute Creek, PC-F1 on Pine Creek, and WC-T1 on Woodchuck Creek. Four locations on tributaries to

White Pine Creek were observed to be dry and no instantaneous data were collected: Cole-F1 on Cole Creek, LC-T1 on Larch Creek, RC-T1 on Ripper Creek, and SC-T1 on Set Creek.

EPA and DEQ collected shade data on August 13 and 14, 2013 at five locations along White Pine Creek (WPC-T1, WPC-T2, WPC-T3, WPC-T4, and WPC-T8) using a Solar Pathfinder™. The riparian vegetation at these monitoring locations was also characterized.

This information is collectively used within the QUAL2K models to evaluate impairment and the potential for improvement associated with the implementation of all reasonable land, soil, and water conservation practices. Shade and vegetation data are used to create a Shade model, which is a component of QUAL2K that computes hourly effective shade using vegetation and topography data. This is discussed further in **Appendix B, Section B1-5.2**. These data are presented and described in detail in **Appendix B**. Monitoring locations are shown in **Figure 5-1**.

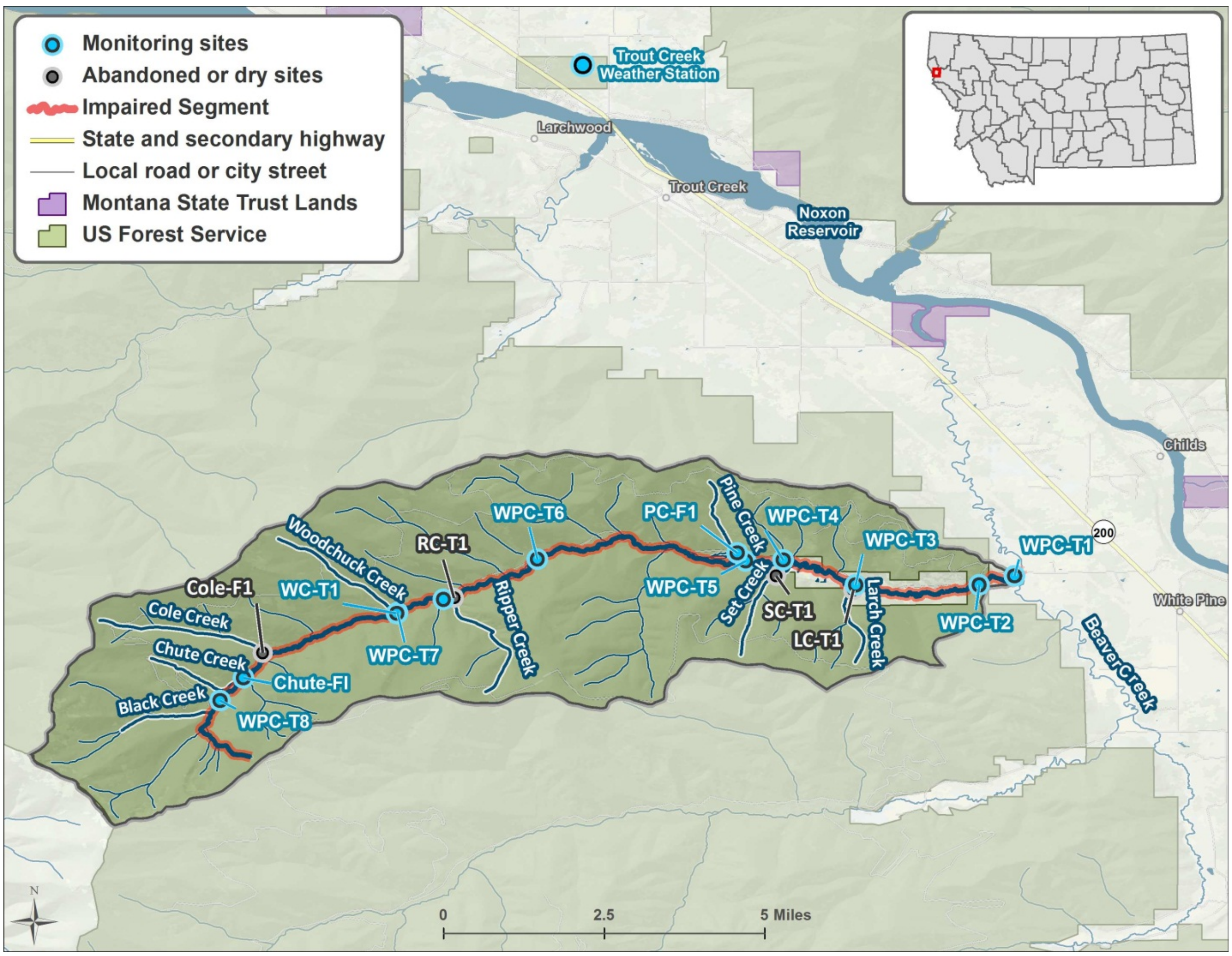


Figure 5-1. Temperature data logger sampling sites on White Pine Creek and nearby weather station.

5.3.3 Climate Data

Climate data, including air temperature, dew point temperature, wind speed, and cloud cover, are major inputs to the QUAL2K model and are also drivers for stream temperature. Climatic data inputs, including hourly air temperature, were obtained from nearby Cabinet (Trout Creek) Remote Automatic Weather Station (RAWS) (**Figure 5-1**).

5.3.4 Department of Natural Resources & Conservation Water Usage Data

Spatial Department of Natural Resources & Conservation (DNRC) water usage data that include identification of active points of diversion and places of use were obtained from the Natural Resources Information System (Natural Resource Information System, 2012). This information was necessary because streamflow is an important input for the QUAL2K model and irrigation withdrawals have the potential to influence stream temperatures.

5.4 Target Development

The following section describes 1) the framework for interpreting Montana's temperature standard; 2) the selection of target parameters and values used for TMDL development; and 3) a summary of the temperature target values for White Pine Creek; and 4) a comparison of the existing White Pine Creek temperature data to the targets in order to determine whether a TMDL is necessary.

5.4.1 Framework for Interpreting Montana's Temperature Standard

Montana's water quality standard for temperature is narrative in that it specifies a maximum allowable increase above the naturally occurring temperature to protect fish and aquatic life. Under Montana water quality law, naturally occurring temperatures incorporate natural sources and human sources that are applying all reasonable land, soil, and water conservation practices. Naturally occurring temperatures can be estimated for a given set of conditions using QUAL2K or other modeling approaches, but because water temperature changes daily and seasonally, no single temperature value can be identified to represent standards attainment. Therefore, in addition to evaluating if human sources are causing the allowable temperature change to be exceeded, a suite of temperature TMDL targets were developed to translate the narrative temperature standard into measurable parameters that collectively represent attainment of applicable water quality standards at all times. The goal is to set the target values at levels that occur under naturally occurring conditions but are conservatively selected to incorporate an implicit margin of safety that helps account for uncertainty and natural variability. The target values are protective of the use most sensitive to elevated temperatures, aquatic life; as such, the targets are protective of all designated uses for the applicable waterbody segments.

A QUAL2K model was used for White Pine Creek to estimate the extent of human influence on temperature by evaluating the temperature change between existing conditions and naturally occurring conditions. The models used the data described in **Section 5.3** to simulate existing conditions, and then the models were re-run with riparian shade and water use altered to reflect naturally occurring conditions. If the modeled temperature change between the two scenarios (i.e., existing and naturally occurring) is greater than allowed by the water quality standard (i.e., 1.0°F), this verifies the existing temperature impairment. This section discusses whether the model outcome supports the existing impairment listing, and model scenario details are presented in **Section 5.5**, **Source Assessment** and **Appendix B**.

5.4.2 Temperature Target Parameters and Values

The primary temperature target is the allowable human-caused temperature change (i.e., 1.0°F). However, surrogate temperature-influencing targets are provided for those parameters that influence temperature and can be linked to human causes. The temperature-influencing targets are riparian shade, channel geometry, and improved streamflow conditions. All targets are described in more detail below.

5.4.2.1 Allowable Human-Caused Temperature Change

The target for allowable human-caused temperature change links directly to the numeric portion of Montana's temperature standard for B-1 streams (Administrative Rules of Montana (ARM) 17.30.623(e)): When the naturally occurring temperature is less than 66^{o}F, the maximum allowable increase is 1^{o}F. Within the naturally occurring temperature range of 66–66.5^{o}F, the allowable increase cannot exceed 67^{o}F. If the naturally occurring temperature is greater than 66.5^{o}F, the maximum allowable increase is 0.5^{o}F. As stated above, naturally occurring temperatures incorporate natural sources, yet also include human sources that are applying all reasonable land, soil, and water conservation practices.

5.4.2.2 Riparian Shade

Increased shading from riparian vegetation reduces sunlight hitting the stream and, thus, reduces the heat load to the stream. Riparian vegetation also reduces near-stream wind speed and traps air against the water surface, which reduces heat exchange with the atmosphere (Poole and Berman, 2001). In addition, lack of established riparian areas can lead to bank instability, which can result in an overwidened channel.

To help minimize the influence of upland activities on stream temperature, a riparian buffer close to 100 feet is commonly recommended (Ledwith, 1996; Knutson and Naef, 1997; Ellis, 2008). White Pine Creek flows through a portion of the Kootenai National Forest. The U.S. Forest Service abides by Inland Native Fish Strategy standards for Riparian Habitat Conservation Areas, which sets a buffer ranging from a minimum of 50 feet for seasonally flowing streams to a minimum of 300 feet for fish-bearing streams (U.S. Department of Agriculture, Forest Service, 1995). However, several studies have shown that most (85-90%) of the maximum shade potential is obtained within the first 50 feet (Brazier and Brown, 1973; Broderson, 1973; Steinblums et al., 1984) or 75 feet of the channel (CH2M, 2000; Castelle and Johnson, 2000; Christensen, 2000). The Natural Resources Conservation Service (NRCS) conservation practice standard for riparian buffers, recommends a minimum buffer width of 35 feet, and also includes recommendations to use species with a medium or high shade value and to meet the minimum habitat requirements of aquatic species of concern (Natural Resources Conservation Service, 2011a; 2011b). Based on several literature sources finding that most shade is obtained within a buffer width of 50 feet and that 50 feet is the minimum buffer width for the Montana Streamside Management Zone (Montana Department of Natural Resources and Conservation, 2006) the temperature influencing target is a healthy riparian buffer width of 50 feet.

Reference conditions were defined for the White Pine Creek QUAL2K modeling as vegetation communities that were at potential and representative of what the vegetation of nearby segments affected by anthropogenic activities should look like. Water Consulting, Inc. (2002) suggests that the vegetative potential for the lower reaches of White Pine Creek is a mixed conifer, cottonwood, and shrub community. The reference condition, the vegetation observed at monitoring location WPC-T2 (refer back to **Figure 5-1**), is a mixed coniferous/shrub community that is at potential.

DEQ realizes most healthy riparian buffers are composed of more than a single category of vegetation, and the reference conditions were each set to one vegetation type for two reasons: 1) the actual composition of the riparian zone under target shade conditions will vary over time and is too complex to model with QUAL2K, and 2) based on existing vegetation in the watershed and what is known of historical conditions, the effective shade provided by these reference conditions was determined to be a reasonable target. Effective shade is the result of topography and vegetative height and density, so the target shade condition could be achieved by a large combination of vegetation types and densities. Additionally, the effective shade potential at any given location may be lower or higher than the target depending on natural factors such as fire history, soil, topography, and aspect but also because of human alterations to the near-stream landscape including roads and structural bank armoring that may not feasibly be modified or relocated. The target is provided as a quantitative guide for meeting the standard and is intended to represent all reasonable land, soil, and water conservation practices. If those are being implemented, then White Pine Creek will be meeting the riparian shade target. The rationale for target selection is further described in **Section 5.4.4.1** in the discussion of existing conditions as compared with the target.

5.4.2.3 Width/Depth Ratio

A narrower channel with a lower width-to-depth ratio results in a smaller contact area with warm afternoon air and is slower to absorb heat (Poole and Berman, 2001). Also, a narrower channel increases the effectiveness of shading produced by the riparian canopy. A target for width/depth ratio was developed for the sediment TMDLs using reference data and stream surveys (Montana Department of Environmental Quality, 2010) and will also apply for temperature. The width/depth ratio target for Rosgen stream types C and F is ≤ 25 for sections with gradients less than 2%. The target is not intended to be specific to every given point on the stream but to maintain current conditions where the target is generally being met. In areas where the target is not being met, actions to improve riparian shade are also anticipated to lower width/depth ratios. For additional information regarding the width/depth ratio refer to the sediment TMDL report (Montana Department of Environmental Quality, 2010).

5.4.2.4 Instream Flow (Water Use)

Because larger volumes of water take longer to heat up during the day, the ability of a stream to buffer incoming solar radiation is reduced as instream water volume decreases. In other words, a channel with little water will heat up faster than an identical channel full of water, even if they have identical shading and are exposed to the same daily air temperatures.

The proposed target for instream flow (water use) is the increased instream flow that can be achieved via a 15% reduction in flow diverted for irrigation purposes based on improvements in irrigation water management and irrigation system and delivery efficiencies during the summer (June through September). Per Montana's water quality law, TMDL development cannot be construed to divest, impair, or diminish any water right recognized pursuant to Title 85 (Montana Code Annotated (MCA) §75-5-705). Therefore, any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights. The 15% water savings could be achieved through best management practices including delivery system upgrades, irrigation scheduling, and application management (Waskom, 1994).

5.4.3 Target Values Summary

The allowable human-caused temperature change is the primary target that must be achieved to meet the standard. Alternatively, compliance with the temperature standard can be attained by meeting the three temperature-influencing targets (i.e., riparian shade, width/depth ratio, and instream flows). In this approach, if all reasonable land, soil, and water conservation practices are installed or practiced, water quality standards will be met. **Table 5-1** summarizes the temperatures targets for White Pine Creek.

Table 5-1. Temperature Targets for White Pine Creek

Target Parameter	Target Value
Primary Target	
Allowable Human-Caused Temperature Change	If the naturally occurring temperature is less than 66ºF, the maximum allowable increase is 1ºF. Within the naturally occurring temperature range of 66–66.5ºF, the allowable increase cannot exceed 67ºF. If the naturally occurring temperature is greater than 66.5ºF, the maximum allowable increase is 0.5ºF.
Temperature-Influencing Targets: Meeting all three will meet the primary target	
Riparian Health - Shade	Improve riparian vegetative communities along the modeled segments to a reference condition of mixed riparian forest/shrubs at logger WPC-T2.
Width/depth Ratio	Within the expected range for a Rosgen type C or F stream with <2% gradient (Montana Department of Environmental Quality, 2010): ≤25
Instream Flows (Water Use)	15% reduction of irrigation withdrawals due to improvements in irrigation efficiency during the summer (June through September)

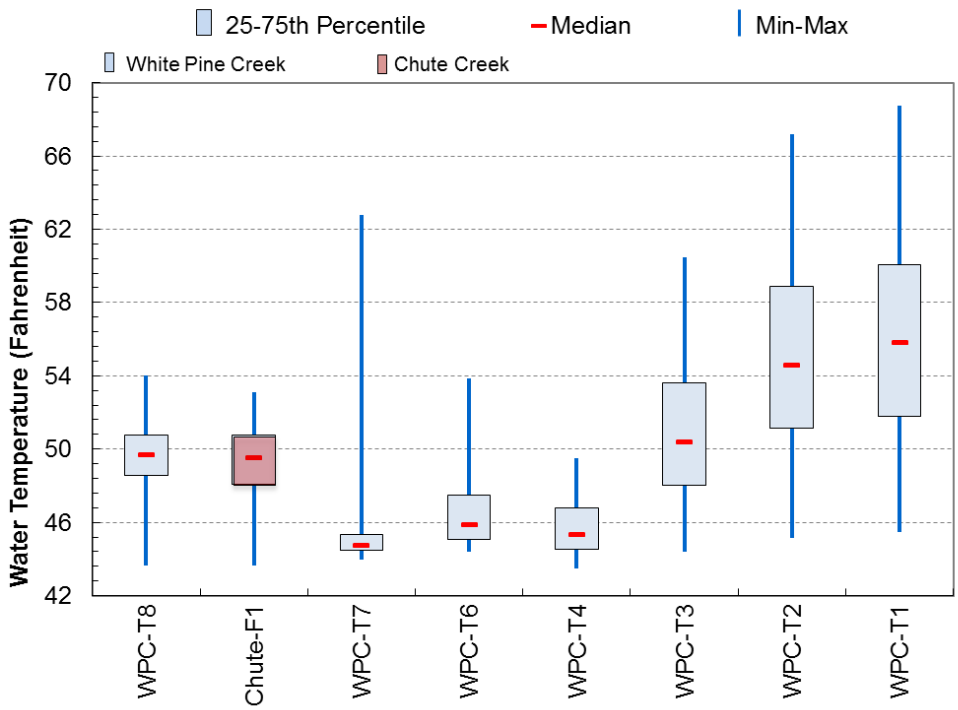
5.4.4 Existing Conditions and Comparison to Targets

This section includes a comparison of existing data with water quality targets, along with a TMDL development determination for White Pine Creek. QUAL2K model results will be compared to the allowable human-caused temperature change to determine if the target is being exceeded, but most model details will be presented in **Section 5.5**, **Source Assessment**.

White Pine Creek (MT76N003_120) was initially listed for temperature impairment in 2006. The assessment file noted that “[h]istoric, natural catastrophes such as the large, landscape fires in 1889 and 1910 and then the large flood of 1916 have resulted in loss of important features in the riparian areas” (Montana Department of Environmental Quality, 2014, p. 61). It was also noted that elevated water temperatures that affect native fish populations “may be linked to historic riparian logging and relatively recent stand replacing fires” (Montana Department of Environmental Quality, 2014, p. 61). DEQ (2014, p. 63) concluded that elevated instream temperatures are derived from four sources: grazing in riparian or shoreline zones, streambank modification/destabilization, natural sources, and watershed runoff following forest fire.

5.4.4.1 Existing Stream Temperatures

To help evaluate the extent and implications of impairment it is useful to evaluate the degree to which existing temperatures may harm fish or other aquatic life. Observed temperatures were often within the optimal growth range for westslope cutthroat trout (**Figure 5-2**), and maximum daily temperatures never exceeded 69°F. Measured temperatures were warmest for the longest period of time near the mouth at WPC-T1. Temperatures never exceeded the LD10 (73°F) and 7-day UUILT (75.4°F) but daily maximum temperatures in July and August did exceed the optimal growth range maximum for westslope cutthroat trout (62.6°F; **Figure 5-3**).



Notes:

Logger WPC-T6 was likely exposed to ambient air from June 29, 2013 through August 13, 2013, when it was observed in a dry channel. The data presented in this figure are limited to a subset of the monitored temperatures, from June 26, 2013 through June 27, 2013.

Logger WPC-T7 was likely exposed to ambient air from July 10, 2013 through August 14, 2013, when it was observed in a dry channel. The data presented in this figure are limited to a subset of the monitored temperatures, from June 26, 2013 through July 9, 2013.

Logger WPC-T8 may have been exposed to ambient air prior to the mid-season field data acquisition on August 14, 2013 when the logger was observed to be partially exposed to ambient air. The logger was moved and was then fully submerged. No data were excluded from this figure.

Figure 5-2. 2013 temperature logger monitoring data for White Pine Creek and its tributary.

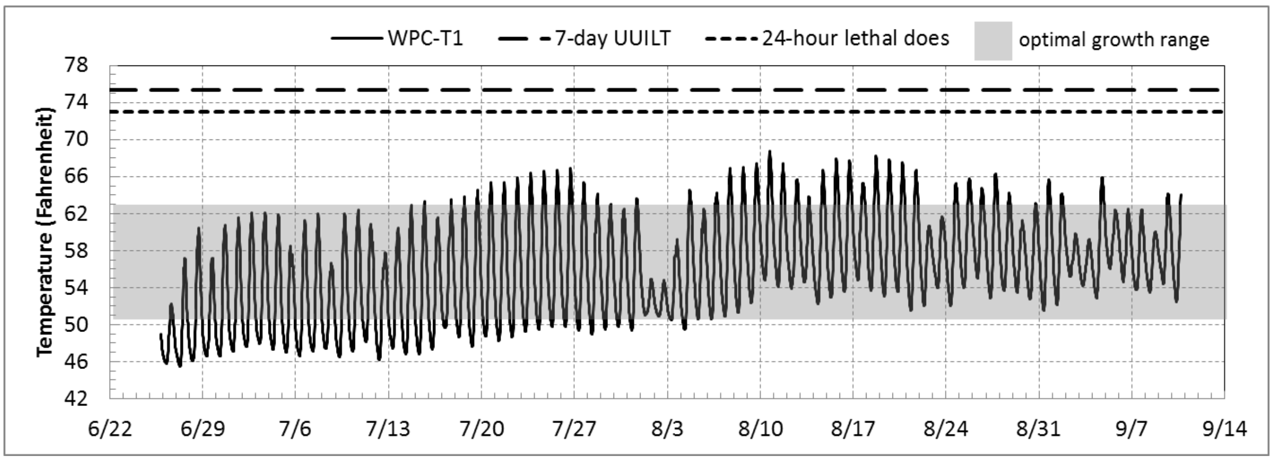


Figure 5-3. Observed diurnal temperatures in White Pine Creek upstream of the mouth at logger WPC-T1.

The QUAL2K model results (see **Appendix B**) indicate that the maximum naturally occurring summer temperatures in White Pine Creek are less than 66.0° F over the modeled segment (RM 3.7 to mouth). This means that human sources cannot cause the temperature to be exceeded by more than 1.0°F in White Pine Creek. Based on the model and temperature data, human sources have caused the allowable change target to be exceeded from RM 2.3 downstream to the mouth.

5.4.4.2 Existing Riparian Shade

High and medium density trees are the most common cover types along White Pine Creek, followed by shrubs, herbaceous vegetation (grass), and low density trees (**Table 5-2**). Sparse trees, roads, and bare ground compose only a small percentage of the riparian area, found mostly in the lower portion of the watershed. **Figure 5-4** shows the percent difference between the existing effective shade and the target effective shade in the lower segments of White Pine Creek (based on the Shade Model results for the entire length of White Pine Creek provided in **Appendix B**). In the lower segments of White Pine Creek, the greatest shade deficit is between WPC-T3 and WPC-T2 (i.e. RMs 2.4 to 0.8) where White Pine Creek flows through private property.

Table 5-2. Composition of the existing riparian buffer 50 feet on both sides of White Pine Creek

Land cover type	Area (acres)	Relative area (percent)
Bare ground	7.1	1.6%
Herbaceous	62.7	13.9%
Roads	17.8	3.9%
Shrub	66.7	14.7%
Sparse trees	31.4	6.9%
Low density trees	40.9	9.0%
Medium density trees	81.2	17.9%
High density trees	144.6	31.9%

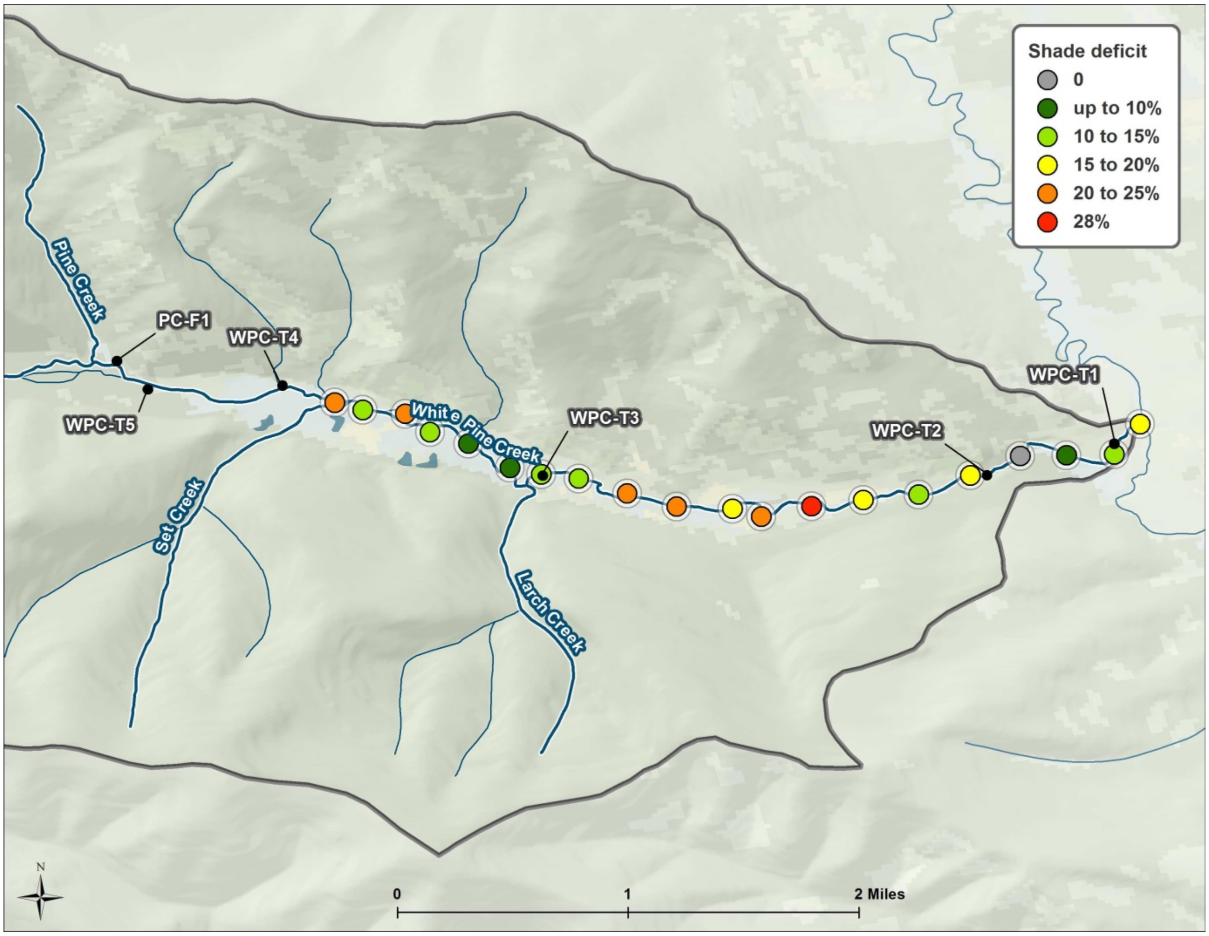


Figure 5-4. The percent of additional effective shade needed to meet the target along the modeled segments of White Pine Creek.

5.4.4.3 Existing Width/Depth Ratio

Channel morphology, including the width depth ratio, were evaluated by DEQ (2010) when DEQ developed sediment TMDLs for White Pine Creek. DEQ evaluated width and depth data collected in 2008 at three sites, and the width/depth ratio at one site (32.4 at site WPC 9-2, located shortly downstream of Set Creek) exceeded the target of less than or equal to 25 for Rosgen type C and F with gradients less than 2%. Refer to the target assessment section of the sediment TMDL (Montana Department of Environmental Quality, 2010, Section 5.4.3.5) for additional discussion of White Pine Creek.

5.4.5 Summary and TMDL Development Determination

The human-influenced allowable temperature change target is exceeded along 2.3 miles of the 3.7 miles of White Pine Creek that were modeled. As described above, stream shading was up to 28 percent less than the reference condition along the lower reaches of White Pine Creek. This information supports the existing impairment listing and a temperature TMDL will be developed for White Pine Creek.

5.5 Source Assessment

As discussed above, the source assessment largely involved QUAL2K temperature modeling. There are no permitted point sources in the watershed. The watershed has been affected by the road networks, present and historic agricultural activities, and instream flows. Instead of focusing on the potential contribution of these sources, the source assessment focused on two factors that can be influenced by human activities and are drivers of stream temperature: instream flow and riparian shade.

Although channel morphology plays a role in determining effective shade and can be an important target, it was not incorporated into the QUAL2K model. Based on the lack of sufficiently detailed data for a QUAL2K scenario, changing channel morphology was not evaluated as a management scenario. DEQ (2010) did evaluate channel morphology while developing a sediment TMDL for White Pine Creek. The TMDL requires a 43% reduction in sediment load, and identified many instances of overwidening. Actions taken to address the sediment impairment and reduce channel overwidening are expected to have beneficial effects on stream temperatures as well. As these actions are likely to be undertaken in conjunction with improvements to riparian vegetation, this unmodeled improvement provides an additional margin of safety.

A QUAL2K model was used to determine the extent that human-caused disturbances within the White Pine Creek watershed have increased the water temperatures above the naturally occurring level. The evaluation of model results focuses on the maximum daily water temperatures in White Pine Creek during the summer because those are conditions mostly likely to harm aquatic life, the most sensitive beneficial use.

QUAL2K is a one-dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model uses steady state hydraulics that simulates non-uniform steady flow. Within the model, water temperatures are estimated based on climate data, riparian shading, and channel conditions. A stream is segmented into reaches within the model and channel and shade characteristics are uniform throughout each reach. Segmentation is largely based on the location of field data, tributaries, irrigation withdrawal/returns, channel slope, and changes in channel conditions or shading.

Within the model, White Pine Creek was segmented into reach lengths of 984 feet. The water temperature and flow data collected from White Pine Creek and its tributaries in 2013, along with channel measurements, irrigation data, and climate data (**Section 5.3** and **Appendix B**), were used to calibrate and validate the model. The relative error for the daily maximum stream temperatures (at the loggers, modeled versus observed) for the calibration and validation were 2.8% and 2.9%, respectively, indicating the model provides a reasonable approximation of maximum daily temperatures in White Pine Creek. While the influence of White Pine Creek tributaries was evaluated, the White Pine Creek tributaries were not explicitly modeled; only the mainstem of White Pine Creek from RM 3.7 to the mouth was modeled. As previously mentioned, White Pine Creek ran dry in its upper segments, and QUAL2K cannot simulate dry reaches. Thus, the QUAL2K model was developed for White Pine Creek from the confluence of Set Creek, which is at RM 3.7 and just downstream of site WPC-T4, to the mouth of White Pine Creek on Beaver Creek. Tributaries to White Pine Creek within the modeled portion of the stream ran dry during the summer of 2013 and are not simulated in the White Pine Creek model. Human influences on tributary water temperatures (e.g., irrigation withdrawals or shading along the tributaries) were not evaluated.

Flow data at the United States Geological Survey (USGS) gage at Prospect Creek at Thompson Falls, MT (12907000) were evaluated to determine how August streamflow in 2013 (when data were collected) compared to the average August streamflow; flows were at the 34th percentile, indicating they were lower than average. This provides an added margin of safety, discussed below in **Section 5.7**.

A baseline scenario and three additional scenarios were modeled to investigate the potential influences of human activities on temperatures in White Pine Creek. The following sections describe those modeling scenarios. Although channel width and depth can influence stream temperatures, the existing channel dimensions were not changed for any of the scenarios. A more detailed summary of the development and results of the QUAL2K model are included in **Appendix B**.

5.5.1 White Pine Creek Baseline Scenario (Existing Conditions)

The baseline scenario represents stream temperatures under existing measured flows, and meteorological, shade, and channel conditions on August 14, 2013. This is the scenario that all other scenarios are compared against to evaluate the influence of human sources. Based on long-term flow data at the nearby Prospect Creek USGS gage, flows in August 2013 were at the 34th percentile of flows recorded between 1957 and 2013. Under the baseline scenario, maximum daily temperatures range from about 48.6°F near the beginning of the modeled section (RM 3.7)to 67.2°F at RM 0.8 (**Figure 5-5**). Temperatures generally increase in a downstream direction. However, the last 0.7 mile is simulated as a few degrees cooler than the mile immediately upstream. This temperature difference is likely due to considerably more inflowing groundwater, which is cooler and the instream water, in the last 0.7 miles (as determined with a water balance of monitored flows).

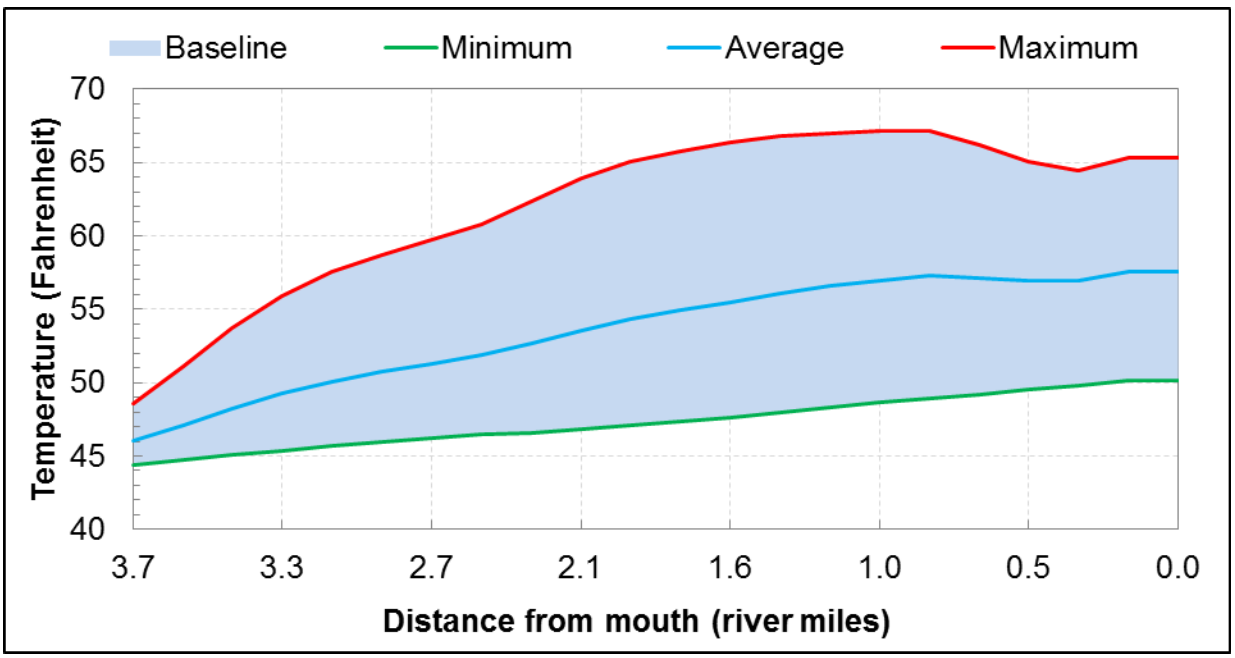


Figure 5-5. Modeled temperatures for the White Pine Creek baseline scenario.

5.5.2 White Pine Creek Water Use Scenario

A water use scenario was modeled to evaluate the effect that water conservation measures resulting in more instream flow would have on temperatures. In this scenario, the volume of water diverted from White Pine Creek for irrigation (which was estimated at about 0.64 cfs daily, see **Appendix B)** are reduced by 15% within the model and that savings of 0.10 cfs (0.64 * 0.15 = 0.10) is allowed to remain in the stream. It is estimated that a 15% water savings can be achieved through improvements in irrigation water management, irrigation system structural upgrades, and irrigation water delivery system efficiencies. The Irrigation Guide in the National Engineering Handbook from the NRCS (Natural Resources Conservation Service, 1997) states typical irrigation system efficiencies for several different types of irrigation systems. This data can be used to determine the effectiveness of irrigation system improvements on water savings. For example, if a field is currently under flood irrigation with average irrigation efficiency of 35%, by converting to center pivot irrigation, which has an average irrigation efficiency of 85%, the upgraded irrigation system is now 50% more efficient at using the same volume of irrigation water. This allows the irrigator to manage water more efficiently, and reduce runoff or deep percolation (Natural Resources Conservation Service, 1997). These improvements in irrigation efficiency can be used to produce higher crop yields, or ultimately divert less water from the stream. Since leaving additional water instream could lower the maximum daily temperature, converting efficiency savings to a lower amount of water usage is the focus of this scenario.

TMDL development cannot be construed to divest, impair, or diminish any water right recognized pursuant to Title 85 (Montana Code Annotated Section (MCA) 75-5-705); thus, any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights. In the water use scenario, a 15% reduction in withdrawal volume was used to simulate the outcome of leaving some of the water saved by implementing improvements to the irrigation network in the stream. Considering the statistics presented above from the NRCS Irrigation Guide and other sources that evaluated efficiency improvements for different irrigation practices (Negri et al., 1989; Howell and Stewart, 2003; Osteen et al., 2012) and savings left instream (Kannan et al., 2011), using efficiency gains to reduce withdrawal volume by 15% was selected for the water use scenario. Fifteen percent was chosen to be a reasonable starting point, but as no detailed analysis was conducted of the irrigation network in the White Pine Creek watershed, this scenario is not a formal efficiency improvement goal; it is an example intended to represent the application of water conservation practices for water withdrawals.

There are three points of diversion on White Pine Creek distributed from about RM 2.0 downstream to RM 0.4 (**Figure 5-6**). The 15% reduction in withdrawal volume would yield less than 0.1° F reduction in daily maximum, minimum, and average temperatures along White Pine Creek (**Figure 5-6**). The water use scenario indicates that withdrawals, independently, are not a source of temperature impairment.

