Montana Department of Environmental Quality

Tobacco Planning Area Nutrient and Temperature TMDLs and Water Quality Improvement Plan

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ACRONYMS

Acronym	Definition
AFDM	Ash-free Dry Mass
ARM	Administrative Rules of Montana
BMP	Best Management Practices
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
EPA	Environmental Protection Agency (U.S.)
EQIP	Environmental Quality Incentives Program
FWP	Fish, Wildlife, and Parks (Montana)
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
IR	Integrated Report
KRN	Kootenai River Network
LA	Load Allocation
MCA	Montana Code Annotated
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSU	Montana State University
NHD	National Hydrography Data[set]
NPS	Nonpoint Source
NRCS	National Resources Conservation Service
SMZ	Streamside Management Zone
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TPA	TMDL Planning Area
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UUILT	Ultimate Upper Incipient Lethal Temperature
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan

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DOCUMENT SUMMARY

This document presents total maximum daily loads (TMDLs) and a water quality improvement plan for two impaired streams in the Tobacco TMDL Planning Area (TPA): Fortine Creek and Lime Creek (see **Map A-1** found in **Appendix A**). The three TMDLs in this document address impairment from nutrients and temperature.

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 majority of the Tobacco River watershed is located in Lincoln County in northwest Montana, with a small section in upper Lime Creek located in Flathead County (**Map A-1, Appendix A**). The Tobacco River forms at the confluence of Grave and Fortine Creeks and flows into the Kootenai River at Lake Koocanusa near the town of Eureka. The Tobacco River watershed is sparsely populated and the majority of the land (67.5%) is public land managed by the United States Forest Service. Private land holdings account for 28.8% and are primarily located in the valley bottoms adjacent to stream corridors and in the vicinity of Eureka, the largest town (population 1,037, 2010 Census). Evergreen forest is the dominate land cover in the Tobacco River watershed at almost 75%. Only small areas of the watershed have been cultivated. Significant economic activities include rural land development and associated construction, forest management and associated timber products, and recreation.

DEQ split the Tobacco watershed into two areas for TMDL development: the Grave Creek TPA and the Tobacco TPA. A sediment TMDL was developed for Grave Creek in 2005 (Montana Department of Environmental Quality et al., 2005) and sediment TMDLs were developed for eight streams in the Tobacco TPA in 2011 (Montana Department of Environmental Quality, 2011). Since completion of the sediment TMDLs, DEQ and EPA collected metals, nutrient, and temperature data to further evaluate the remaining impairments on the 303(d) list. This information supports the nutrient and temperature impairments identified on the 2012 303(d) List, but indicates Lime Creek is no longer impaired for arsenic, which was the only identified metals impairment in the TPA. Therefore, the arsenic impairment for Lime Creek has been removed from the 2014 303(d) List and is not discussed within this document. This document is reflective of the 2014 303(d) List and addresses remaining impairments in the Tobacco TPA, which are for nutrients in Lime Creek and temperature in Fortine Creek.

Nutrients

Two nutrient TMDLs are provided for Lime Creek (**Table DS-1**): total nitrogen and total phosphorus. Nutrient and biological data indicate nutrients are present in concentrations that can cause algal growth that harms recreation and aquatic life beneficial uses. Water quality restoration goals for nutrients were based on Montana's draft numeric nutrient criteria, measures of algal growth/density, and biological metrics for macroinvertebrates and periphyton.

Potential sources are grazing, timber harvest, and residential development. Based on monitoring data, most of the loading is occurring in the lower watershed near the mouth, which is an area of mixed land use. TMDL examples based on monitoring data indicate reductions up to 70% are necessary for total nitrogen. However, exceedances of the water quality standard are very sporadic, indicating only minor improvements are necessary to meet the TMDLs. None of the recent samples exceeded the water quality target for total phosphorus, so the TMDL examples do not show a reduction is needed for total phosphorus. However, nutrient uptake by algae and other primary producers may decrease nutrient loads, which can make it appear as though there is not a nutrient problem, but several biological parameters indicate excess nutrient loading is occurring in Lime Creek. Best management practices are discussed for each potential source category, but additional sampling and source evaluation is recommended to help determine where additional best management practices are needed and which type is most appropriate.

Temperature

A temperature TMDL was completed for Fortine Creek. Historic removal of riparian vegetation, which is important for regulating stream temperature by providing shade, is the primary cause of impairment. Water quality restoration 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.

The Fortine Creek temperature TMDL indicates that based on conditions in 2012, reductions in maximum daily water temperatures ranging from 1.4°F to 3.5°F are necessary but greater reductions may be necessary during years of lower streamflow. General strategies for achieving the in-stream water temperature reduction goals are also presented in this plan and the focus is on riparian BMPs to improve shade.

Water Quality Improvement Measures

Implementation of water quality improvement measures described in this plan 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.

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

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Tobacco TMDL Planning Area with Completed Nutrient and Temperature TMDLs Contained in this Document

Waterbody & Location Description	Waterbody ID	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
Fortine Creek, headwaters to mouth (Grave Creek)	MT76D004_020	Temperature	Temperature	Aquatic Life
Lime Creek, headwaters to mouth (Fortine Creek)	MT76D004_050	Total Phosphorus	Nutrients	Aquatic Life Primary Contact Recreation
		Total Nitrogen	Nutrients	Aquatic Life Primary Contact Recreation

1.0 PROJECT OVERVIEW

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for nutrients and temperature problems in the Tobacco TMDL Planning Area (TPA). This document also presents a general framework for resolving these problems. **Figure A-1** found in **Appendix A** shows the location of the project area and **Figure A-8** shows the waterbodies in the Tobacco TPA with nutrient and temperature pollutant impairments.

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 A-1** in **Appendix A** identifies all impaired waters for the Tobacco TPA from Montana's 2014 303(d) List, and includes 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, 2014). **Table A-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 incorporated in TMDL documents to help facilitate TMDL implementation (see **Section 7.0**).

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, 2014) that are addressed in this document (also see **Figure A-1** in **Appendix A**). Each pollutant impairment falls within a TMDL pollutant category (e.g., metals, nutrients, sediment, or temperature), and this document is organized by those categories.

A TMDL is completed for each waterbody – pollutant combination, and this document contains three TMDLs (**Table 1-1**). A temperature TMDL is presented for Fortine Creek and total nitrogen and total phosphorus TMDLs are presented for Lime Creek.

DEQ sometimes develops TMDLs in a watershed at varying phases, with a focus on a specific subwatershed or limited number of specific pollutant types: a sediment TMDL was completed for Grave Creek in 2005 and for eight other waterbody segments in the Tobacco watershed, including the Tobacco River (**Figure A-1** in **Appendix A**), in 2011. Collectively, this document and those completed in 2005 and 2011 address all currently identified pollutant impairments in the Tobacco watershed. There are several non-pollutant types of impairment in the Tobacco TPA, and as noted above, TMDLs are not required for non-pollutants. In many situations the solution to one or more pollutant problems will be consistent with, or equivalent to, the solution for one or more non-pollutant problems. The previously completed TMDL documents for streams in the Tobacco watershed as well as **Section 7.0** of this document provide some basic water quality solutions to address those non-pollutant causes not specifically addressed by TMDLs in this document.

The "Grave Creek Watershed Water Quality and Habitat Restoration Plan and Sediment Total Maximum Daily Load" (Montana Department of Environmental Quality et al., 2005) and the "Tobacco Planning Area Sediment TMDLs and Framework Water Quality Improvement Plan" (Montana Department of Environmental Quality, 2011) include strategies for implementation and monitoring. After substantial implementation occurs, DEQ will conduct water quality monitoring and complete TMDL Implementation

Evaluations to evaluate water quality conditions and determine if water quality standards are being met and designated uses are being supported.