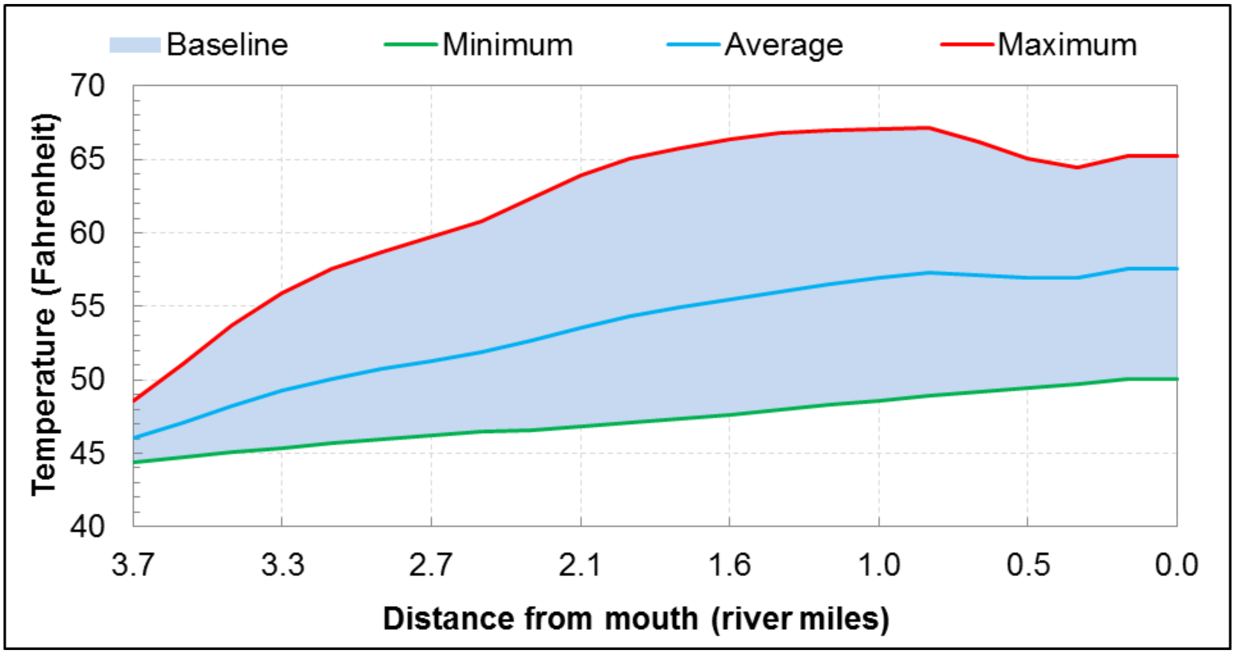


Figure 5-6. Comparison of modeled temperatures in White Pine Creek between the water use and baseline scenarios.

5.5.3 White Pine Creek Shade Scenario

For the shade scenario, the effective shade inputs to the model were set to represent the target shade condition (**Appendix B**). The shade targets were developed based upon reference condition segments that represent the least impact from anthropogenic activities.

Based on an assessment including site reconnaissance and review of historic aerial photographs, Water Consulting, Inc. (2002) concluded the following regarding the condition of riparian vegetation in the lower reaches of White Pine Creek (i.e., the reach that was modeled[1]):

> *Poor cottonwood and willow recruitment in the lower watershed contrasts with the diverse gallery forest in upper White Pine Creek. Restoring this diversity in the lower watershed should be a priority for the restoration effort.*

Water Consulting's assessment suggests that the vegetative potential for the lower reaches of White Pine Creek is a mixed conifer, cottonwood, and shrub community.

Based on site reconnaissance work conducted by EPA and DEQ during the summer of 2013, site WPC-T2 represents a mixed conifer/shrub community that was at potential within the lower reach of White Pine Creek. In the Improved Shade Scenario, modeled shade at location WPC-T2 is the reference condition that was applied to anthropogenically impacted reaches in lower White Pine Creek.

This scenario resulted in maximum daily temperatures ranging from 48.6°F to 64.6°F, which is a decrease from the baseline scenario, which ranged from 48.6°F to 67.2°F (**Figure 5-7**). Meeting the shade target caused an average decrease in the maximum daily temperatures of 1.7°F from the baseline

[1] Given intermittent flow in the upper reaches of White Pine Creek, only the lower reach (i.e., below WPC-T4) of White Pine Creek has been modeled.

scenario. The water temperatures for White Pine Creek in this scenario decrease throughout the system. A maximum change in the maximum daily water temperature of 2.6° F from the existing condition was observed at river mile 0.8. The difference in the daily maximum water temperature between the existing condition and maximum potential shade scenario was greater than 1.0° F from river mile 2.3 to the mouth.

The shade scenario indicates that human changes to the riparian vegetation are the primary source of temperature impairment. To illustrate how this scenario relates to current conditions, the average daily effective shade (which is averaged across all daylight hours) is presented in **Table 5-3** for the baseline scenario and shade scenario.

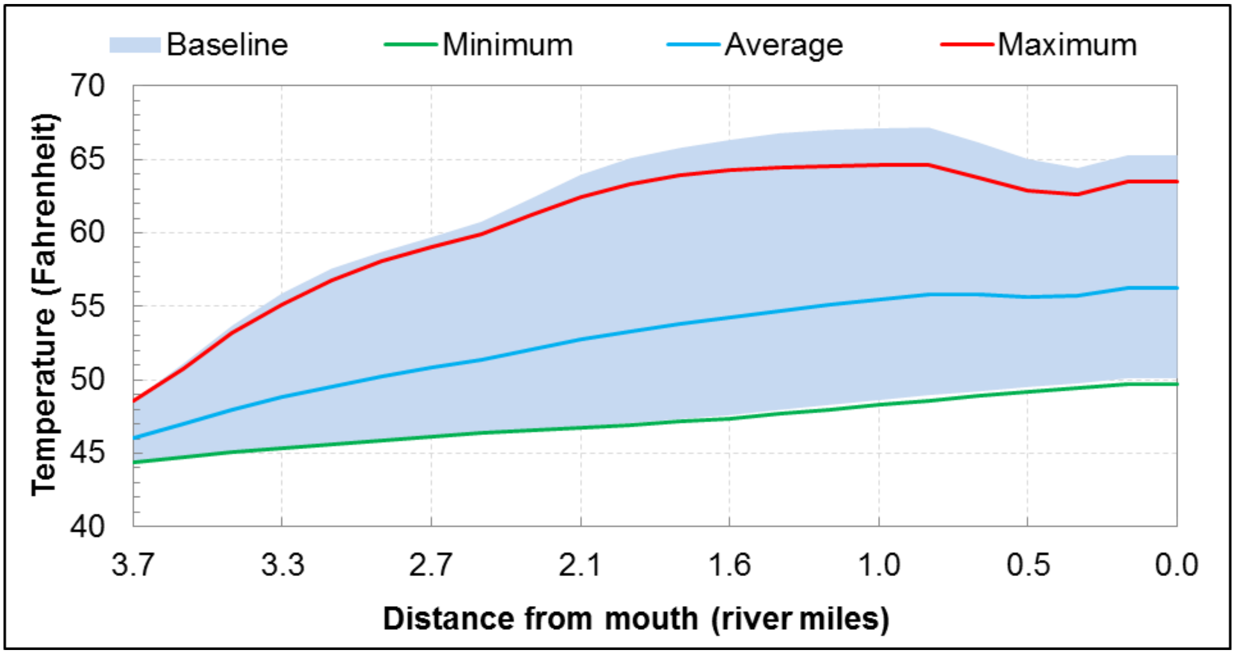


Figure 5-7. Comparison of modeled temperatures in White Pine Creek between the shade and baseline scenarios.

Table 5-3. Increase in effective shade from the existing condition to the shade scenario in White Pine Creek.

Segment	Effective Shade Improvement Over Baseline Scenario 1 (Existing Conditions)
WPC-T4 to WPC-T3	21%
WPC-T3 to WPC-T2	55%
WPC-T2 to WPC-T1	0%
WPC-T1 to mouth	36%

5.5.4 White Pine Creek Naturally Occurring Scenario (Full Application of Best Management Practices with Current Land Use)

The naturally occurring scenario represents White Pine Creek water temperatures when all reasonable land, soil, and water conservation practices are implemented (ARM 17.30.602). The naturally occurring scenario is a combination of the shade and water use scenarios. The conditions applied in the water use scenario were included because water conservation is a component of the naturally occurring condition.

Water users in the White Pine Creek watershed are encouraged to work with the United States Department of Agriculture, Natural Resource Conservation Service, the Montana Department of Natural Resources and Conservation, the local conservation district, and other local land management agencies to review their irrigation systems, practices, and the variables that may affect overall irrigation efficiency (Negri and Brooks, 1990; Natural Resources Conservation Service, 1997). If warranted and practical, users may consider changes that increase instream flows, and/or reduce warm water return flows in White Pine Creek.

The naturally occurring scenario maximum daily temperatures ranged from approximately 48.6 °F to 64.6°F, with an average of 60.5°F. Based on these results, the naturally occurring temperature is less than 66.0°F. An increase of 1.0°F is allowed from human sources (**Figure 5-8**).

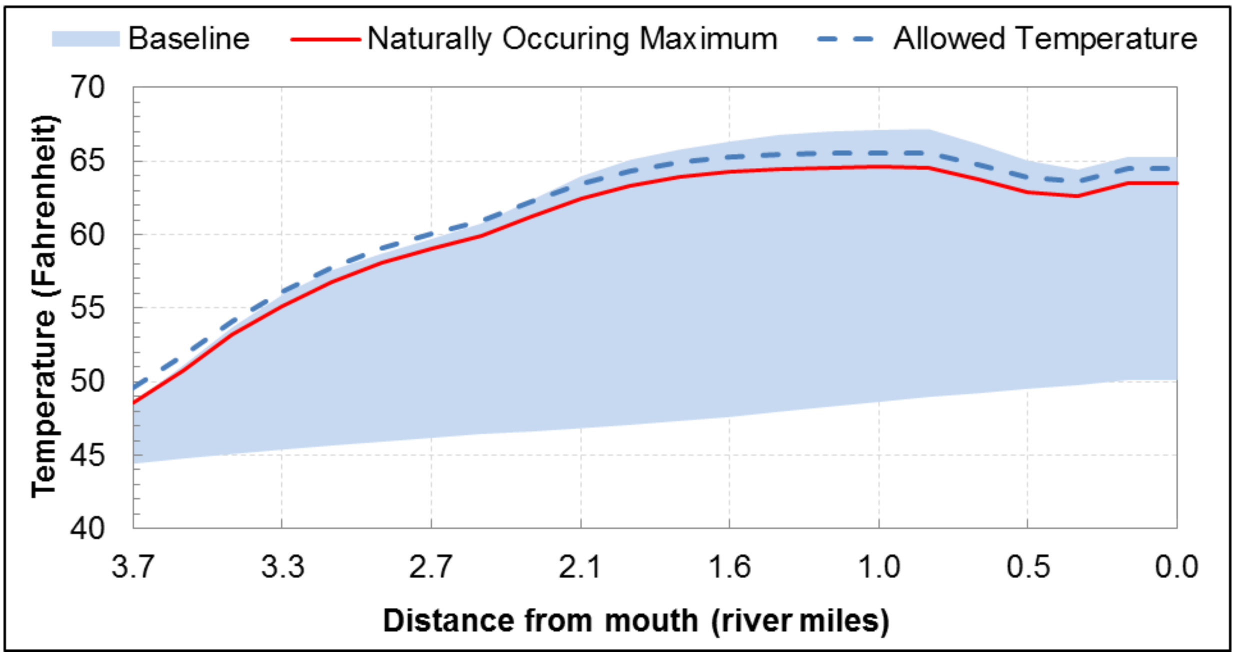
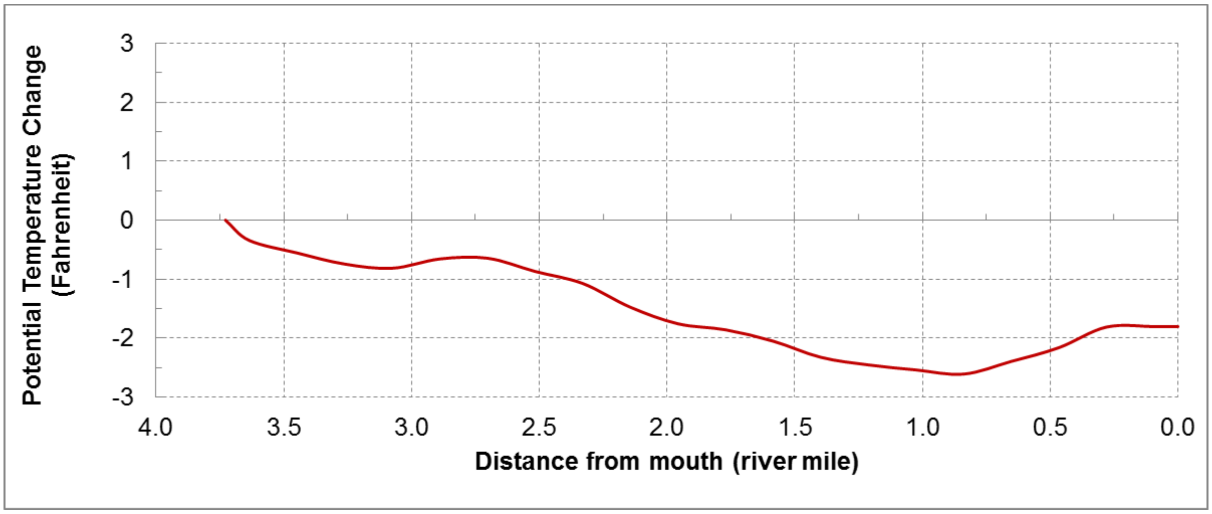


Figure 5-8. The maximum naturally occurring temperature in White Pine Creek relative to the existing condition (baseline scenario) and the allowed temperature.

The naturally occurring scenario results indicate there is the potential for reductions in stream temperatures relative to the existing condition (baseline scenario) along the modeled segments: the potential temperature decreases from this scenario as compared to the baseline scenario ranged from 0.3°F to 2.6°F, with an average decrease of 1.6°F (**Figure 5-9**). This corresponds to reductions ranging from 0°F to 1.6°F to meet the allowable temperature. Like the shade scenario, the maximum decrease was in the downstream segments at RM 0.8. The smallest changes were in the upstream segments near the model's upstream boundary condition (**Figure 5-10**).



Note: A negative temperature change indicates potential decreases in temperatures from the baseline existing conditions to the naturally occurring conditions.

Figure 5-9. Potential temperature changes in White Pine Creek between the baseline (existing conditions) and naturally occurring scenario.

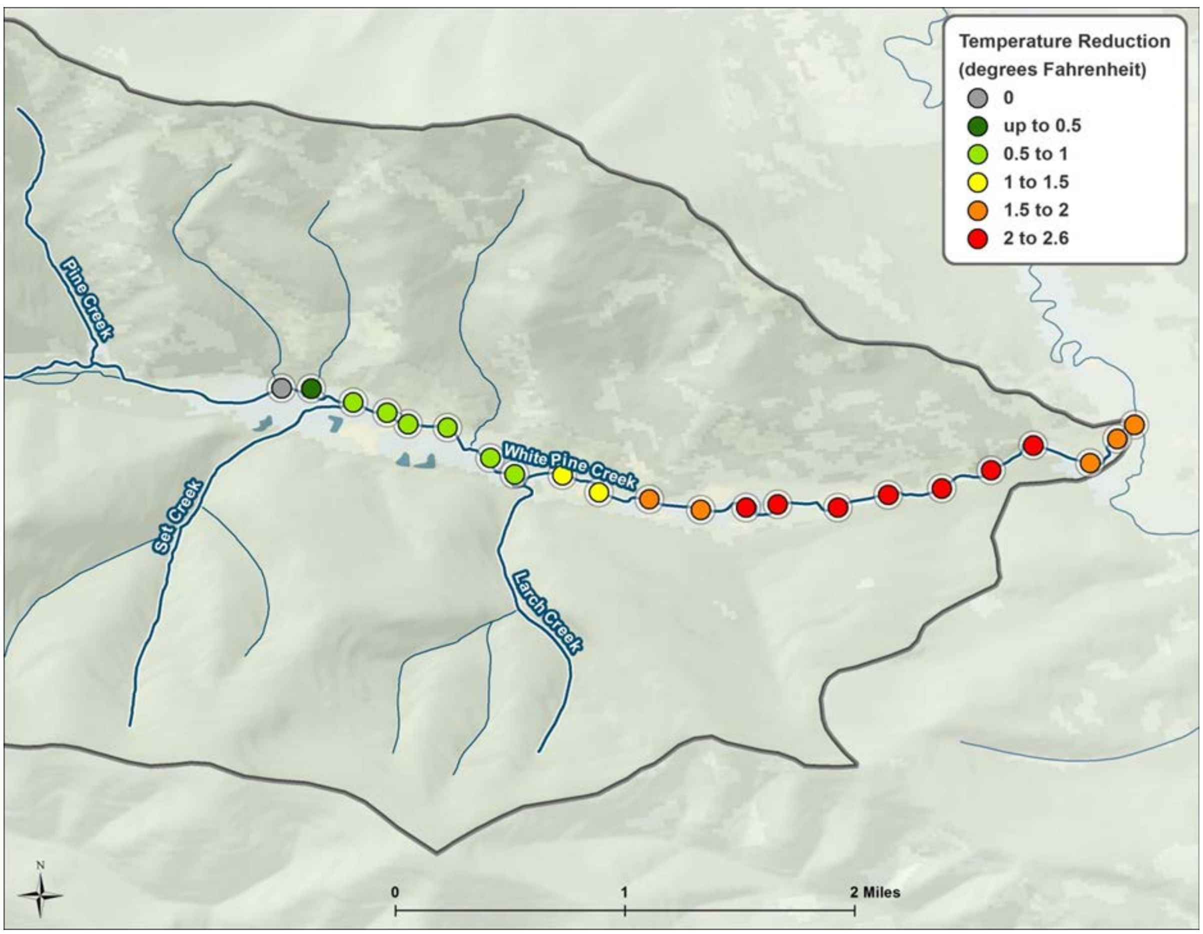


Figure 5-10. Temperature reductions in White Pine Creek that can be obtained under naturally occurring conditions (relative to the baseline scenario).

5.5.5 White Pine Creek QUAL2K Model Assumptions

The following is a summary of the significant assumptions used during the QUAL2K model development:

- White Pine Creek can be divided into distinct segments, each considered homogeneous for shade, flow, and channel geometry characteristics. Monitoring site locations were selected to be representative of segments of White Pine Creek.
- Spatial variability of velocity and depth (e.g. stream meander and hyporheic flow paths) are represented through exponents and coefficients of the selected rating curves for each segment.
- Weather conditions at The Cabinet (Trout Creek) RAWS are representative of local weather conditions along White Pine Creek.
- Shade Model results are representative of riparian shading along segments of White Pine Creek.
- Application of some water conservation measures resulting in a 15% decrease in water withdrawn is reasonable and consistent with the definition of the naturally occurring condition.
- The effective shade using a reference condition is achievable and consistent with the definition of the naturally occurring condition.

5.6 Temperature TMDLs and Allocations

Total maximum daily loads (TMDLs) are a measure of the maximum load of a pollutant that a particular waterbody can receive and still maintain water quality standards (**Section 4.0**). A TMDL is the sum of wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. A TMDL includes a margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. Allocations represent the distribution of allowable load applied to those factors that influence loading to the stream. In the case of temperature, thermal loading is assessed.

5.6.1. Temperature TMDL and Allocation Framework

Because stream temperatures change throughout the course of a day, the temperature TMDL is expressed as the instantaneous thermal load associated with the stream temperature when in compliance with Montana's water quality standards. As stated above, the temperature standard is defined as follows: The maximum allowable increase over the naturally occurring temperature is 1°F, when the naturally occurring temperature is less than 66°F. Within the naturally occurring temperature range of 66–66.5°F, the allowable increase cannot exceed 67°F. If the naturally occurring temperature is greater than 66.5°F, the maximum allowable increase is 0.5°F. Montana's temperature standard that applies to White Pine Creek relative to naturally occurring temperatures is depicted in **Figure 5-11**.

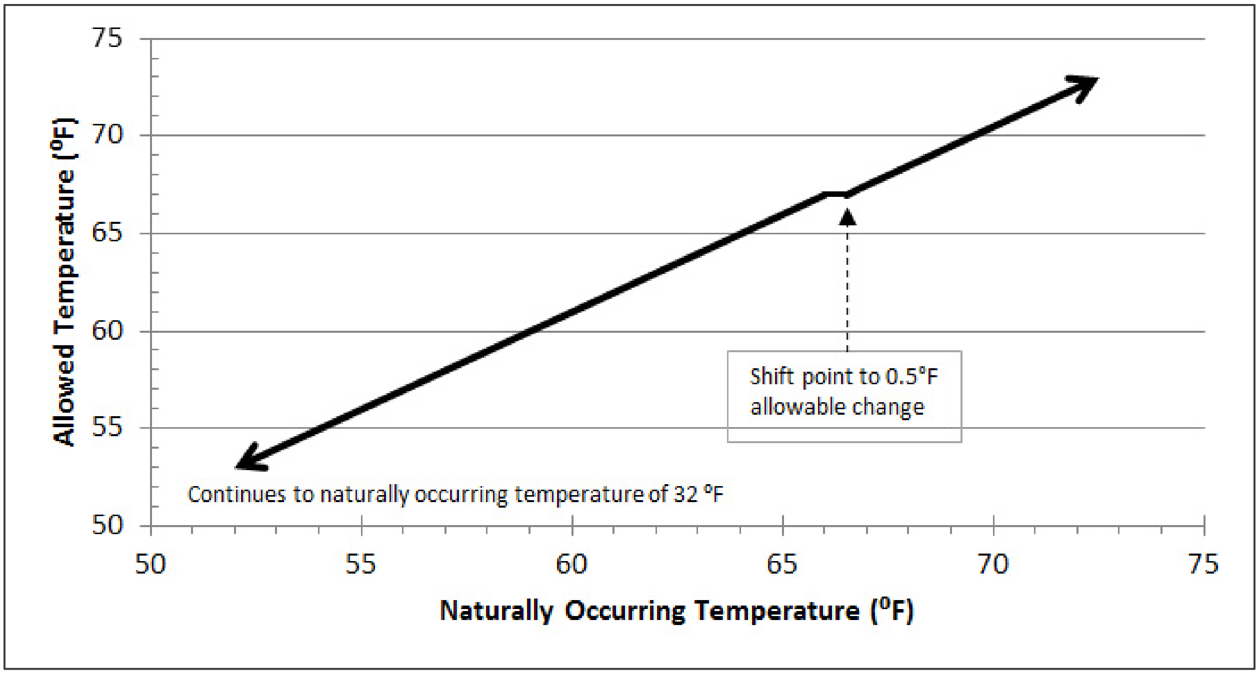


Figure 5-11. Line graph of the temperature standard that applies to White Pine Creek

For any naturally occurring temperature over 32°F (i.e., water's freezing point), the allowable instantaneous thermal total maximum load (kilocalories per second [kcal/s]) can be calculated using the standard to identify the allowable human-caused increase (stated above and shown in **Figure 5-11**) and **Equation 5-1.**

Equation 5-1: $TMDL = (((T_{NO} + \Delta) - 32) * 5/9) * Q * 28.3$

Where:

TMDL = allowable thermal load (kcal/s) above 32°F
T_{NO} = naturally occurring water temperature (°F)
Δ = allowable increase above naturally occurring temperature (°F)
Q = streamflow (cfs)
5/9 = conversion factor from degrees Fahrenheit to Celsius
28.3 = conversion factor from degrees Celsius to kcal/s

The instantaneous load is most appropriate expression for a temperature TMDL because water temperatures fluctuate throughout the day and an instantaneous load allows for evaluation of human caused thermal loading during the daytime when fish are most distressed by elevated water temperatures and when human-caused thermal loading would have the most effect. Although EPA encourages TMDLs to be expressed in the most applicable timescale, it also requires TMDLs to be presented as daily loads (Grumbles, Benjamin, personal communication 2006). Any instantaneous TMDL calculated using **Equation 5-1**, which provides a load per second, can be converted to a daily load (kcal/day) by multiplying by 86,400 (i.e., the number of seconds in a day).

Because calculation of the TMDL on any timescale relies on the identification of the naturally occurring condition, which fluctuates over time and within a stream, it generally requires a water quality model. However, the shade, width/depth, and instream flow targets that will be met when all reasonable land, soil, and water conservation practices are applied and the water conservation efforts that fall under the definition of naturally occurring are also measurable components of meeting the TMDL and water quality standard. Meeting targets for effective shade and width/depth, and applying all reasonable water conservation measures collectively provide an alternative method for meeting and evaluating the TMDL that more directly translates to implementation than an instantaneous or daily thermal load.

Therefore, these temperature-influencing measures are being provided as a surrogate TMDL. An example instantaneous TMDL will also be provided. Conceptually, the allocations for the surrogate TMDL and numeric TMDL are the same: the entire load is allocated to natural sources and nonpoint human sources that influence temperature (by altering effective shade, width/depth ratio, and instream flow). Human sources should follow all reasonable land, soil, and water conservation practices.

5.6.2 Temperature TMDL and Allocations

An example TMDL for White Pine Creek, expressed as instantaneous load, is presented in **Table 5-4** and the surrogate TMDL and allocations are presented in **Table 5-5**. The example TMDL is a direct translation of the water quality standard into a thermal load. There are no point sources and the entire allowable loads are allocated to the load allocation for natural and human sources that influence temperature ($LA_{Naturally\ Occuring}$).

The example TMDL for White Pine Creek is based on the modeled naturally occurring maximum daily temperature at the mouth (WPC-T1) during August 2013 flows (11.10 cfs). The naturally occurring temperature used in the example is 63.48°F, which means there is an allowable increase of 1.0°F and the allowable temperature would be 64.48°F. The calculation for the example TMDL following **Equation 5-1** is shown below:

$TMDL = LA_{Naturally\ Occuring} = ((63.48 + 1.0) – 32) * 5/9) * 11.10 * 28.3 = 5,668$ kcal/second

In this example, the maximum daily stream temperature from the baseline scenario was 65.28°F, 1.8°F above the naturally occurring temperature, and 0.8°F above the standard. With the observed flow, the thermal load was calculated as 5,808 kcal/second.

The surrogate TMDL for White Pine Creek contains allocations to temperature-influencing factors that will result in standards attainment when met. Because there are no point sources, there are no wasteload allocations. There is an implicit margin of safety (MOS); the main factor in the MOS is that although there is an allowable increase over the naturally occurring condition, when implementing the TMDL, human sources should follow all reasonable land, soil, and water conservation practices. Additional details about the MOS are described in **Section 5.7**.

Table 5-4. Example Instantaneous Temperature TMDL and Allocation for White Pine Creek (at the mouth).

Waterbody	**Modeled Existing Load (kcal/sec)**	**TMDL/** $LA_{Naturally\ Occuring}$ **(kcal/sec)**	**Percent Reduction Needed**
White Pine Creek	5,808	5,668	2.4%

This example represents a condition where a 0.8°F reduction is needed to achieve the TMDL. As discussed in **Section 7.5.4**, the needed reductions, based on modeling results along White Pine Creek, range from 0°F to 1.6°F. This means that in many locations, as shown by **Figure 5-11**, the thermal load reduction is significantly greater. Thermal loads can only be calculated at the four locations that were along the modeled segment where flow was monitored. The largest relative temperature differential between the baseline (4,850 kcal/sec) scenario and the allowed temperature (4,651 kcal/sec) scenarios was at logger WPC-T2 (RM 0.68, flow of 9.03 cfs) with a percent reduction of 4.1% (and temperature reduction of 1.6° F). This location corresponds to the reference shade condition, which likely allows instream temperatures to recover slightly before flowing into the more open reach above the mouth.

Table 5-5. Surrogate Temperature TMDL and Allocations for White Pine Creek

Source Type	Surrogate Allocation
Land uses and practices that reduce riparian health and shade provided by near-stream vegetation along White Pine Creek	Improve shade along the modeled segment (RM 3.7 to mouth) to the reference condition at logger WPC-T2.
Overwidening of the stream due to channel and bank erosion associated with historical logging, grazing, and road maintenance (Montana Department of Environmental Quality, 2010)	Improve width/depth ratio to ≤25, the expected range for a Rosgen type C or F stream with gradient <2%
Inefficient consumptive water use	Application of all reasonable water conservation practices
Surrogate TMDL	**Application of all reasonable land, soil, and water conservation practices for human sources that could influence stream temperatures. This primarily includes those affecting riparian shade and instream flow.**

5.6.2.1 Meeting Temperature Allocations

Diminished riparian shade is the primary source of the impairment. Watershed Consulting, LLC (2001) concluded in their watershed assessment that "riparian forests are the answer to most problems within the lower portion of the drainage." The context was bank and channel stability and sediment load, but the QUAL2K model demonstrates the relevance for temperature as well. In most instances, current management practices are meeting the intent of the allocations, and many landowners described their individual efforts at riparian planting. DEQ realizes that re-establishment of a riparian overstory and meeting the effective shade target will take a long time, likely measure in decades. The commitment to improving water quality needs to be maintained so that the existing riparian vegetation can continue to mature, diversify and expand. The targets and allocations represent the desired conditions that would be expected in most areas along the stream, but as discussed relative to shade and water conservation in the target and source assessment sections (**5.4.2** and **5.5**), DEQ acknowledges that the allocations may not be achievable at all locations along the stream. The surrogate TMDL provides a measure of conditions that equate to meeting the temperature standard, but the intent and measure of success for all allocations is to follow all reasonable land, soil, and water conservation practices.

5.7 Seasonality and Margin of Safety

Seasonality and margin of safety are both required elements of TMDL development. This section describes how seasonality and margin of safety (MOS) were applied during development of the White Pine Creek temperature TMDL.

Seasonality addresses the need to ensure year-round beneficial-use support. Seasonality is addressed for temperature in this TMDL document as follows:

- Temperature monitoring and modeling occurred during the summer, which is the warmest time of the year and when instream temperatures are most stressful to aquatic life.

- Effective shade was based on the August solar path, which is typically the hottest month of the year.
- Although the maximum daily temperature was the focus of the source assessment and impairment characterization, because it is mostly likely to stress aquatic life, sources affecting maximum stream temperatures can also alter daily minimum temperatures year-round.
- Addressing the sources causing elevated summer stream temperatures will also address sources that could lower the minimum temperature at other times of the year.
- Temperature targets, the TMDL, and load allocations apply year round, but it is likely that exceedances occur mostly during summer conditions.

This TMDL includes an implicit MOS. The MOS is included to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. The MOS is addressed in several ways for temperature as part of this document:

- Although there is an allowable increase from human sources beyond those applying all reasonable land, soil, and water conservation practices, the surrogate allocations are expressed so human sources must apply all reasonable land, soil, and water conservation practices.
- Montana's water quality standards are applicable to any timeframe and any season. The temperature modeling analysis for White Pine Creek investigated stream temperatures during summer when effects of increased water temperatures are most likely to have a detrimental effect on aquatic life.
- August 2013 flows at a nearby stream gage (Prospect Creek near Thompson Falls, 12907000) were at the 34th percentile of the period of record, suggesting that the flows modeled and measured in White Pine Creek are likely to be lower than average. This represents a conservative condition, and an additional margin of safety.
- Actions taken to improve channel stability and reduce width-to-depth ratio are also expected to reduce instream temperatures. Such work is likely to coincide with efforts to improve riparian vegetation, providing an additional improvement in instream temperatures not accounted for in this document.
- Residents of White Pine Creek report that despite the DNRC water rights and use data, there is no active irrigation within the watershed. Although the modeled withdrawals are small, their inclusion in the water use and naturally occurring scenarios represents a further margin of safety.
- Meeting targets and refinement of load allocations are all based on an adaptive management approach (**Section 5.8**) that relies on future monitoring and assessment for updating planning and implementation efforts.

5.8 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, source assessments, water quality models, loading calculations and other considerations are inherent when evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainty through adaptive management approaches is a key component of ongoing TMDL implementation activities. Uncertainties, assumptions and considerations are applied throughout this document and point to the need for refining analyses when needed.

The process of adaptive management is predicated on the premise that TMDLs, allocations, and their supporting analyses are not static, but are processes that are subject to periodic modification and adjustment as new information and relationships are better understood. As further monitoring and assessment is conducted, uncertainties with present assumptions and consideration may be mitigated via periodic revision or review of the assessment which occurred for this document. As part of the adaptive management approach, changes in land and water management that affect temperature should be tracked. As implementation of restoration projects which reduce thermal input or new sources that increase thermal loading arise, tracking should occur. Known changes in management should be the basis for building future monitoring plans to determine if the thermal conditions meet state standards.

Uncertainty was minimized during data collection because EPA temperature and field data were collected following a Quality Assurance Project Plan (QAPP) (Tetra Tech, 2013) and adhering to DEQ sampling protocols (Montana Department of Environmental Quality, 2005b; 2005a). A QAPP was also completed for the QUAL2K model (Tetra Tech, 2013), but there was more uncertainty associated with the model than with the field data because numerous assumptions had to be made to help simulate existing and naturally occurring conditions. Modeling assumptions are briefly described in **Section 5.5.5** but are further detailed within the model reports in **Appendix B**.

The largest source of uncertainty is regarding the targets and conditions used to represent the naturally occurring condition. The target for effective shade from riparian vegetation is intended to represent the reference condition (i.e., highest achievable) and is based on field observations, a previous study (Water Consulting, Inc., 2002), communication with stakeholders, and best professional judgment. It was selected to be conservative yet achievable. As discussed in the target and source assessment sections (**5.4** and **5.5**), the ultimate goal and measure of success is implementation of all reasonable land, soil, and water conservation practices. Literature values were used to estimate the potential for additional instream flow if additional water conservation measures are necessary and implemented. Other areas of uncertainty related to the model are associated with assumptions regarding channel dimensions and groundwater temperatures; limited information for those sources was used and applied throughout the watershed. Riparian shade is highly variable in the watershed but a comparison between the field measured effective shade values and values simulated via the Shade Model indicate the model reasonably approximated existing shade conditions within the watershed. Additional details regarding uncertainty associated with the model are contained in **Appendix B**.

The TMDLs and allocations established in this section are meant to apply to recent conditions of natural background and natural disturbance. Under some periodic natural conditions, such as fire, it may not be possible to satisfy all targets, loads, and allocations because of natural short-term affects to temperature. Additionally, fire has the potential to alter the long-term vegetative potential. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDL within a reasonable time frame and to prevent significant long-term excess loading during recovery from significant natural events.

Any factors that increase water temperatures, including global climate change, could impact thermally sensitive fish species in Montana. The assessments and technical analysis for the temperature TMDL considered a worst case scenario reflective of current weather conditions, which inherently accounts for any global climate change to date. Allocations to future changes in global climate are outside the scope of this project but could be considered during the adaptive management process if necessary.

6.0 MONITORING STRATEGY AND ADAPTIVE MANAGEMENT

6.1 MONITORING PURPOSE

The monitoring strategies discussed in this section are an important component of watershed restoration, and a requirement of total maximum daily load (TMDL) implementation under the Montana Water Quality Act (Montana Code Annotated (MCA) 75-5-703(7)), and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis. The scale of the watershed analysis, coupled with constraints on time and resources, often result in necessary compromises that include estimations, extrapolation, and a level of uncertainty in TMDLs. The margin of safety (MOS) (**Section 4.4**) is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities, the amount of reduction of instream pollutants (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate.

The monitoring strategy presented in this section provides a starting point for the development of more detailed planning efforts regarding monitoring needs; it does not assign monitoring responsibility. Monitoring recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet the water quality improvement goals outlined in this document. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on funding opportunities and stakeholder priorities for restoration. Once restoration measures have been implemented for a waterbody with an approved TMDL and given time to take effect, Department of Environmental Quality (DEQ) will conduct a formal evaluation of the waterbody's impairment status and determine whether TMDL targets and water quality standards are being met.

6.2 ADAPTIVE MANAGEMENT AND UNCERTAINTY

In accordance with the Montana Water Quality Act (MCA 75-5-703 (7) and (9)), DEQ is required to assess the waters for which TMDLs have been completed and restoration measures, or best management practices (BMPs), have been applied to determine whether compliance with water quality standards has been attained. This aligns with an adaptive management approach that is incorporated into DEQ's assessment and water quality impairment determination process.

Adaptive management as discussed throughout this document is a systematic approach for improving resource management by learning from management outcomes, and allows for flexible decision making. There is an inherent amount of uncertainty involved in the TMDL process, including: establishing water quality targets, calculating existing pollutant loads and necessary load allocations, and determining effects of BMP implementation. Use of an adaptive management approach based on continued monitoring of project implementation helps manage resource commitments and achieve success in meeting the water quality standards and supporting all water quality beneficial uses. This approach further allows for adjustments to restoration goals, TMDLs, and/or allocations, as necessary.

For an in-depth look at the adaptive management approach, view the U.S. Department of the Interior's (DOI) technical guide and description of the process at: http://www.doi.gov/archive/initiatives/AdaptiveManagement/. DOI includes **Figure 6-1** below in their technical guide as a visual explanation of the iterative process of adaptive management (Williams et al., 2009).

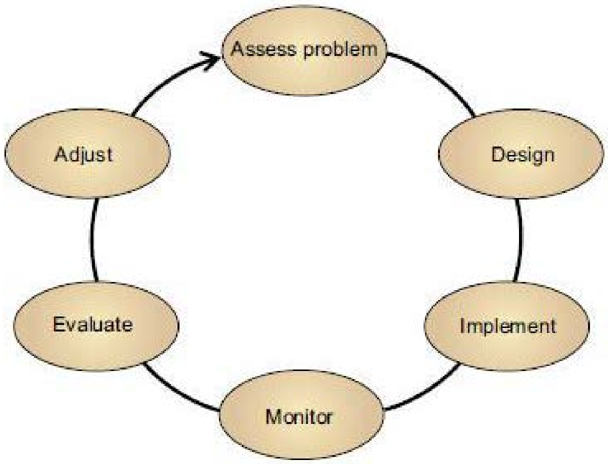


Figure 6-1. Diagram of the adaptive management process

6.3 Future Monitoring Guidance

The objectives for future monitoring in the White Pine Creek watershed include:

- Strengthen the spatial understanding of sources for future restoration work, which will also improve source assessment analysis for future TMDL review
- Gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development
- Coordinate among agencies and watershed groups to ensure that information is comparable to the established water quality targets and allows for common threads in discussion and analysis
- Track restoration projects as they are implemented and assess their effectiveness

6.3.1 Strengthening Source Assessment

In the White Pine Creek watershed, the identification of pollutant sources was conducted largely through reviewing and analyzing available data, tours of the watershed, assessments of aerial photographs, the incorporation of geographic information system information, and the review of published scientific studies. In many cases, assumptions were made based on known watershed conditions and extrapolated throughout the project area. As a result, the level of detail often does not provide specific areas on which to focus restoration efforts, only broad source categories to reduce pollutant loads. Strategies for strengthening source assessments for each of the pollutant categories are outlined below.

- Field surveys to better identify and characterize riparian area conditions and potential for improvement
- Identification of possible areas for improvement in shading along major tributaries
- Collection of flow measurements at all temperature monitoring locations during the time of data collection

- Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use in White Pine Creek
- Assessment of irrigation practices and other water use in White Pine Creek and potential for improvements in water use that would result in increased instream flows
- Use of additional collected data to evaluate and refine the temperature targets

6.3.2 Increasing Available Data

While White Pine Creek and its watershed has undergone restoration activities, data are still often limited. Infrequent sampling events at a small number of sampling sites may provide some indication of overall water quality and habitat condition. However, regularly scheduled sampling at consistent locations, under a variety of seasonal conditions is the best way to assess overall stream health and monitor change.

Temperature investigation for White Pine Creek included a total of eight data loggers, deployed throughout these streams and selected tributaries in summer months of 2013. Increasing the number of data logger locations and the number of years of data, including collection of associated flow data, would improve our understanding of instream temperature changes and better identify influencing factors on those changes. Collecting additional stream temperature data in sections with the most significant temperature changes and/or largest spatial gaps between loggers will also help refine the characterization of temperature conditions in White Pine Creek. In addition, riparian shade data were collected using a combination of field data and aerial imagery analysis. A Solar Pathfinder™ was used to measure effective shade on dates during the late summer at five sites. Since shade is the major focus of the allocations, a more detailed assessment of existing riparian conditions and identification of areas for passive and active restoration of riparian vegetation on White Pine Creek and its major tributaries is recommended. Finally, coordinating with other organizations to incorporate suitable temperature data will improve future assessments of White Pine Creek.

6.3.3 Consistent Data Collection and Methodologies

Data have been collected in the White Pine Creek watershed for many years and by many different agencies and entities; however, the type and quality of information is often variable. Wherever possible, it is recommended that the type of data and methodologies used to collect and analyze the information are consistent so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals.

DEQ is the lead agency for developing and conducting impairment status monitoring; however, other agencies or entities may work closely with DEQ to provide compatible data. Water quality impairment determinations are made by DEQ, but data collected by other sources can be used in the impairment determination process. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking. Future monitoring efforts should consult DEQ on updated monitoring protocols. Improved communication between agencies and stakeholders will further improve accurate and efficient data collection. The development of a DEQ approved Sampling and Analysis Plan (SAP) and a Quality Assurance Project Plan (QAPP) will ensure that the data collected meet DEQ standards for data quality.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect water quality beneficial uses in a manner consistent with Montana's water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, state, and federal laws.

It is important that temperature data are collected in consistent locations and using consistent methods. Data loggers should be deployed at the same locations through the years to accurately represent the site-specific conditions over time, and recorded temperatures should at a minimum represent the hottest part of the summer when aquatic life is most sensitive to warmer temperatures. Data loggers should be deployed in the same manner at each location and during each sampling event, and follow a consistent process for calibration and installation. Any modeling that is used should refer to previous modeling efforts (such as the QUAL2K analysis used in this document) for consistency in model development to ensure comparability. In addition, flow measurements should also be conducted using consistent locations and methodology.

6.3.4 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, monitoring is valuable to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. Monitoring can help attribute water quality improvements to restoration activities and ensure that restoration activities are functioning effectively. Restoration projects will often require additional maintenance after initial implementation to ensure functionality. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in fine sediment deposition and channel substrate embeddedness, changes in channel cumulative width/depths, improvements in bank stability and riparian habitat, increases in instream flow, and changes in communities and distribution of fish and other bio-indicators. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints. Riparian vegetation targets are chosen such that they can provide an efficient means of assessing improvement in riparian shade, and by extension, instream temperatures.

As restoration activities begin throughout the project area, pre and post monitoring to understand the change that follows implementation will be necessary to track the effectiveness of specific projects. Monitoring activities should be selected such that they directly investigate those subjects that the project is intended to effect, and when possible, linked to targets and allocations in the TMDL. For example, as bank erosion is addressed, pre and post Bank Erosion Hazard Index (BEHI) analysis on the subject banks will be valuable to understand the extent of improvement and the amount of sediment reduced.

7.0 STAKEHOLDER AND PUBLIC PARTICIPATION

Stakeholder and public involvement is a component of total maximum daily load (TMDL) planning supported by Environmental Protection Agency (EPA) guidelines and required by Montana state law (Montana Code Annotated (MCA) 75-5-703, 75-5-704) which directs Department of Environmental Quality (DEQ) to consult with watershed advisory groups and local conservation districts during the TMDL development process. Technical advisors, stakeholders and interested parties, state and federal agencies, interest groups, and the public were solicited to participate in differing capacities throughout the TMDL development process in the White Pine Creek temperature TMDL project.

7.1 PARTICIPANTS AND ROLES

Throughout completion of the White Pine Creek TMDL project, DEQ maintained contact with stakeholders to keep them apprised of project status. A description of the participants in the development this TMDL and their roles is contained below.

7.1.1 Montana Department of Environmental Quality

Montana state law (MCA 75-5-703) directs DEQ to develop all necessary TMDLs. DEQ has provided resources toward completion of these TMDLs in terms of staff, funding, internal planning, data collection, technical assessments, document development, and stakeholder communication and coordination. DEQ has worked with other state and federal agencies to gather data and conduct technical assessments.

7.1.2 U.S. Environmental Protection Agency

EPA is the federal agency responsible for administering and coordinating requirements of the Clean Water Act (CWA). Section 303(d) of the CWA directs states to develop TMDLs (see **Section 1.1**), and EPA has developed guidance and programs to assist states in that regard. EPA has provided funding and technical assistance to Montana's overall TMDL program and is responsible for final TMDL approval.

7.1.3 TMDL Advisory Group

White Pine Creek is located within the Lower Clark Fork Watershed Group's geographic area. Following the watershed group's close involvement with sediment and habitat TMDL development a few years prior, the watershed group functioned as a TMDL Advisory Group for this TMDL project. The White Pine Creek temperature TMDL Advisory Group consisted of resource professionals who possess a familiarity with water quality issues and processes in the project area, and also representatives of applicable interest groups. All members were solicited to participate in an advisory capacity per Montana state law (75-5-703 and 704). DEQ requested participation from the interest groups defined in MCA 75-5-704 and included local county representatives, conservation groups, watershed groups, state and federal land management agencies, and representatives of recreation and tourism interests. The advisory group also included additional stakeholders and landowners with an interest in maintaining and improving water quality and riparian resources.

Advisory group involvement was voluntary and the level of involvement was at the discretion of the individual members. Members had the opportunity to provide comment and review of technical TMDL assessments and reports. A draft document was released to the advisory group for review under a limited timeframe, prior to the public comment period. Final technical decisions regarding document modifications resided with DEQ.

Communications with the group members was typically conducted through e-mail and draft documents were made available through DEQ's wiki for TMDL projects (http://montanatmdlflathead.pbworks.com). Opportunities for review and comment were provided for participants at varying stages of TMDL development, including opportunity for review of the draft TMDL document prior to the public comment period.

7.1.4 Montana Conservation Districts

White Pine Creek is in Sanders County. Therefore, DEQ provided the Green Mountain Conservation Districts with consultation opportunities during TMDL development. This included opportunities to provide comment during the various stages of TMDL development, and an opportunity for participation in the TMDL advisory group.

7.1.5 Area Landowners

Since portions of the project area are in private ownership, local landowner cooperation in the TMDL process has been important for stream monitoring. The DEQ sincerely thanks the project area landowners for their support of these efforts.

7.2 Response to Public Comments

Upon completion of the draft TMDL document, and prior to submittal to EPA, DEQ issues a press release and enters into a public comment period. During this timeframe, the draft TMDL document is made available for general public comment, and DEQ addresses and responds to all formal public comments.

The public review period began on September 8, 2014, and ended on October 9, 2014. DEQ made the draft document available to the public, solicited public input and comments, and announced a public meeting at which the TMDL was presented to the public. These outreach efforts were conducted via e-mails to watershed advisory group members and other interested parties, posts on the DEQ website, and announcements in the following newspapers: the Sanders County Ledger (Thompson Falls), the Clark Fork Valley Press (Plains), and The Missoulian. DEQ provided an overview of the TMDL at a landowners meeting in White Pine Creek on August 25, 2014 and in a public presentation in Trout Creek on September 15, 2014.

During the public comment period, DEQ received one submittal that included several comments. The comments and accompanying responses are provided below. The original comments are held on file at DEQ and are available upon request.

Comment 1

We concur with improving water quality by decreasing temperature, but based on our extensive experience with stream habitat improvement and revegetation efforts in this and other lower Clark Fork tributaries (Horn 2011, Watershed Consulting 2009), temperature impairment should be considered in connection to, rather than separate from, the more significant sediment impairment occurring in the drainage. We recommend that the linkages between excess sediment (identified in the sediment TMDL) and increased channel and stream bank instability, which precludes reestablishing mature woody riparian vegetation, is emphasized throughout. In light of the standard top-down approach for stream *rehabilitation, the prescription to begin revegetation lower in the drainage with miles of sediment-delivering channel upstream may not be effective. The report could highlight the concurrent benefits to temperature that can be achieved by increasing bank stability and lowering width to depth ratios.*

Response 1

Many of the specific comments (below) question DEQ's temperature impairment determination, while others emphasize the scale of the sediment and habitat impairment. However, this demonstrates general agreement regarding the nature of impairment to White Pine Creek: a substantial sediment impairment (43% required reduction: DEQ, 2010) and a modest temperature impairment (≤4% required reduction). As sediment and temperature impairments commonly arise from similar sources, actions to address the excess sediment loading and bank stability are expected to also address the temperature impairment. Additional text emphasizing this relationship has been added to several locations in the document: **Sections 4.5**, **5.5,** and **5.6.2.1**.

This document identifies deficient riparian vegetation and the resulting reduced shade as the major source of temperature impairment. However, revegetation of the lower drainage is only part of DEQ's recommendation for improving instream temperatures. The relationship between channel geometry and instream temperatures is also acknowledged at multiple points. DEQ prepared a sediment and habitat TMDL for White Pine Creek in 2010, and is familiar with the magnitude and sources of these impairments. DEQ further expects that restoration activities intended to improve channel geometry and bank stability will also improve instream temperatures. This relationship is mentioned at several points in this document, and expanded upon and strengthened in response to these comments (e.g. **Sections 5.5** and **5.6.2.1**).

Comment 2

We were concerned that modeled temperatures may have received undue emphasis due to the influence of limited data and/or validating temperatures that were taken at lower than average flows. If these temperatures were warmer than may be typical, then the impairment may need to be reassessed or validated by another season of typical flows and therefore temperatures. There is some doubt as to whether the modeled temperature response would be attainable or detectable in light of the time frame needed for vegetation shading as opposed to the predicted warming of northern Rocky Mountain streams modeled in recent publications (Wenger et al. 2011, Isaak and Rieman 2012; among others).

Response 2

The model is intended to simulate conditions during the hottest and driest part of the year. Although flows were likely below average for August, based on the 34th percentile flows at a nearby gage (Prospect Creek, 12907000), this still represents conditions that occur with some frequency. These conditions have the potential to impact aquatic life. Simulating these conditions is the purpose of the QUAL2K model, and lower than average flows are appropriate in a system like White Pine Creek, where the temperature impairment is modest. In systems where DEQ investigates the potential for delisting, the stream is generally modeled with 25th percentile flows to simulate drought conditions. Although changing climate is predicted to have a region-wide warming effect on stream temperatures, the baseline for naturally occurring conditions would change accordingly. Increased shade would still have a measureable effect on reducing in-stream temperatures.

Specific draft TMDL Report Comments

The specific comments were ordered according to page number in the draft document. DEQ has re-ordered these comments to address the three identified areas of concern subject-by subject. The original letter is on file at DEQ and available upon request.

Limited mention of the influence of sediment impairment

Comment 3

Pg.2-6 (also Fig 2-7): Notable that soils classified as "moderate-highly" susceptible to erosion constitutes the revegetation area (area of unstable banks). These erodible soils are also described in Watershed Consulting (2001) and history of unsuccessful stream work along private areas of White Pine Creek (Thom 2011); the potential impact that this may have on being able to reestablish riparian vegetation and channel morphology, width/depth ratios is not mentioned or analyzed.

Response 3

The watershed assessment prepared by Watershed Consulting (Water Consulting, Inc., 2002) discusses soil types, but does not include a discussion of erodibility beyond a statement on page 10 that "fluvent soils, landforms and native vegetation community are extremely sensitive to degradation." The discussion of mass wasting and erosion that follows on page 12 is focused on parent geologic materials exposed in tall banks. Soils with K-factors of 0.3 to 0.4 are not particularly uncommon in western Montana, and their mapped occurrence does not predict riparian communities. **Figure 2-7** does help provide some context for why the system, once destabilized, continues to exhibit bank instability and poorly developed riparian vegetation. Additional text on this point has been added to **Section 2.1.5**.

Comment 4

Pg 5-2, 5.3.2: It would be helpful to cite where the collected "channel geometry" data is presented, as width/depth ratios, BEHI indexes, etc. are particularly relevant for solar input and relative bank stability needed to establish riparian vegetation.

Response 4

DEQ added the location of sediment TMDL site WPC 9-2 to **Section 5.4.4.3**.

Comment 5

Pg 5-5, 5.4.2.3 (and 5-10) Width/Depth Ratio: As stated, a default W/D ratio from Rosgen was used as a target value. However, on-the ground measurements would appear to be more relevant but were not mentioned until 5-10, and the locations of these W/D measurements and other pertinent measurements such as bank stability indices that may have been taken on-the-ground or during the watershed assessment (WC 2001), were not mentioned. For example, earlier measurements of lower channel from assessment (WC 2001) pg 37, stated a W/D of 26-30; and also described an over-widened and aggraded lower channel (pg 31 and 36).

Response 5

The target provided in **Section 5.4.2.3** is taken from the sediment TMDL for White Pine Creek (Montana Department of Environmental Quality, 2010). DEQ believes that carrying this target from the sediment TMDL to the temperature TMDL is reasonable and logical, given the closely related nature of these impairments. While it is not specifically stated in this section, the sediment TMDL and target selection was based upon fluvial geomorphology surveys of White

Pine Creek in addition to regional reference data. As noted above, the location of the most relevant sediment/habitat field site (WPC 9-2) is added to **Section 5.4.4.3**.

Comment 6

Pg 5-11 (2nd paragraph): The link between channel morphology and shade, as well as the "lack of available data", and ability to incorporate this data into the model could be more thoroughly described. This is particularly true as it is mentioned in next sentence that this was "evaluated" in the sediment TMDL; which suggests that the data exists. This next sentence also stated a required 43% reduction in sediment load: this large departure, as well as the highly erodible soils should be given greater emphasis. It is recommended that past experience both in this drainage (WC 2001, Horn 2011) and throughout the lower Clark Fork (WC 2009) is reviewed, referenced, and incorporated into the recommendations of this report.

Response 6

This paragraph has been edited to remove inconsistency and further clarify why changing channel geometry was not evaluated as a model scenario.

Undue emphasis on native salmonid species in impairment criteria

Comment 7

Pg.2-10, Fish Distribution (and Fig 2-11): "The project area provides habitat for bull trout...and westslope cutthroat trout... mapped distribution... based on MFWP..." As stated and portrayed in Figure 2-11, the report implies that all of White Pine is occupied by westslope cutthroat trout and all of lower area is occupied by bull trout. A more accurate portrayal would be to have the large area of intermittency portrayed with westslope cutthroat limited to the upper perennial area and a different color denoting non-native dominated fish assemblage, with few westslope cutthroat and individual juvenile bull trout specified for the lower perennial area. Also, it would be helpful to specify whether the whole stream or just the lower channel was the "project area" as stated at the beginning of this sentence.

Pg.5-1 Fish Presence in White Pine Creek: Please note that more complete fisheries data (Katzman and Tholl 2003, Moran 2005) exists that depicted the lower perennial channel as dominated by non-native species (see attached Table I). Multiple pass electrofishing along three sections totaling over 300m of lower White Pi ne Creek in 2004 resulted in the capture of one juvenile bull trout, one westslope cutthroat trout versus 235 brook trout, 15 brown trout, 10 rainbow trout and nine suspected westslope cutthroat x rain bow hybrids (Moran 2005). This type of data is more descriptive than the presented "fisheries value resource ratings...Substantial (rating score 3) (MFISH)." Non-natives also dominated the fish captured during electrofishing efforts this area in 2001 (Katzman and Tholl 2003). Although one juvenile bull trout was captured (Katzman and Tholl 2003); no bull trout redds were observed during surveys conducted over three years, leading Moran (2005) to surmise that bull trout use of lower White Pine was due to very few juveniles straying upstream from Noxon Reservoir as has been observed in other lower Clark Fork River reservoir tributaries.

Pg.5-1 Temperature (Thermal) Effects: Recommend dropping Bear et al. 2007 competitive advantage citation sentence as the temperature difference in White Pine Creek was not as great as we have observed in other cooler streams where brook trout competitively displaced cutthroat trout.

Response 7
DEQ appreciates the detailed information regarding fish presence in White Pine Creek. Some of this information has been added to provide improved context to the watershed characterization and the aquatic life beneficial-use support.

Bull trout and Westslope cutthroat trout are discussed because they are the most temperature-sensitive species. However, it is important to understand that the water quality standard is not based upon presence or absence of native salmonids (although the state requires that B-1 waters be maintained suitable for growth and propagation of salmonids and related aquatic life (ARM 17.30.623)). The temperature standard for a B-1 waterbody is an allowable increase in temperature from naturally occurring temperatures. This is explained in **Section 3.2** (moved from **Section 5.1** in the final version of the document for improved clarity). Therefore, the presence or absence of Westslope cutthroat trout and/or bull trout played no role in the impairment determination.

Potential problems with modeled temperature

Comment 8

Pg. 5-7 through 5-9 (Figures 5-2 and 5-3): The most restrictive temperature criteria of optimal cutthroat trout growth (62.6 °F) was only exceed in the afternoon at lowest site (Fig 5-3). Given that these temperatures appeared to be based on (or at least validated with) loggers that "may or likely exposed to ambient air temps" (and/or decreased/warmer flow), or only recorded one day or two weeks of data (pg 5-8), it may be illustrative to mention this potential logger shortcoming in the text in addition to beneath-figure (5-2) sub-script.

Response 8
DEQ disagrees with this analysis. Although temperatures only rose above 62.6° F during the day, **Figure 5-3** shows that instream temperatures at the lowest site (WPC-T1) exceeded this temperature repeatedly for seven weeks. DEQ presented data from this logger since it recorded the highest temperatures and greatest potential impact to use. However, this temperature threshold was also repeatedly exceeded at logger location WPC-T2, shown below in **Figure 7-1**, and also in **Appendix B** (**Figure B-4**).

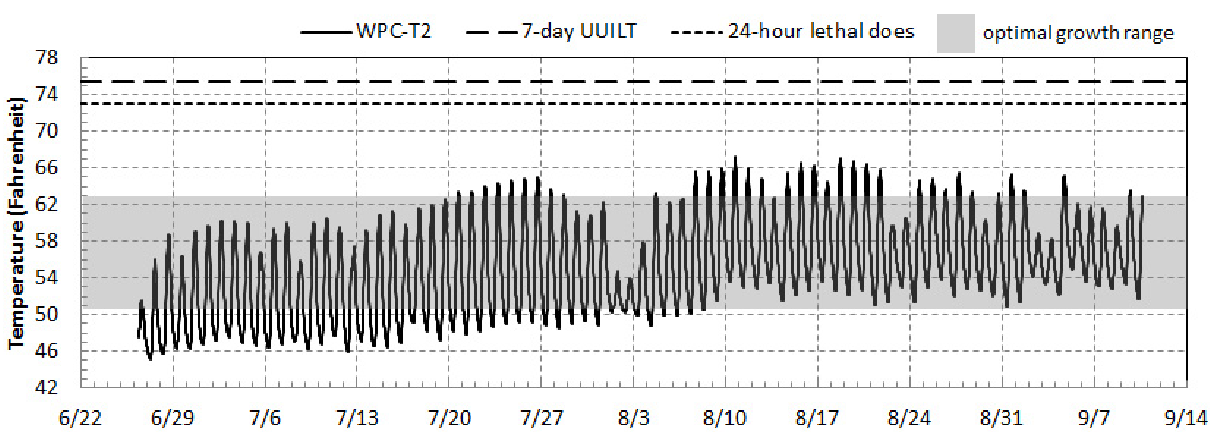


Figure 7-1. Observed diurnal temperatures in White Pine Creek at logger WPC-T2

These temperatures are not based on or nor validated with compromised loggers. The data presented in **Figure 5-3** (and above in **Figure 7-1**) are from individual locations, unrelated to data from any other temperature logger, and therefore do not represent a logger shortcoming or data collection issue.

Comment 9

Pg 5-11: The ability of the model results, which variously state that a 2 to 4% reduction is needed, to be accurate given the 2.8 to 2.9% relative error should be explicitly stated instead of the "provides a reasonable approximation of maximum daily temperatures". The influence that recordings taken when flows were at the 34th percentile could have on modeled temperatures should be acknowledged or clarified.

Response 9

The model errors statistics: 2.8% for calibration and 2.9% for validation, reflect the deviation between the simulated and observed data. Both scenarios (e.g., baseline and naturally occurring scenario; see **Section 5.5.1** and **Section 5.5.4**) are model generated, and the calibration and validation error statistics have no bearing on the simulated deviation. The difference is relative and scales nearly linearly across the range of temperatures evaluated. The 2% and 4% reduction in heat load reflects the change necessary to satisfy a relative temperature difference of 0.8° F and 1.6° F respectively between the baseline condition and naturally occurring condition at two specific points in the stream (see page 5-20 in **Section 5.6**). That the required reduction in thermal loading varies from point to point in the stream is clearly shown in **Figure 5-8**.

The use of below average flows is discussed above. To repeat, although flows were likely below average (based on 34th percentile flows at a nearby gage), this represents conditions that occur with some frequency. Simulating these conditions is the purpose of the QUAL2K model, and below average flows are appropriate in a system like White Pine Creek, where the temperature impairment is modest. DEQ has added text to **Section 5.7** stating that the 34th percentile flows provide an additional margin of safety in the form of conservative flow values which approach stressed conditions. In previous temperature TMDL projects, DEQ has taken a more conservative approach and modeled a 25th percentile flow scenario. In this case DEQ decided that the recorded flows provided a reasonable balance between this approach and average flows.

Comment 10

Pg 5-12: There are no withdrawals from White Pine, so this water use scenario adjustment may not be appropriate.

Response 10

After residents of the White Pine Creek watershed provided this information, DEQ revised the document to reflect this. However, the water rights are not abandoned and withdrawals from White Pine Creek could take place in the future. Therefore DEQ retains this scenario to provide an added margin of safety.

Comment 11

Pg 5-17: Some of the model assumptions, particularly section homogeneity, number of monitoring sites/sections, and withdrawals, may not reflect conditions of lower White Pine Creek. lf the report will include these "significant assumptions", it would be helpful to describe their relative importance, the difficulty of incorporating them into the model and the fact that these assumptions are typically not addressed in other systems.

Pg 6-2, bullet listed under 6.3.1: Considering these shortcomings including the need for: "Riparian area surveys, collection of flow measurements, groundwater investigations, use of additional collected data", it may be prudent to address these to refine modeled temperature and existing riparian conditions including channel shape and stream bank/soil erodibility measurements. Or barring this, consider describing how a phased approach addressing the much larger sediment impairment may be sufficient to lower temperature or at least facilitate the stability needed to establish maturing riparian vegetation besides the existing inadequate alder gallery.

Response 11

The assumptions underlying the model were chosen based on DEQ's extensive prior experience with other watersheds and temperature impairments. They were chosen to reflect conditions in lower White Pine Creek as accurately as practicable. DEQ identifies and includes the assumptions in the report to a) illustrate that DEQ is aware of these considerations and limitations and b) to provide suggestions for focusing and improving future monitoring and modeling efforts. The fact that streambank and channel restoration will have a concurrent benefit to instream temperatures is mentioned at multiple points in the document.

Comment 12

Appendix B, Pg B-26 (Figures B11 and 12): An explanation of why site WPC-T3 was modeled ~4 °F warmer than actual recording is recommended here.

Response 12

DEQ agrees that there is a large deviation between the simulated and observed maximum temperature at WPC-T3. This situation may be addressed in several ways, of which the appropriateness of each depends on system knowledge, quality of the data at that location, and the deviation between adjacent upstream and downstream simulated and observed values. Accordingly, a judgment call must be made on what course of action is most appropriate. One can: (a) further investigate the point in question and thereby make changes to the model made as appropriate to remedy the deviation (i.e., if a known groundwater inflow or coldwater return flow was missed), (b) change the model without having a suitable explanation, which is in essence curve-fitting, or (c) accept the simulated behavior since the model was configured to best available information and did seem to represent adjacent locations suitably (notably downstream stations WPC-T2 and WPC-T1). DEQ chose the final option as the most appropriate.

A possible explanation for the deviation is groundwater input. Diurnal temperature variation at WPC-T1 and WPC-T2 averaged approximately 16 °F. Diurnal temperature variation at WPC-T3 averaged approximately 12 °F. The increase in flow between WPC-T4 (6.55 cfs) and WPC-T3 (10.6 cfs) is likely to be all groundwater (**Figure B-8** in **Appendix B**) and it is possible that the logger location was influenced by groundwater input.

Comment 13

Appendix B, Pg B-46 and 48 (Table B1-1): That current riparian vegetation was only "qualitatively assessed" at three locations deemed to be "at potential" and providing 78-82% shade should be more thoroughly defined. As presented it suggests that riparian vegetation and percent shade is at 78-82% at stations (WPC-T2 — 4) that might be expected to influence water temperature. Also as stated in table B1-1, it suggests that a mono-typical alder swamp is at potential, which is at odds with stated upstream riparian vegetation potential.

Response 13

Riparian vegetation was assessed along the entire length of White Pine Creek, using recent aerial photographs, canopy cover data from the 2001 NLCD (REF), and the Shade model. This is discussed in more detail in **Appendix B** (page B-49). The three locations referenced in the comment above were used to validate the aerial assessment.

The heading of **Table B1-1** is in error, and should present the fifth column as vegetative density, rather than percent shade. Percent shade is provided by the Shade model, and confirmed by field measurements with a Solar Pathfinder™. The density and shade measurements are quantitative assessments. However, the vegetative potential is a qualitative field assessment. DEQ anticipates that potential vegetation will change with varying land uses, in keeping with the state's definition of "naturally occurring" (ARM 17.30.602). Accordingly, it is reasonable to expect that potential riparian vegetation may be different upstream in USFS lands at WPC-T8, versus downstream where the land ownership is private. DEQ agrees with the Water Consulting (2002) assessment that the vegetative potential for lower White Pine Creek is for a diverse community of conifers, cottonwoods, and woody shrubs. DEQ also agrees with Watershed Consulting's conclusion that "riparian forests are the answer to most problems within the lower portion of the drainage" (Watershed Consulting, LLC, 2001). The qualitative vegetative potential score was a reflection of effective cover and shade, as well as land management at the site. DEQ agrees that scoring the vegetation at these two sites as 'at potential' is misleading in terms of the desired riparian community, and these two scores are changed to reflect that the vegetation is not at potential.

Comment 14

Appendix B, Pg B-54 (Table B1-6) Table subscript states that August 13-14 temperatures were rejected, but they are referenced earlier in the document.

Response 14

As described in the table heading, the August 13-14 temperatures referenced in **Table B1-6** are instantaneous water temperatures measured by field staff with temperature probes. They are not datalogger temperatures. **Table B1-6** is the only instance where they are reported or referenced.

Comment 15

As currently presented the items in the above listed edits (pg 5-11 on) cast some doubt on the applicability of the modeled temperature to: 1) reflect the "naturally occurring" temperature, 2) the ability to measure for a response to increased shading, 3) being within MOS for cutthroat growth, or 4) for comparative purposes for future monitoring and ultimately delisting.

Response 15

DEQ disagrees with this conclusion, and suggests that the model error is better than 80% of the modeling studies where temperature has been reported (see Arhonditsis and Brett, 2004). Likewise, as indicated in other comments, relative modeled changes can be used to scale observed temperatures accordingly, so concern about the model and its relative predictive capability is unfounded. DEQ does however recognize that naturally occurring temperatures are a difficult benchmark to quantify. The only way to estimate them is either to use a reference approach, restore the waterbody to its naturally occurring state (and observe the change in temperature), or simulate them through modeling.

Obviously, the latter is the most pertinent for water quality management, and accordingly, DEQ feels the model provides a reasonable estimate of the relative change in temperature under a given set of flow and climatic conditions. The ability to evaluate different management options under different flow and climatic conditions would be difficult to consider otherwise, and DEQ believes this work reflects the best available science on White Pine Creek at the time (given the available data).

Other comments

Comment 16

Pg. DS-1, 3rd paragraph: Project area is limited to the lower X miles of White Pine Creek, not "the watershed".

Pg. 3-1, Table 3-1: Again, it would be best to specify project area as this table states "headwaters to mouth impaired" while upper areas are not impaired.

Response 16

While the QUAL2K model is limited to the lower 3.7 miles of White Pine Creek, the project area includes the entire assessment unit from headwaters to mouth. Although impaired conditions may be observed in some portions of the stream and not in others, the impairment applies to the entire assessment unit.

Comment 17

Pg. DS-1 5th paragraph: Dependence of recruiting shade vegetation on channel morphology and instream flow are recognized here and in the Temperature Modeling Appendix (as factors influencing stream temperature: pg B-7), but are not considered again, measured, or modeled (pg 5-11).

Response 17

The effects of improved riparian vegetation were modeled to measure the temperature response to improved shade. The other benefits provided by a healthy riparian corridor are recognized, but not modeled. This reduces model complexity. It is also a conservative assumption, consistent with DEQ's approach to margin of safety.

Comment 18

Pg. DS-1 6th paragraph: "White Pine Creek exceeds... by 4%. Example TMDL in Section 5.7..." Section 5.7 is Seasonality and Margin of Safety not Example TMDL. Also, there was some confusion as to what percent reduction is called for as it was mentioned as 2.4% reduction in Table 5-4. No mention of BMPs for managing riparian areas as referenced.

Response 18

DEQ corrected this reference to **Section 5.6**.

The required reduction in thermal load varies from point to point in the stream. This is shown graphically in **Figure 5-8**. The example TMDL with 2.4% required reduction presented in **Table 5-4** is based on conditions at the mouth, where instream temperatures are the highest, and impact to use is presumably greatest. However, this location does not correspond to the greatest deviation between existing and naturally occurring temperatures. This is found at WPC-T2, where a 4% reduction is necessary. The smaller reduction near the mouth is likely explained either by the presence of improved vegetation in the area of WPC-T2, allowing temperatures to recover somewhat, or by the influence of increased groundwater input where the valley narrows. Additional text clarifying this is added to page 5-20.

Comment 19

Pg.2-5 (also pg 2.9 and Fig 2-10): The sentence that includes "...massive fires..." is lacking a citation. A comprehensive review of lower Clark Fork River tributaries compiled by GEI (2005) stated that 16% of the watershed burned in 1910. Watershed Consulting (2001) pg 1 states large flood in 1916 (and again as rain-on-snow in 1996) mobilizing sediment to lower channel.

Response 19

DEQ added a citation here to better integrate this sentence with **Section 2.2.3**, Fire History, which includes a map of burned areas using digital data provided by USFS Region 1.

Comment 20

Pg 5-9 (Table 5-2): High and medium density trees were listed as the most common (32%) riparian cover type, however tree species and density measurement were not specified. Based on observations of the lower channel, it would appear that alder forms the dominant species. However, this species, as illustrated by the attached photographs of alder clumps in the channel (see Figure 1), illustrate that this shallow-rooted species is less suitable for bank stability. The apparent shortcoming of existing riparian species and densities as opposed to the relative merit of other species in terms of rooting depth, etc. (that may be recommended by this report) should be clearly stated.

Response 20

This report does not recommend specific species, nor provide a detailed plan for addressing the causes of temperature (or sediment) impairment. The purpose of the TMDL document is to identify the degree of impairment, the sources that can and should be addressed, and to identify measurable targets as surrogates for non-impaired conditions. The restoration framework is provided by a watershed restoration plan (WRP). A WRP has been established for White Pine Creek and its sediment impairment (Miller, 2010). Given the similar sources of impairment, the WRP requires minimal updating to incorporate the temperature impairment. The detailed steps required to achieve the goals established within the WRP would be provided within the scopes of work for specific projects designed to achieve those goals.

Comment 21

Limited reference was made to previous work and reports performed in this stream, notably the watershed assessment for this stream (Watershed Consulting 2001). We recommend that this report include further consideration of these existing studies (see Additional References below).

Response 21

DEQ did review the 2001 Watershed Consulting watershed assessment (Watershed Consulting, LLC, 2001). However, this resource was not widely cited in the document as its findings and information are generally consistent with the Water Consulting (2002) document, which was cited more frequently. Given DEQ’s previous experience in White Pine Creek, the sediment load, channel stability, and bank erosion issues are sufficiently well understood to provide background for the temperature study.

8.0 REFERENCES

Arhonditsis, George B. and Michael T. Brett. 2004. Evaluation of the Current State of Mechanistic Aquatic Biogeochemical Modeling. *Marine Ecology Progress Series.* 271(2004): 13-26.

Bear, Elizabeth A., Thomas E. McMahon, and Alexander V. Zale. 2007. Comparative Thermal Requirements of Westslope Cutthroat Trout and Rainbow Trout: Implications for Species Interactions and Development of Thermal Protection Standards. *Transactions of the American Fisheries Society.* 136: 1113-1121.

Brazier, Jon R. and G. W. Brown. 1973. Buffer Strips for Stream Temperature Control. Oregon State University, School of Forestry, Forest Research Laboratory. Research Paper 15.

Broderson, J. M. 1973. Sizing Buffer Strips to Maintain Water Quality. Seattle, WA: University of Washington.

Brown, R. S. 1999. Fall and Early Winter Movements of Cutthroat Trout, Oncorhynchus Clarki, in Relation to Water Temperature and Ice Conditions in Dutch Creek, Alberta. *Environmental Biology of Fishes.* 55: 359-368.

Brown, R. S., S. S. Stanislawski, and William C. Mackay. 1993. The Effects of Frazil Ice on Fish. Prowse, T. D. Saskatoon, Saskatchewan: National Hydrology Research Institute. NHRI Symposium Series.

Castelle, Andrew J. and Alan W. Johnson. 2000. Riparian Vegetation Effectiveness. Research National Park, NC: National Council for Air and Stream Improvement. Technical Bulletin No. 799.

CH2M. 2000. Review of the Scientific Foundations of the Forests and Fish Plan. Washington Forest Protection Association. www.wfpa.org.

Christensen, D. 2000. Protection of Riparian Ecosystems: A Review of Best Available Science. Jefferson County Health Department.

Ellis, Janet H. 2008. Scientific Recommendations on the Size of Stream Vegetated Buffers Needed to Protect Fish and Aquatic Habitat. Helena, MT: Montana Audubon. The Need for Stream Vegetated Buffers: What Does the Science Say?

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States. *PE&RS.* 77(9): 858-864.

Grumbles, Benjamin. 2006. Letter From Benjamin Grumbles, US EPA, to All EPA Regions Regarding Dail Load Development. U.S. Environmental Protection Agency.

Harrison, Jack E., Allan B. Griggs, and John D. Wells. 2000. Geologic and Structure Maps of the Wallace 1° X 2° Quadrangle, Montana and Idaho. U.S. Geological Survey. http://pubs.usgs.gov/imap/i1509a/wal250k.pdf.

Hewlett, John D. and J. C. Fortson. 1982. Stream Temperature Under an Inadequate Buffer Strip in the Southeast Piedmont. *Water Resources Bulletin.* 18: 983-988.

Howell, Terry A. and B. A. Stewart. 2003. "Irrigation Efficiency," in *Encyclopedia of Water Science*, (New York, NY: Marcel Dekker): 467-472.

Jakober, Michael J., Thomas E. McMahon, Russell F. Thurow, and Christopher C. Clancy. 1998. Role of Stream Ice on Fall and Winter Movements and Habitat Use by Bull Trout and Cutthroat Trout in Montana Headwater Streams. *Transactions of the American Fisheries Society.* 127: 223-235.

Kannan, N., J. Jeong, and R. Srinivasan. 2011. Hydrologic Modeling of a Canal-Irrigated Agricultrual Watershed With Irrigation Best Management Practices. *Journal of Hydrologic Engineering.*: 746-757.

Kendy, Eloise and Ruth E. Tresch. 1996. Geographic, Geologic, and Hydrologic Summaries of Intermontane Basins of the Northern Rocky Mountains, Montana. Helena, MT: US Geological Survey. Water-Resources Investigations Report 96-4025.

Knutson, K. Lea and Virginia L. Naef. 1997. Management Recommendations for Washington's Priority Habitats: Riparian. Olympia, WA: Washington Department of Fish and Wildlife (WDFW).

Ledwith, Tyler S. 1996. The Effects of Buffer Strip Width on Air Temperature and Relative Humidity in a Stream Riparian Zone. *Watershed Council Networker.* Summer 1996

Liknes, George Alton and Patrick J. Graham. 1988. Westslope Cutthroat Trout in Montana: Life History, Status, and Management. In: American Fisheries Society Symposium. American Fisheries Society Symposium. [Place unknown]: American Fisheries Society; 53-60.

Miller, Mike. 2010. Watershed Restoration Plan for Lower Clark Fork TMDL Planning Area. Lower Clark Fork Watershed Group.

Montana Department of Environmental Quality. 2005a. Temperature Data Logger Protocols Standard Operating Procedure. WQPBWQM-006, Rev. 1. http://www.deq.mt.gov/wqinfo/QAProgram/PDF/SOPs/WQPBWQM-006.pdf.

-----. 2005b. Water Quality Planning Bureau Field Procedures Manual for Water Quality Assessment Monitoring WQPBWQM-020. http://www.deq.state.mt.us/wqinfo/QAProgram/SOP%20WQPBWQM-020.pdf:

-----. 2010. Lower Clark Fork Tributaries Sediment TMDLs and Framework for Water Quality Restoration: Final. Helena, MT: Montana Department of Environmental Quality. C13-TMDL-03a-F.

-----. 2012. Circular DEQ-7: Montana Numeric Water Quality Standards. Helena, MT: Montana Department of Environmental Quality. http://deq.mt.gov/wqinfo/Circulars.mcpx. Accessed 1/15/2013.