Table 1-1. Water Quality Impairment Causes for the Tobacco TMDL Planning Area in the "2014 Water Quality Integrated Report" Addressed within this Document

Waterbody & Location Description[1]	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status
Fortine Creek, headwaters to mouth (Grave Creek)	MT76D004_020	Temperature, water	Temperature	Temperature TMDL completed
Lime Creek, headwaters to mouth (Fortine Creek)	MT76D004_050	Nitrogen (Total)	Nutrient	TN TMDL Completed
		Phosphorus (Total)	Nutrient	TP TMDL completed
		Chlorophyll-*a*	Non-Pollutant	Addressed by TN and TP TMDLs

[1.] All waterbody segments within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset (NHD)
TN = Total Nitrogen, TP = Total Phosphorus

1.3 What This Document Contains

This document addresses all of the required components of a TMDL and includes an implementation and monitoring strategy, as well as a strategy to address impairment causes other than metals, nutrients, sediment, and temperature. The TMDL components are summarized within the main body of the document. Additional technical details are contained in the appendices and attachments. In addition to this introductory section, this document includes:

Section 2.0 Tobacco TMDL Planning Area Description:
Describes the physical characteristics and social profile of the TPA.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to the Tobacco TPA.

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

Sections 5.0 and 6.0 Temperature and Nutrients TMDL Components (sequentially):
Each section includes (a) a discussion of the affected waterbodies 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 for each waterbody, (f) the allocations of the allowable pollutant load to the identified sources.

Section 7.0 TMDL Implementation and Monitoring Framework:
Discusses water quality restoration objectives and a strategy to meet the identified objectives and TMDLs. Also provides water quality monitoring suggestions for evaluating the long-term effectiveness of the "Tobacco Planning Area Nutrient and Temperature TMDLs and Water Quality Improvement Plan."

Section 8.0 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 TOBACCO TMDL PLANNING AREA DESCRIPTION

This section includes a summary of the physical and social profile of the Tobacco TMDL Planning Area; associated maps are contained in **Appendix A**.

2.1 PHYSICAL CHARACTERISTICS

The following information describes the physical characteristics of the Tobacco TMDL Planning Area including the location, climate, hydrology, and geology.

2.1.1 Location

The majority of the Tobacco TMDL Planning Area is located in Lincoln County in northwest Montana, with a small section (a portion of the Lime Creek watershed) located in Flathead County (**Map A-1, Appendix A**). The Tobacco TMDL Planning Area encompasses 414 square miles (265,250 acres) and is bounded by the Kootenai River on the west, the Whitefish Range on the east, and the Salish Mountains to the south. The Tobacco River is located south of the United States-Canadian border and north of the Fisher River watershed. While a small, northern portion of the planning area drains into the Canada's Elk River basin, most of the landmass drains into the Tobacco River on the United States side. The Tobacco River forms at the confluence of Grave and Fortine Creeks and flows into the Kootenai River at Lake Koocanusa near the town of Eureka. Lime Creek is a tributary to Fortine Creek. The Grave Creek watershed is a separate TMDL Planning Area where previous TMDL efforts have taken place (Montana Department of Environmental Quality et al., 2005), therefore the land is not included in this document even though it falls within the boundaries of the Tobacco River watershed.

2.1.2 Climate

The average precipitation ranges from 16.5 inches/year near the town of Fortine to between 47 and 70 inches/year at higher elevations in the Galton and Whitefish Mountain Ranges to the north (Western Regional Climate Center, 2012). May and June are consistently the wettest months of the year and winter precipitation is dominated by snowfall. Temperature patterns reveal that July is the hottest month and January is the coldest throughout the watershed. Summertime highs are typically in the high 70s to low 80s Fahrenheit, and winter lows fall to approximately 11˚F. **Map A-2** in **Appendix A** shows the average annual precipitation in the Tobacco TMDL Planning Area from 1981 through 2010.

2.1.3 Hydrology

Streamflows are at their highest between May and June, which also sees the greatest amount of precipitation. Historical data indicate peak flows on the Tobacco River in May average approximately 750 cubic feet per second (cfs). However, flows from 2,300 to 3,180 cfs have been recorded in the month of May. The last 50 years of data from the Tobacco River USGS gaging station (12301300) show on average a mean monthly discharge below 150 cfs for August through February. Rain on snow events occur periodically in early fall or spring, producing high flows over short periods of time. USGS established a gaging station on Fortine Creek near Trego (12300500) in 1946 and has collected sporadic water quality and discharge measurements there; most recently in 1982. No historic or current USGS stations exist on Lime Creek.

2.1.4 Geology and Soils
Much of the soil in the Tobacco valley is relatively erodible as it is compiled of glacial deposits that create sandy loams (**Maps A-3** and **A-4**, **Appendix A**). Majority of the bedrock in the area belongs to the Belt Supergroup of Precambrian age that includes the Missoula group, Piegan group, Ravalli group, and Wallace formation. Highly erodible, unconsolidated Quaternary alluvium and glacial lake deposits are found throughout the Tobacco River and Fortine Creek valleys. The Fortine Creek headwaters region, including Lime Creek, are dominated by dolomitic siltstone, quartzite and siltite.

2.2 Social Profile

The following information describes the social profile of the Tobacco TMDL Planning Area including land ownership, land use and cover, population, and point sources.

2.2.1 Land Ownership
The majority of the land (67% or 177,000 acres) in the Tobacco TMDL Planning Area is managed by the U.S. Forest Service. Private land holdings account for another 30% (80,600 acres) of the planning area and are primarily located in the valley bottoms adjacent to stream corridors. Slightly over 1,500 of these acres (0.5%) are managed by private timber companies. The remaining 3% of land is owned by various public entities such as city, county and state governments. **Map A-5** in **Appendix A** shows land ownership in the Tobacco TMDL Planning Area as recorded in the 2014 Montana cadastral.

2.2.2 Land Use and Land Cover
Evergreen forest is the dominate land cover in the Tobacco TMDL Planning Area at almost 75%. Shrubland comprises just over 10% and grasslands/herbaceous makes up approximately 7% of the land area. In direct correlation, timber production is the primary land use in the watershed. Historically, much of the watershed has been logged and riparian habitat altered by log drives, riparian harvest, and road construction. Only small areas of the watershed have been cultivated. **Map A-6** in **Appendix A** shows the types of land cover and land use of the Tobacco TMDL Planning Area.

2.2.3 Population
The Tobacco TMDL Planning Area is sparsely populated with an estimated population of 4,600 individuals according to the 2010 census. Eureka is the largest town with 1,037 residents, then Trego with 541 and Fortine with 325. Larger regional centers include cities of Whitefish and Libby, both roughly 25 miles from the planning area boundary. Census data indicates the population is growing. Primary employment is in services, retail trade, and manufacturing.

2.2.4 Point Sources
According to Environmental Protection Agency's (EPA) Integrated Compliance Information System (ICIS) database as of May 27, 2014, there are four active point sources permitted under the Montana Pollution Discharge Elimination System (MPDES) within the project area. All four are general permits; two for construction stormwater, one for industrial stormwater and one for Eureka's sewage treatment facility. Because all of the permitted point sources are near Eureka and the mouth of the Tobacco River (**Map A-7 in Appendix A**), none are directly relevant to the TMDL streams within this document.

2.3 Fish and Aquatic Life

As a tributary to the Kootenai River, the Tobacco River and its tributaries provide important spawning and rearing habitat for fluvial and adfluvial fish populations that produce some of western Montana's popular sport fisheries, such as brook trout (*Salvelinus fontinalis)* and rainbow trout (*Oncorhynchus mykiss*). Streams in this watershed also support species of concern, including westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), bull trout (*Salvelinus confluentus)* and torrent sculpin *(Cottus rhotheus)*. Species of concern are species that are at-risk because of factors such as declining population trends, limited distribution, and habitat threats. Bull trout are also listed as threatened under the Endangered Species Act. The Tobacco River, which provides migratory habitat for bull trout, and Grave Creek, which provides spawning and rearing habitat, have been identified as critical habitat for bull trout (50 CFR Part 17, 2010). In Montana, the torrent sculpin is found only in the Kootenai River system (Montana Department of Fish, Wildlife and Parks, 2014).

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 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 (Montana Code Annotated (MCA) 75-5-301 & 302), and Montana's Surface Water Quality Standards and Procedures (Administrative Rules of Montana (ARM) 17.30.601 thru 17.30.670) 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. All streams and lakes within the Tobacco River watershed, other than Deep Creek, are classified as B-1, which specifies that the water must be maintained suitable to support all of the following uses (Administrative Rules of Montana (ARM) 17.30.623(1)):

- 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
- Agricultural and industrial waters supply

Deep Creek is classified as A-1, which must be maintained suitable for all of the same uses as B-1, as well as drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities. At the time Deep Creek was classified, it was being used as the drinking water supply for the town of Fortine. The language "for removal of naturally occurring impurities" implies a higher level of protection, given the drinking water use. 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.

DEQ's 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(s) assessed for temperature is aquatic life and for nutrients is aquatic life and primary contact recreation.

DEQ determined that in the Tobacco TPA one waterbody segment does not meet the temperature water quality standard and one waterbody segment does not meet the nutrient water quality standards (**Table 3-1**).

Table 3-1. Impaired Waterbodies and their Impaired Designated Uses in the Tobacco TMDL Planning Area

Waterbody & Location Description	Waterbody ID	Impairment Cause [1]	Impaired Use(s)
Fortine Creek, headwaters to mouth (Grave Creek)	MT76D004_020	Temperature	Aquatic Life
Lime Creek, headwaters to mouth (Fortine Creek)	MT76D004_050	Total Phosphorus	Aquatic Life Primary Contact Recreation
		Total Nitrogen	Aquatic Life Primary Contact Recreation

[1.] Only includes those pollutant impairments addressed by TMDLs in this document.

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 are designed to protect the designated uses. For the temperature and nutrient TMDL development process in the Tobacco TPA, only the narrative standards are applicable.

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).

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. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface water quality standard (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.

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. More details regarding the applicable standards for temperature and nutrients are described below.

3.2.1 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, which applies to Fortine Creek (Administrative Rules of Montana (ARM) 17.30.622(e) and 623(e)):
A 1º F maximum increase above naturally occurring water temperature is allowed within the range 32º F to 66º F; within the naturally occurring range of 66º F to 66.5º F, no discharge is allowed which will cause the water temperature to exceed 67º F; and where the naturally occurring water temperature is 66.5º F or greater, the maximum allowable increase in water temperature is 0.5º F. A 2º F per-hour maximum decrease below naturally occurring water temperature is above 55º F. A 2º F maximum decrease below naturally occurring water temperature is allowed within the range of 55º F to 32º F.

3.2.2 Nutrient Standards

The narrative standards applicable to nutrients in Montana are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. As stated above, undesirable aquatic life includes bacteria, fungi, and algae. Montana has recently developed draft nutrient criteria for total nitrogen (TN) and total phosphorus (TP) based on the Level III ecoregion in which a stream is located (Suplee et al., 2008). For the Northern Rockies Level III Ecoregion, draft water quality criteria for TN and TP are presented in **Table 3-2**. These criteria are growing season, or summer, values applied from July 1st through September 30th. Additionally, numeric human health standards exist for nitrogen (**Table 3-3**), but the narrative standard is most applicable to nutrients as the concentration in most waterbodies in Montana is well below the human health standard and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standard.

Table 3-2. Draft Numeric Nutrient Criteria for the Northern Rockies Ecoregion.

Parameter	Target Value
Total Nitrogen (TN)	≤ 0.275 mg/L
Total Phosphorus (TP)	≤ 0.025 mg/L

Table 3-3. Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)[1]
Nitrate as Nitrogen (NO_3-N)	10,000
Nitrite as Nitrogen (NO_2-N)	1,000
Nitrate plus Nitrite as N	10,000

[1]Maximum Allowable Concentration.

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.

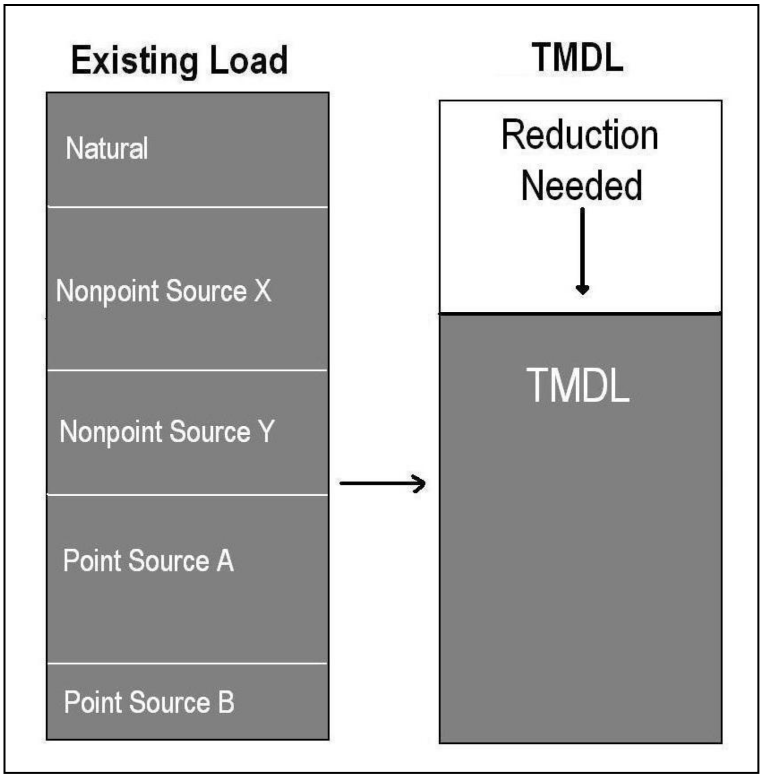

Figure 4-1. Schematic Example of TMDL Development

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. Nonpoint sources are quantified by source categories (e.g., unpaved roads, mining) and/or by land uses (e.g., crop production, timber harvest). 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 (Code of Federal Regulation (CFR) , Section 130.2(l)). 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 "TMDL" implies "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, sediment TMDLs may be expressed as an allowable annual load.

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 sediment, 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. Where 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 (Code of Federal Regulation (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.