-----. 2014. Water Quality Standards Attainment Record for White Pine Creek (MT76N003_120). http://deq.mt.gov/wqinfo/cwaic/reports/2014/mt76N003_120.pdf. Accessed 10/28/2014.

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2011. Water Quality Assessment Method. Helena, MT: Montana Department of Environmental Quality. Revision 3.0.

-----. 2014a. Montana 2014 Draft Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality. WQPBIMTSTR-009d.

-----. 2014b. Montana 2014 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality. WQPBIMTSTR-009d.

Montana Department of Fish, Wildlife and Parks. 2014. Montana's Fisheries Information System (MFISH). http://fwp.mt.gov/fishing/mFish/. Accessed 2/20/2013.

Montana Department of Natural Resources and Conservation. 2006. Montana Guide to the Streamside Management Zone Law & Rules. Helena, MT: Montana Department of Natural Resources and Conservation. http://dnrc.mt.gov/forestry/assistance/practices/documents/smz.pdf. Accessed 3/27/2014.

Natural Resource Information System. 2012. GIS Data List. http://nris.mt.gov/gis/gisdatalib/gisdatalist.aspx. Accessed 6/28/12 A.D.

Natural Resources Conservation Service. 1997. National Engineering Handbook Irrigation Guide, Vol. Part 652, Washington, D.C.: Natural Resources Conservation Service.

-----. 2011a. Montana Conservation Practice Standard: Filter Strips, Code 393. http://efotg.sc.egov.usda.gov/references/public/mt/393_standard_june_2011.pdf. Accessed 11/7/11 A.D.a.

-----. 2011b. Montana Conservation Practice Standard: Riparian Forest Buffer, Code 391. MT: NRCS. http://efotg.sc.egov.usda.gov/references/public/mt/391_standard_june_2011.pdf. Accessed 11/7/11 A.D.b.

Negri, Donald and D. H. Brooks. 1990. Determinants of Irrigation Technology Choice. *Western Journal of Agricultural Economics.* 15: 213-223.

Negri, Donald, John J Hanchar, and U.S. Department of Agriculture, Economic Research Service. 1989. Water Conservation Through Irrigation Technology. Washington, D.C.: Economic Research Service. AIB-576.

Osteen, C., J. Gottlieb, and U. Vasavada. 2012. Agricultural Resources and Environmental Indicators. Washington, D.C.: United States Department of Agriculture, Economic Research Service. EIB-98.

Poole, Geoffrey C. and Cara H. Berman. 2001. An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation. *Environmental Management.* 276(6): 787-802.

Schwarz, Gregory E. and Richard B. Alexander. 1995. Soils Data for the Conterminous United States Derived From the NRCS State Soil Geographic (STATSGO) Data Base. [Original Title: State Soil Geographic (STATSGO) Data Base for the Conterminous United States.]. Reston, VA: U.S. Geological Survey. USGS Open-File Report 95-449. http://water.usgs.gov/GIS/metadata/usgswrd/XML/ussoils.xml.

Steinblums, Ivars J., Henry A. Froehlich, and Joseph K. Lyons. 1984. Designing Stable Buffer Strips for Stream Protection. *Journal of Forestry.* 82(1): 49-52.

Tetra Tech. 2013. Mill Creek and White Pine Creek Temperature Modeling: Ssampling Analysis Plan and Quality Assurance Project Plan. U.S. EPA. QAPP 370.

U.S. Department of Agriculture, Forest Service. 1995. Inland Native Fish Strategy: Interim Strategies for Managing Fish-Producing Watersheds in Eastern Oregon and Washington, Idaho, Western Montana and Portions of Nevada. Washington, D.C.: USDA Forest Service.

U.S. Environmental Protection Agency. 1999a. Protocol for Developing Nutrient TMDLs. Washington, D.C.: Office of Water, U.S. Environmental Protection Agency. EPA 841-B-99-007.

-----. 1999b. Protocol for Developing Sediment TMDLs. Washington, D.C.: Office of Water, United States Environmental Protection Agency. EPA 841-B-99-004.

Waskom, Reagan M. 1994. Best Management Practices for Irrigation Management. Colorado State University Coorperative Extension Office.

Water Consulting, Inc. 2002. White Pine Creek Reconnaissance and Watershed Assessment Validation. Hamilton, MT: Water Consulting, Inc.

Watershed Consulting, LLC. 2001. Whitepine Creek Watershed Assessment. Whitefish, MT: Watershed Consulting, LLC.

Williams, B. K., R. C. Szara, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Washington, D.C.: Adaptive Management Working Group, U.S. Department of the Interior.

Wischmeier, Walter H. and Dwight D. Smith. 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Washington, D.C.: United States Department of Agriculture. Agriculture Handbook No. 537. http://topsoil.nserl.purdue.edu/usle/AH_537.pdf.

Woods, Alan J., James M. Omernik, John A. Nesser, Jennifer Shelden, Jeffrey A. Comstock, and Sandra J. Azevedo. 2002. Ecoregions of Montana, 2nd ed., Reston, VA: United States Geographical Survey.

APPENDIX A – REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

This appendix presents details about applicable Montana Water Quality Standards (WQS) and the general and statistical methods used for development of reference conditions.

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ACRONYMS

Acronym	Definition
ARM	Administrative Rules of Montana
BER	Board of Environmental Review (Montana)
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
EPA	Environmental Protection Agency (US)
HHC	Human Health Criteria
MCA	Montana Codes Annotated
MCL	Maximum Contaminant Level
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
WQA	Water Quality Act
WQS	Water Quality Standards

A1.0 TMDL DEVELOPMENT REQUIREMENTS

Section 303(d) of the federal Clean Water Act (CWA) and the Montana Water Quality Act (WQA) (Section 75-5-703) requires development of TMDLs for impaired waterbodies that do not meet Montana WQS. Although waterbodies can become impaired from pollution (e.g., low flow alterations and habitat degradation) and pollutants (e.g., nutrients, sediment, metals, pathogens, and temperature), the CWA and Montana state law (75-5-703) require TMDL development only for impaired waters with pollutant causes. Section 303(d) also requires states to submit a list of impaired waterbodies to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, EPA and DEQ referred to this list simply as the 303(d) list.

Since 2004, EPA has requested that states combine the 303(d) list with the 305(b) report containing an assessment of Montana's water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) list also includes identification of the probable cause(s) of the water quality impairment (e.g., pollutants such as metals, nutrients, sediment, pathogens or temperature), and the suspected source(s) of the pollutants of concern (e.g., various land-use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each waterbody is used for consistency. The impairment status determination methodology is identified in DEQ's Water Quality Assessment Process and Methods found in Attachment 1 of Montana's Water Quality Integrated Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012).

Under Montana state law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State law and Section 303(d) of the CWA require states to develop all necessary TMDLs for impaired or threatened waterbodies. None of the waterbodies being addressed within the scope of this document are listed as threatened.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable WQS to be exceeded (violated). TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS. **Section 4.0** of the main document provides a description of the components of a TMDL.

To satisfy the federal CWA and Montana state law, TMDLs are developed for each waterbody-pollutant combination identified on Montana's 303(d) list of impaired or threatened waters, and are often presented within the context of a water quality restoration or protection plan. State law (Administrative

Rules of Montana 75-5-703(8)) also directs Montana DEQ to "…support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing federal, state, or local regulations.

A2.0 Applicable Water Quality Standards

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all water quality standards are met. Water quality standards form the basis for the targets described in **Sections 5.0**, **6.0**, **7.0** and **8.0**. Pollutants addressed in this framework water quality improvement plan include sediment, nutrients, temperature, and metals. This section provides a summary of the applicable water quality standards for these pollutants.

A2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated uses or beneficial uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana WQA directs the Board of Environmental Review (BER) (i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (ARM 17.30.607-616) and to adopt standards to protect those uses (ARM 17.30.620-670).

Montana, unlike many other states, uses a watershed-based classification system, with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications have multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example as a public drinking water supply; however, the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or nonpoint source activities or pollutant discharges must not make the natural conditions worse.

Modification of classifications or standards that would lower a water's classification or a standard (i.e., B-1 to a B-3), or removal of a designated use because of natural conditions, can only occur if the water was originally misclassified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table A2-1**. In 2003, Montana added four classes: D, E, F, and G. These classes include ephemeral streams (E-1 and E-2), ditches (D-1 and D-2), seasonal or semi-permanent lakes and ponds (E-3, E-4, E-5) and waters with low or sporadic flow (F-1). All waterbodies within the Central Clark Fork Tributaries Project Area are classified as B-1 (see **Section 3.1** and **Table 3-1** in the main document for individual stream classifications).

Table A2-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
A-CLOSED:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.
B-1:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-2:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply.
I:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
D-1:	Waters classified D-1 are to be maintained suitable for agricultural purposes and secondary contact recreation.
D-2:	Waters classified D-2 are to be maintained suitable for agricultural purposes and secondary contact recreation. Because of conditions resulting from low flow regulations, maintenance of the ditch, or geomorphologic and riparian habitat conditions, quality is marginally suitable for aquatic life.
E-1:	Waters classified E-1 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife.
E-2:	Waters classified E-2 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife. Because of habitat, low flow, hydro-geomorphic, and other physical conditions, waters are marginally suitable for aquatic life.
E-3:	Waters classified E-3 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife.

Table A2-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
E-4:	Waters classified E-4 are to be maintained suitable for aquatic life, agricultural purposes, secondary contact recreation, and wildlife.
E-5:	Waters classified E-5 are to be maintained suitable for agricultural purposes, secondary contact recreation, saline-tolerant aquatic life, and wildlife.
F-1:	Waters classified F-1 are to be maintained suitable for secondary contact recreation, wildlife, and aquatic life, not including fish.
G-1:	Waters classified G-1 are to be maintained suitable for watering wildlife and livestock; aquatic life, not including fish; secondary contact recreation; marginally suitable for irrigation after treatment or with mitigation measures.

A2.2 STANDARDS

In addition to the use classifications described above, Montana's WQS include numeric and narrative criteria as well as a nondegradation policy.

Numeric Standards

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular DEQ-7 (Montana Department of Environmental Quality, 2012) . The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., lifelong) exposures as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies including a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant", or an authorization to degrade must be granted by the DEQ. However, under no circumstance may standards be exceeded. It is important to note that waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the waterbody.

Narrative Standards

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface WQS. The General Prohibitions are also called the "free from" standards; that is, the surface waters of the state must be free from substances attributable to discharges, including thermal pollution, that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi, and algae.

The standards applicable to the list of pollutants addressed in the Central Clark Fork Tributaries Project Area TMDLs are summarized below. In addition to the standards below, the beneficial-use support standard for B-1 streams, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include effects from dewatering/flow alterations and effects from habitat modifications.

A2.3 Temperature Standards

Montana's temperature standards were originally developed to address situations associated with point source discharges, making them somewhat awkward to apply when dealing with primarily nonpoint source issues. In practical terms, the temperature standards address a maximum allowable increase above "naturally occurring" temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana's temperature standards address the maximum allowable decrease or rate at which cooling temperature changes (below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as B-1; from Rule 17.30.622(e) and 17.30.623(e):
A 1^{o} F maximum increase above naturally occurring water temperature is allowed within the range 32^{o} F to 66^{o} F; within the naturally occurring range of 66^{o} F to 66.5^{o} F, no discharge is allowed which will cause the water temperature to exceed 67^{o} F; and where the naturally occurring water temperature is 66.5^{o} F or greater, the maximum allowable increase in water temperature is 0.5^{o} F. A 2^{o} F per-hour maximum decrease below naturally occurring water temperature is above 55^{o} F. A 2^{o} F maximum decrease below naturally occurring water temperature is allowed within the range of 55^{o} F to 32^{o} F.

A4.0 References

Montana Department of Environmental Quality. 2012. Circular DEQ-7: Montana Numeric Water Quality Standards. Helena, MT: Montana Department of Environmental Quality. http://deq.mt.gov/wqinfo/Circulars.mcpx. Accessed 1/15/2013.

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2012. Montana 2012 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. WQPBIMTSR-004f.

APPENDIX B – WHITE PINE CREEK QUAL2K REPORT

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Acronyms and Abbreviations

AME	absolute mean error
EPA	U.S. Environmental Protection Agency
DEQ	Montana Department of Environmental Quality
MPDES	Montana Pollutant Discharge Elimination System
QUAL2K	River and Stream Water Quality Model
REL	relative error
TMDL	total maximum daily load
USGS	U.S. Geological Survey (U.S. Department of the Interior)

Units of Measure

°F	degrees Fahrenheit
cfs	cubic feet per second
cm^2/s	square centimeter per second
g/cm^3	grams per cubic centimeter
MSL	mean sea level
RM	river mile

EXECUTIVE SUMMARY

White Pine Creek was identified by the Montana Department of Environmental Quality (DEQ) as being impaired due to elevated water temperatures. The cause of the impairment was attributed to grazing in riparian or shoreline zones, streambank modification/destabilization, natural sources, and watershed runoff following forest fire (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014). The U.S. Environmental Protection Agency (EPA) contracted with Tetra Tech to develop a QUAL2K water quality model to investigate the relationship between flow, shade, and instream water temperature.

Field studies were carried out in 2013 to support water quality model development for the project. A QUAL2K water-quality model was then developed for White Pine Creek to evaluate management practices suitable for meeting state temperature standards. The QUAL2K model was constructed, in part, using field-collected data from the summer of 2013. Shade v3.0 models were also developed to assess shade conditions using previously collected field data. The calibrated and validated QUAL2K model met previously designated acceptance criteria. Once developed, various water temperature responses were evaluated for a range of potential watershed management activities. Four scenarios were considered:

- Scenario 1: Baseline condition (i.e., measured August flow and weather conditions).
- Scenario 2: Baseline with a 15 percent reduction of water withdrawals.
- Scenario 3: Baseline with improved riparian vegetation in certain segments based upon reference segments.
- Scenario 4: An improved flow and shade scenario that combines the potential benefits associated with a 15 percent reduction in water withdrawals with improved shading along certain segments.

In comparison to scenario 1, results ranged from minimal change in water temperature (scenario 2) to considerable reductions (scenarios 3 and 4). The improved flow and shade scenario (scenario 4), which combined the potential benefits associated with a 15 percent reduction in water withdrawals (scenario 2) with improved shading to certain segments based upon reference segments (scenario 3) to represent application of conservation practices, resulted in overall reductions along the entire reach that ranged from no effect to 2.6° F. Generally, small changes in shade or inflow had minimal effects on water temperature while large increases in shade had a considerable effect on water temperature.

B1.0 INTRODUCTION

Tetra Tech, Inc. is under contract with the U.S. Environmental Protection Agency (EPA) to set up, calibrate, validate, and conduct scenario analysis with a temperature model (QUAL2K) for White Pine Creek in support of total maximum daily load (TMDL) development by the Montana Department of Environmental Quality (DEQ). Background information is provided in the following section (**Section B2.0**). A summary of model set up and calibration is provided in **Section B3.0** and a series of model scenarios and results are presented in **Section B4.0**.

B2.0 BACKGROUND

This section presents background information to support QUAL2K model development.

B2.1 Problem Statement

White Pine Creek is in western Montana and is part of the Lower Clark Fork Tributaries TMDL Planning Area. The White Pine Creek watershed is in the Lower Clark Fork 8-digit HUC (17010213). The impaired segment is 12.37 miles long and extends from the headwaters to the mouth on Beaver Creek (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014) (**Figure B-1**).

White Pine Creek has a B-1 use class. The impaired segment is not supporting its Aquatic Life use (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014). Three potential causes of impairment are identified in the assessment record, including water temperature (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014). The potential sources of the water temperature impairment are: grazing in riparian or shoreline zones, streambank modification/destabilization, natural sources, and watershed runoff following forest fire (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014). Large forest fires occurred in 1889 and 1910 and a large flood occurred in 1916; "elevated stream temperature may be linked to historic riparian logging and relatively recent stand replacing fires" (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014, p. 62).

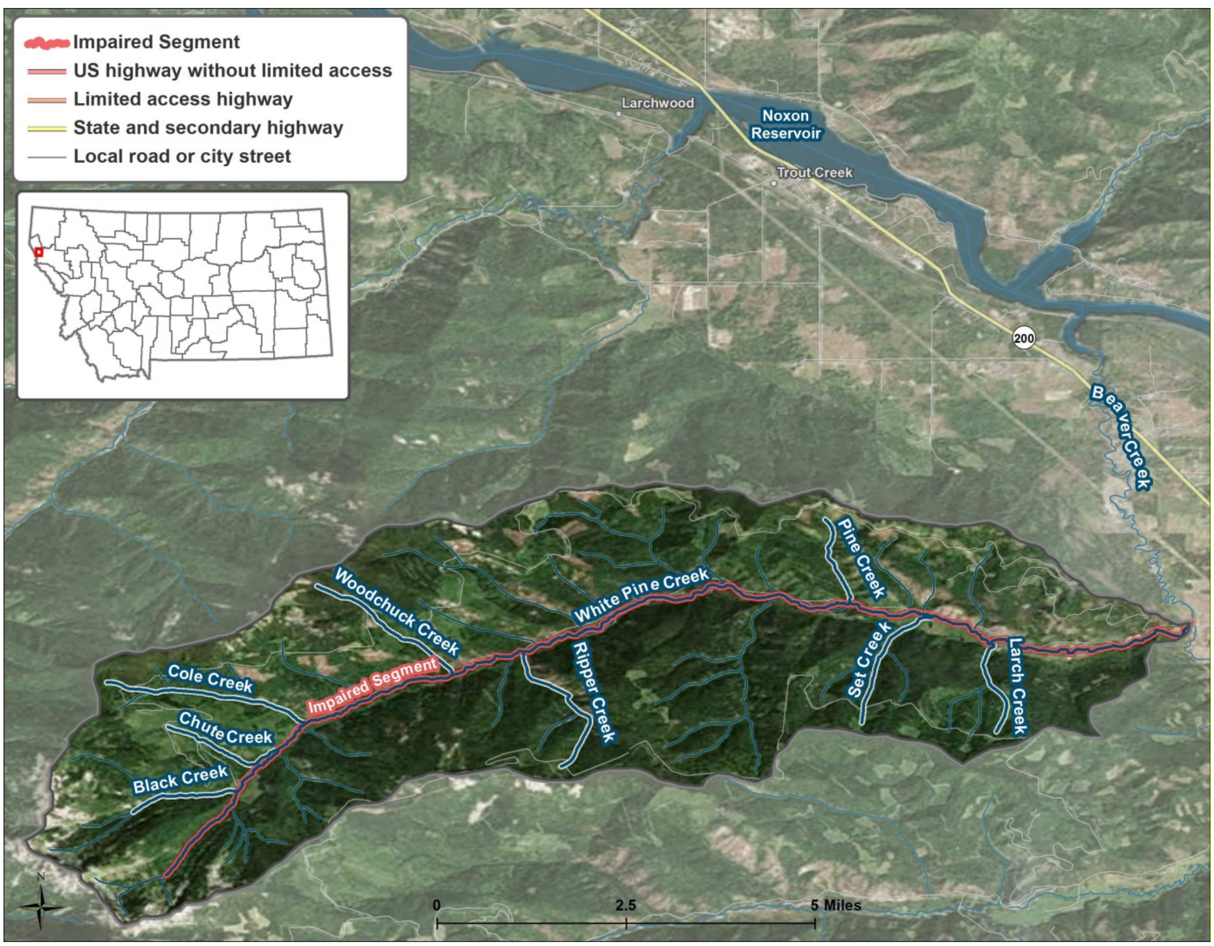


Figure B-1. White Pine Creek watershed.

B2.2 Montana Temperature Standard

For a waterbody with a use classification of B-1, the following temperature criteria apply:[1]

> *A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring2 range of 66° F to 66.5° F, no discharge is allowed [that] will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F. A 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.*

The model results will ultimately be compared to these criteria.

B2.3 Project History

Tetra Tech was contracted by EPA in May 2013 to develop the QUAL2K temperature model using data and information that was collected in the summer of 2013. Temperature and flow data were collected in White Pine Creek in 2013 by EPA and DEQ. Field teams collected data on July 25-26, 2013, August 13-14, 2013, and September 10, 2013 to characterize flow and shade in support of the modeling effort.

B2.4 Factors Potentially Influencing Stream Temperature

Stream temperature regimes are influenced by processes that are external to the stream as well as processes that occur within the stream and its associated riparian zone (Poole et al., 2001). Examples of factors external to the stream that can affect instream water temperatures include: topographic shade, land use/land cover (e.g., vegetation and the shading it provides, impervious surfaces), solar angle, meteorological conditions (e.g., precipitation, air temperature, cloud cover, relative humidity), groundwater exchange and temperature, irrigation return flows, and tributary inflow temperatures and volumes. The shape of the channel can also affect temperature—wide shallow channels are more easily heated and cooled than deep, narrow channels. The amount of water in the stream is another factor influencing stream temperature regimes. Streams that carry large amounts of water resist heating and cooling, whereas temperature in small streams (or reduced flows) can be changed more easily.

The following factors that may have an influence on stream temperatures in White Pine Creek were evaluated prior to model development and are further discussed in **Attachment B-1**:

- Local/regional climate
- Land ownership
- Land use
- Riparian vegetation
- Shade
- Hydrology
- Point sources

[1] ARM 17.30.623(e).

[2] "Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied.

B2.5 Observed Stream Temperatures

EPA and DEQ collected stream temperature data using instream loggers at multiple locations in the White Pine Creek watershed. These data are presented and summarized in the following sections.

B2.5.1 Available Temperature Data

In 2013, EPA and DEQ collected continuous temperature data at seven sites along White Pine Creek and at one tributary site (Chute Creek) in support of this modeling effort (**Figure B-2**). During logger deployment, the following tributaries were observed to flow to subsurface (go underground) instead of discharging to White Pine Creek: Larch, Set, Ripper, and Cole creeks. Thus, loggers were not deployed on these streams as originally planned, and no field data were acquired. Additionally, an unnamed tributary was observed to be dry. White Pine Creek itself was observed to be dry at site WPC-T5; thus, no logger was deployed nor field data acquired.

During the mid-season data collection, White Pine Creek was observed to be dry at loggers WPC-T6 and WPC-T7; the loggers were recovered and no field data were acquired. Logger WPC-T8 was found to be partially exposed to ambient air; the logger was moved upstream 25 feet and was then fully submerged.

Data loggers recorded temperatures every one-half hour for two months between June 25-26 and September 10, 2013. EPA and DEQ also collected instantaneous temperatures from White Pine Creek and three of its tributaries (Chute, Pine, and Woodchuck creeks; **Attachment B1**). Temperatures varied spatially and temporally; generally, the warmest instantaneous temperatures were detected in September. Additionally, Montana DEQ recorded an instantaneous temperature of 44.7° F on September 22, 2004, at the C13WPINC10 station.

White Pine Creek ran dry at loggers WPC-T6 and WPC-T7. Temperature data from time periods in which the loggers were suspected to be exposed to ambient air were excluded from analyses. The valid data for logger WPC-T6 are from June 26-27, 2013. The valid data for logger WPC-T7 are from June 26, 2013 to July 9, 2013. These two subsets of data were included in the analyses described in this section.

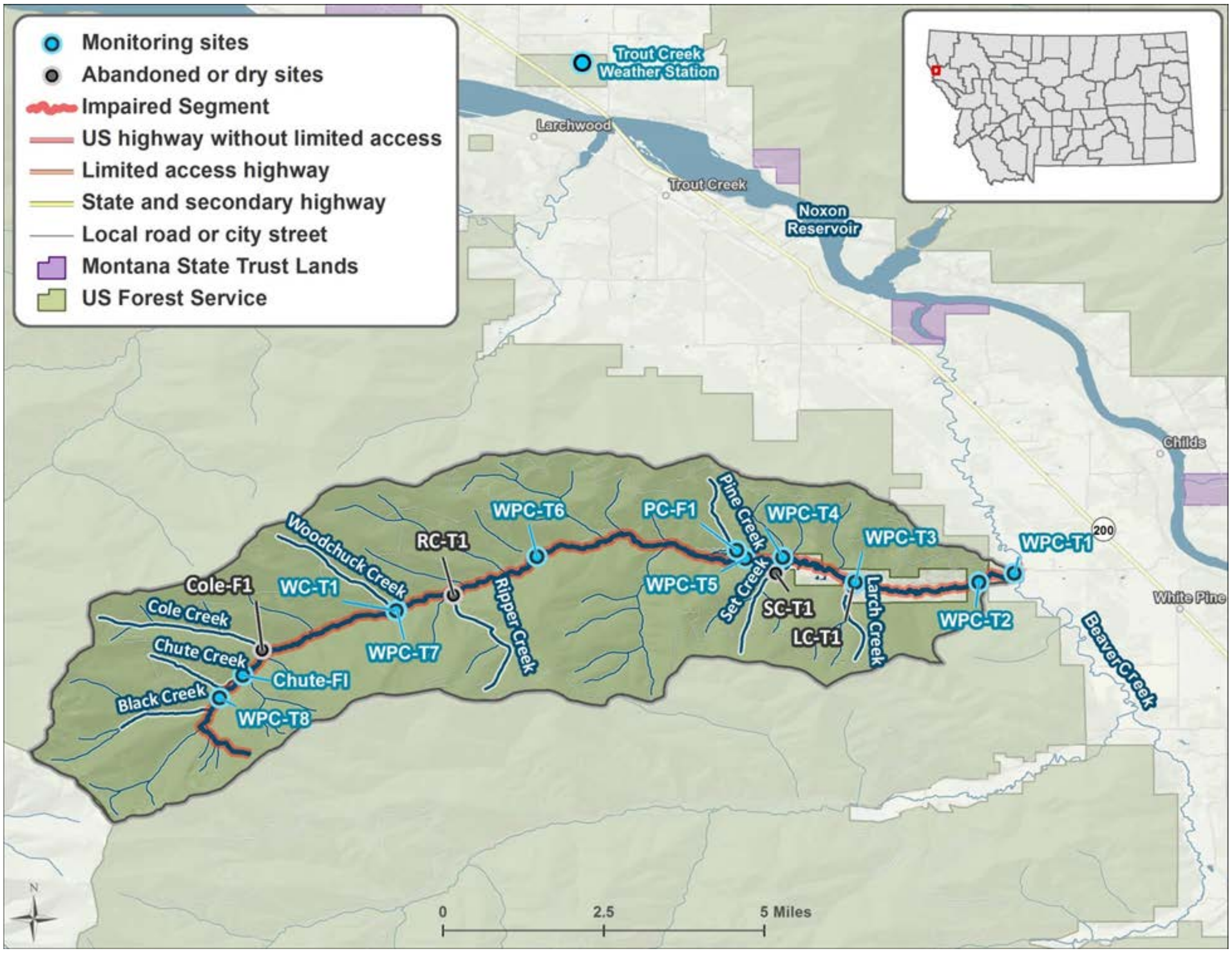
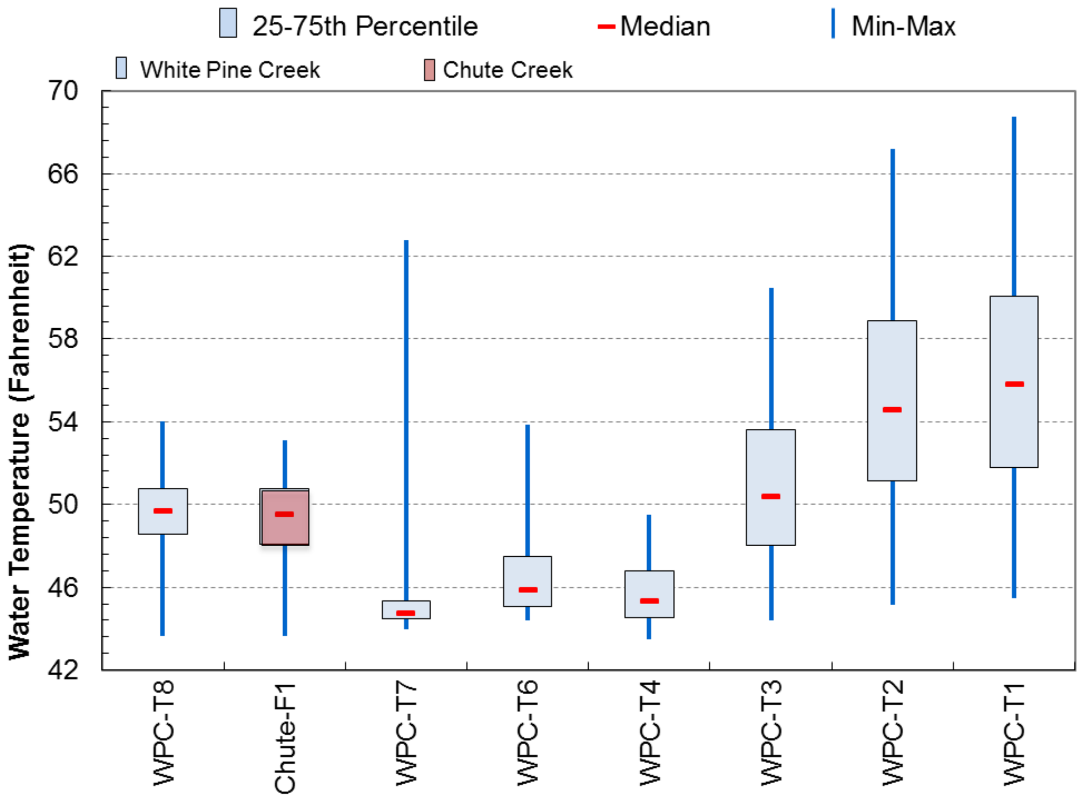


Figure B-2. Temperature loggers in the White Pine Creek watershed.

B2.5.2 Temperature Data Analysis

Stream temperatures in White Pine Creek generally increase from its source downstream to its mouth. No trends are apparent along White Pine Creek from just below the confluence of Chute Creek to near the confluence of Set Creek; some of the reaches of White Pine Creek along this segment ran dry. A summary of the continuous temperature data collected by EPA and DEQ is provided in (**Figure B-3**)**.** Excluding loggers WPC-T6 and WPC-T7, median temperatures in White Pine Creek ranged from approximately 45.5° F to approximately 55.8° F in 2013 (**Figure B-3**).



Note:

- Logger WPC-T6 was likely exposed to ambient air from June 29, 2013 through August 13, 2013, when it was observed in a dry channel. The data presented in this figure are limited to a subset of the monitored temperatures, from June 26, 2013 through June 27, 2013.
- Logger WPC-T7 was likely exposed to ambient air from July 10, 2013 through August 14, 2013, when it was observed in a dry channel. The data presented in this figure are limited to a subset of the monitored temperatures, from June 26, 2013 through July 9, 2013.
- Logger WPC-T8 may have been exposed to ambient air prior to the mid-season field data acquisition on August 14, 2013 when the logger was observed to be partially exposed to ambient air. The logger was moved and was then fully submerged. No data were excluded from this figure.

Figure B-3. Box-and-whisker plots of summer 2013 continuous temperature data.

Maximum daily temperatures in White Pine Creek ranged from approximately 49.5° F to 68.7° F (**Table B-1** and **Figure B-4**). The highest maximum temperatures were recorded at near the mouth at logger WPC-T1 on August 10, 2013. With the exception of WPC-T6 and WPC-T7, the warmest temperatures were detected in the second or third week of August. The warmest weeks were generally the third week of August (excluding loggers WPC-T6 and WPC-T7 that were in dry channels by mid-August). As shown in **Figure B-5**, the diurnal variation in White Pine Creek in the upper watershed (as shown with WPC-T8) is considerably smaller than the diurnal variation in the lower watershed (as shown with logger WPC-T1). All loggers showed a considerable decrease in stream temperatures between July 31 and August 4, 2013.

Table B-1. Maximum & maximum weekly temperatures in White Pine Creek and Chute Creek

Temperature logger site	Maximum temperatures [a]		Maximum weekly maximum temperature [b]	
	Temperature (°F)	Date	Temperature (°F)	Date
WPC-T8 [c] (upper segment)	54.0	Aug 11	52.6	Aug 9-15
Chute-F1	53.1	Aug 17	52.5	Aug 14-20
WPC-T7 [d]	50.4	Jul 9	46.9	Jul 3-9
WPC-T6 [e]	53.9	Jun 27	--	--
WPC-T4	49.5	Aug 19	49.2	Aug 15-21
WPC-T3	60.5	Aug 19	59.8	Aug 15-21
WPC-T2	67.2	Aug 10	66.2	Aug 14-20
WPC-T1 (mouth)	68.7	Aug 10	67.3	Aug 14-20

Notes

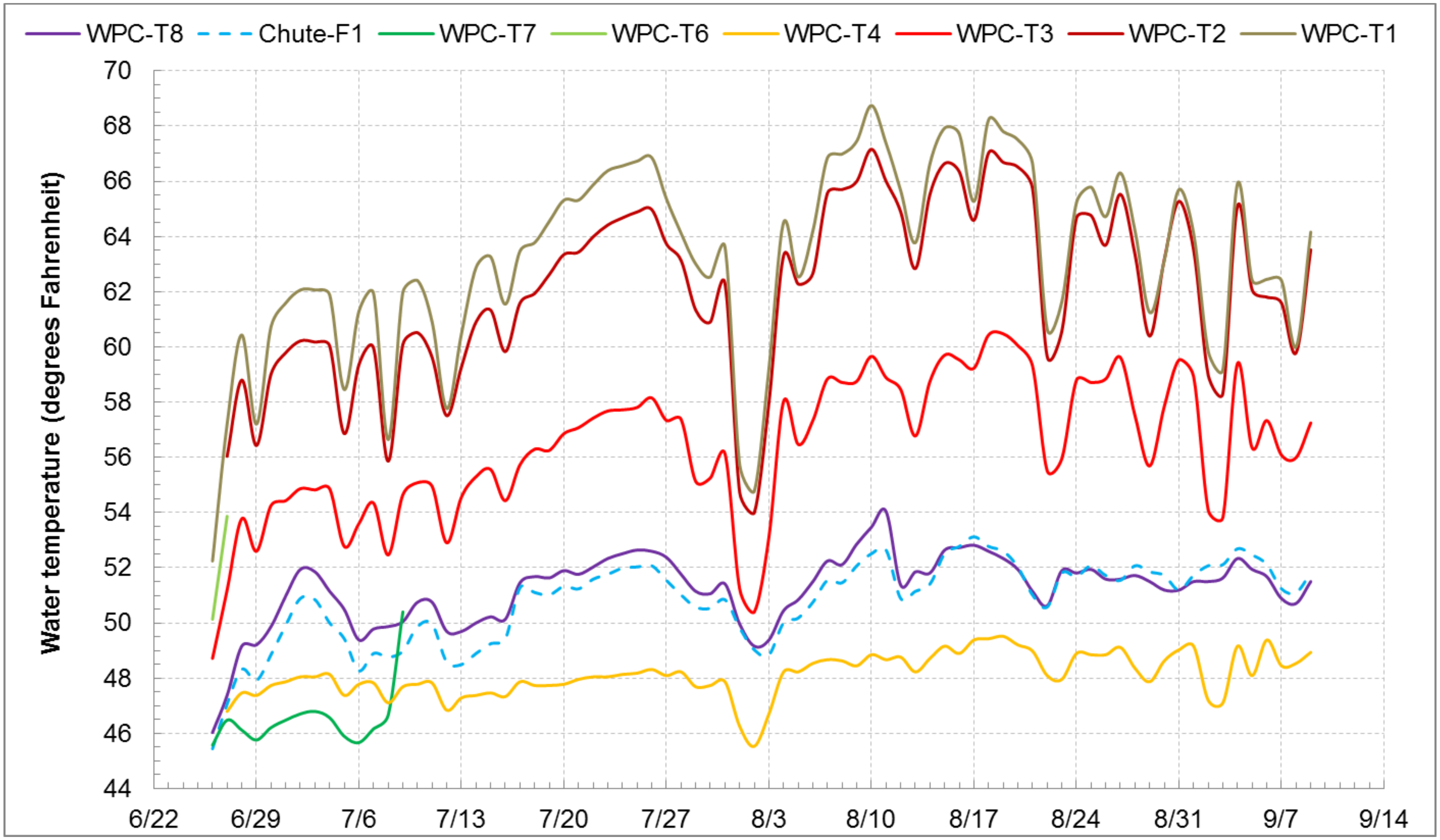
a. Maximum temperature is the maximum of recorded one-half hourly temperatures.

b. Maximum weekly maximum temperature is the mean of daily maximum water temperatures measured over the warmest consecutive seven-day period.

c. Logger WPC-T8 may have been exposed to ambient air prior to the mid-season field data acquisition on August 14, 2013 when the logger was observed to be partially exposed to ambient air. The logger was moved and was then fully submerged. No data were excluded from this table.

d. Logger WPC-T7 was likely exposed to ambient air from June 10, 2013 through the August 14, 2013, when it was observed in a dry channel. The data presented in this table are limited to a subset of the monitored temperatures from June 26, 2013 through July 9, 2013.

e. Logger WPC-T6 was likely exposed to ambient air from June 29, 2013 through the August 13, 2013, when it was observed in a dry channel. The data presented in this figure are limited to a subset of the monitored temperatures from June 26, 2013 through June 27, 2013.



Notes

A rainstorm occurred on August 2, 2013 with 0.92 inch of rain and ambient air temperatures decreased considerably.

Logger WPC-T6 was likely exposed to ambient air from June 29, 2013 through the August 13, 2013, when it was observed in a dry channel.

Logger WPC-T7 was likely exposed to ambient air from June 10, 2013 through the August 14, 2013, when it was observed in a dry channel.

Logger WPC-T8 may have been exposed to ambient air prior to the mid-season field data acquisition on August 14, 2013 when the logger was observed to be partially exposed to ambient air. The logger was moved and was then fully submerged. No data were excluded from this figure.

Figure B-4. Daily maximum temperatures, White Pine Creek and a tributary (dashed line), June 25-26 to September 10, 2013.