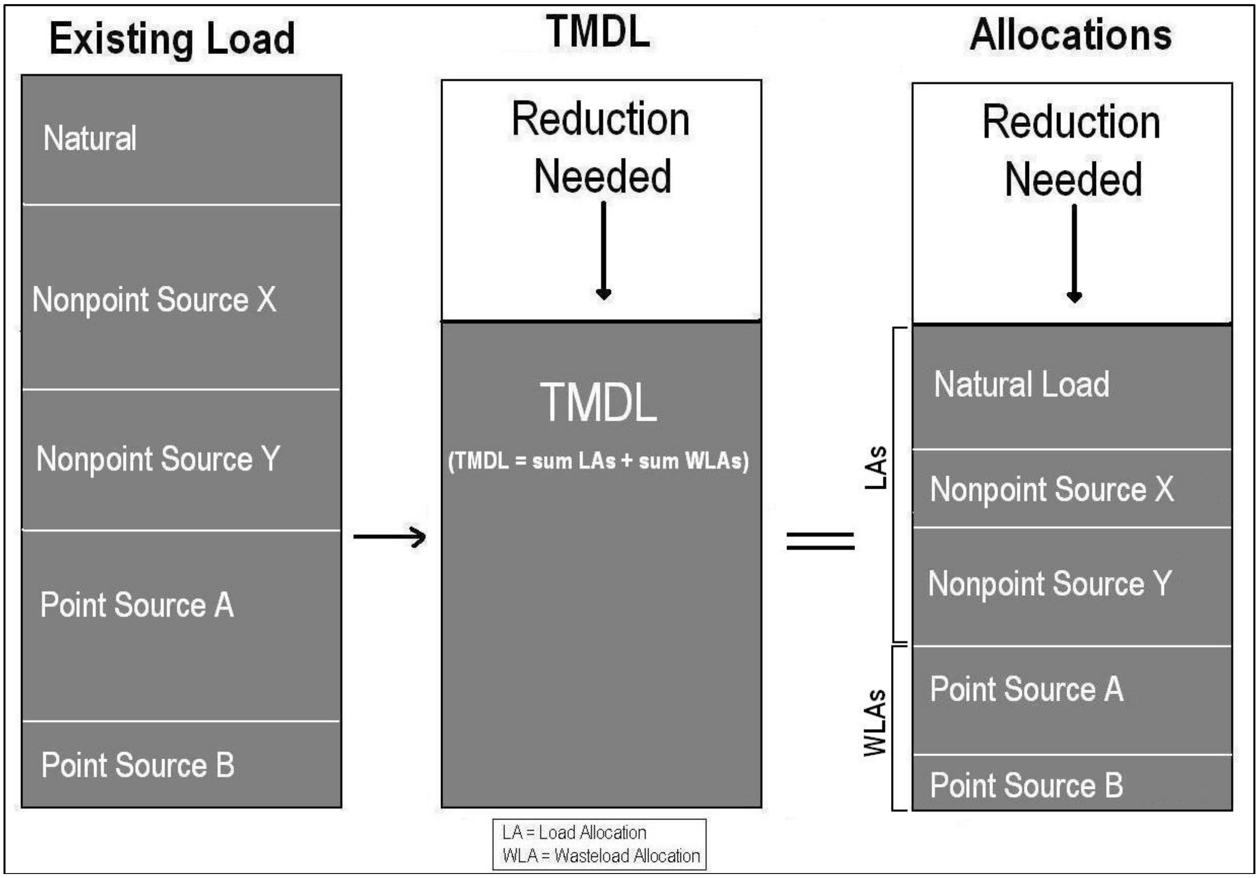

Figure 4-2. Schematic Diagram of a TMDL and its Allocations

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 = WLA + LA + MOS) (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. In Montana, TMDLs typically incorporate implicit margins of safety.

4.5 Implementing TMDL Allocations

The Clean Water Act (CWA) and Montana state law (Montana Code Annotated (MCA) 75-5-703) 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. This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 7.0** provides a water quality improvement plan and monitoring strategy. The section discusses restoration strategies by pollutant group and source category, recommended best management practices (BMPs) per source category (e.g., urban development, timber harvest, grazing, etc.), and general monitoring recommendations to strengthen the source assessment and evaluate restoration activities. **Section 7.7** discusses potential funding sources that stakeholders can use to implement BMPs for nonpoint sources. Other site-specific pollutant sources are discussed throughout the document, and can be used to target implementation activities. Additional implementation details are also discussed in the "Tobacco Planning Area Sediment TMDLs and Framework Water Quality Improvement Plan" (Montana Department of Environmental Quality, 2011). Department of Environmental Quality's 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 BMPs. Montana's Nonpoint Source Management Plan (available at http://www.deq.mt.gov/wqinfo/nonpoint/nonpointsourceprogram.mcpx) further discusses nonpoint source implementation strategies at the state level.

DEQ uses an adaptive management approach to implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 7.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute (Montana Code Annotated (MCA) 75-5-703). 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 Tobacco TMDL Planning Area (TPA). It describes: (1) the mechanisms by which temperature affects beneficial uses of streams; (2) the stream segment of concern; (3) information sources used for temperature 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 depend 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 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 (**Section 3.2.1**) and subsequently developing temperature TMDLs.

5.2 Stream Segments of Concern

One waterbody segment in the Tobacco TPA appears on the draft 2014 Montana impaired waters list as having temperature limiting a beneficial use: Fortine Creek (**Appendix A**, **Table A-1**).

To help put sampling data into perspective and understand how elevated stream temperatures may affect aquatic life, information on fish presence in Fortine Creek and temperature preferences for the most sensitive species are described below.

5.2.1 Fish Presence in Fortine Creek and Temperature Tolerances

Because different fish species have varying optimal temperature ranges for survival and some are more sensitive than others to elevated stream temperatures, it is important to identify the fish species within Fortine Creek. Based on a query of the Montana Fisheries Information System (MFISH), brook trout, westslope cutthroat trout, longnose dace, and torrent sculpin are all common in Fortine Creek, and rainbow trout, mountain whitefish, largescale sucker, and longnose sucker are rare (Montana Department of Fish, Wildlife and Parks, 2014). Bull trout spawn in Grave Creek, the other headwaters tributary of the Tobacco River, but are not known to be more than an occasional transient in Fortine

Creek (U.S. Fish and Wildlife Service, 2002). It is suspected that Fortine Creek may naturally pose a thermal barrier to bull trout because it primarily receives inputs from low elevation lands (U.S. Fish and Wildlife Service, 2002). Montana Fish, Wildlife, and Parks (FWP) has identified westslope cutthroat trout, bull trout, and torrent sculpin as species of concern. According to the FWP fisheries resource value ratings, Fortine Creek is considered "moderate" (rating score 4) (Montana Department of Fish, Wildlife and Parks, 2014).

5.2.2 Temperature Levels of Concern

Of the fish found in Fortine Creek, salmonids (i.e., trout) tend to be the most sensitive to elevated temperatures. However torrent sculpin will also be discussed in this section because they are a Montana species of concern. Research by Bear et al. (2007) found that westslope cutthroat trout maximum growth occurs around 56.5°F, with an optimum growth range (based on 95% confidence intervals) from 50.5 –62.6°F. Rainbow trout have a similar optimum growth temperature to westslope cutthroat trout but have the ability to grow better over a wider range of temperatures, with growth significantly better at temperatures below 44.2°F and above 69.4°F (Bear et al., 2007). Bull trout, however, tend to be more sensitive than westslope cutthroat trout; maximum growth occurs around 55.8°F and they have an optimum growth range (based on 95% confidence intervals) from 51.6 – 59.7°F (Selong et al., 2001). Because sculpin are less sensitive to elevated temperatures than salmonids, only a limited amount of research has been conducted to identify temperatures limiting growth. However, a sculpin distribution study was conducted in the Kootenai and Flathead National Forests (Gangemi, 1992) that noted stream temperatures in relation to abundance: the mean temperature at sites with torrent sculpin was 59.8°F, but they were abundant at sites with temperatures up to 70°F.

Fish also have varying tolerance levels for prolonged (i.e., chronic) exposure to elevated temperatures before they die. 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. In contrast, Bear et al. (2007) observed that rainbow trout had a 60-day UUILT of 75.7°F and a 7-day UUILT of 78.8°F. For bull trout, Selong et al. (2001) found the 60-day UUILT to be 69.6°F and predicted the 7-day UUILT to be 74.3°F. Considering a higher rate of survival, the lethal temperature dose that will kill 10% of the population in a 24-hour period for westslope cutthroat trout is 73.0°F (Liknes and Graham, 1988).

5.3 Information Sources and Data Collection

As part of this TMDL project, several information and data sources were used to assess temperature conditions in Fortine Creek:

- DEQ assessment file information
- Temperature Related Data Collection
    - 2012 Department of Environmental Quality (DEQ)/Environmental Protection Agency (EPA) stream temperature, flow, riparian shade, and channel geometry data
    - 2012 US Forest Service (USFS) temperature data

As discussed in **Section 3.2.1**, 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. Model details are presented in **Appendix B** but the model summary and outcome is provided in **Section 5.5**, **Source Assessment**. To assist with model development and assessment of temperature conditions in Fortine Creek, two other categories of data were needed:

- Climate Data
- Montana Department of Natural Resources and Conservation (DNRC) water usage data

5.3.1 DEQ Assessment File

DEQ maintains assessment files that provide a summary of available water quality and other existing condition information, along with a justification for impairment determinations. The assessment file for Fortine Creek was last updated in 2005: it summarizes DEQ field data from 2003 and information from FWP, USFS, and other sources documenting fish population dynamics, macroinvertebrate health, low streamflows, habitat alterations, siltation, and temperature impairment (Montana Department of Environmental Quality, 2014).