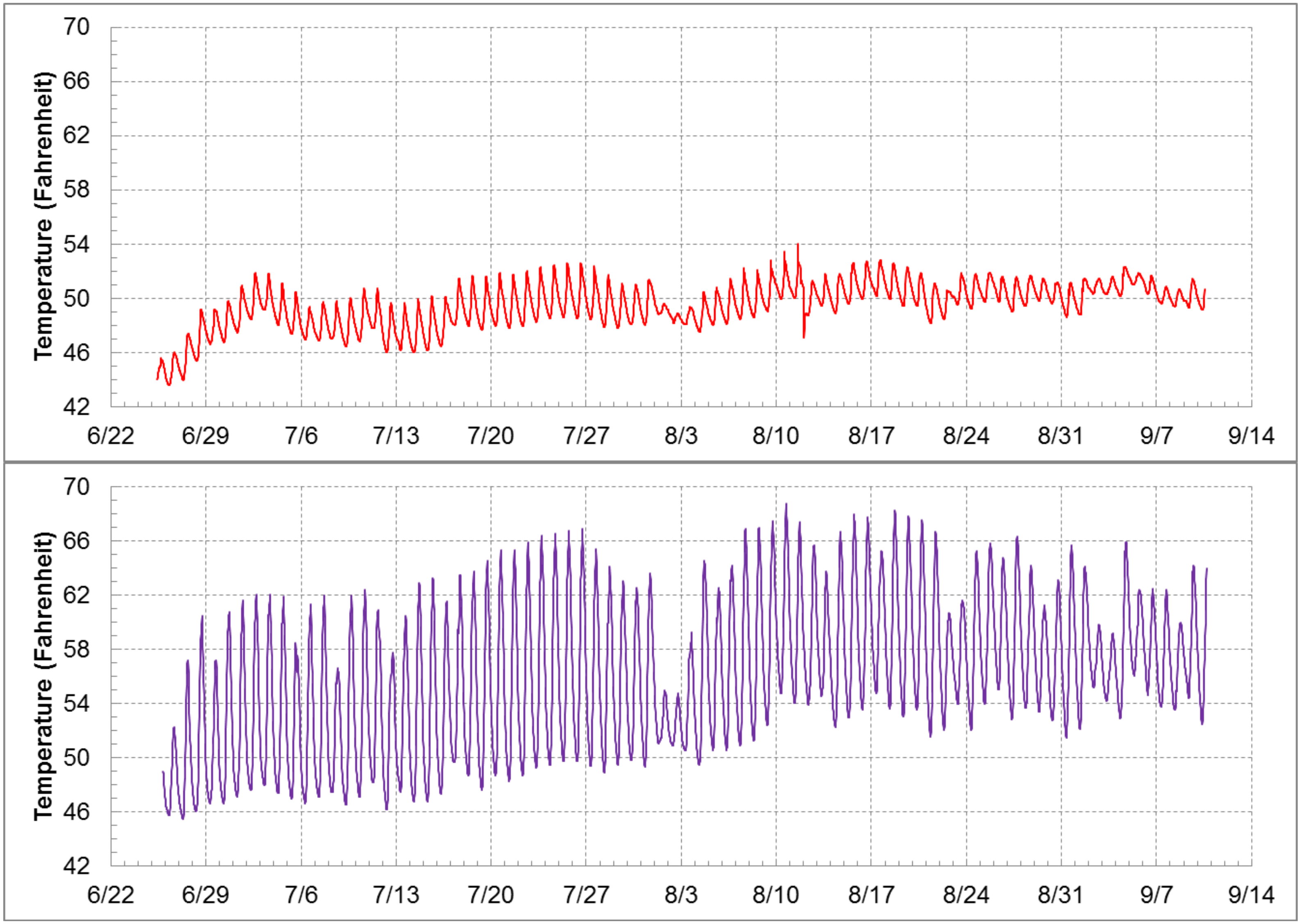


Figure B-5. Continuous temperature at logger WPC-T8 (top) in upper White Pine Creek and logger WPC-T1 (bottom) in lower White Pine Creek, June 26-27 to September 10, 2013.

B3.0 QUAL2K MODEL DEVELOPMENT

EPA and DEQ selected the QUAL2K model to simulate temperatures in White Creek. QUAL2K is supported by EPA and has been used extensively for TMDL development and point source permitting across the country. The QUAL2K model is suitable for water temperatures in small rivers and creeks. It is a one-dimensional uniform flow model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The heat budget and temperature are simulated as a function of meteorology on a diel time scale. Heat and mass inputs through point and nonpoint sources are also simulated. The model allows for multiple waste discharges, water withdrawals, nonpoint source loading, tributary flows, and incremental inflows and outflows. QUAL2K simulates instream temperatures via a heat balance that accounts “for heat transfers from adjacent elements, loads, withdrawals, the atmosphere, and the sediments” (Chapra et al., 2008, p. 19).

The current release of QUAL2K is version 2.11b8 (January 2009). The model is publicly available at http://www.epa.gov/athens/wwqtsc/html/QUAL2K.html and http://qual2k.com/. Additional information regarding QUAL2K is presented in the *Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling* (Tetra Tech, Inc., 2012)

The following describes the process that was used to setup, calibrate, and validate the QUAL2K models for White Pine Creek.

B3.1 MODEL FRAMEWORK

The QUAL2K model (Chapra et al., 2008) was selected for modeling White Pine Creek. The modeling domain was limited to the mainstem below WPC-T4, which is approximately RM 3.7, to the mouth (refer back to **Figure B-2** for a map of the White Pine Creek watershed). The reaches of White Pine Creek upstream of about RM 3.7 ran dry during the summer of 2013 and were excluded from the model domain.

Data were specifically collected to support the QUAL2K model for the White Pine Creek. Flow, shade, and continuous temperature were acquired during June, August, and September 2013.

B3.2 MODEL CONFIGURATION AND SETUP

Model configuration involved setting up the model computational grid and setting initial conditions, boundary conditions, and hydraulic and light and heat parameters. All inputs were longitudinally referenced, allowing spatial and continuous inputs to apply to certain zones or specific stream segments. This section describes the configuration and key components of the model.

B3.2.1 Modeling Time Period

The calibration and validation steady-state model periods were June 27, 2013 and August 14, 2013, respectively. These dates were selected since they had the most complete datasets that could be used for model setup, calibration, and validation. Flow and logger temperature data were available for most sites on those dates and weather data were also available for those dates.

B3.2.1.1 Calibration Period
The calibration period was June 27, 2013 and was selected due to the availability of flow and temperature data (**Attachment B1**). Flow was monitored at the loggers on June 25-26, 2013. The first full day of temperature data for all the loggers was June 27, 2013. Flows monitored on June 25-26 were assumed to be representative of flow conditions on June 27, 2013 as no precipitation was recorded July 25-27, 2013[3].

B3.2.1.2 Validation Period
The validation period was August 14, 2013 and was selected due to the availability of flow and temperature data (**Attachment B1**). Flow was monitored at the loggers on August 14, 2013. No precipitation was recorded on August 14, 2013[4]. The loggers recorded the full 24-hours on this date.

B3.2.2 Segmentation
Segmentation refers to discretization of a waterbody into smaller computational units (e.g., reaches and elements). Reaches in QUAL2K have constant hydraulic characteristics (e.g. slope, bottom width) and each reach is further divided into elements that are the fundamental computational units in QUAL2K. The White Pine Creek mainstem from WPC-T4 downstream to the mouth was segmented into reach lengths of 984 feet (300 meters), which were sufficient to incorporate any point inputs to the waterbody and to maintain Courant stability. In addition since shading is applied at the reach level this allowed for better representation of the spatial variability observed in the Shade Model results along White Pine Creek (see **Attachment B1** for shade modeling discussion). Refer back to **Figure B-2** for a map that shows the White Pine Creek mainstem and its tributaries.

B3.2.3 Streamflow and Hydraulics
The flow rates were estimated through flow mass balance (continuity) calculations at the loggers and other sites where flows were monitored. The rating curve method was used to relate the depth and the velocity to the flow rate in a reach. This method requires specification of the empirical coefficients and exponents based on numerous measurements of depths, velocities, and flows. Due to the limited amount of field data, coefficients of the rating curve were treated to be the calibration parameters against the observed depths and velocities.

Typical exponents for velocity (0.43) and depth (0.45) are described in the QUAL2K manual (Chapra et al., 2008). Exponents were also calculated for two nearby U.S. Geological Survey (USGS) gages of similar size to White Pine Creek, which is 31 square miles (**Table B-2**). The exponents were set to the averages calculated from the two USGS gages: 0.49 for velocity and 0.26 for depth.

Table B-2. Calculated exponents for nearby USGS gages

Gage ID	Gage name	Drainage area (square miles)	Exponents	
			Velocity	Depth
12353820	Dry Creek near Superior, MT	44.76	0.46	0.28
12374250	Mill Creek above Bassoo Creek near Niarada, MT	19.60	0.52	0.23

[3] Precipitation data reported for June 25, 2013 at the Cabinet (Trout Creek) RAWS were possibly erroneous. Weather data were also retrieved from National Weather Service station 243380, which is 7 miles north White Pine Creek; no precipitation occurred at or just before the selected calibration period.

[4] No precipitation was recorded at the National Weather Service station 248380 and 0.01 inch was reported at the Cabinet (Trout Creek) RAWS. For the purpose of model development, it was assumed that no precipitation occurred.

B3.2.4 Boundary Conditions

Boundary conditions represent external contributions to the waterbody being modeled. A flow and temperature input file was therefore configured for inputs to White Pine Creek. Boundary conditions were specified at the upstream terminus of the modeled reach of White Pine Creek (at logger WPC-T4) and for diffuse sources along the creek. There are many small tributaries in the watershed; however, monitoring data were only available for a few major tributaries upstream of logger WPC-T4, which is outside of the model domain. These are further discussed in the following sections.

QUAL2K requires specification of the headwater flow and temperature. Diurnal temperatures (June 27, 2013 for calibration and August 14, 2013 for validation) at the upstream boundary were specified using observed data from the instream logger at site WPC-T4. A flow of 31.85 cubic feet per second (cfs) was specified for the calibration period and 6.55 cfs was specified for the validation period. **Figure B-6** shows the headwater temperatures specified in the model.

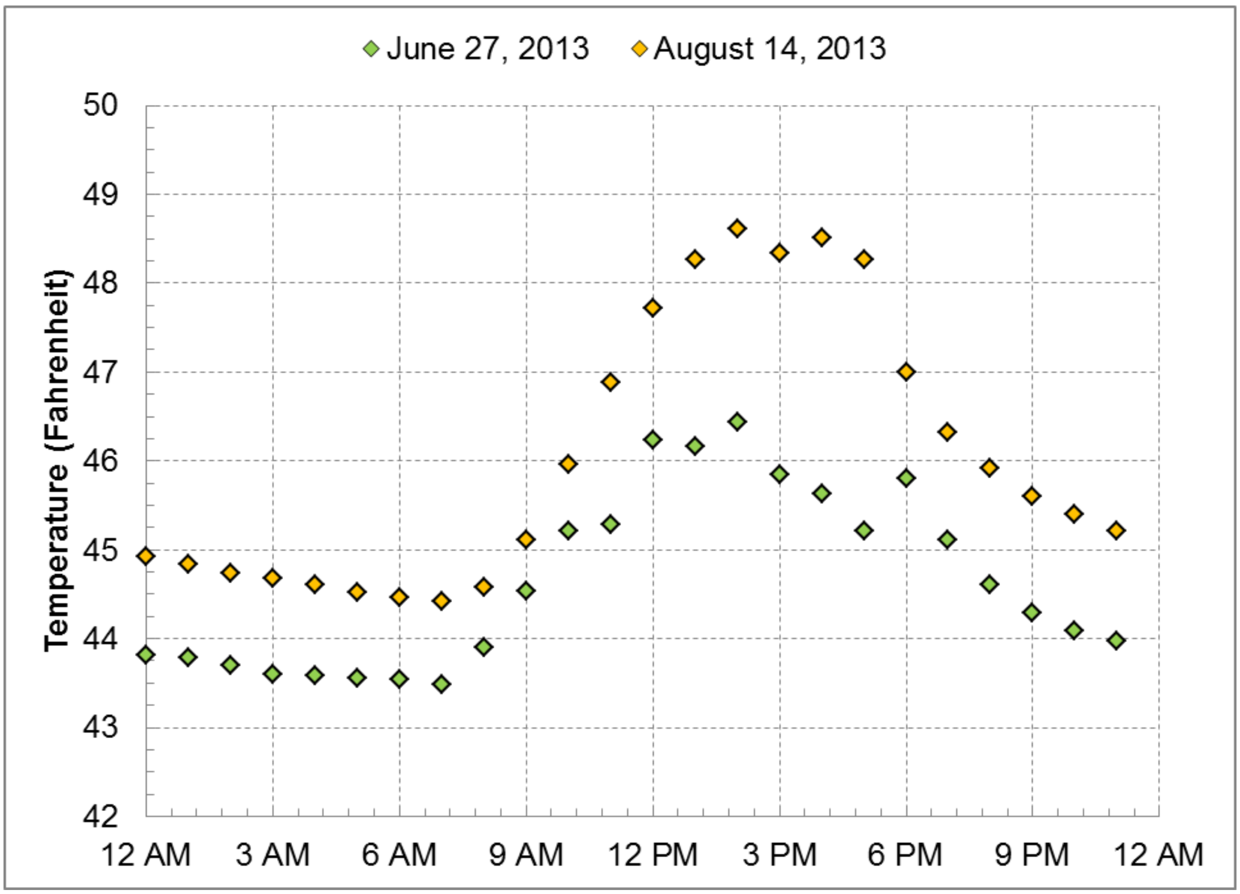


Figure B-6. Diurnal temperature at the headwaters boundary condition for the White Pine Creek model.

B3.2.5 Irrigation Inputs

Irrigation withdrawals from White Pine Creek were also identified (see **Attachment B1** for a discussion of these withdrawals) and assigned in the model. Net irrigation requirements to irrigate the fields were queried from the Montana Natural Resource Information System for the months of June and August. A maximum daily flow rate was estimated using the net irrigation requirements and the maximum area irrigated (50 acres[5]). For the irrigation withdrawal (row identified as *irrigation withdrawal* in **Table B-3**), it was calculated that up to 0.26 cfs may be withdrawn from White Pine Creek on a daily basis during June and 0.34 cfs in August.

The two other withdrawals from the simulated segment of White Pine Creek were for a fishery and domestic use. A total of 1.85 cfs may be withdrawn in June and 1.93 cfs in August. More information on the withdrawals can be found in **Attachment B1**.

Table B-3. QUAL2K model flow and temperature inputs to White Pine Creek - Withdrawals

Description	Location	Point sources [a]		Temperature [b]		
		Abstraction	Inflow	Daily mean	½ daily range	Time of maximum
	(RM)	(cfs)	(cfs)	(°F)	(°F)	(hour)
June 27, 2013						
irrigation withdrawal	2.02	0.26	--	--	--	--
fishery	1.65	1.54	--	--	--	--
domestic	0.45	0.05	--	--	--	--
August 14, 2013						
irrigation withdrawal	2.02	0.34	--	--	--	--
fishery	1.65	1.54	--	--	--	--
domestic	0.45	0.05	--	--	--	--

Notes:
°F = degrees Fahrenheit; cfs = cubic feet per second; RM = river mile.
a. Points sources represent abstractions (i.e., withdrawals) or inflows. Each point source can be an abstraction or an inflow.
b. The daily mean temperature, one-half of the daily range of temperatures across the model period, and time of the maximum hourly temperature are only applicable to point source inflows.

B3.2.6 Diffuse Sources

Groundwater, irrigation return flows, and other sources of water not accounted for in the tributaries can be specified along the length of the waterbody using the Diffuse Sources worksheet in the QUAL2K model. A flow balance was constructed using the observed flows along White Pine Creek and its tributary. The amount of diffuse flow along White Pine Creek was calculated for June 27, 2013 and August 14, 2013.

The initial diffuse flow temperature was selected as the maximum reported groundwater temperature (range: 45.7° F to 56.5° F) from nearby wells, which was further evaluated during calibration. A diffuse inflow temperature of 49.1° F was selected to account for potentially warmer, open channel irrigation return flows. The final flow and water temperature assignment are shown below in **Table B-4**.

[5] The 50 acres of irrigated land was calculated using the “places of use” data associated with the “points of diversion” data available from the Natural Resources Information System (http://nris.mt.gov/gis/gisdatalib/gisDataList.aspx).

Table B-4. QUAL2K model flow and temperature inputs to White Pine Creek - Diffuse sources

Segment	Location [a]		Diffuse	Diffuse Inflow	
	Upstream	Downstream	Abstraction	Inflow	Temp
	(RM)	(RM)	(cfs)	(cfs)	(°F)
June 27, 2013					
WPC-T4 to WPC-T3	3.72	2.41	--	7.41	49.1
WPC-T3 to WPC-T2	2.41	0.69	--	6.71	49.1
WPC-T2 to WPC-T1	0.69	0.13	--	15.15	49.1
August 14, 2013					
WPC-T4 to WPC-T3	3.72	2.41	--	4.05	49.1
WPC-T3 to WPC-T2	2.41	0.69	--	0.35	49.1
WPC-T2 to WPC-T1	0.69	0.13	--	2.42	49.1

Notes:
°F = degrees Fahrenheit; cfs = cubic feet per second; RM = river mile.
a. Upstream and downstream termini of segments.

B3.2.7 Meteorological Data

Forcing functions for heat flux calculations are determined by the meteorological conditions in QUAL2K. The QUAL2K model requires hourly meteorological input for the following parameters: air temperature, dew point temperature, wind speed, and cloud cover. One of the nearest weather stations in the vicinity of the White Pine Creek watershed is the Cabinet (Trout Creek) RAWS (National Weather Service ID 241210), which is 7 miles to the north of the White Pine Creek watershed at an elevation of 2,350 feet above mean sea level. The other nearby weather station is the Trout Creek Ranger Station (National Weather Service ID 24830); however, its dataset does not include hourly data for the pertinent weather parameters. Since the Cabinet (Trout Creek) RAWS has a complete hourly dataset, the RAWS was used to develop the QUAL2K model (refer to **Attachment B1** for more discussion of these two weather stations).

The Cabinet (Trout Creek) RAWS records hourly air temperature, dew point temperature, wind speed and solar radiation. Therefore, the Cabinet (Trout Creek) RAWS hourly observed meteorological data were used to develop the QUAL2K model after appropriate unit conversions.

The wind speed measurements at the Cabinet (Trout Creek) RAWS were measured at 20 feet (6.10 meters) above the ground. QUAL2K requires that the wind speed be at a height of 7 meters. The wind speed measurements ($U_{w,z}$ in meters per second) taken at a height of 6.10 meters (z_w in meters) were converted to equivalent conditions at a height of z = 7 meters (the appropriate height for input to the evaporative heat loss equation), using the exponential wind law equation suggested in the QUAL2K user's manual (Chapra et al., 2008):

$$U_w = U_{wz}\left(\frac{z}{z_w}\right)^{0.15}$$

B3.2.8 Shade Data

The QUAL2K model allows for spatial and temporal specification of shade, which is the fraction of potential solar radiation that is blocked by topography and vegetation. A Shade Model was developed and calibrated for White Pine Creek. The calibrated Shade Model was first run to simulate shade estimates for June 27, 2013 to simulate hourly shade every 49 feet (15 meters, the resolution of the Shade Model) along White Pine Creek. Reach-averaged integrated hourly effective shade results were then computed at every 0.19 mile (300 meters; i.e., each reach). The reach-averaged results were then input into each reach within the QUAL2K model. A more detailed discussion on the shade modeling can be found under **Attachment B1**.

B3.3 Model Evaluation Criteria

The goodness of fit for the simulated temperature using the QUAL2K model was summarized using the absolute mean error (AME) and relative error (REL) as a measure of the deviation of model-predicted temperature values from the measured values. These model performance measures were calculated as follows:

$$AME = \frac{1}{N}\sum_{n=1}^{n} |P_n - O_n|$$

$$\text{REL} = \frac{\sum_{n=1}^{n} |P_n - O_n|}{\sum_{n=1}^{n} O_n}$$

These performance measures are detailed later in the section in evaluation of the model calibration.

B3.4 Model Calibration and Validation

The time periods selected for calibration and validation were June 27, 2013 and August 14, 2013; the travel times were 3.1 hours and 9.8 days, respectively. The June 27, 2013 travel time reflects the high flow conditions during spring melt, which are not representative of summer low-flow conditions. These dates were selected as they had the most comprehensive datasets available for modeling and corresponded to the synoptic study done for White Pine Creek, which included collecting flow, temperature, and shade.

Flow, depth, velocity and temperature data were available at four locations along the mainstem of White Pine Creek. **Table B-5** shows the monitoring sites used for calibration.

Table B-5. Temperature calibration locations

Site name	Distance (river mile)	Available Data	Source
WPC-4	3.71	Flow, depth, velocity and temperature	EPA
WPC-3	2.40	Flow, depth, velocity, and temperature	EPA
WPC-2	0.68	Flow, depth, velocity, and temperature	EPA
WPC-1	0.12	Flow, depth, velocity, and temperature	EPA

The first step for calibration was adjusting the flow balance and calibrating the system hydraulics. A flow balance was constructed for the calibration date. This involved accounting for all the flow in the system. Observed flows along White Pine Creek and withdrawals were used to estimate the amount of diffuse flow along the system.

After the mass balance of the flow rates, the modeled velocity and depth were simulated using the previously described rating curve method. To summarize, the exponents of the rating curve for the depth and the velocity were set to be 0.26 and 0.46 respectively. While the exponents were not varied during the model calibration, the rating curve coefficients were modified and evaluated against the observed data. The model results indicated a reasonable model representation. The calibrated coefficients were deemed appropriate since they were based upon observed data and yielded reasonable fits of velocity and depth. The model results indicated a reasonable model simulation as shown in **Figure B-7** and **Figure B-8.**

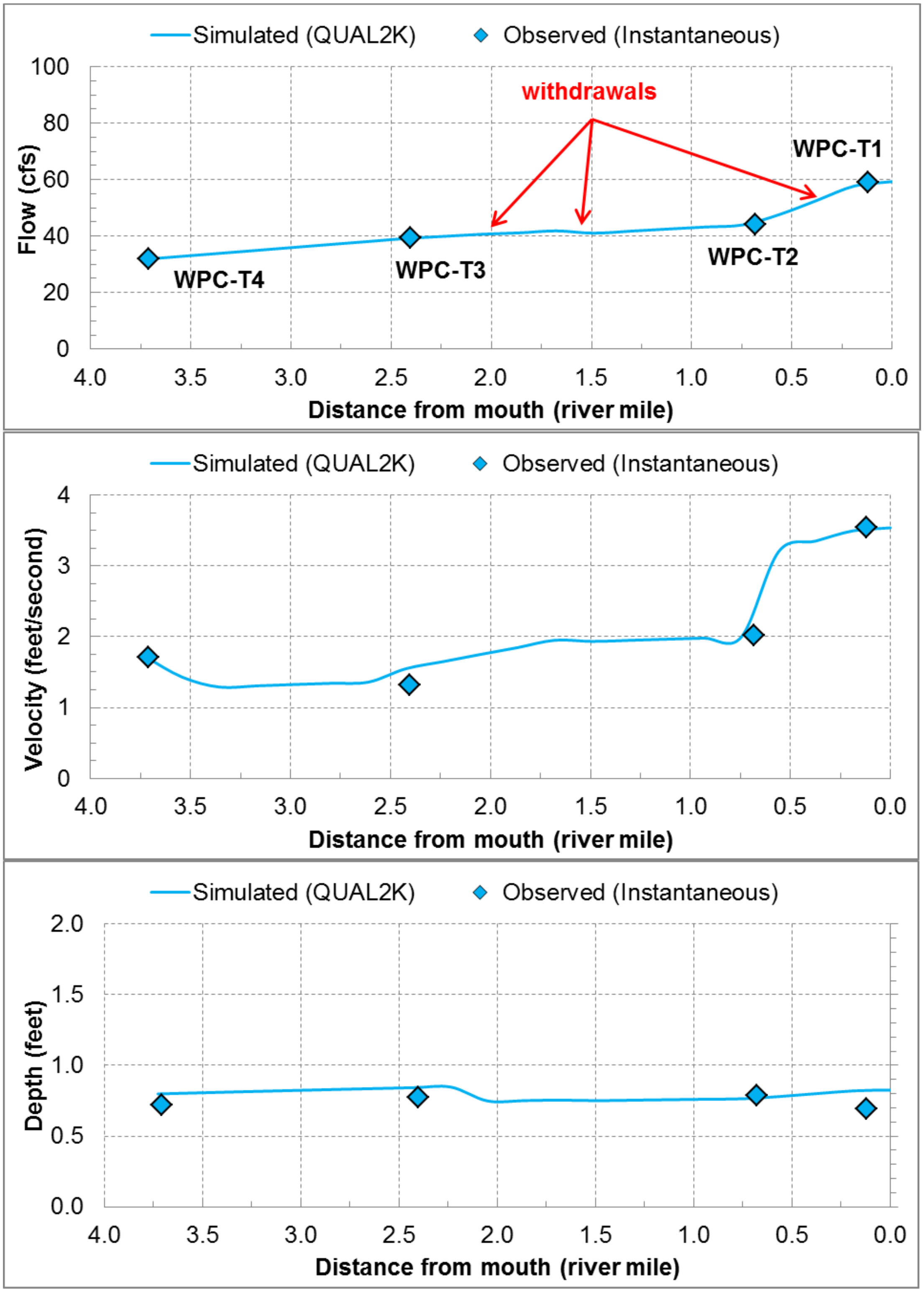


Figure B-7. Observed and predicted flow, velocity, and depth on June 27, 2013 (calibration).

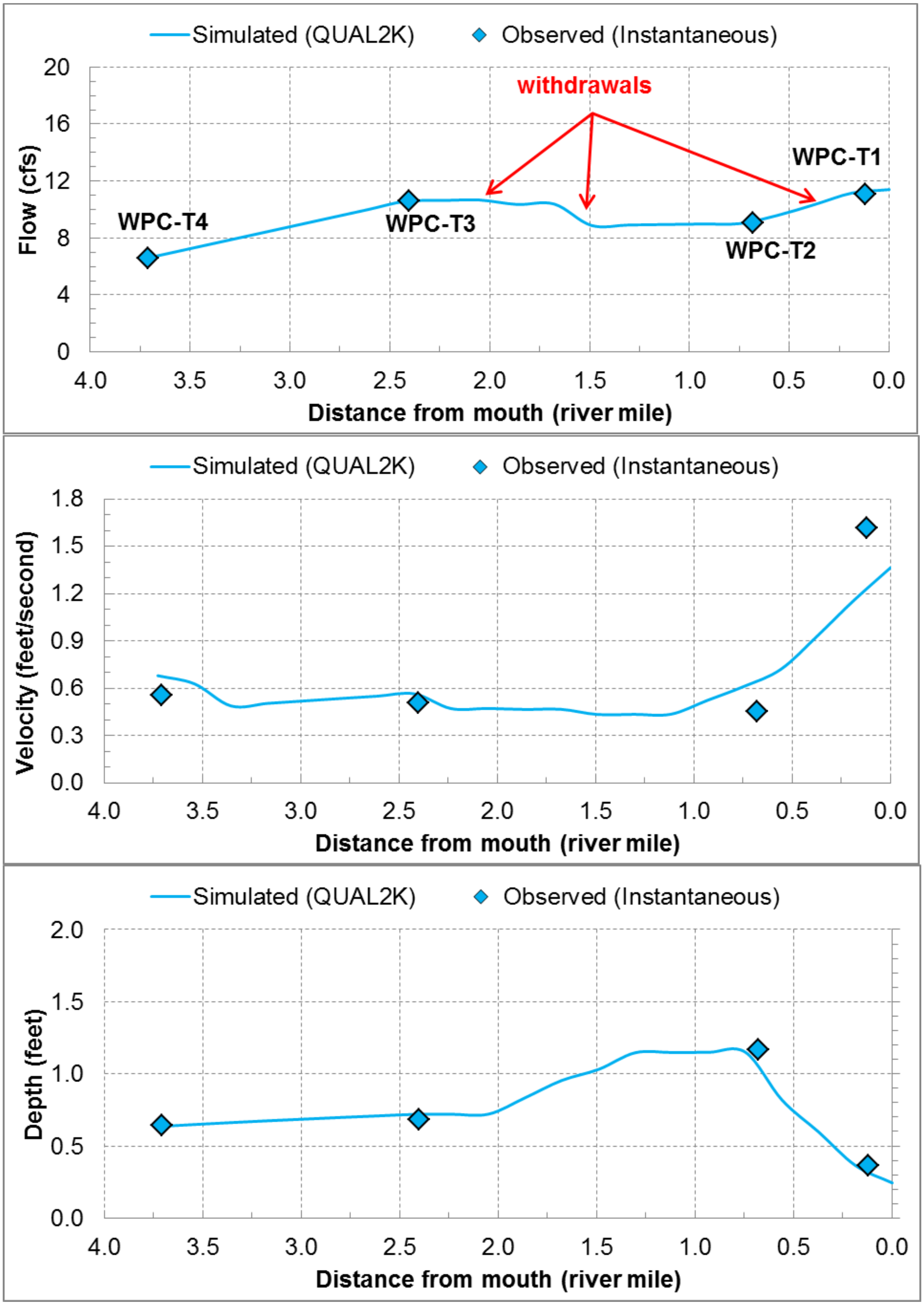


Figure B-8. Observed and predicted flow, velocity, and depth on August 13, 2013 (validation).

Once the system hydraulics were established, the model was then calibrated for water temperature. Temperature calibration included calibrating the model by adjusting the light and heat parameters with available data. A discussion of the solar radiation model and calibration along with other heat related inputs that were selected is presented below.

Hourly solar radiation is an important factor that affects stream temperature. The QUAL2K model does not allow for input of solar radiation. Instead the model calculates short wave solar radiation using an atmospheric attenuation model. For White Pine Creek, the Ryan-Stolzenbach model was used to calculate the solar radiation. The calculated solar radiation values (without stream shade) for the calibration and validation were compared with observed solar radiation measurements at the Cabinet (Trout Creek) RAWS. **Figure B-9** and **Figure B-10** show the observed and predicted solar radiation for the calibration and validation, respectively. The Ryan-Stolzenbach atmospheric transmission coefficient was set at 0.85 for the calibration to reflect the atmospheric conditions (i.e., cloudy) to minimize the deviation between the observed and modeled short wave solar radiation. Cloud cover was also adjusted to ensure the model simulated solar radiation was similar to the solar radiation reported for the RAWS.

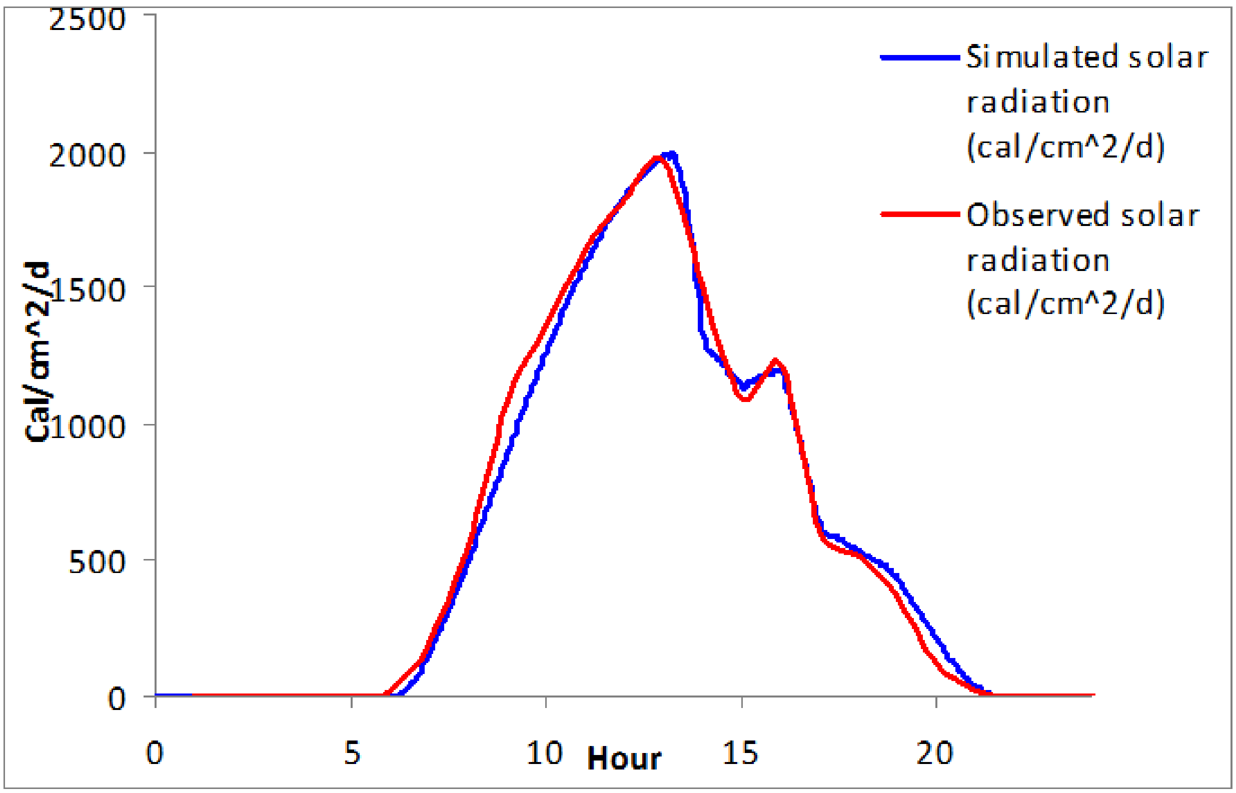


Figure B-9. Observed and predicted solar radiation on June 27, 2013 (calibration).

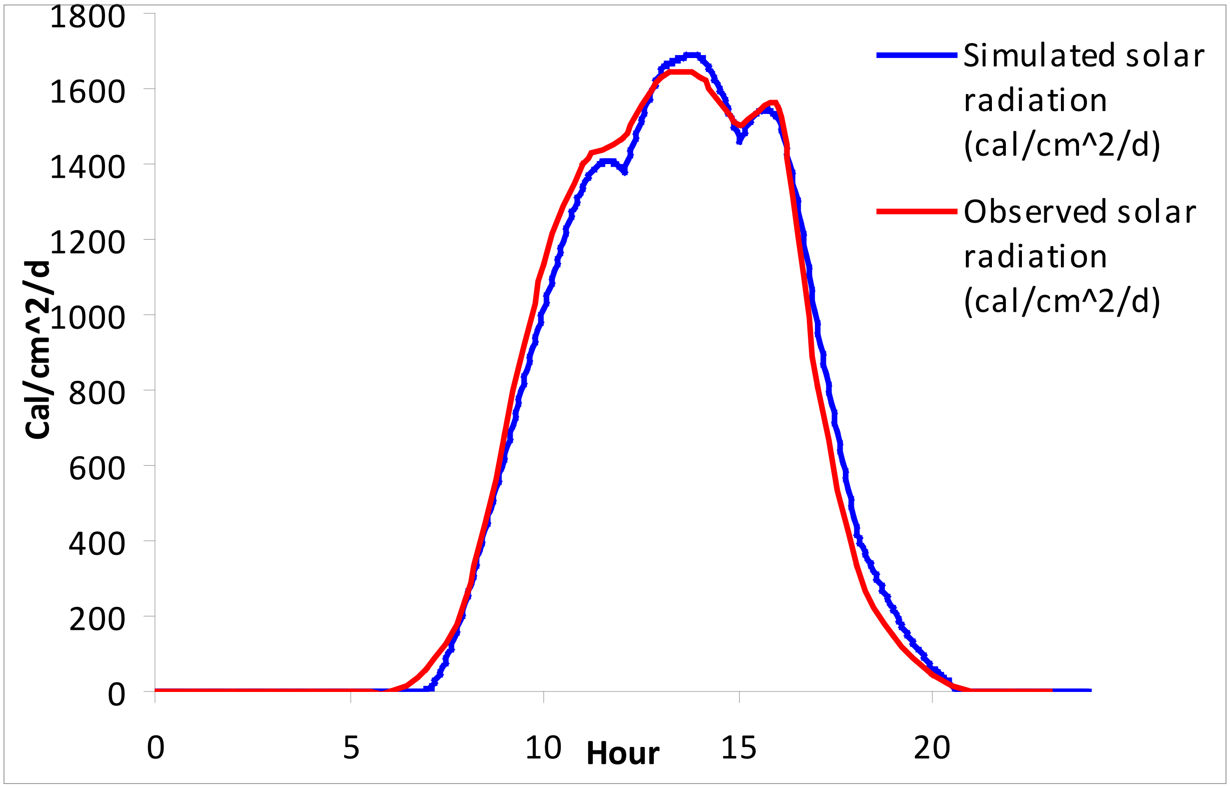


Figure B-10. Observed and predicted solar radiation on August 14, 2013 (validation).

The longwave solar radiation model and the evaporation and air conduction/convections models were kept at the default QUAL2K settings. The solar radiation settings are shown in **Table B-6**.

Table B-6. Solar radiation settings

Parameter	Value
Solar Shortwave Radiation Model	
Atmospheric attenuation model for solar	Ryan-Stolzenbach
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient [a]	0.85
Downwelling atmospheric longwave infrared radiation	
Atmospheric longwave emissivity model	Brutsaert
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	Adams 2

Note: a. The range of atmospheric transmission coefficients is 0.70 to 0.91 and the QUAL2K model default is 0.80 (Chapra et al. 2008).

The sediment heat parameters were also evaluated for calibration. In particular the sediment thermal thickness, sediment thermal diffusivity, and sediment density were adjusted during calibration. The sediment thermal thickness was increased from the default value of 10 cm to 20 cm, and the sediment heat capacity of all component materials of the stream was set to 0.4 calories per gram per degree Celsius, which is the QUAL2K default (Chapra et al., 2008).

The sediment density was set to 2.04 grams per cubic centimeter (g/cm^3). Based on the field photographs, the surface layer of the stream substrate was estimated to be composed of 80 percent rock gravel and 20 percent of silt and clay. The following calculation was conducted:

$$\text{sediment density} = (\text{ratio} * \text{density})_{gravel} + (\text{ratio} * \text{density})_{silt\ and\ clay}$$
$$= (0.80 * 2.00\ g/cm^3) + (0.20 * 2.20\ g/cm^3)$$
$$= 2.04\ g/cm^3$$

where 2.00 g/cm^3 is the density of gravel and 2.20 g/cm^3 is typical of clay and silt densities.

The sediment thermal diffusivity was set to a value of 0.0112 square centimeters per second (cm^2/s; Chapra et al. 2008). The following calculation was conducted:

$$\text{thermal diffusivity} = (\text{ratio} * \text{thermal diffusivity})_{rock+gravel} + (\text{ratio} * \text{thermal diffusivity})_{sand} + (\text{ratio} * \text{thermal diffusivity})_{silt}$$
$$= (0.80 * 0.0118\ cm^2/s) + (0.097 * 0.0079\ cm^2/s) + (0.103 * 0.0098\ cm^2/s)$$
$$= 0.0112\ cm^2/s$$

where 0.118 cm^2/s is the thermal diffusivity of rock, 0.0079 cm^2/s is the thermal diffusivity of sand, and 0.0098 cm^2/s is the thermal diffusivity of clay, which is assumed to be representative of silt.

These adjustments helped in improving the minimum temperatures simulated.

Calibration was followed by validation. The validation provides a test of the calibrated model parameters under a different set of conditions. Only those variables that changed with time were changed during validation to confirm the hydraulic variables. This included headwater instream temperatures, air and dew point temperatures, wind speed, cloud cover, solar radiation, and shade. All other inputs were based on observed data June 28, 2013. Groundwater temperatures, for which there were no direct observed data, were unchanged since they are not expected to vary greatly.
Figure B-11 and **Figure B-12** show the calibration and validation results along White Pine Creek. The temperature calibration and validation statistics of the average, maximum, and minimum temperatures are shown in **Table B-7** and **Table B-8**, respectively.

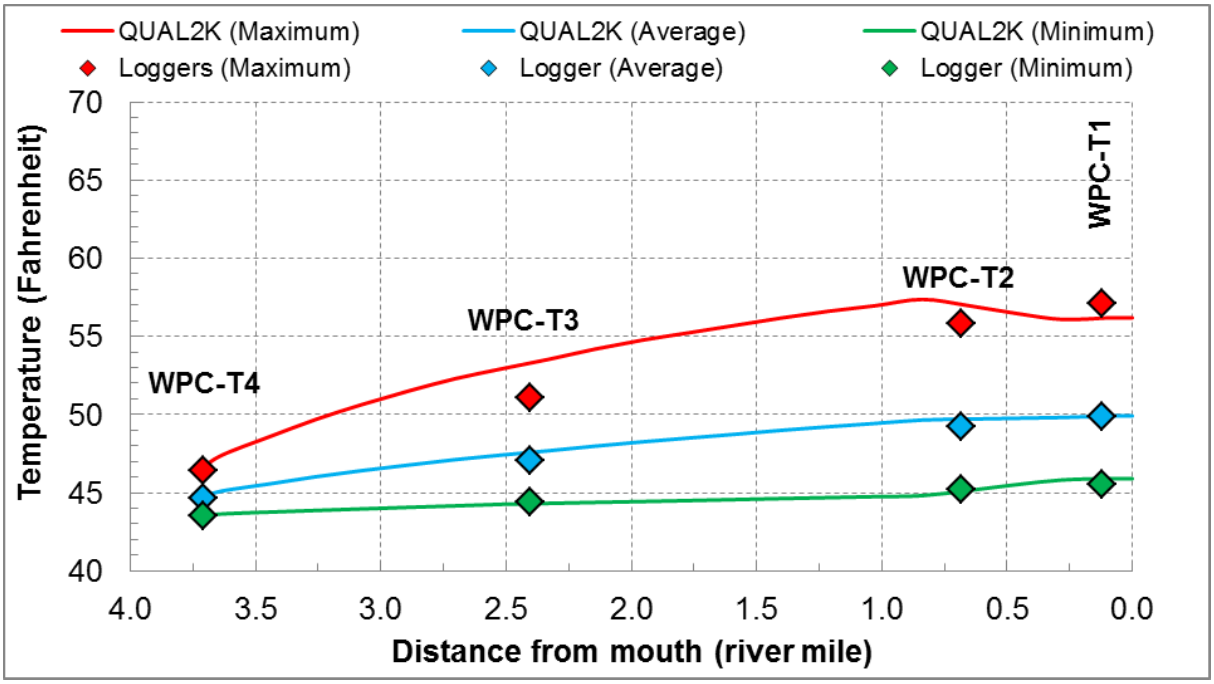


Figure B-11. Longitudinal profile of the temperature calibration (June 27, 2013).

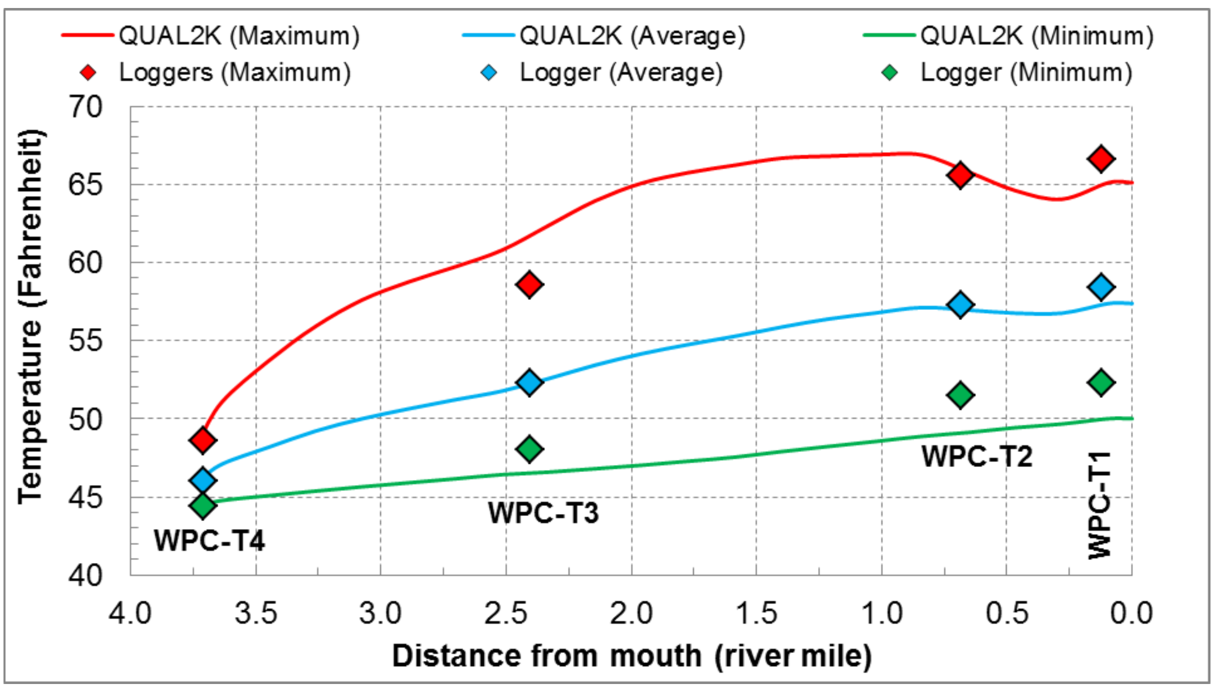


Figure B-12. Longitudinal profile of the temperature validation (August 14, 2013).

Table B-7. Calibration statistics of observed versus predicted water temperatures

Site name	RM	Average daily temperature		Maximum daily temperature		Minimum daily temperature	
		AME (°F)	REL (%)	AME (°F)	REL (%)	AME (°F)	REL (%)
WPC-T4	3.71	0	0%	0.01	<0.1%	0	0%
WPC-T3	2.40	0.65	1.4%	2.45	4.8%	0.08	0.2%
WPC-T2	0.68	0.51	1.0%	1.12	2.0%	4.51	10.0%
WPC-T1	0.12	0.02	0%	0.95	1.7%	0.41	0.9%
Overall Calibration		**0.39**	**0.8%**	**1.51**	**2.8%**	**1.67**	**3.7%**

Note: AME = absolute mean error; REL = relative error; RM = river mile.

Table B-8. Validation statistics of observed versus predicted water temperatures

Site name	RM	Average daily temperature		Maximum daily temperature		Minimum daily temperature	
		AME (°F)	REL (%)	AME (°F)	REL (%)	AME (°F)	REL (%)
WPC-T4	3.71	0	0%	0	0%	0	0%
WPC-T3	2.40	0.30	0.6%	3.83	3.6%	1.39	2.9%
WPC-T2	0.68	0.99	0.5%	0.26	0.4%	2.27	4.6%
WPC-T1	0.12	0.28	1.7%	1.51	2.3%	2.26	4.3%
Overall Validation		**0.9**	**0.52%**	**1.87**	**2.9%**	**2.01**	**4.0%**

Note: AME = absolute mean error; REL = relative error; RM = river mile.

Based upon the calibration results, the model is able to simulate the flow, depth, and velocity and the minimum, mean, and maximum temperatures reasonably well. The model over-predicts the maximum temperature at loggers WPC-T2 and WPC-T3 and under-predicts the maximum temperature at WPC-T1. The calibration results showed an overall 2.8 percent relative error with an AME of 1.51° F for the maximum temperatures (**Table B-7**); thus, the model simulation is acceptable.

The model results for the validation are similar to those of the calibration. The model over-predicts the maximum temperatures at loggers WPC-T2 and WPC-T3 and under-predicts the maximum temperature at logger WPC-T1. The validation results showed an overall 2.9 percent relative error with an AME of 1.87° F for the maximum temperatures (**Table B-8**).

B3.5 Model Sensitivity

Sensitivity analysis measures the relative importance of parameters, such as shade and water withdrawals, on model response. Model sensitivity was generally evaluated by making changes to shade[6] and water use[7] (i.e., the key thermal mechanisms [Tetra Tech 2012]) in separate model runs and evaluating the model response. Model sensitivity analyses with similar QUAL2K models for streams in western Montana (Fortine, Wolf, and McGregor creeks) suggest that the QUAL2K models developed with the data typically available for the Montana temperature projects are not very sensitive to changes in water use but are sensitive to changes in shade. The sensitivity of water withdrawals and shade were

[6] To assess model sensitivity to shade, all vegetation was converted to high density trees (with the exception of roads and hydrophytic shrubs) to represent the maximum potential shade.

[7] To assess model sensitivity to water withdrawals, the point source abstractions representing the withdrawals were removed and the existing condition model was run to represent the maximum achievable change in water temperatures from changes in water use.

explored with the White Pine Creek QUAL2K model during model development and the results were generally consistent with previous Montana streams QUAL2K projects.

B4.0 Model Scenarios and Results

The White Pine Creek QUAL2K model was used to evaluate instream temperature response associated with multiple management scenarios. **Table B-9** summarizes the alterations for each model scenario. The following subsections present discussions of the modifications to the QUAL2K models and the results for each scenario.

Table B-9. QUAL2K model scenarios for White Pine Creek

Scenario a		Description	Rationale
Baseline Scenario			
1	Existing Condition	Existing shade and irrigation practices under validation model flowsb and weather.	The baseline model simulation from which to construct the other scenarios and compare the results against.
Water Use Scenario			
2	15 % reduction in withdrawals	Reduce existing withdrawals by 15 percent	Represent application of conservation practices for agricultural and domestic water use.
Shade Scenario			
3	Shade increased to reference levels	Increase anthropogenically influenced reaches' shade to that of a conifer/shrub reference reach at site WPC-T2	Represent application of conservation practices for riparian vegetation.
Improved Flow and Shade			
4	Improved flow and shade	Existing conditions with 15% reduction in withdrawals (scenario 2) and increase to reference levels (scenario 3).	Represent application of conservation practices for water withdrawals and riparian vegetation.

Notes

a. Scenarios were developed in accordance with electronic correspondence from the DEQ project manager Eric Sivers to Tetra Tech's project manager Ron Steg on May 12, 2014.

b. Based on an analysis of discharge records from a nearby USGS gage (Prospect Creek at Thompson Falls [12390700]), flows in White Pine Creek during the validation timeframe were likely below average.

B4.1 Baseline Scenario

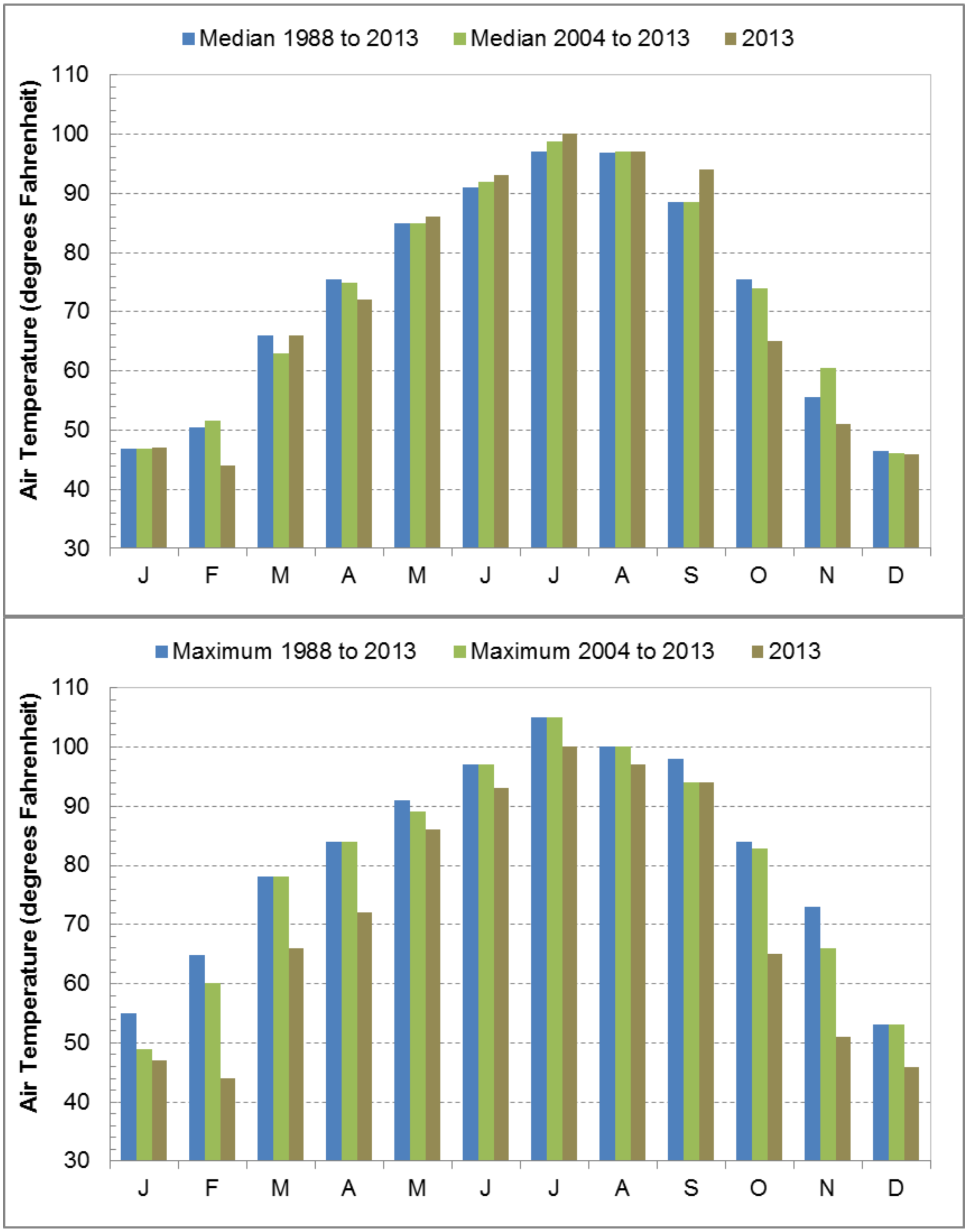
The baseline model (scenario 1) serves as the baseline model simulation from which to construct the other scenarios and compare the results against. The baseline scenario was run using the existing flow and weather conditions on the validation date (i.e., the validation model).

The Cabinet (Trout Creek) RAWS has hourly data available for the period from January 2004 through May 2014[8]. Since the weather data extends only for a period of 10 years, a nearby station with long-term meteorological data (Missoula International Airport [1988-2013]) was queried to confirm if the years from 2004 to 2013 were (1) not anomalously warm or cold and (2) similar to the overall historical normal. Additionally, comparisons with the year 2013 (during which the QUAL2K model calibration period occurs) were made to ensure that 2013 was not an anomalous year. The long-term monthly

[8] Data are available for a few months in the years 2001, 2002, and 2003.

median and maximum air temperatures for the period from 2004 to 2013 and for the year 2013 were estimated to be similar to the overall period from 1988 through 2013 (**Figure B-13**)[9]. The monthly maximum air temperatures in the summer of 2013 were cooler than the monthly long-term maximum of monthly maximum air temperatures of the years 1988-2013 and 2004-2013 (**Figure B-13**). Therefore, since neither the period from 2001 through 2013 nor the summer of 2013 was substantially anomalous, it is appropriate to use the Cabinet (Trout Creek) RAWS data for QUAL2K modeling.

[9] Hourly average air temperatures were obtained for the Missoula International Airport (KMSO). Monthly maximum air temperatures were calculated for each month from January 1988 through December 2013 using the hourly average air temperatures. Monthly long-term medians and maximums were calculated from the 26 years of monthly maximums of hourly average air temperatures.



Note: Hourly average air temperatures were obtained for the Missoula International Airport (KMSO). Monthly maximum air temperatures were calculated for each month from January 1988 through December 2013 using the hourly average air temperatures. Monthly long-term medians and maximums were calculated from the 26 years of monthly maximums of hourly average air temperatures.

Figure B-13. Long-term median (chart on top) and maximum (chart on bottom) of monthly maximum air temperature at Missoula.

Existing conditions weather (August 14, 2013) used for the validation model was also used for the baseline model.

No continuous flow datasets are available in the White Pine Creek watershed. The closest continuously recording USGS gage in a watershed of similar size is gage 12390700 (Prospect Creek at Thompson Falls; water years 1957-2013). The daily average flow on August 14, 2013 at gage 12390700 was low (38th percentile) as compared to the daily average flows on all August 14ths on record. The daily average flow for August 2013 at USGS gage 12390700 was also low (34th percentile) as compared to the daily average flow for all Augusts on record (see **Attachment B1, Section B6**). The existing condition flow was used for the analysis.

The modeled water temperatures for the baseline scenario are shown below in **Figure B-14**. The simulated maximum temperatures ranged from 48.6° F to 68.2° F. The warmest temperature (67.2° F) occurred at river mile 0.84, just upstream of logger WPC-T2).

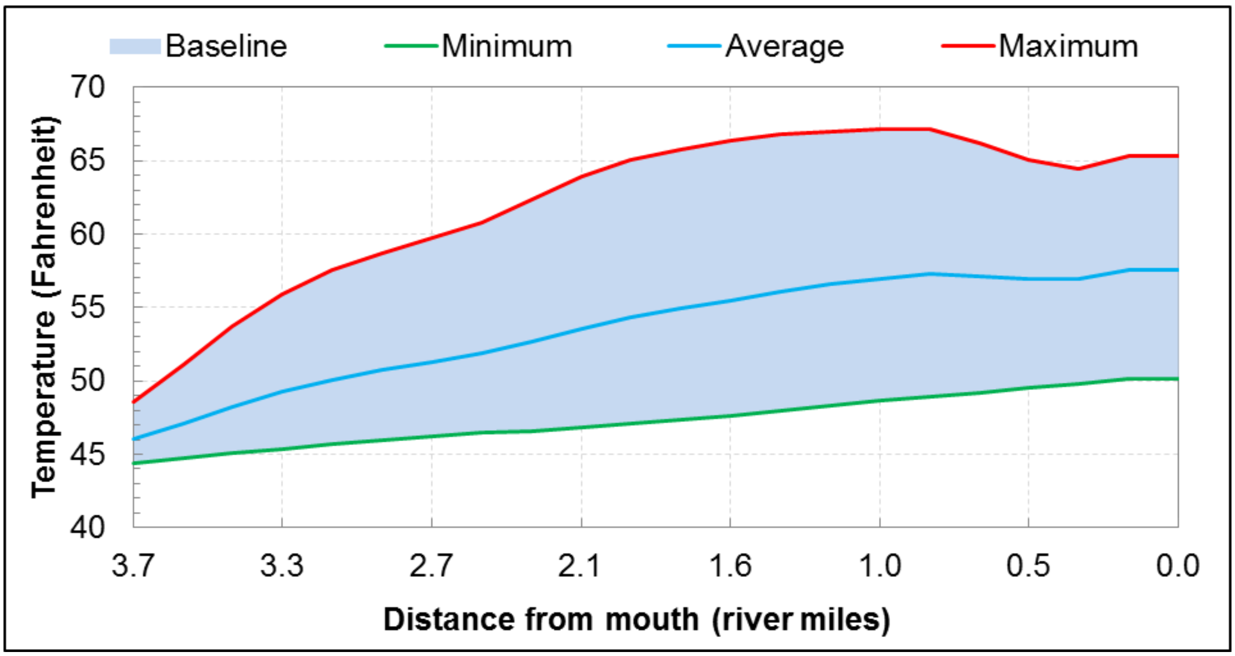


Figure B-14. Simulated water temperature for baseline condition (August 14, 2013).

B4.2 Water Use Scenario

Irrigation (or other water withdrawals) deplete the volume of water in the stream and reduce instream volumetric heat capacity. Theoretically the reduced stream water volume heats up more quickly (and also cools more quickly), given the same amount of thermal input. A single water use scenario was modeled to evaluate the potential benefits associated with application of water use best management practices (scenario 2).

In this scenario, the point sources abstractions representing the withdrawals (see **Attachment B1** and **Table B-3** for the withdrawals) in the QUAL2K model are reduced by 15 percent (Natural Resources Conservation Service, 1997). The water previously withdrawn is now allowed to flow down White Pine Creek. This scenario is intended to represent application of conservation practices relative to water use.

The water temperatures under this scenario generally were the same as the baseline scenario (**Figure B-15**). The maximum change in the maximum daily water temperature is representative of the worst case conditions. A maximum change in the maximum daily water temperature of 0.04° F from the existing condition was observed at RM 0.8. The temperature difference of the daily maximums was less than 0.5° F for the entire stream of the stream.

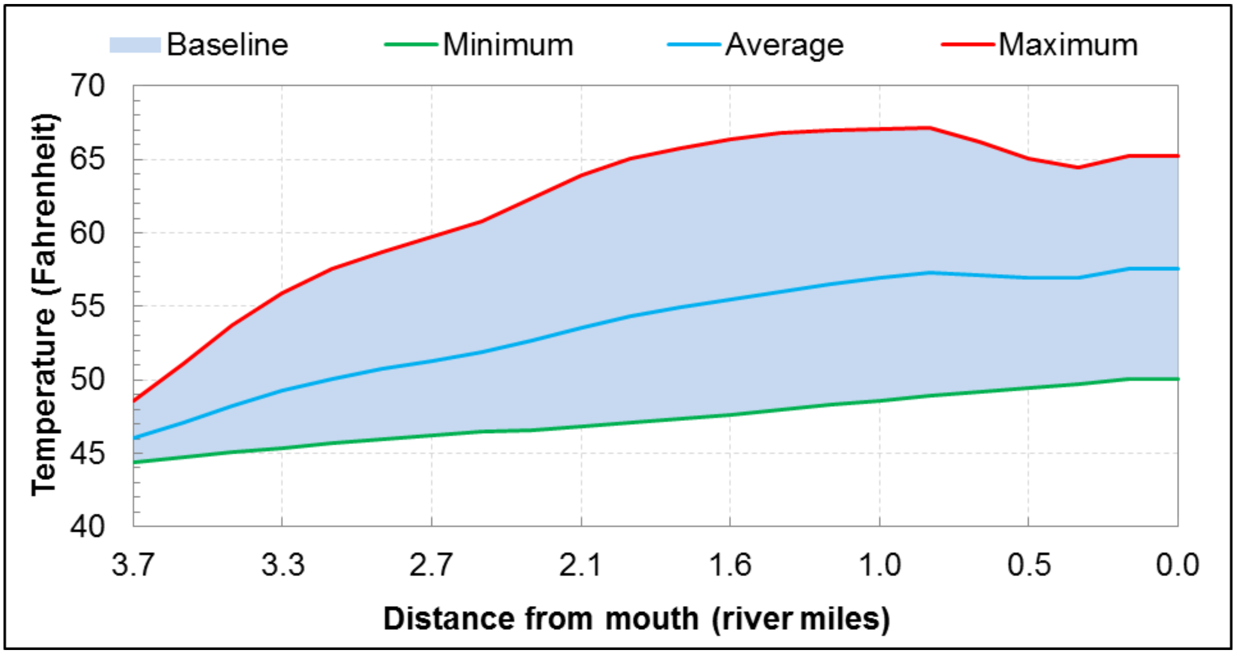


Figure B-15. Simulated water temperatures for the baseline (scenario 1) and 15-percent withdrawal reduction (scenario 2).

B4.3 Shade Scenario

The riparian plant community blocks incoming solar radiation, which directly reduces the heat load to the stream. A single shade scenario was modeled to evaluate the potential benefits associated with increased shade along certain segments of White Pine Creek.

Based on an assessment including site reconnaissance and review of historic aerial photographs, Water Consulting, Inc.(2002) concluded the following regarding the condition of riparian vegetation in the lower reaches of White Pine Creek (i.e., the reach that was modeled[10]):

> *Poor cottonwood and willow recruitment in the lower watershed contrasts with the diverse gallery forest in upper White Pine Creek. Restoring this diversity in the lower watershed should be a priority for the restoration effort.*

Water Consulting recommended a re-vegetation plan, following a multi-year schedule directed at redirecting plant succession towards a riparian forest. Specifically, they recommended the following re-vegetation steps:

- Conifer plantings in senescent alder stands

[10] Given intermittent flow in the upper reaches of White Pine Creek, only the lower reach (i.e., below WPC-T4) of White Pine Creek has been modeled.

- Shrub and conifer plantings in moist-soil/tall grass sites
- Shrub and conifer plantings in sand and gravel floodplains
- Shrub and conifer plantings on well-drained, short grass/knapweed dry terraces

Water Consulting's assessment suggests that the vegetative potential for the lower reaches of White Pine Creek is a mixed conifer, cottonwood, and shrub community.

Based on site reconnaissance work conducted by EPA and DEQ during the summer of 2013, Shade Monitoring Site WPC-T2 represents a mixed conifer/shrub community that was at potential within the lower reach of White Pine Creek. Average daily shade measured at WPC-T2 was approximately 70%, compared to approximately 30% at the other three sites in the lower reach of White Pine Creek (WPC-T1, WPC-T3, and WPC-T4). In the Improved Shade Scenario, modeled shade in the vicinity of WPC-T2 is the reference condition that will be applied to anthropogenically impacted reaches in lower White Pine Creek.

The White Pine Creek QUAL2K model was re-run using the altered shade inputs, based upon the findings presented above (**Table B-10**. This scenario is intended to represent application of conservation practices relative to shade although it is important to note that even in natural forested conditions, there are still openings in the canopy and some areas without vegetation. Hence this is likely an upper limit to what plausibly could occur from vegetation management practices.

Table B-10. Average daily shade inputs per model segment

Segment	Existing condition (scenario 1)	Shade (scenario 3)
WPC-T4 to WPC-T3	37%	45%
WPC-T3 to WPC-T2	29%	45%
WPC-T2 to WPC-T1	45%	45%
WPC-T1 to mouth	33%	45%

Note: For each segment, the effective shade per hour was averaged across 15 meter intervals for each hour from 5:00 am through 9:59 pm (yielding average effective shade per hour per model segment) and then averaged across daylight hours (yielding average effective shade per day per model segment.

Water temperatures in White Pine Creek downstream of logger WPC-T4 decreased (**Figure B-16**). A maximum change in the maximum daily water temperature of 2.6° F from the baseline was observed at RM 0.8. The difference in the daily maximum water temperature between the baseline and shade scenario was greater than 0.5° F from RM 3.5 to the mouth, which is almost the entire length of the modeled stream. It is important to note the caveats previously stated: that this is likely the largest improvement that could be observed through vegetation management practices.

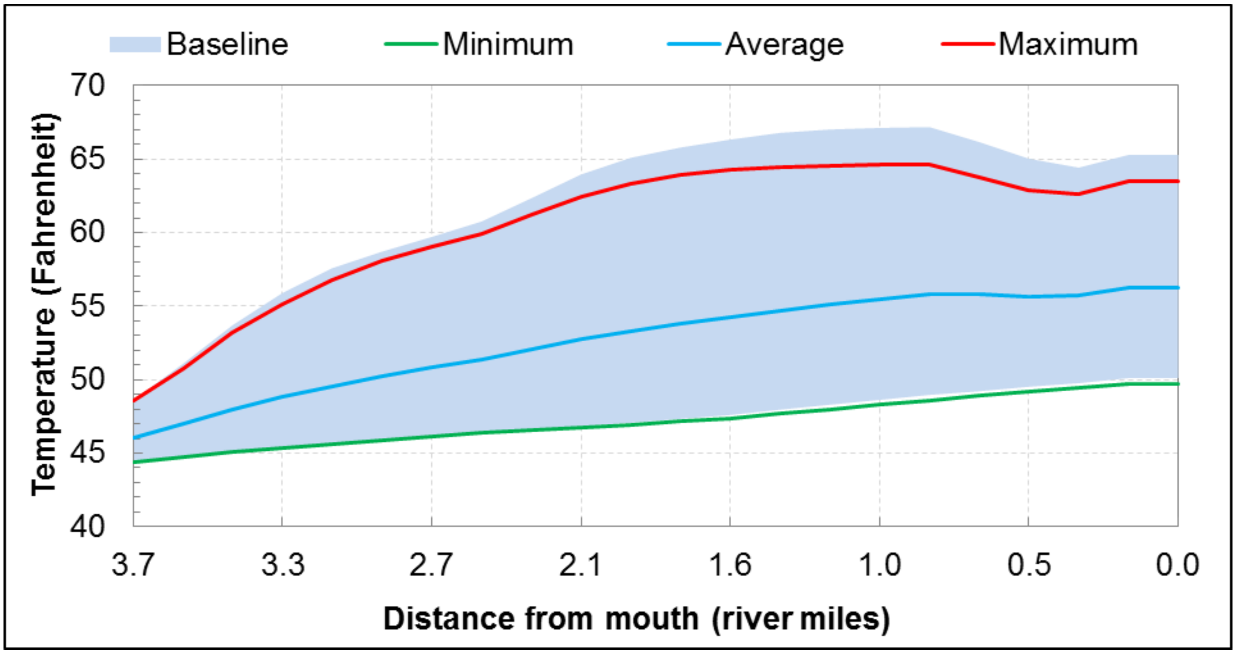


Figure B-16. Simulated water temperatures for the baseline (scenario 1) and increased shade (scenario 3).

B4.4 Improved Flow and Shade Scenario

The improved flow and shade scenario (scenario 4) combines the potential benefits associated with a 15 percent reduction in water withdrawals (scenario 2) with increases shade to reference levels along certain segments (scenario 3).

Simulated maximum daily temperatures ranged from 48.6° to 64.6° from logger WPC-T4 at rivermile 3.7 to the mouth. As per the temperature standard discussed in **Section B2.2**, anthropogenic activities may increase the instream temperatures by 1.0° F for the segment from rivermile 3.7 to the mouth.

In this scenario, water temperatures in White Pine Creek decrease throughout much of the system (**Figure B-17** and **Figure B-18**). A maximum change in the maximum daily water temperature of 2.6° F from the baseline was observed at RM 0.8. The difference in the daily maximum water temperature between the baseline and the improved flow and shade scenario was greater than 0.5° F from RM 3.5 to the mouth, which is almost the entire length of the modeled stream.

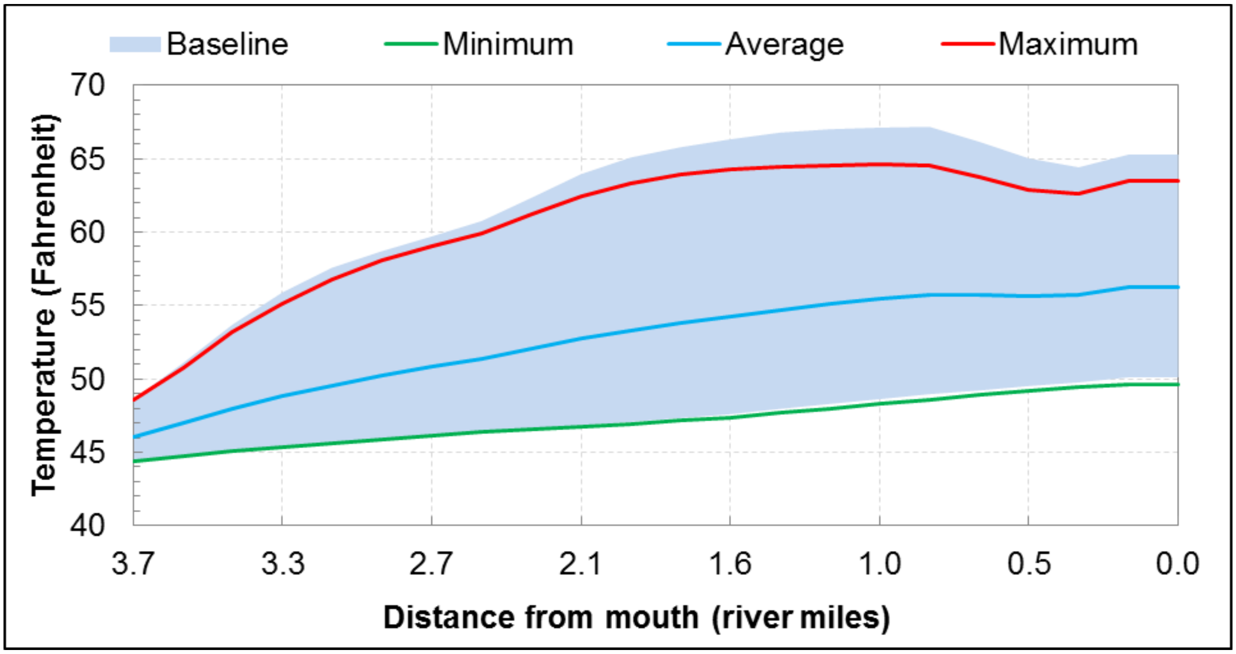


Figure B-17. Simulated water temperature for the baseline (scenario 1) and the improved flow and shade scenario (scenario 4).

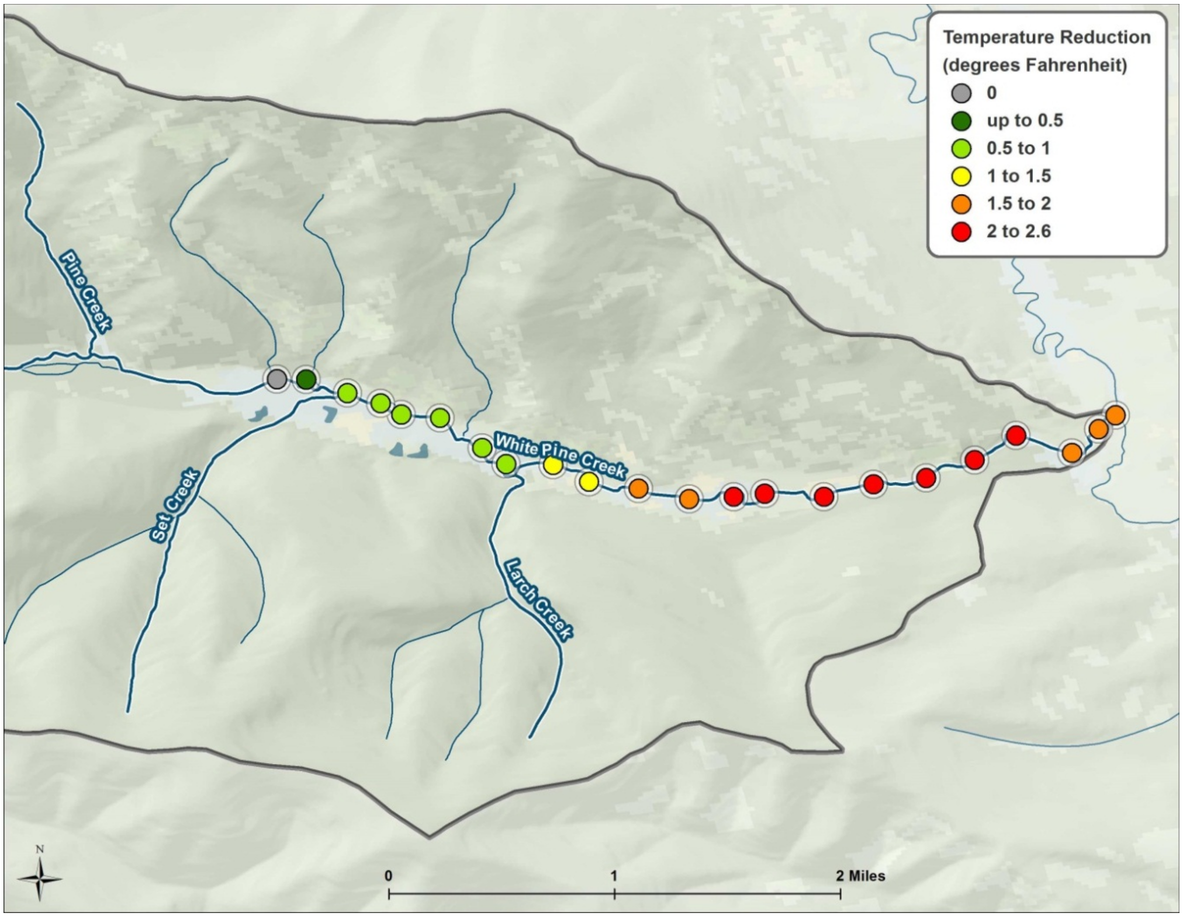


Figure B-18. Instream temperature difference from the baseline (scenario 1) to the improved flow and shade scenario (scenario 4).

B5.0 Assumptions and Uncertainty

As with any model, the QUAL2K model is subject to uncertainty. The major sources of model uncertainty include the mathematical formulation, input and boundary conditions data uncertainty, calibration data uncertainty, and parameter specification (Tetra Tech, Inc., 2012). As discussed in the quality assurance project plan (Tetra Tech, Inc., 2012), the QUAL2K model code has a long history of testing and application, so outright errors in the coding of the temperature model are unlikely. The Shade Model has also been widely used so a similar sentiment exists. A potentially significant amount of the overall prediction uncertainty is due to uncertainty in the observed data used for model setup, calibration, and validation, and assumptions used in the scenario analysis itself.