5.3.2 Temperature Related Data Collection

In summer 2012, DEQ and EPA collected continuous temperature data, along with measurements of streamflow, riparian shade, and channel geometry. Other continuous temperature data were collected in Fortine Creek by FWP in 2004/2005 and the USFS in 2003 and 2012. All 2012 data were collectively used within the QUAL2K model to evaluate impairment and the potential for improvement associated with the implementation of all reasonable land, soil, and water conservation practices. Older data were used to assist with overall characterization of temperature trends in the watershed and as a basis for comparison to the 2012 data. The following sections describe the data collected in Fortine Creek for temperature assessment.

5.3.2.1 Temperature Monitoring

In summer 2012, EPA deployed seven temperature loggers in Fortine Creek dispersed from its headwaters to its mouth at the Tobacco River and two temperature loggers in tributaries (**Figure 5-1**). The tributary loggers were deployed near the mouth of Swamp and Deep Creeks; loggers were also proposed to be deployed in Edna and Meadow Creeks, but access could not be secured near the mouth of Edna Creek and Meadow Creek had insufficient flow. All tributary loggers were deployed in late June but loggers were not deployed in Fortine Creek until mid-July because of high flows in June. All loggers recorded temperatures every 30 minutes until they were retrieved in mid-September.

Water temperature data were collected when streamflow tends to be the lowest and air temperatures the highest because that is when aquatic life are exposed to the highest water temperatures of the year. Temperature monitoring sites on Fortine Creek were selected to bracket stream reaches with similar hydrology, riparian vegetation type, valley type, stream aspect, and channel width. Tributary loggers were deployed in the largest tributaries (based on stream order) to help with model development and to identify if those tributaries are having a warming or cooling effect on Fortine Creek. Loggers were deployed following DEQ protocols and a Quality Assurance Project Plan (DEQ 2005a; DEQ 2005b; Atkins 2012). Temperature data can be obtained by contacting DEQ but are summarized within this section and **Appendix B**.

The USFS deployed three temperature loggers in summer 2012, and those data were also used for TMDL development. The USFS loggers were deployed partway up the stream in Edna and Deep Creeks and in Fortine Creek approximately 1.5 miles downstream of its confluence with Edna Creek (**Figure 5-1**). Like the EPA loggers, the USFS loggers recorded water temperature every 30 minutes. The USFS loggers were deployed from mid-June to mid-September 2012.

In coordination with DEQ, the USFS collected continuous temperature data at five locations in Fortine Creek in 2003 ranging from Swamp Creek to the mouth (**Figure 5-1**). In 2004/2005, FWP coordinated with DEQ to collect continuous temperature data at four locations in Fortine Creek extending from near Trego (and EPA site FRTNC-T5) to the mouth (**Figure 5-1**).

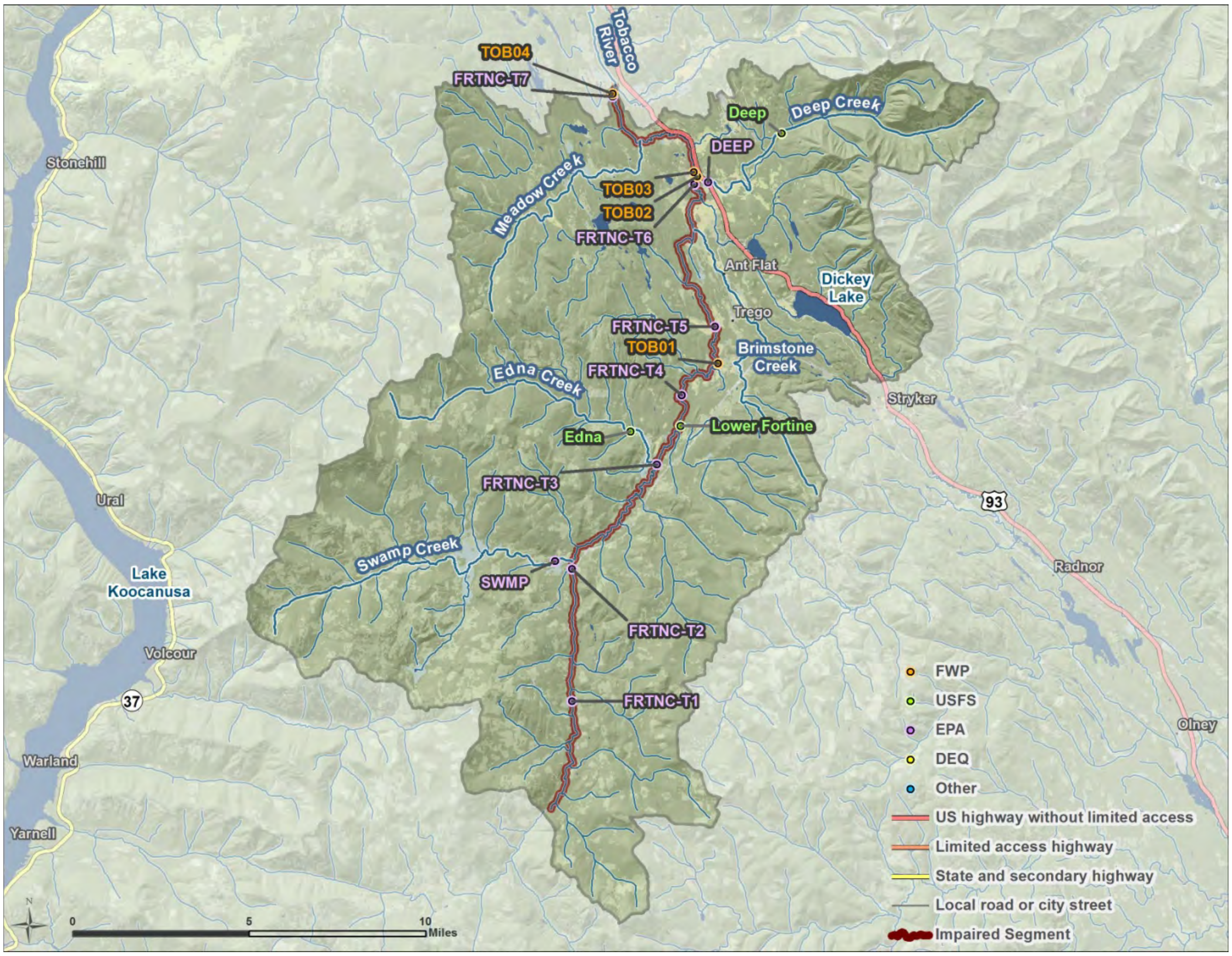

Figure 5-1. Temperature data logger sampling sites on Fortine Creek.

5.3.2.2 Streamflow

To assist with model development, streamflow measurements were collected following DEQ protocols at all temperature monitoring sites (**Figure 5-1**) during logger deployment (June/July), mid-season (August) and logger retrieval (September). The USFS collected flow and stage measurements for Deep Creek in 2011 and Edna and Fortine Creeks in 2012.

5.3.2.3 Riparian Shading

Characterization of riparian shade was based on a combination of field data and aerial imagery analysis. EPA and DEQ used a Solar Pathfinder to measure effective shade in September 2012 at eight locations; shade measurement sites were collocated with the temperature loggers sites on Fortine Creek (**Figure 5-**

1) but an extra measurement was collected near FRTNC-T5 because of variable conditions in that area. Effective shade is the percent reduction of incoming solar radiation that reaches the stream because of riparian vegetation and topography. Because of the variability in riparian cover and topography throughout the watershed, a Geographic Information System (GIS)-based model called TTools (v.3.0) (Oregon Department of Environmental Quality, 2001) was used along with field measurements for trees, shrubs, and herbaceous vegetation and a spreadsheet tool (Shadev3.0.xls) (Pelletier, 2012) to estimate the hourly effective shade approximately every 100 feet along the entire stream. The analysis was performed using August 2012 Google Earth aerial imagery to classify vegetation into broad categories (i.e., bare ground/road, herbaceous, shrub, and trees). The 2001 National Land Cover Database identified percent canopy cover for trees, and that information was used to classify trees as sparse, low, medium, or high density. Although the eight Solar Pathfinder measurements were sparse compared to the Shade model output, they indicate the model reasonably approximated effective shade along Fortine Creek; the average error between the field measurements and model output was 7%. Additional details regarding the shade assessment are contained in **Appendix B**.

5.3.2.4 Channel Geometry
Channel geometry (i.e., width and depth) can influence the rate of thermal loading and is a necessary input for the QUAL2K model. Wide, shallow streams transfer heat energy faster than narrow, deep streams. Human activities that alter peak flows or disturb the riparian vegetation, streambanks, and/or stream channel have the potential to alter channel geometry. Therefore, channel geometry can be used to identify areas that may be destabilized and more prone to rapid thermal loading, particularly in locations where shading is minimal. Channel width (wetted and bankfull) was collected at each of the Fortine Creek shade sites in 2012 (**Figure 5-1**) and bankfull width/depth ratios were measured at five locations in 2008 in support of sediment TMDL development for the Tobacco watershed (Montana Department of Environmental Quality, 2011).

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. Most climatic data inputs, including hourly air temperature, were obtained from Eureka Remote Automatic Weather Station, the closest station with hourly data. Cloud cover was estimated based on hourly data from the Kalispell Glacier Park International Airport, which is the closest station that measures cloud cover. Climate and weather data are discussed in more detail in **Sections B2.3.1** and **B3.5** of **Appendix B**.

5.3.4 DNRC Water Usage Data
Water usage data is important to consider when evaluating stream temperature because reduced instream flow caused by irrigation withdrawals, as well as warm irrigation return water, have the potential to influence stream temperatures. Additionally, water usage information is important because water diversions influence streamflow, which is an important input for the QUAL2K model. Spatial DNRC water usage data that identifies active points of diversion and places of use was obtained from the Natural Resources Information System (Natural Resource Information System, 2012). Diversion locations are shown on **Figure B-9** of **Appendix B** and associated data are summarized within **Table B-6**.

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 Fortine Creek.

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 was 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 aquatic life, the use most sensitive to elevated temperatures; as such, the targets are protective of all designated uses for Fortine Creek.

For Fortine Creek a QUAL2K model was used to estimate the extent of human influence on temperature by evaluating the temperature change between existing conditions and naturally occurring conditions. The model used the data described in **Section 5.3** to simulate existing conditions, and then the model was 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., 0.5-1.0°F, depending on the naturally occurring temperature), this would verify the existing temperature impairment for Fortine Creek. This section discusses whether the model outcome supports the existing impairment listing, but 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., 0.5-1.0°F, depending on the naturally occurring temperature), and the other targets are those parameters that influence temperature and can be linked to human causes. The temperature-influencing targets that can be affected my human sources are riparian shade, channel geometry, and instream streamflow (depending on consumptive water usage). 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 for Fortine Creek 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°F, the maximum allowable increase is 1°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. 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). 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 NRCS Conservation Practice Standard 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 target used here is a buffer width of 50 feet. Based on areas of reference riparian health dispersed throughout the watershed that were observed during field work in 2012 and historical removal of riparian vegetation in the valley(Montana Department of Environmental Quality, 2011; Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014), as well as the NRCS recommendation for buffers with medium to high shade value, this 50 foot buffer should consist of medium density trees or any vegetation providing equivalent effective shade. The target does not apply to portions where the riparian zone is already at potential or is dominated by vegetation not likely to attain great heights at maturity (e.g., wetland shrub community).

Although the target is 50 feet, the USFS abides by Inland Native Fish Strategy standards in the Fortine Creek watershed 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).

DEQ realizes most healthy riparian buffers are comprised of more than a single category of vegetation, but a buffer of medium density trees was used as a shade target throughout Fortine Creek 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 medium density trees was determined to be a reasonable target. Considering the variability in potential vegetation and shade, medium density trees was used as a surrogate to represent the average achievable shade condition; 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, the railroad, and riprap that may not feasibly be modified or relocated. The target is provided as a quantitative guide for meeting the standard but since it is intended to represent all reasonable land, soil, and water conservation practices, if those are being implemented, then Fortine Creek will be meeting the riparian shade target.

5.4.3.3 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 completed in 2011 for the Tobacco watershed (Montana Department of Environmental Quality, 2011), and will also apply for temperature: ≤ 21 for sections with a bankfull width equal to or less than 30 feet and ≤ 35 for sections with a bankfull width greater than 30 feet. 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.

5.4.3.4 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.

DNRC water use data indicates there are 697 diversions in the Fortine Creek watershed but that only 31 are directly from Fortine Creek. Of those 31, only 15 were not direct access points for livestock and were considered potentially significant. The diversions are dispersed over 25 miles starting approximately 2 miles downstream of Swamp Creek and extending to the mouth of Fortine Creek (**Appendix B, Figure B-9**). Using the USDA Irrigation Water Requirements program for crop irrigation (Dalton, 2003), it is estimated that up to 6.24 cfs may be withdrawn on a daily basis during July and August (**Appendix B, Table B-6**). Only one of the diversions is estimated to withdraw greater than 1 cfs on a daily basis; it is located downstream of Brimstone Creek (**Figure 5-1**) and is estimated to withdraw up to 3 cfs daily. To put the consumptive use into broader context, streamflow in August 2012 (which was used to represent existing conditions in the model) was approximately 3.7 cfs near the headwaters and 59.3 cfs at the mouth. Tributary inputs were estimated to be 28.2 cfs.

Because low streamflow associated with consumptive use is documented in the DEQ assessment file for Fortine Creek and identified as a cause of impairment (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014), and streamflow is a significant determinant of water temperature and a stream's ability to buffer incoming solar radiation, there will be an instream flow target for Fortine Creek. The naturally occurring condition referenced in the temperature standard includes the use of all reasonable water conservation practices (Administrative Rules of Montana (ARM) 17.30.602(17)). Since a detailed analysis was not conducted of the irrigation network, there is no numeric target for water use. Instead the target is based on applying best management practices and is for water users in the watershed to apply all reasonable water conservation practices. The goal of this is to use some of the water currently wasted due to inefficiency instream but not to alter water rights.

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, instream flow, and width/depth ratio). 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 Fortine Creek.

Table 5-1. Temperature Targets for Fortine Creek

Target Parameter	Target Value
Primary Target	
Allowable Human-Caused Temperature Change	If the naturally occurring temperature is less than 66°F, the maximum allowable increase is 1°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.
Temperature-Influencing Targets: Meeting all will meet the primary target	
Riparian Health - Shade	50 foot buffer with medium density trees, or vegetation providing equivalent effective shade
Instream Flow	Apply all reasonable water conservation practices so that water currently wasted due to inefficiency can be left instream
Width/Depth Ratio	Where bankfull width is less than or equal to 30ft: $\leq$ 21 Where bankfull width exceeds 30ft: $\leq$ 35

5.4.4 Fortine Creek 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 Fortine 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**.

Fortine Creek (MT76D004_020) extends 33.46 miles from its headwaters to the mouth at Grave Creek, where the Tobacco River is formed. Fortine Creek was initially listed for temperature impairment in 2006 because of macroinvertebrate assemblages in the middle and lower part of Fortine Creek that indicated elevated temperatures as well as stream temperatures reaching the mid to upper 70s (°F) in the summer. Channel widening, low streamflow associated with irrigation withdrawals (particularly in the last 5 miles), and riparian harvest were noted as causes (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014).