B5.1 Uncertainty with Model Development

With respect to input data (including instantaneous flow, continuous temperature, channel geometry, hourly weather, spatial data or other secondary data), weather and spatial data were obtained from other government agencies and were found to be in reasonable ranges, and are therefore assumed to be accurate. Uncertainty was minimized for the use of other these data following procedures described in the quality assurance project plant (Tetra Tech, Inc., 2012).

In addition, assumptions regarding how these data are used during model development contain uncertainty. The following key assumptions were used during White Pine Creek QUAL2K model development:

- The lower portion of White Pine Creek can be divided into distinct segments, each considered homogeneous for shade, flow, and channel geometry characteristics. Monitoring sites at discrete locations were selected to be representative of segments of White Pine Creek.
- Spatial variability of velocity and depth (e.g. stream meander and hyporheic flow paths) are represented through exponents and coefficients of the selected rating curves for each segment.
- Weather conditions at the Cabinet (Trout Creek) RAWS are representative of local weather conditions along White Pine Creek.
- Shade Model results are representative of riparian shading along segments of White Pine Creek. Shade Model development relied upon the following three estimations of riparian vegetation characteristics:
  - Riparian vegetation communities were identified from visual interpretation of aerial imagery.
  - Tree height and percent overhang were estimated from other similar studies conducted outside of the White Pine Creek watershed.
  - Vegetation density was estimated using the National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium 2001) and best professional judgment.
- Shade Model results were corroborated with field measured Solar PathfinderTM results and were found to be reasonable. The average absolute mean error is 6 percent. (i.e., the average error from the Shade Model output and Solar PathfinderTM measurements was 5 percent daily average shade).
- Simulated diffuse flow rates are representative of groundwater inflow/outflow, irrigation diversion, irrigation return flow, and other sources of inflow and outflow not explicitly modeled. Diffuse flow rates were estimated using flow mass balance equations for each model reach.

B5.2 Uncertainty with Scenario Development

The increased shade scenario (scenario 3) assumes that the shade from vegetation along the reference segment is achievable in the segments with anthropogenically diminished shade. The increased shade scenario (scenario 3) represents the feasible temperature benefit that could be achieved over a time period long enough to allow vegetation to mature (tens of years). Therefore, temperature improvements in the short term are likely to be less than those identified in the scenario 3 results. Natural events such as flood and fire may also alter the maximum potential for the riparian vegetation or shift the time needed to achieve the maximum potential. This condition may not be achievable for all areas due to the coarse scaled used to identify the current and potential shade conditions and the fact that even natural systems tend to have spatial patchiness of tree canopy cover.

B6.0 Model Use and Limitations

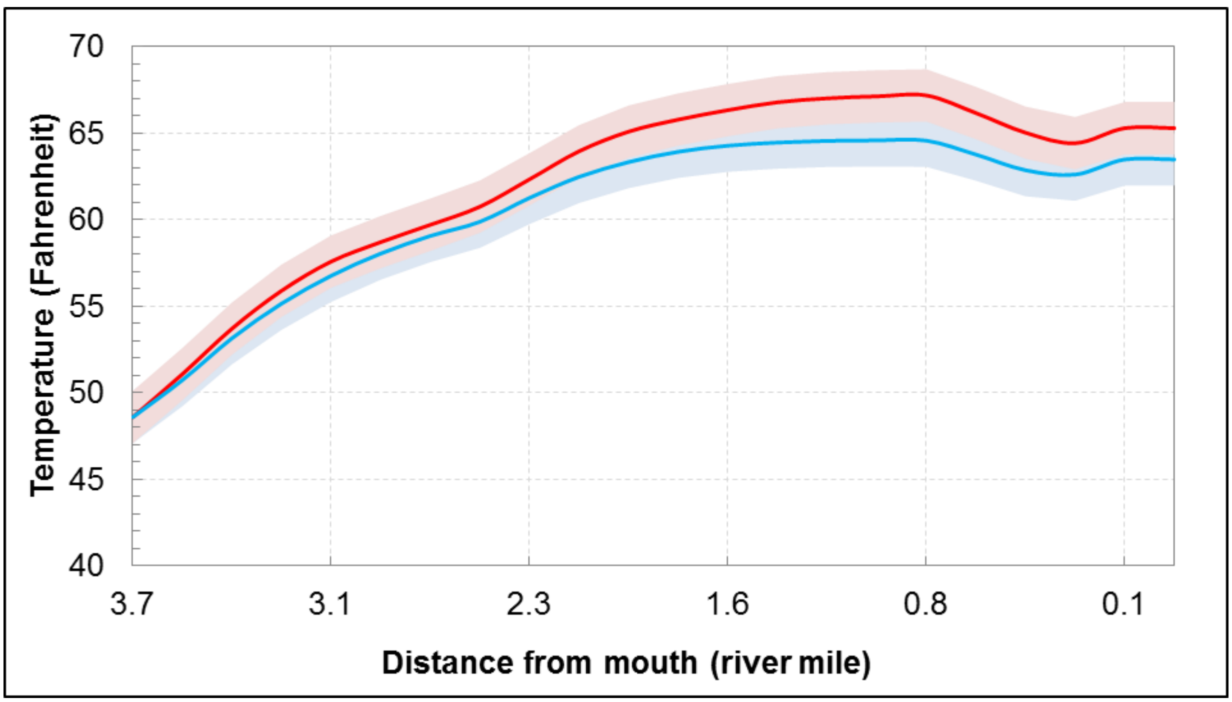
The model is only valid for summertime, warm-weather conditions and should not be used to evaluate high flow or other conditions. As described above, steps were taken to minimize uncertainty as much as possible. Despite the uncertainty, the model adequately addresses the primary questions:

1. What is the sensitivity of instream temperature to the following thermal mechanisms and stressors: shade, irrigation withdrawal and return?
2. What levels of reductions in controllable stressors are needed to achieve temperature standards?

The first question can be answered using the calibrated and validated QUAL2K model for White Pine Creek. As previously discussed, White Pine Creek is sensitive to shade.

The second question can be answered using the validated QUAL2K model and the scenarios developed to assess water use and shade. In this instance, increasing riparian shading will decrease instream temperatures significantly (generally between 0.6°F and 2.6°F); however, there is uncertainty in the magnitude of temperature reduction as estimates are contingent on what was considered to be reference shade. While a "good" model calibration was achieved, the overall Absolute Mean Error (AME) for the maximum daily temperature was 1.5° F.

Figure B-19 graphically summarizes the comparison between the baseline condition and improved flow and shade scenario. Based on these results, and the fact that Montana's temperature standard as applied to White Pine Creek is limited to an increase of 1° F, it is appears that impacts are occurring to the stream. Since the scenarios are sometimes within the AME, it is difficult to draw conclusions between the improved flow and shade scenario and the baseline. Regardless, the mechanism to address elevated stream temperatures will be the mitigation of stream shade through plantings or riparian enhancement and reduction of irrigation withdrawals to allow more water to flow down the stream. Continued monitoring should be done in conjunction with these activities to ensure that they are of benefit, in particular given that model results are uncertain as described previously.



Note: The baseline (scenario 1) is the red line and the improved flow and shade scenario (scenario 4) is the blue line. The shaded areas are plus or minus the average AME (1.5° F).

Figure B-19. Simulated daily maximum water temperatures from the baseline (red; scenario 1) and improved flow and shade scenario (blue; scenario 4).

B7.0 Conclusions

The scenarios resulted in water temperatures reductions as much as 2.6° F.

A flow scenario representing irrigation efficiency was evaluated and the locations that showed the greatest potential for improvement were localized to areas just downstream of the existing withdrawals. However, the 15-percent reductions in water use did not result in appreciable reductions to the temperature in the middle segments of White Pine Creek. The largest reductions (<1° F) occurred from RMs 1.4 to 0.7.

The shade scenario showed the greatest extent and impact (reduction) to water temperatures along much of the stream. Reductions of 0.5° F occurred from RM 3.5 to the mouth and reductions of 1.0° F to 2.6° F occurred from RM 2.3 to the mouth.

The improved flow and shade scenario that combined the potential benefits associated with a 15 percent reduction in water withdrawals (scenario 2) with increased shading based upon reference levels (scenario 3) to represent application of conservation practices relative to the temperature impairment was also simulated. This scenario resulted in overall reductions along the most of the stream, which ranged from <0.1° F to 2.6° F (**Table B-11**). The scenario shows that reductions in water temperatures are achievable throughout the stream: reductions of 0.5° F are achievable from RMs 3.5 to 2.3 and reductions of 1.0° F are achievable from RM 2.3 to the mouth. Refer back to **Figure B-18** for a map of potential temperature reductions. The greatest potential improvement (i.e., reduction) occurs at RM 0.8 (2.6 ° F improvement) (**Figure B-20**). Above logger WPC-T4 (about RM 3.7), segments of White Pine Creek ran dry and were not modeled. The difference in shading due to differing vegetation scenarios is shown on **Figure B-21**. Efforts should be focused on re-vegetation in areas of lower White Pine Creek most amenable to this type of restoration activity.

Table B-11. Instream temperature difference from the baseline scenario

Scenario ID	Scenario name	Daily maximum			Daily average		
		Range of change[a]	**Average change[b]**	**Median change[c]**	**Range of change[a]**	**Average change[b]**	**Median change[c]**
2	Water Use	<-0.1 to <+0.1	<-0.1	0	<-0.1 to 0	<-0.1	0
3	Shade	-0.3 to -2.6	-1.6	-1.8	-0.2 to -1.5	-0.9	-1.1
4	Improved Flow and Shade	-0.3 to -2.6	-1.6	-1.8	-0.2 to -1.6	-0.9	-1.1

Notes

Results are reported in degrees Fahrenheit. Negative values represent scenario results that were cooler than the Baseline scenario while positive values represent scenario results that were warmer than the baseline scenario.

[a.] The range of temperature changes along White Pine Creek as compared with the baseline scenario.

[b.] The distance-weighted average temperature change along White Pine Creek as compared with the baseline scenario.

[c.] The distance-weighted median temperature change along White Pine Creek as compared with the baseline scenario.

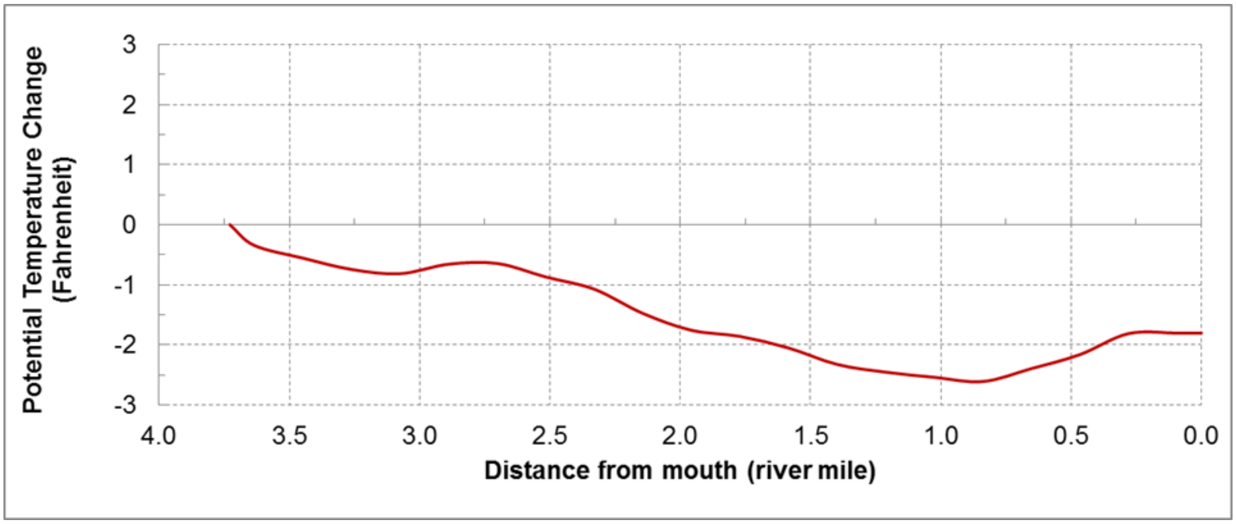


Figure B-20. Simulated water temperature reduction from the baseline (scenario 1) to the improved flow and shade scenario (scenario 4).

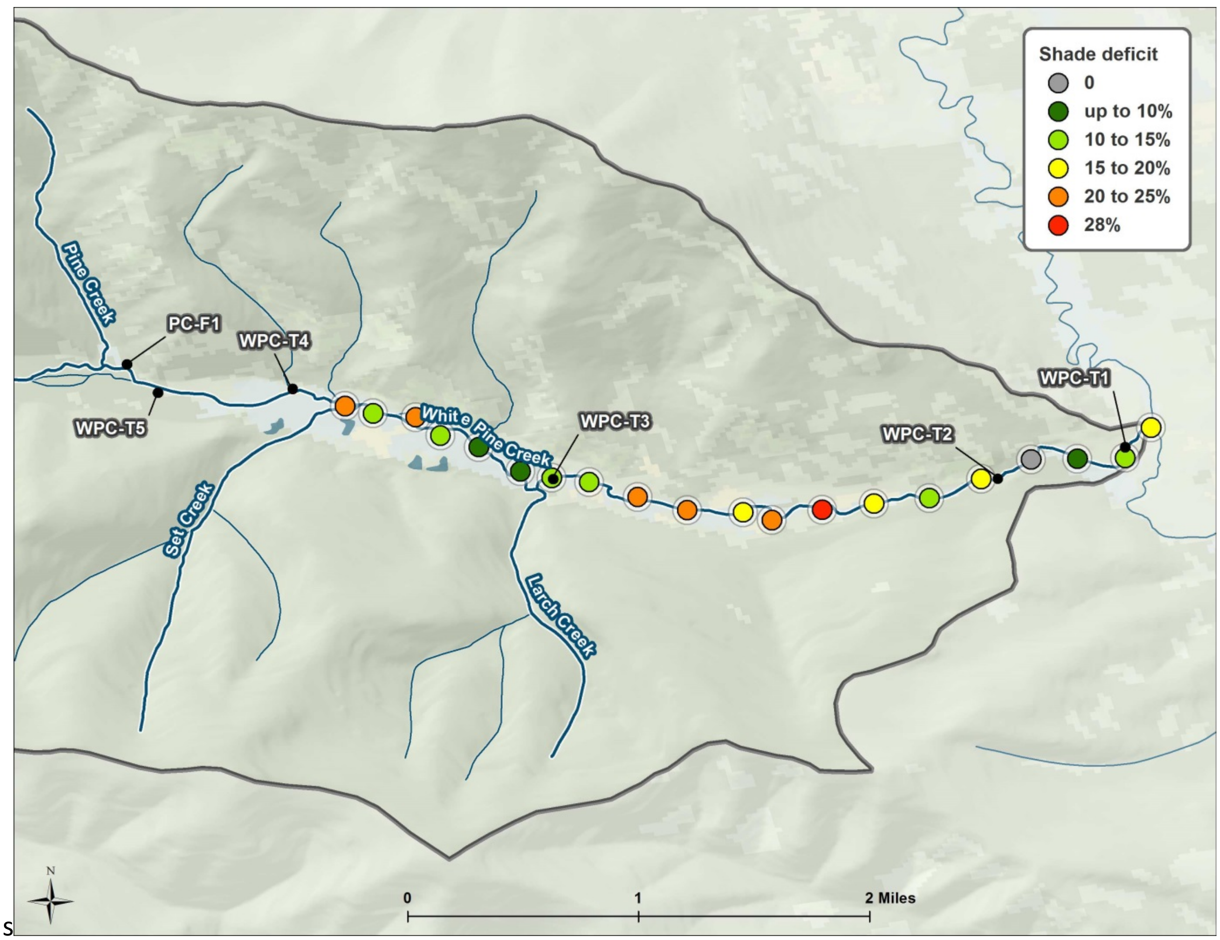


Figure B-21. Shade deficit of the baseline (scenario 1) from the improved flow and shade scenario (scenario 4).

Attachment B1 – Factors Potentially Influencing Stream Temperature in White Pine Creek

B1-1.0 Introduction

Stream temperature regimes are influenced by processes that are external to the stream as well as processes that occur within the stream and its associated riparian zone (Poole et al., 2001). Examples of factors external to the stream that can affect instream water temperatures include: topographic shade, land use/land cover (e.g., vegetation and the shading it provides, impervious surfaces), solar angle, meteorological conditions (e.g., precipitation, air temperature, cloud cover, relative humidity), groundwater exchange and temperature, and tributary inflow temperatures and volumes. The shape of the channel can also affect the temperature—wide shallow channels are more easily heated and cooled than deep, narrow channels. The amount of water in the stream is another factor influencing stream temperature regimes. Streams that carry large amounts of water resist heating and cooling, whereas temperature in small streams (or reduced flows) can be changed more easily.

The following factors that may have an influence on stream temperatures in White Pine Creek are discussed below:

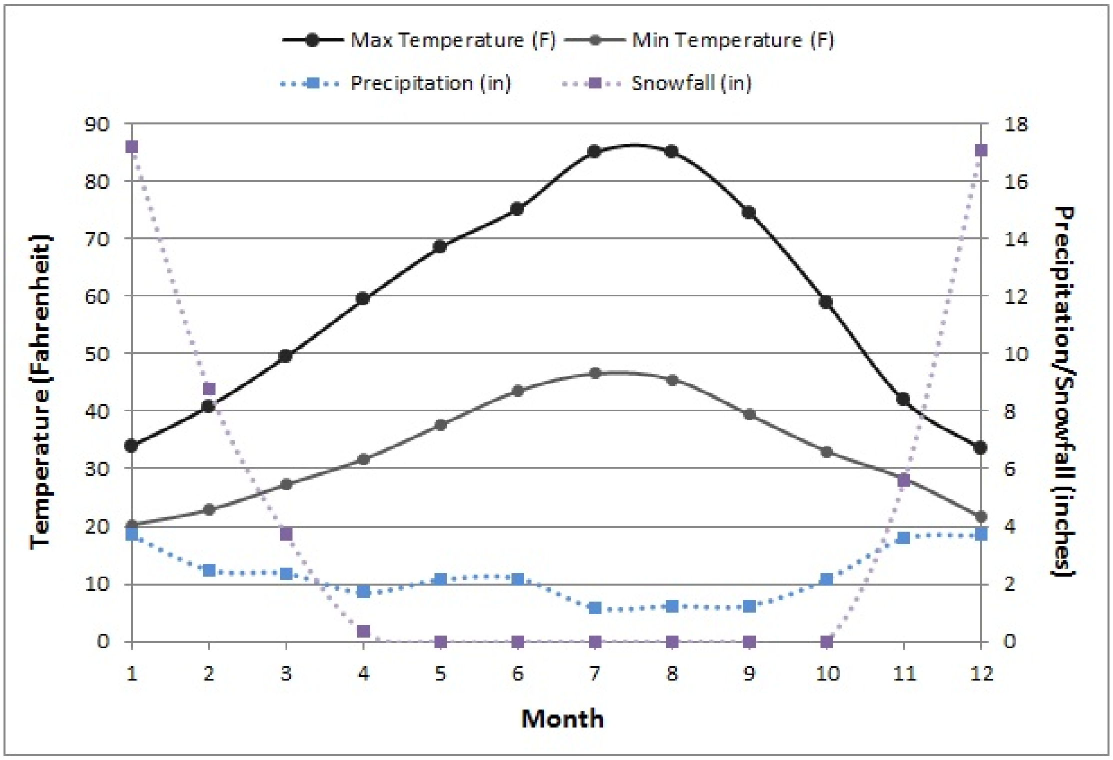
- Local/regional climate
- Land ownership
- Land use
- Riparian vegetation
- Shade
- Hydrology
- Point sources

B1-2.0 Climate

The nearest weather station to the White Pine Creek watershed (**Figure B1-1**) is at the Ranger Station in the city of Trout Creek, Montana (National Weather Service station 24830). Average annual precipitation is 27.7 inches with the greatest amounts falling in December and January (**Figure B1-2**, National Climate Data Center, 2012). Average maximum temperatures occur in July and August and are both 84.9 ºF.

It should be noted that the Trout Creek weather station is at an elevation of 2,356 feet above MSL, compared to White Pine Creek that ranges in elevation from approximately 2,500 to 6,500 feet above MSL.

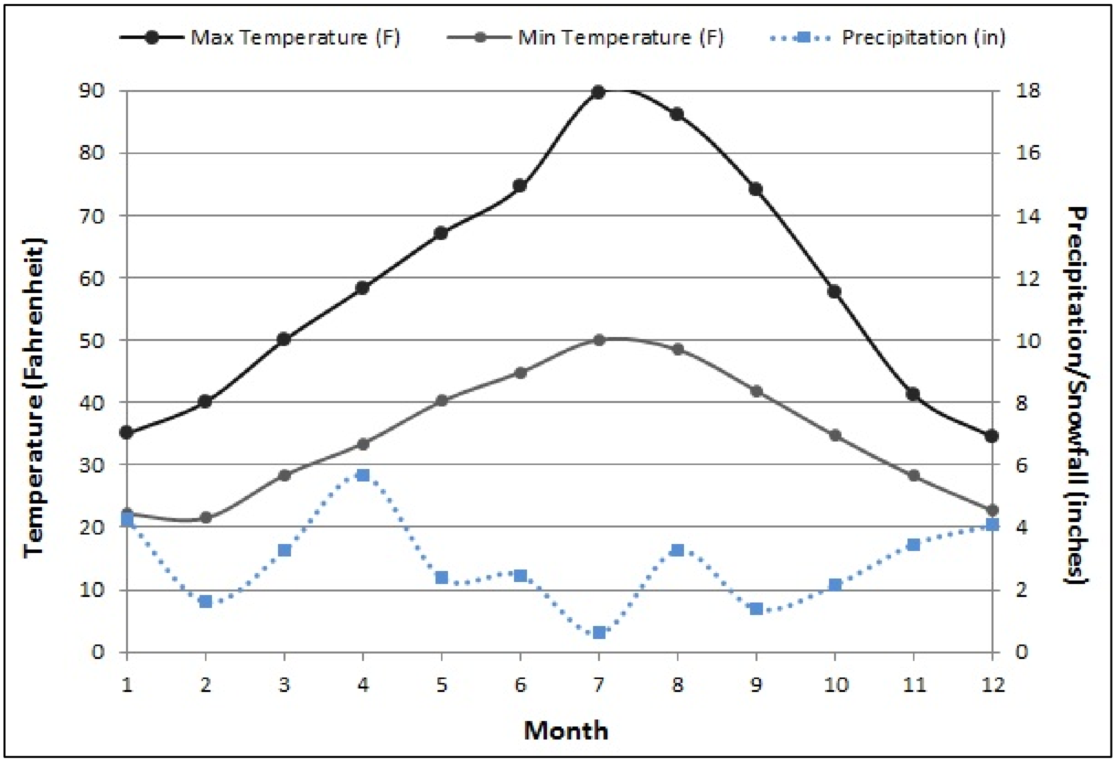
Figure B1-1. White Pine Creek watershed.



Source: Summary of GHCN Daily Summaries from 1970 to 2012 at station 24830 (National Climate Data Center, 2013).

Figure B1-2. Monthly average temperatures and precipitation at Trout Creek Ranger Station, Montana

As briefly discussed in the main report, the Trout Creek Ranger Station only has hourly air temperature data and does not have additional hourly datasets necessary for QUAL2K modeling. The Cabinet (Trout Creek) RAWS (National Weather Service station 241210) records hourly air temperature, dew point temperature, wind speed and solar radiation and these data were used to develop the QUAL2K model. RAWS data are summarized in **Figure B1-3**.

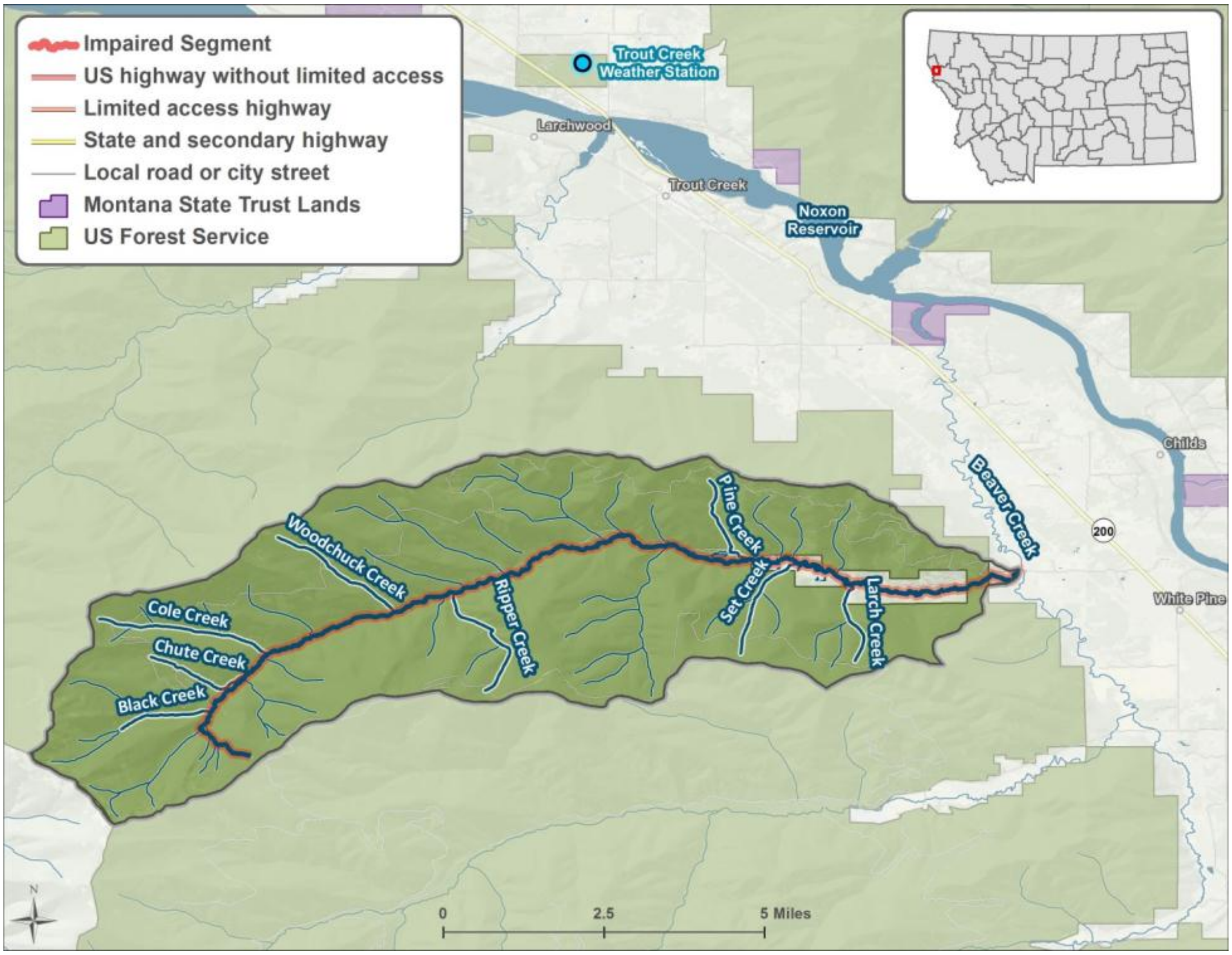


Source: RAWS weather data from 2001 to 2013 at Cabinet (Trout Creek) station (Western Regional Climate Center, 2013).

Figure B1-3. Monthly average temperatures and precipitation at Cabinet (Trout Creek) RAWS.

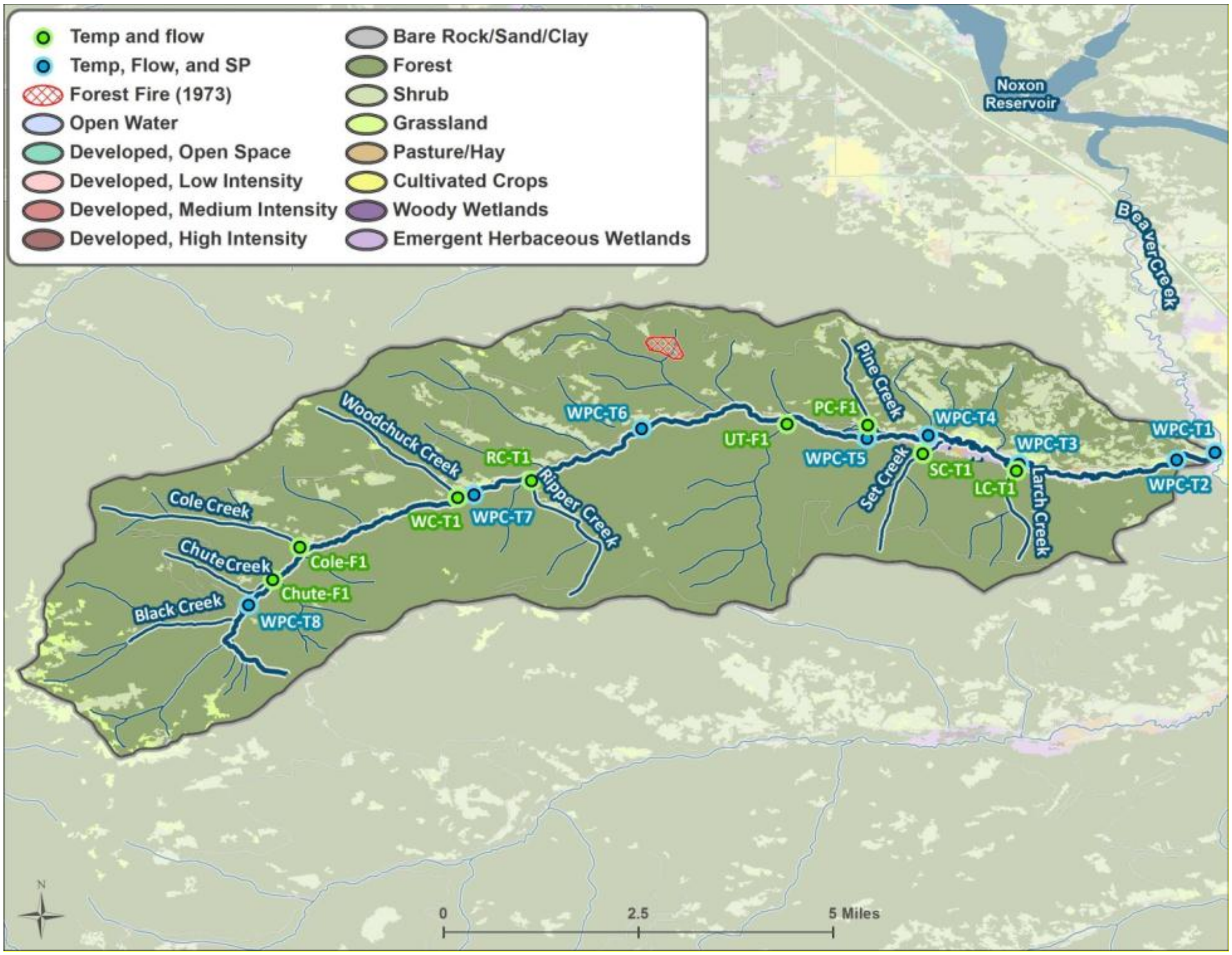
B1-3.0 Land Ownership and Land Use

The majority of the White Pine Creek watershed is owned by the U.S. Forest Service (97 percent) and is predominantly forested (**Figure B1-4** and **Figure B1-5**). One fire, covering 38 acres (0.2 percent of the watershed) has occurred in recent history (1973) within the watershed (U.S. Department of Agriculture, Forest Service, 2008) (**Figure B1-5**). Several small ranches and residences are within the small section of privately owned land surrounding the riparian zone in the lower reaches of the watershed.



Source of land ownership: NRIS 2012.

Figure B1-4. Land ownership in the White Pine Creek watershed.



Source of land cover: 2006 National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium, 2006).
Figure B1-5. Land cover and land use in the White Pine Creek watershed.

B1-4.0 Existing Riparian Vegetation

A comprehensive inventory and assessment of the current riparian vegetation communities adjacent to White Pine Creek was not conducted as part of this project. Riparian vegetation communities, however, were qualitatively assessed, and the height and density of the dominant vegetation were measured at the five shade monitoring sites in August 2013. A summary of the observed characteristics of the vegetation communities is provided in **Table B1-1**.

The impaired reach of White Pine Creek is 12.37 miles in length. The upper nine miles flow through the Kootenai National Forest. Although an unimproved road parallels the stream for much of this length, the riparian corridor appears to be largely intact, dominated by dense conifers, and at potential. A review of historic aerial photographs conducted by Watershed Consulting, Inc. (2002), indicate that the riparian zone in this upper reach has recovered from a fire in 1910 and a substantial flood in 1916. It appears that the channel has narrowed and the riparian vegetation increased in density since the 1940s (Water Consulting, Inc., 2002). This portion of White Pine Creek is represented by sites WPC-T6, WPC-T7, and WPC - T8.

Downstream, White Pine Creek flows out of the Kootenai National Forest and onto private property for the remainder of its length. The lower reach flows through a complex floodplain with a broad riparian zone composed of low-density residential and agricultural land uses. With the exception of one reach (dominated by conifer forest) where the valley narrows as White Pine Creek flows through a small parcel of U.S. Forest Service land (WPC-T2), vegetation in the lower reach is typified by alder-grass monoculture with varying degrees of disturbance. The greatest disturbance was observed at site WPC-T1. The riparian zone in the vicinity of WPC-T1 is currently grazed.

Based on review of aerial photography (GoogleEarth™ 2013) and site reconnaissance, it appears that site WPC-T3 may represent a vegetation community that has recovered from past grazing practices. Evaluation of historic aerial photography (Water Consulting, Inc., 2002) suggests that, over the years, lower White Pine Creek was subjected to alterations of the riparian corridor due to anthropogenic activities. The following anthropogenic activities may have influenced the riparian vegetation community: floodplain filling, bridge and road construction, timber harvest, grazing, vegetation removal, and bank armoring. They also suggest that cottonwood and willow recruitment has been limited by past and current anthropogenic activities in the lower watershed.

Table B1-1. Observed characteristics of the White Pine Creek riparian vegetation community

Station ID	Site Name	Dominant Vegetation	Vegetation at potential?	Average Vegetative Density[a]	Dominant Vegetation Height (feet)[a]	Dominant Vegetation Overhang (feet)[a]	Description
WPC-T1	White Pine Cr near mouth	Shrub	N	25	20	4	Grazed alder community. Mosaic of alders (25 - 50% cover) and meadow.
WPC-T2	White Pine Cr near USFS boundary	Tree	Y	82	48	8	Conifer forest set back approximately 25 feet from the bank. Sparse shrub (alder) cover and grass along bank.
WPC-T3	White Pine Cr at Larch Creek Lane	Shrub	N	78	19	--	Monotypical alder swamp. In close proximity to driveway (openings) and meadows on private property. Appears to possibly be recovered grazing land.
WPC-T4	White Pine Cr near Set Cr	Shrub	N	78	15	12	Monotypical alder swamp.
WPC-T5	White Pine Cr near Pine Cr	Dry channel. No observations recorded.					
WPC-T6	White Pine Cr	Dry channel. No observations recorded.					
WPC-T7	White Pine Cr near Woodchuck Cr	Dry channel. No observations recorded.					
WPC-T8	White Pine Cr near headwaters	Tree (conifer dominated)	Y	86	70	12	Dense conifer forest with shrub understory.

Note: a. Average of field measurements.

Vegetation communities between the shade monitoring sites were visually characterized based on aerial imagery (GoogleEarth™ 2012). Observed vegetative communities within 150 feet of the stream centerline were classified as trees, shrubs, or herbaceous. Areas without vegetation, such as bare earth or roads, were also identified. Trees were further divided into the following classes based on percent canopy cover derived from the 2001 NLCD (**Figure B1-6**):

- High density (75 to 100 percent cover)
- Medium density (51 to 74 percent cover)
- Low density (25 to 50 percent cover)
- Sparse density (less than 24 percent cover)

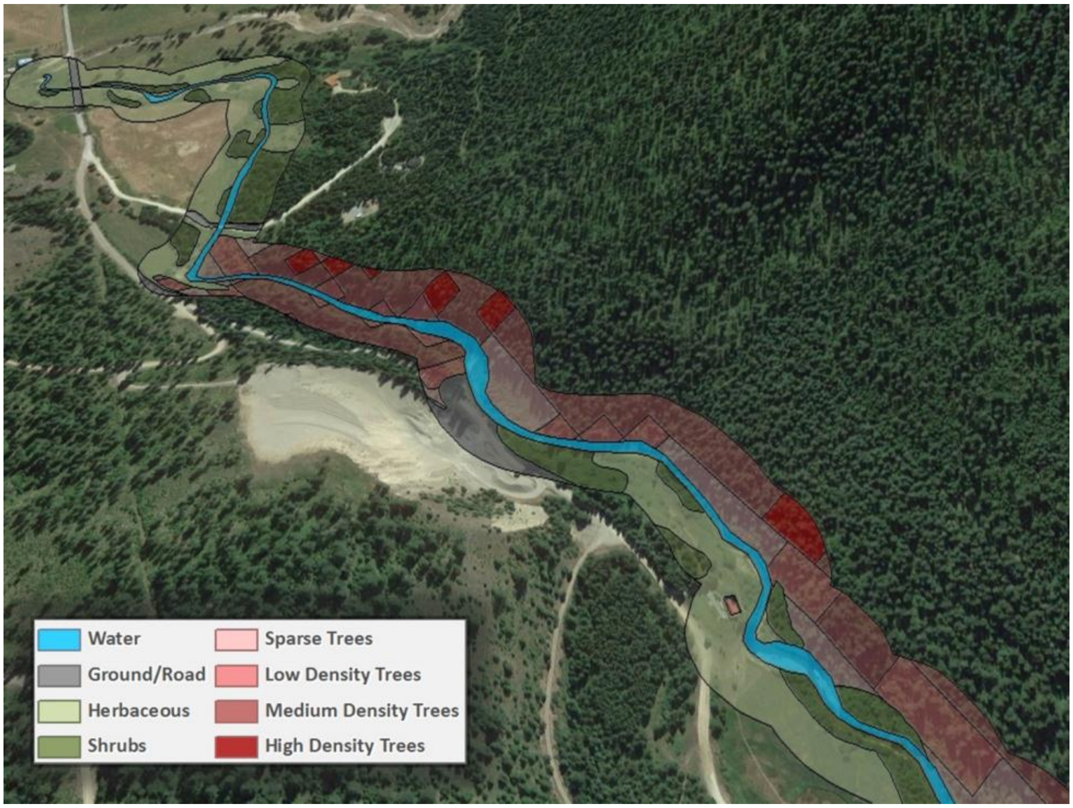


Figure B1-6. Vegetation mapping example for White Pine Creek.