Data Summary and Comparison with Water Quality Targets

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. Measured temperatures were warmest in 2012 for the longest period of time at FRTNC-T6 (just upstream of Deep Creek), where the water temperature peaked at 75.3°F and exceeded 70°F on 27 days. The other warmest sites were Lower Fortine and FRTNC-T5 (**Figure 5-2**). These temperatures are not in the lethal range discussed in **Section 5.2.2**, but maximum daily temperatures throughout Fortine Creek (**Figure 5-2**) were commonly outside of the optimal growth range for westslope cutthroat trout (i.e., 62.6°F). For tributaries, Swamp Creek was the warmest with maximum temperatures up to 70°F.

The data collected between 2003 and 2005 showed similar longitudinal trends with maximum temperatures near Trego (FRTNC-T5) and the mouth (FRTNC-T7), however, the maximum temperatures were warmer than in 2012. Between 2003 and 2005, maximum temperatures were in the mid-70s (°F) at most sites and close to 80°F at the mouth (**Appendix B**). These temperatures are in the range that can be lethal to some of coldwater fish species found in the Fortine watershed.

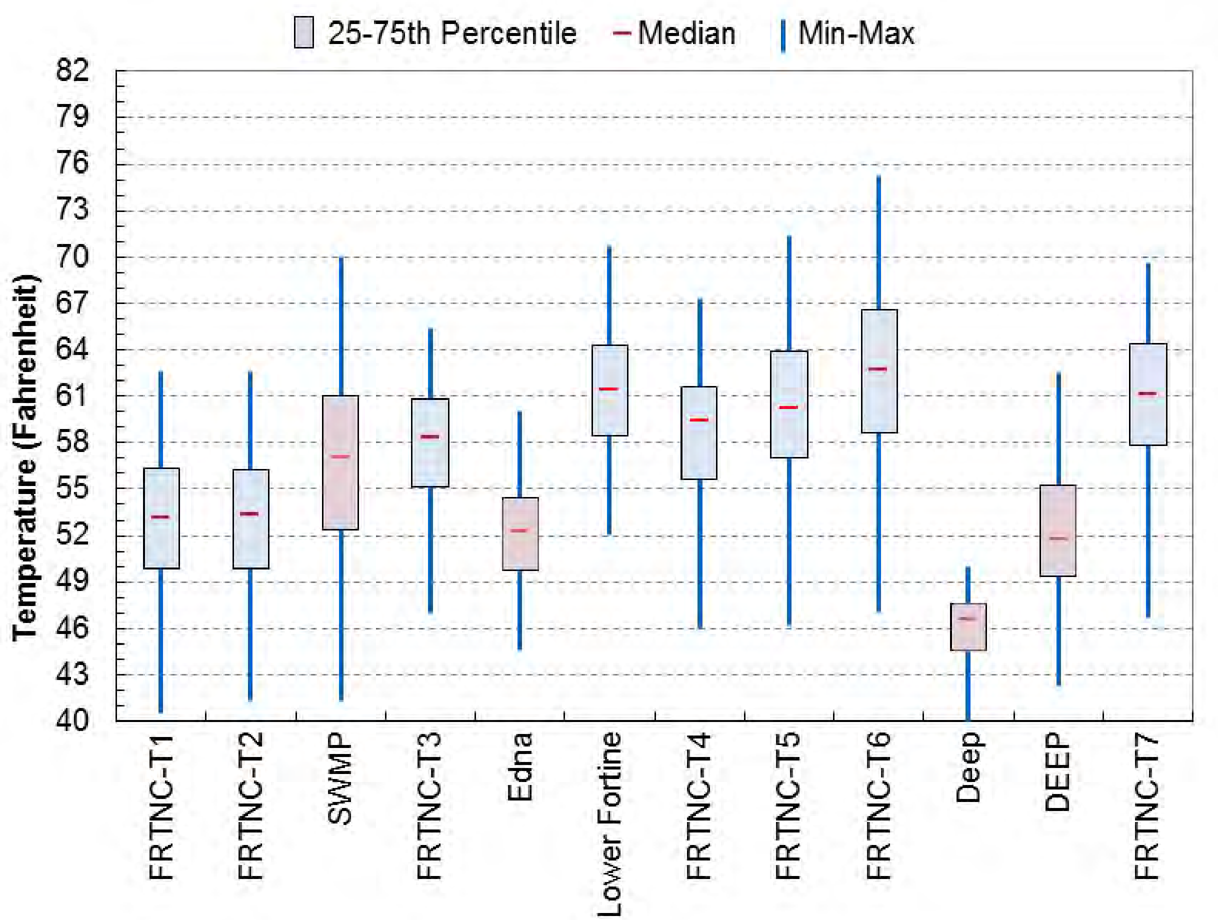

Figure 5-2. 2012 temperature logger monitoring data for Fortine Creek and three tributaries

The QUAL2K model results indicate that the maximum naturally occurring summer temperatures in Fortine Creek are less than 66.0°F, with the exception of 0.6 miles near river mile 9 (between loggers FRTNC-T5 and FRTNC-T6) where the maximum temperature is 66.3°F. As described in discussion of Montana's water quality standard (see **Table 5-1**), this means that in the small portion where naturally occurring temperatures are between 66.0°F and 66.5°F, human sources cannot increase the temperature above 67°F, but in general throughout Fortine Creek human sources cannot cause the temperature to increase by more than 1.0°F. Based on the model and temperature data, human sources have caused the allowable change target to be exceeded throughout Fortine Creek, with the increase ranging from 1.4°F to 3.5°F and averaging 2.6°F.

The existing riparian buffer along Fortine Creek is dominated by a mix of high density trees, medium density trees, shrubs, and herbaceous vegetation (**Table 5-2** and **Figure 5-3**). Much of the riparian vegetation in the upper watershed is a mix of coniferous (spruce and fir) and deciduous (alder) trees. The riparian zone in the lower watershed also contains conifers but cottonwoods are more common in the overstory and shrubs become more prevalent. Riparian vegetation at several Solar Pathfinder sites and various parts of the watershed is at its potential (**Attachment B-3**, **Appendix B**). Areas not meeting potential have been disturbed by overgrazing, timber harvest, or encroachment by development or the transportation network. The shade target is generally not being met but improvements needed to reach the target are variable throughout the watershed (**Figure 5-4,** based on the Shade Model results).

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

Land cover type	Relative area within 150ft buffer (percent)	Relative area within 50ft buffer (percent)
Bare ground/road	0.8%	0.4%
Herbaceous	18.6%	21.3%
Shrub	2.7%	1.0%
Sparse trees	19.5%	25.1%
Low density trees	4.1%	3.0%
Medium density trees	8.7%	8.3%
High density trees	20.5%	20.6%