High Density Trees (32 percent), Medium Density Trees, (18 percent), Shrubs (15 percent), and Herbaceous (14 percent) are the most common cover types along White Pine Creek (**Table B1-2**). All tree classes combine to account for 66 percent of the total watershed area.

Table B1-2. Land cover types in the White Pine Creek riparian zone

Land cover type	Area (acres)	Relative area (percent)
Bare ground	7.1	1.6%
Herbaceous	62.7	13.9%
Roads	17.8	3.9%
Shrub	66.7	14.7%
Sparse trees	31.4	6.9%
Low density trees	40.9	9.0%
Medium density trees	81.2	17.9%
High density trees	144.6	31.9%

B1-5.0 SHADE

Shade is one of several factors that control instream water temperatures. Shade is defined as the fraction of potential solar radiation that is blocked by topography and vegetation.

B1-5.1 MEASURED SHADE

EPA and DEQ collected shade characterization data on August 13 and 14, 2013 at five monitoring locations along White Pine Creek using a Solar Pathfinder™ (**Figure B1-7**). Hourly shade estimates based on the Solar Pathfinder™ measurements are summarized in **Table B1-3**.

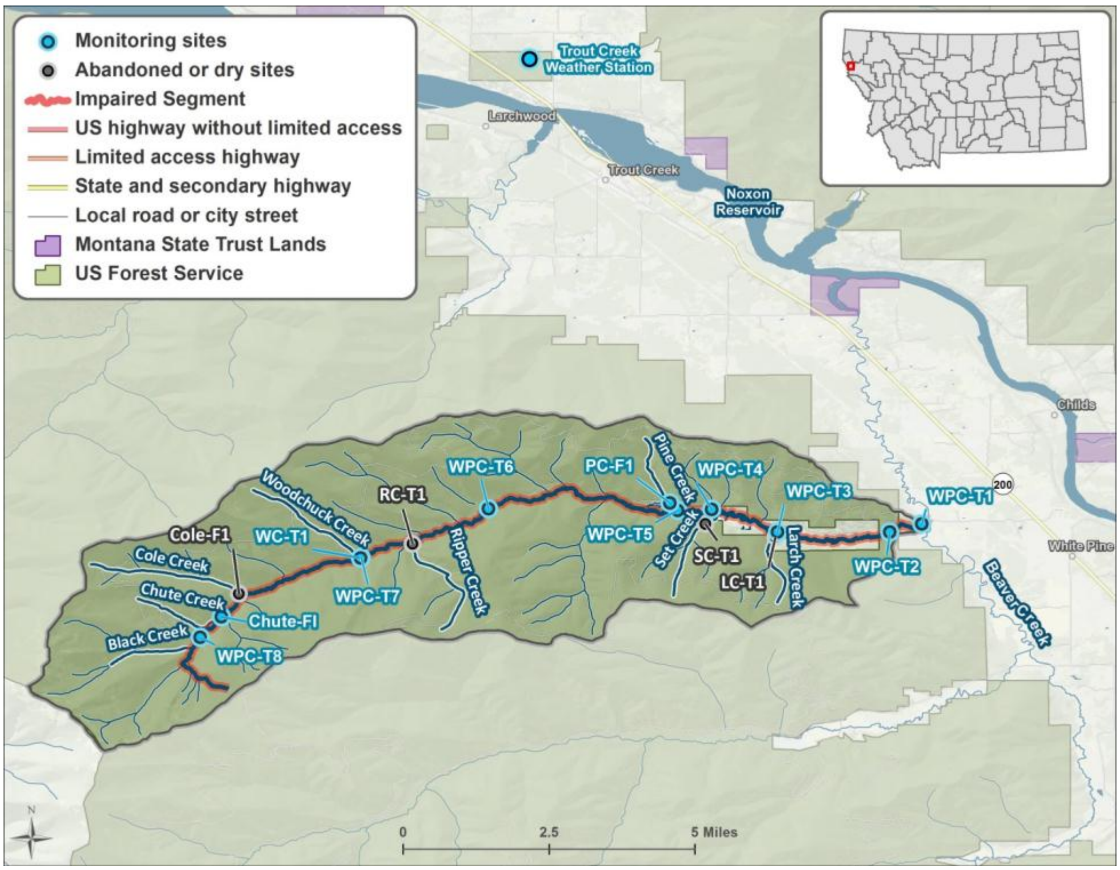


Figure B1-7. EPA flow, shade, and continuous temperature monitoring locations.

Table B1-3. Average shade per reach from Solar Pathfinder™ measurements

Site ID	Average daily shade (averaged across daylight hours)
WPC-T1	30.0
WPC-T2	67.8
WPC-T3	27.1
WPC-T4	30.3
WPC-T8	90.4

Note: Sites are listed as mouth to headwaters from top to bottom.

B1-5.2 SHADE MODELING

An analysis of aerial imagery and field reconnaissance showed that shading along White Pine Creek was highly variable. Therefore, shade was also evaluated using the spreadsheet Shadev3.0.xls. Shade version 3.0 is a riparian vegetation and topography model that computes the hourly effective shade for a single day (Washington State Department of Ecology, 2008). Shade is an Excel/Visual Basic for Applications program. The model uses the latitude and longitude, day of year, aspect and gradient (the direction and slope of the stream), solar path, buffer width, canopy cover, and vegetation height to compute hourly, dawn-to-dusk shade. The model input variables include channel orientation, wetted width, bankfull width, channel incision, topography, and canopy cover. Bankfull width in the shade calculations is defined as the near-stream disturbance zone (NSDZ), which is the distance between the edge of the first vegetation zone on the left and right bank.

B1-5.2.1 Available Data

The application of the Shade Model to White Pine Creek relied upon the vegetation data and analysis described in Section A-4, aerial imagery from GoogleEarth™ (GoogleEarth, 2013), tree canopy density information (Multi-Resolution Land Characteristics Consortium, 2006), and a digital elevation model (U.S. Geological Survey, 2014).

B1-5.2.2 GIS Pre-Processing

TTools version 3.0 is an ArcView extension to translate spatial data into Shade Model inputs (Oregon Department of Environmental Quality, 2001). TTools was used to estimate the following values: elevation, aspect, gradient, distance from the stream center to the left bank, and topographic shade. Elevation was calculated using a 10 meter (33 foot) digital elevation model (DEM) and a stream centerline file digitized from aerial imagery in GoogleEarth™. Aspect was calculated to the nearest degree using TTools with the stream centerline file.

Wetted width was estimated by digitizing both the right and left banks from aerial imagery in GoogleEarth™. TTools then calculates wetted width based on the distance between the stream centerline and the left and right banks. Topographic shade was calculated using TTools with the stream centerline file and a DEM.

B1-5.2.3 Riparian Input

The Shade Model requires the description of riparian vegetation: a unique vegetation code, height, density, and overhang (OH). The results in the field study report and the above described vegetation mapping were used to develop a riparian description table (**Table B1-4**). Vegetation descriptions used the average value for tree/shrub height and overhang from field observation.

Table B1-4. Vegetation input values for the Shade Model

Attribute	Value	Basis
Trees		
Height	18 meters (59 feet)	Average of measured values
Density	Variable	2006 NLCD
Overhang	1.8 meters (5.9 feet)	Estimated as 10% of height (Stuart, 2012).
Shrubs		
Height	5.5 meters (18 feet)	Average of measured values
Density	77%	Average of measured values
Overhang	1.4 meter (4.5 feet)	Estimated as 25% of height (Shumar and de Varona, 2009)
Herbaceous		
Height	1 meter (3.3 feet)	Estimated.
Density	100%	
Overhang	0 meters	

B1-5.2.4 Shade Input

The Shade Model inputs are riparian zones, reach length, channel incision, elevation, aspect, wetted width, near-stream disturbance zone width, distance from the bank to the center of the stream, and topographic shade. Input for the riparian zone is presented above in Error! Reference source not found.. The Shade Model requires reach lengths be an equal interval. The reaches in the field study report were not at an equal interval and were very widely spaced. A uniform reach length interval of 30 meters (98 feet) was used. Channel incision was estimated from an examination of field photos. Incision is the vertical drop from the bankfull edge to the water surface, and was estimated at 0.3 meter (1 foot). The remaining variables were computed as part of the GIS pre-processing described above.

B1-5.3 Shade Model Results

The current longitudinal effective shade profile generated from the Shade Model and the Solar Pathfinder™ measurements are presented in **Figure B1-8**.

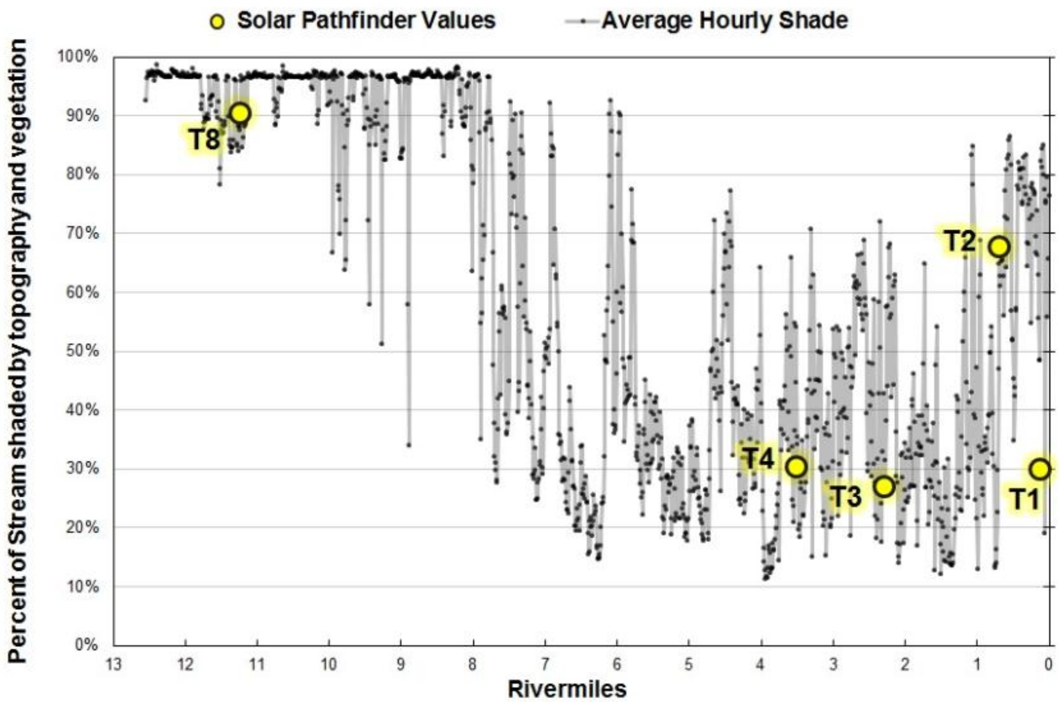


Figure B1-8. Longitudinal estimates of observed and simulated effective shade along White Pine Creek.

The goodness of fit for the Shade Model was summarized using the mean error (ME), average absolute mean error (AME), and root mean square error (RMSE) as a measure of the deviation of model-predicted shade values from the measured values. These model performance measures were calculated as follows:

$$ME = \frac{1}{N}\sum_{n=1}^{n} P_n - O_n$$

$$AME = \frac{1}{N}\sum_{n=1}^{n} |P_n - O_n|$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{n} (P_n - O_n)^2}$$

where

P = model predicted values

O = observed values

n = number of samples

Model error statistics are provided in **Table B1-5** and suggest a good fit between observed and predicted average effective shade values. The average absolute mean error is 6 percent. (i.e., the average error from the Shade Model output and Solar Pathfinder™ measurements was 6 percent daily average shade; see **Table B1-5**).

Table B1-5. Shade model error statistics

Error Statistic	Formula	Result	Units
Mean Error (ME)	$(1/N)*\Sigma(P_n-O_n)$	4%	percent of percent shade
Average Absolute Mean Error (AME)	$(1/N)*\Sigma\lvert(P_n-O_n)\rvert$	6%	percent shade
Root Mean Square Error (RMSE)	$[(1/N)*\Sigma(P_n-O_n)^2]^{1/2}$	9%	percent of percent shade

B1-6.0 Stream Temperatures

In 2013, EPA and DEQ collected continuous temperature data at seven locations in White Pine Creek (sites WPC-T1, WPC-T2, WPC-T3, WPC-T4, WPC-T6, WPC-T7, WPC-T8) and at one tributary (Chute Creek, Chute-F1)[11]. One location on White Pine Creek (WPC-T5) was observed to be dry and no temperature logger was deployed. Data loggers recorded temperatures every one-half hour for approximately two months between June 25 and September 10, 2013. Instantaneous temperatures were also monitored by EPA and DEQ in June, August, and September 2013 on White Pine Creek (**Table B1-6**) and three of its tributaries: Chute-F1 on Chute Creek, PC-F1 on Pine Creek, and WC-T1 on Woodchuck Creek (**Table B1-7**). Four locations on tributaries to White Pine Creek were observed to be dry and no instantaneous data were collected: Cole-F1 on Cole Creek, LC-T1 on Larch Creek, RC-T1 on Ripper Creek, and SC-T1 on Set Creek. Finally, DEQ sampled White Pine Creek in 2004 (**Table B1-8**).

Table B1-6. EPA instantaneous water temperature measurements (°F) from White Pine Creek, summer 2013

Date	WPC-T1	WPC-T2	WPC-T3	WPC-T4	WPC-T6	WPC-T7	WPC-T8
June 25, 2013	49.05	47.35	46.65	44.56	48.00	44.58	43.95
August 13-14, 2013 [a]	--	--	--	--	Dry	Dry	--
September 10, 2013	63.81	63.84	59.31	49.46	Dry	Dry	50.43

Note: a. Temperature data rejected due to quality control issues with the temperature probe calibration.

Table B1-7. EPA instantaneous water temperature measurements (°F) from tributaries to White Pine Creek, summer 2013

Date	Chute-F1 (Chute Creek)	WC-T1 (Woodchuck Creek)	PC-F1 (Pine Creek)
June 25, 2013	44.17	42.71	45.99
August 13-14, 2013 [a]	--	Dry	Dry
September 10, 2013	50.38	Dry	Dry

Note: a. Temperature data rejected due to quality control issues with the temperature probe calibration.

Table B1-8. DEQ instantaneous water temperature measurements (°F) in support of other studies

Date	C13WPINC10	C13WPINC30
September 22, 2004	44.7	47.5

Note: Temperatures were originally reported in degrees Celsius and were converted to degrees Fahrenheit as displayed in this table.

[11] Loggers WPC-T6 and WPC-T7 were observed in dry channels on August 13-14, 2013 and were removed from White Pine Creek at that time.

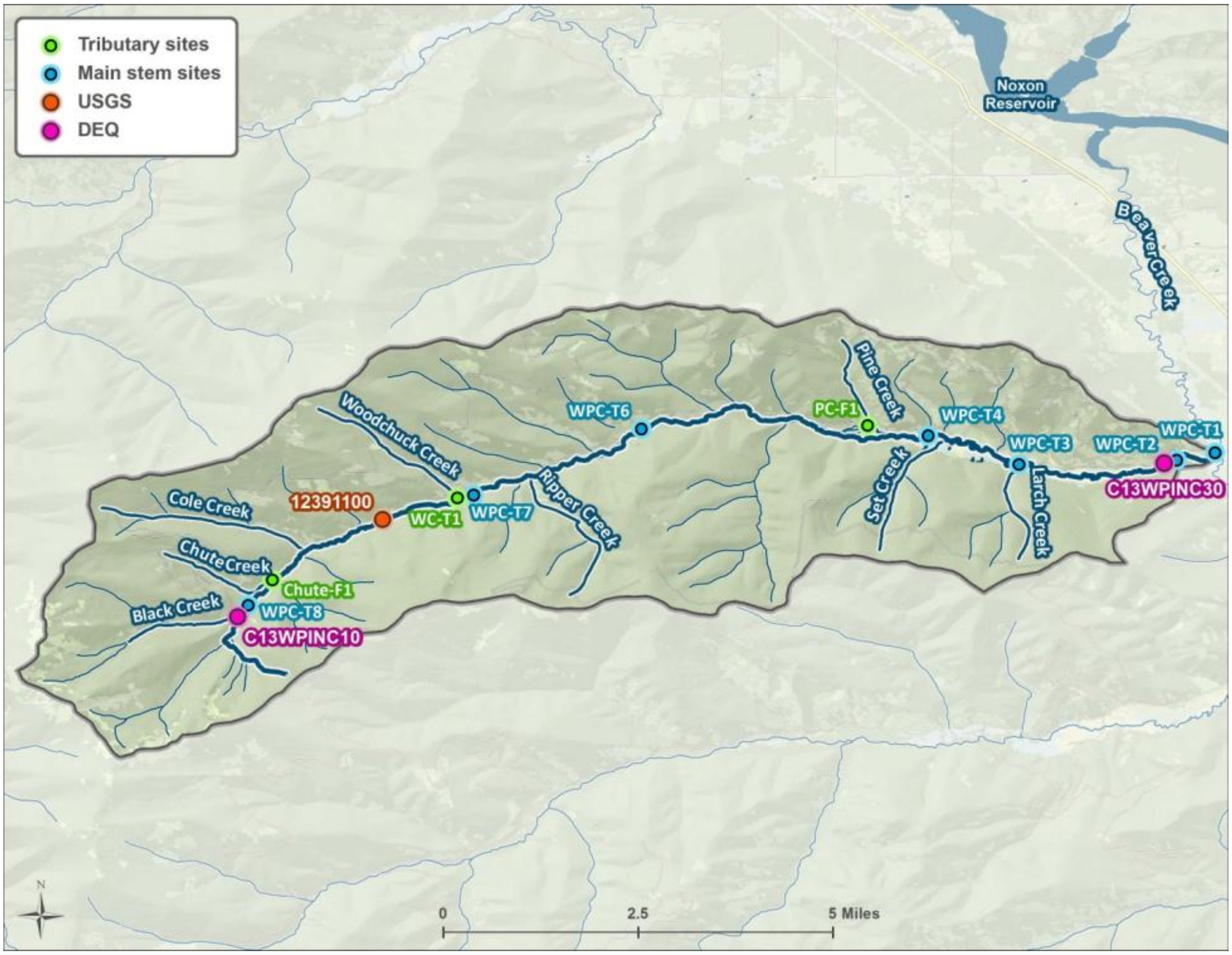


Figure B1-9. Temperature and flow monitoring locations in the White Pine Creek watershed.

B1-7.0 Hydrology

No active U.S. Geological Survey (USGS) continuously recording gages are located on White Pine Creek. EPA collected instantaneous flow measurements in 2013, during temperature data logger deployment and retrieval, as well as during mid-season site visit (**Table B1-9** and **Table B1-10**). DEQ and USGS also monitored flow in support of other studies (**Table B1-11** and **Table B1-12**). Locations of the flow measurements are shown in **Figure B1-9**.

Table B1-9. EPA instantaneous flow measurements (cfs) from White Pine Creek, summer 2013

Date	WPC-T1	WPC-T2	WPC-T3	WPC-T4	WPC-T6	WPC-T7	WPC-T8
June 25, 2013	59.10	44.21	39.26	31.85	3.19	16.79	25.35
August 13-14, 2013	11.10	9.03	10.60	6.55	Dry	Dry	1.51
September 10, 2013	5.04	6.02	6.08	22.71	Dry	Dry	0.72

Table B1-10. EPA instantaneous flow measurements (cfs) from tributaries to White Pine Creek, summer 2013

Date	Chute-F1 (Chute Creek)	WC-T1 (Woodchuck Creek)	PC-F1 (Pine Creek)
June 25, 2013	1.48	2.16	1.83
August 13-14, 2013	0.24	Dry	Dry
September 10, 2013	0.06	Dry	Dry

Table B1-11. DEQ instantaneous flow measurements (cfs) in support of other studies

Date	C13WPINC10	C13WPINC30
September 22, 2004	8.06	2.13

Note: Temperatures were originally reported in degrees Celsius and were converted to degrees Fahrenheit as displayed in this table.

Table B1-12. USGS instantaneous flow measurements (cfs) in support of other studies

Date	12391100
June 14, 1975	161.0
December 4, 1975	51.0
April 26, 1977	23.4
June 7, 1978	20.2
May 6, 1979	3.2
April 24, 1980	1.4
December 26, 1980	116.0
May 18, 1982	21.1
May 26, 1983	15.9
May 21, 1984	3.0

Note: Temperatures were originally reported in degrees Celsius and were converted to degrees Fahrenheit as displayed in this table.

Based on field observations, flow in White Pine Creek was intermittent upstream from the confluence with Set Creek during the summer of 2013. Two dry reaches were observed on August 13 and 14, 2013 (**Figure B1-10**).

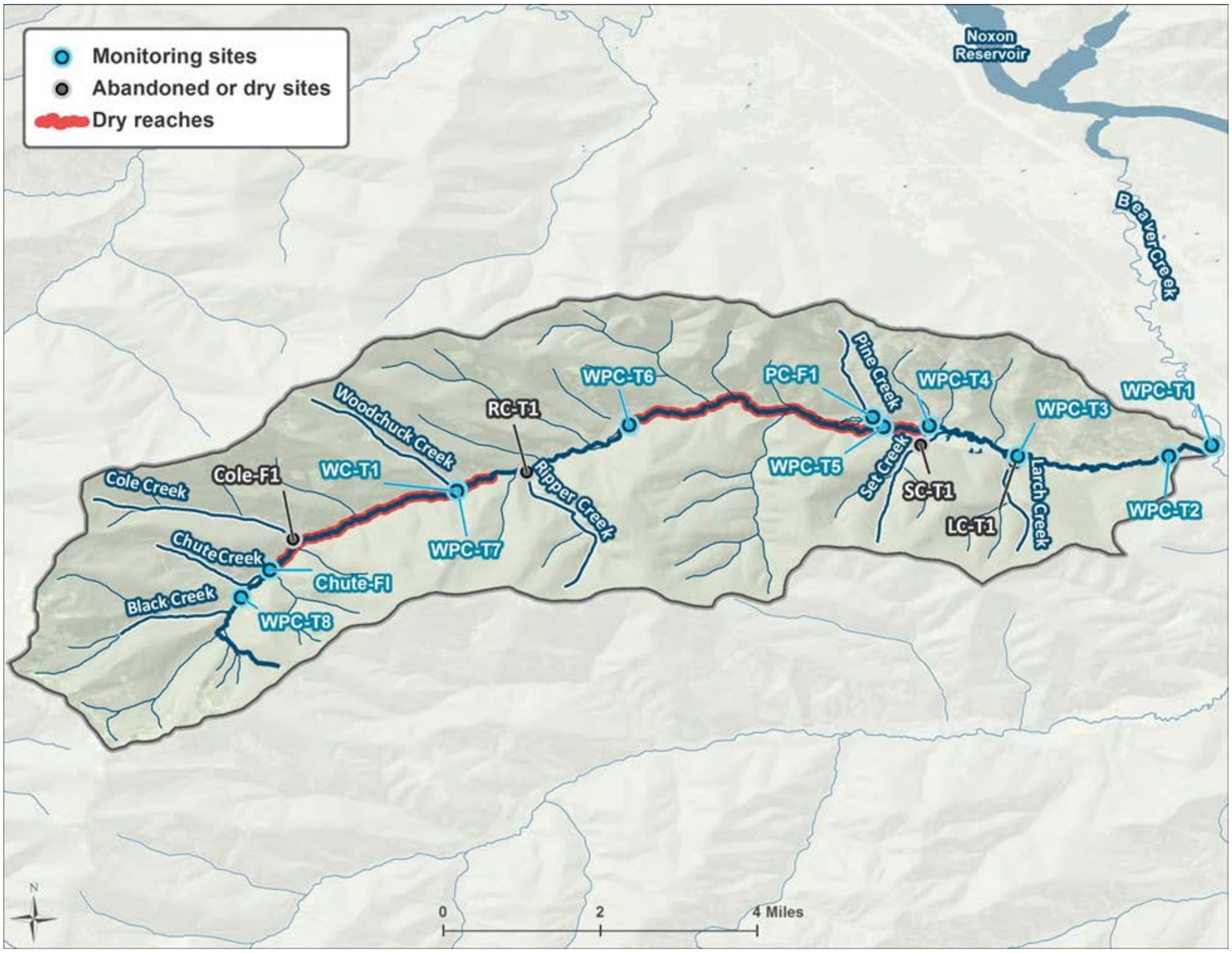
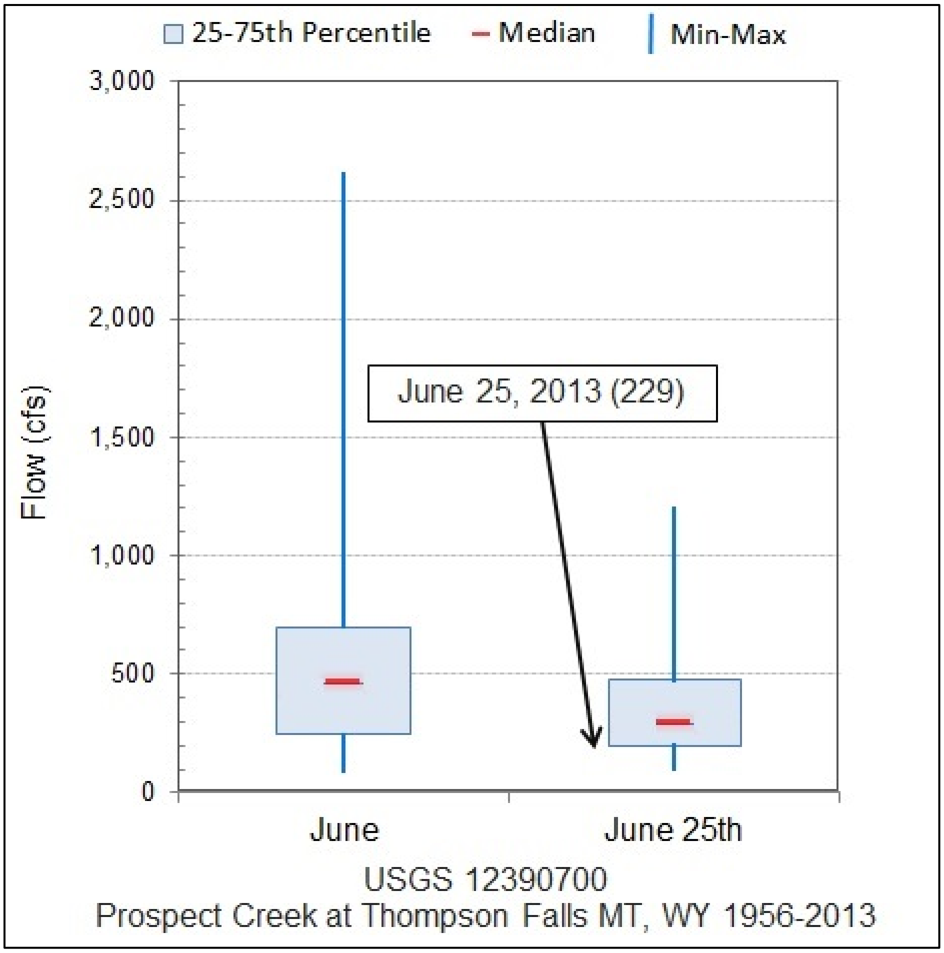


Figure B1-10. Dry reaches of White Pine Creek observed August 13 and 14, 2013.

Continuous flow data monitored on Prospect Creek at USGS gage 12390700 were evaluated with instantaneous discharge data from White Pine Creek to assess the hydrologic conditions of White Pine Creek during the summer of 2013. USGS gage 12390700 was used as a surrogate to represent regional hydrologic conditions. Statistics were calculated for the average daily flows (per year) for the month of June and for June 25th from water years 1956 through 2013 at the gage (**FigureB1-11**).

The flow at gage 12390700 on June 25, 2013 (the calibration date for the QUAL2K model) was 229 cfs, which is near the 25th percentile of flows on June 25th across the period of record.

A similar analysis was performed for August 14, 2013 (the date for the baseline scenario in QUAL2K) and the month of August. The flow at gage 12390700 on August 14, 2013 was 80 cfs, which is the 38th percentile of flows on August 14th across the period of record. The average flow in August of 2013 was 77 cfs, which is the 34th percentile of flows for August across the period of record.

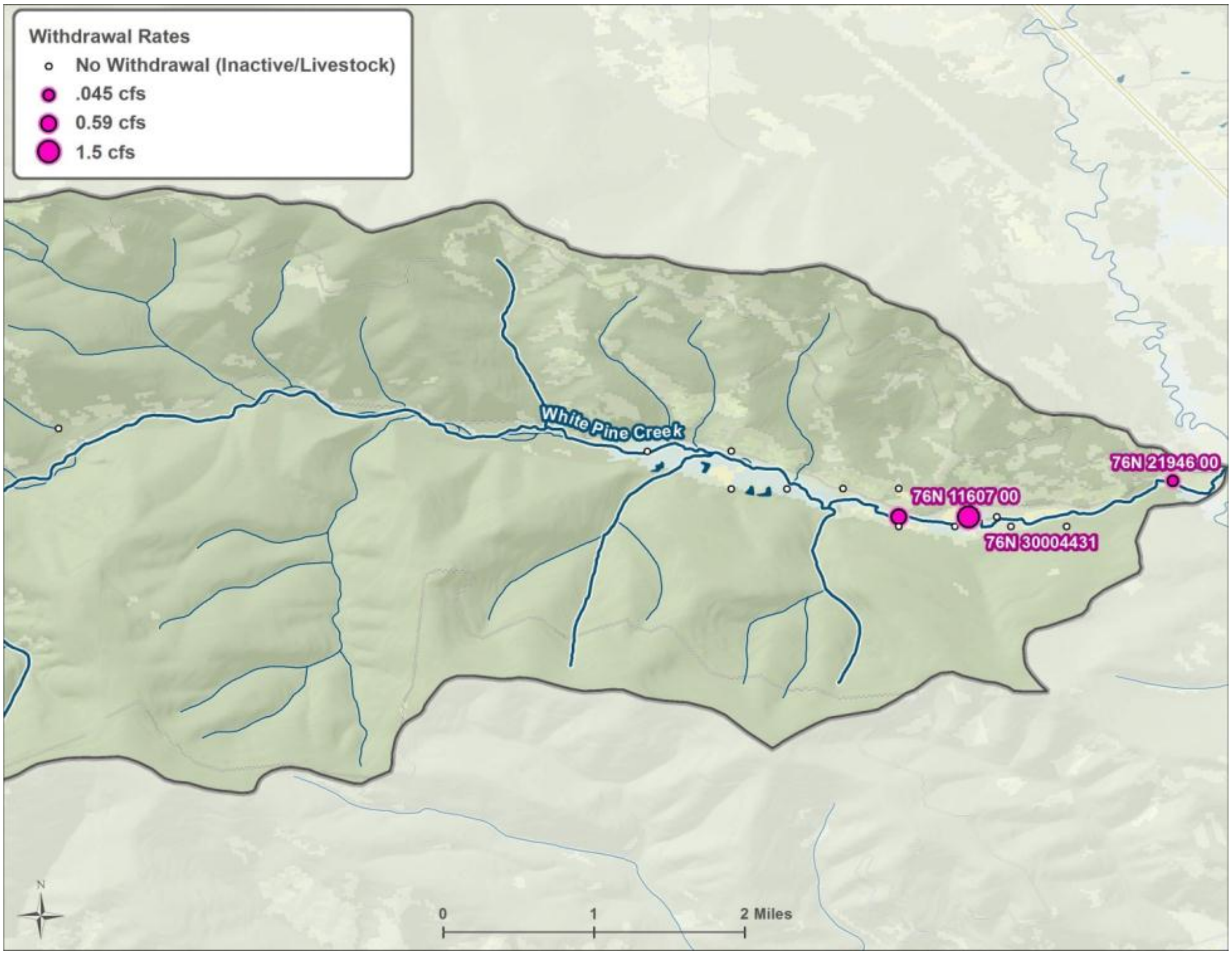


Note: "June" represents the daily average flow for the month of June per year (i.e., the average of 30 daily average flows)

Figure B1-11. Average daily flows for the month of June and for June 25th for the full period of record at USGS gage 12390700 (Prospect Creek), compared to flows on June 25, 2013.

B1-8.0 FLOW MODIFICATION

Based on review of aerial photographs and online water rights data (ftp://nris.mt.gov/dnrc), there are 15 surface diversion permits from White Pine Creek that support a variety of uses. "Points of diversion" and "places of use" spatial data were obtained from the Montana Natural Resource Information System (Natural Resource Information System, 2012). Three of the permitted locations are actively withdrawing water (**Figure B1-12** and **Table B1-13**). It is estimated that up to 2.79 cfs may be withdrawn from White Pine Creek on a daily basis during the month of July (**Table B1-13**).



Source of "points of diversion" data: (Natural Resource Information System, 2012).

Figure B1-12. Surface diversions along White Pine Creek

Table B1-13. Summary of diversions from White Pine Creek

WRNUMBER	Purpose	Irrigation type	Means of withdrawal	Max area (acres)	Max flow rate (cfs)	Volume (acre-ft/yr)	Est. daily volume applied [a] (cf)	Est. daily flow rate [b] (cfs)
76N 11607 00	Irrigation	F	H	50	1.9	125	49,724	0.59
76N 11608 00	Stock[d]	--	L	--	--	--	--	--
76N 11609 00	Domestic[c]	--	P	--	--	--	--	--
76N 21946 00	Domestic	--	P	--	0.045	1.5	--	0.045
76N 30004431	Fishery	--	H	--	1.5	504	--	1.5
76N 52209 00	Stock[d]	--	D	--	--	--	--	--
Total Withdrawal								***2.79***

Source: NRIS 2012

Notes

F = flood; H = headgate; P = pump; D = Dam; L = livestock direct from source.

[a.] The daily volume applied was estimated using the Irrigation Water Requirements (IWR) program developed by the USDA to estimate crop requirements. This method assumes application over the maximum acres reported. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/irrigation/?cid=stelprdb1044890

[b.] Non-shaded cells assume that the estimated daily volume is applied at a constant flow rate across a 24 hour period. Shaded cells assume maximum reported flow rate.

[c.] Water right withdrawn.

[d.] Livestock direct from source uses were not considered in this analysis.

B1-9.0 Point Sources

There are no permitted discharges in the White Pine Creek watershed. One abandoned mine, Golden Roc Mine, is present in the White Pine Creek watershed, located near Woodchuck Creek. In the past it was a gold, silver, lead, and copper producer. The mine is not expected to have an influence on stream temperature and is not considered further.

B1-10.0 References

Chapra, Steven C., Gregory J. Pelletier, and Hua Tao. 2008. A Modeling Framework for Simulating River and Stream Water Quality, Version 2.1: Documentaion and Users Manual. Medford, MA: Civil and Environmental Engineering Department, Tufts University.

Montana Department of Environmental Quality, Water Quality Planning Bureau. 2014. 2013 Water Quality Assessment Records. Accessed 5/1/2014.

Multi-Resolution Land Characteristics Consortium. 2006. National Land Cover Dataset 2006. http://www.mrlc.gov/nlcd2006.php.

National Climate Data Center. 2012. Monthly Summaries GHCND. http://www.ncdc.noaa.gov/land-based-station-data/find-station. Accessed 12/6/12 A.D.

-----. 2013. Monthly Summaries GHCND. National Climatic Data Center. http://www.ncdc.noaa.gov/land-based-station-data/find-station. Accessed 6/18/2013.

Natural Resource Information System. 2012. GIS Data List. http://nris.mt.gov/gis/gisdatalib/gisdatalist.aspx. Accessed 6/28/12 A.D.

Natural Resources Conservation Service. 1997. National Engineering Handbook Irrigation Guide, Vol. Part 652, Washington, D.C.: Natural Resources Conservation Service.

Oregon Department of Environmental Quality. 2001. TTools 3.0 Users Manual. Oregon: Oregon Department of Environmental Quality.

Poole, Geoffrey, John Risley, and Mark Hicks. 2001. Issue Paper 3: Spatial and Temporal Patterns of Stream Temperature (Revised). US Environmental Protection Agency. EPA-910-D-01-003.

Shumar, M. and J. de Varona. 2009. The Potential Natural Vegetation (PNV) Temperature Total Maximum Daily Load (TMDL) Procedures Manaul. Boise, ID: Idaho Department of Environmental Quality, State Technical Services Office.

Stuart, T. 2012. Asotin Creek Temperature Straight-to-Implementation Vegetation Study. Spokane, WA: Washington State Department of Ecology, Easter Regional Office.

Tetra Tech, Inc. 2012. Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling. U.S. Environmental Protection Agency, Region 8. EPA Contract BPA 08RT0049, Task Order 18 and 19. QAPP 303, Rev. 1.

U.S. Department of Agriculture, Forest Service. 2008. Fire History in the Bitterroot National Forest. http://www.fs.usda.gov/detailfull/bitterroot/landmanagement/gis/?cid=stelprdb5157563&width=full. Accessed 2/4/2014.

U.S. Geological Survey. 2014. National Elevation Dataset. http://ned.usgs.gov. Accessed 1/20/2014.

Washington State Department of Ecology. 2008. TTools for ArcGIS (TTools for ArcGIS 9.x (Build 7.5.3).Mxd in TTools_for_ArcGIS.Zip in Models for Total Maximum Daily Load Studies. http://www.ecy.wa.gov/programs/eap/models.html. Accessed 11/29/2011.

Water Consulting, Inc. 2002. White Pine Creek Reconnaissance and Watershed Assessment Validation. Hamilton, MT: Water Consulting, Inc.

Western Regional Climate Center. 2013. Monthly Summary Time Series. http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?mtMSMI. Accessed 2/12/2014.