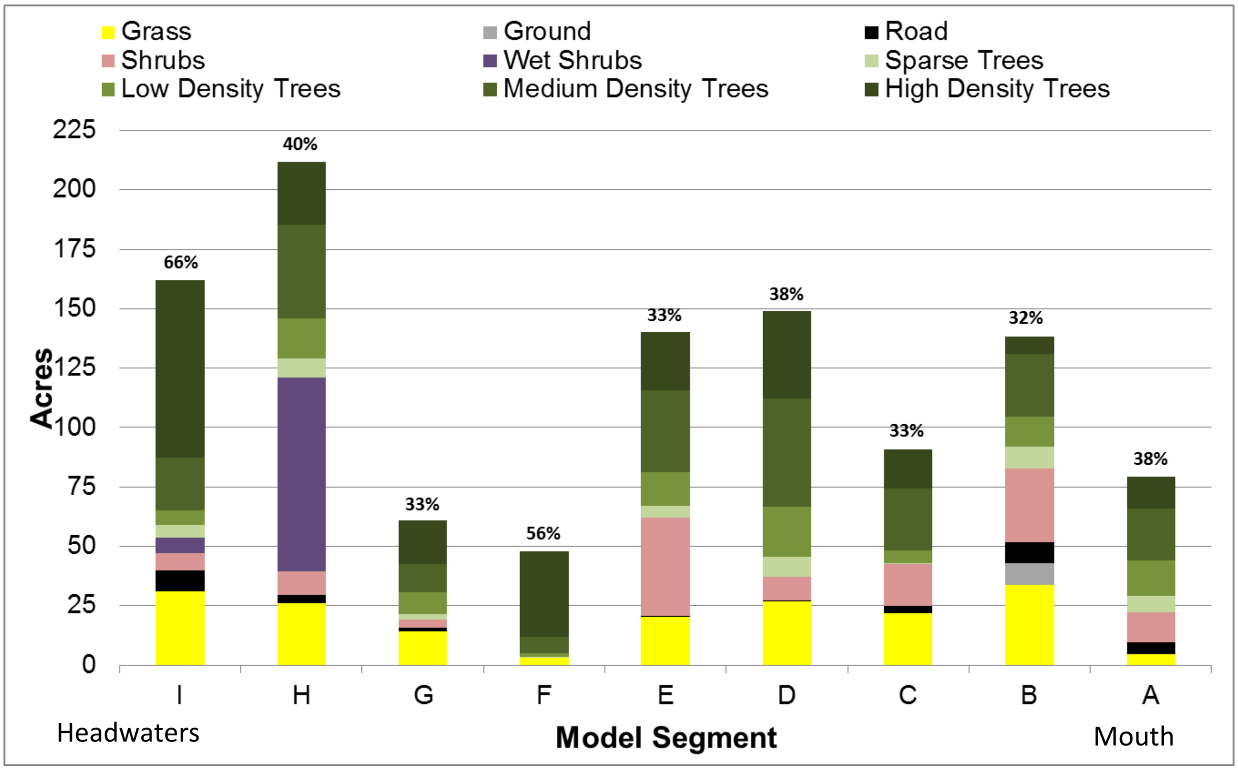

Figure 5-3. Riparian vegetation within a 150 foot buffer along Fortine Creek and the average percent existing shade (indicated above each bar) within each model segment.

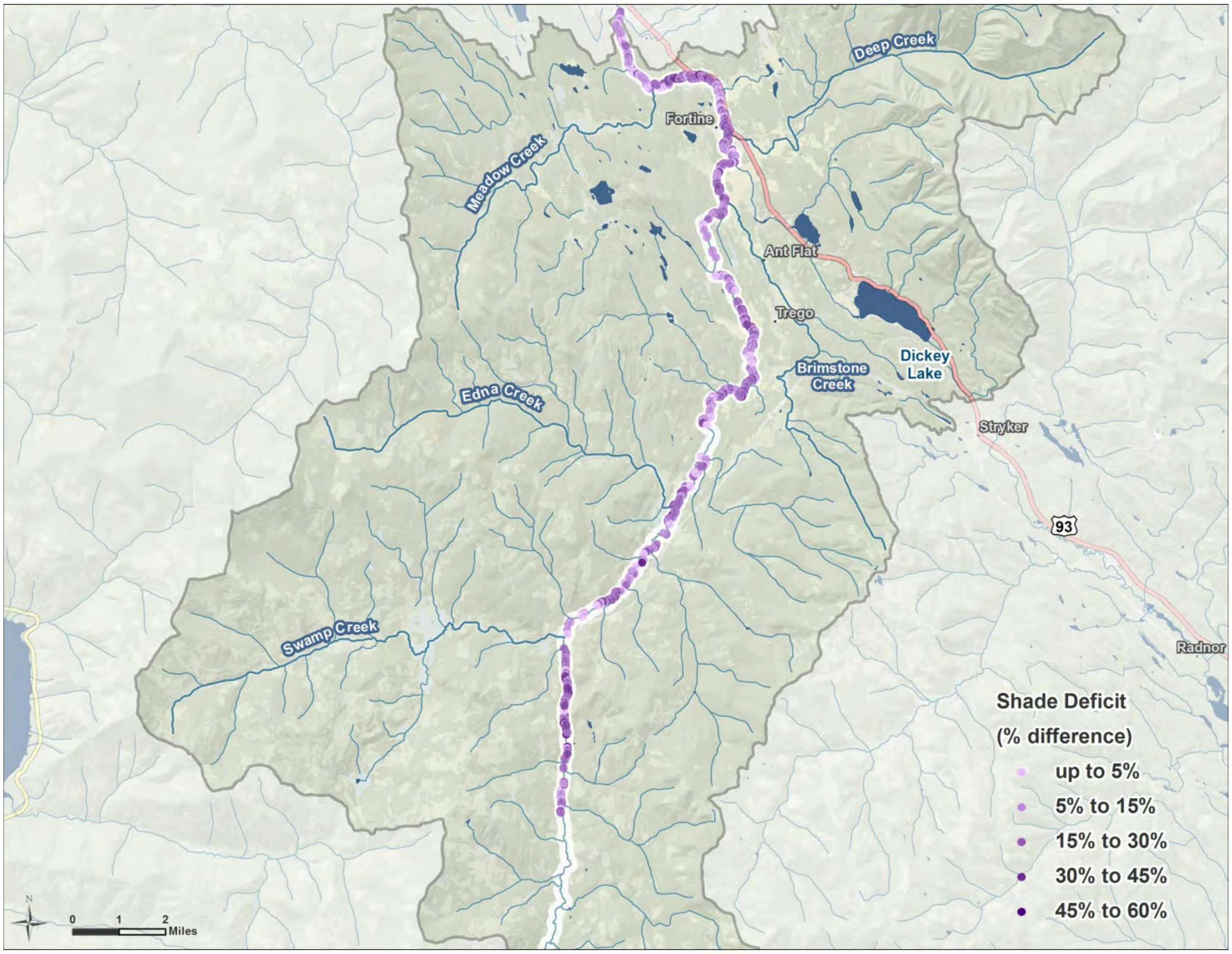

Figure 5-4. The percent of additional effective shade needed to meet the target along Fortine Creek

The width/depth ratios measured at two of the five sites visited in 2008 to support sediment TMDL development exceeded the target value (Montana Department of Environmental Quality, 2011). The overwidened sites were near Swamp Creek and near Trego. Based on bankfull channel widths measured at shade sites in 2012 compared to those measured in 2008, overwidening is still a problem in some areas.

Summary and TMDL Development Determination

The human-influenced allowable temperature change target of 1.0°F is being exceeded throughout almost all of Fortine Creek. Width/depth ratios are meeting the target in some places but measurements in 2008 and 2011, as well as documentation in DEQ's assessment file (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2014) and the Tobacco sediment TMDL document (Montana Department of Environmental Quality, 2011), indicate channel overwidening as a result of human activities is a problem in Fortine Creek. Additionally, although the riparian vegetation is at its potential in several places throughout the watershed, it is generally not meeting the shade target because of historic removal of riparian vegetation, grazing, and encroachment by development and the transportation network. This information supports the existing impairment listing and a temperature TMDL will be developed for Fortine Creek.

5.5 Source Assessment

As discussed above, the source assessment for Fortine Creek largely involved QUAL2K temperature modeling. There are no permitted point sources in the watershed. The watershed has been affected by the railroad, road network, present and historic agricultural activities (mostly grazing), and timber harvest. 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.

5.5.1 Fortine Creek Assessment Using QUAL2K

A QUAL2K model was used to determine the extent that human-caused disturbances within the Fortine Creek watershed have increased the water temperature above the naturally occurring level. The evaluation of model results focuses on the maximum daily water temperatures in Fortine 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. Each stream is segmented into reaches within the model that are assigned the same channel and shade characteristics. Segmentation is largely based on the location of field data, tributaries, irrigation withdrawal/returns, and changes in channel conditions or shading.

Within the model, Fortine Creek was divided into nine linked reaches from the mouth to the headwaters (**Figure 5-5**), with reach breaks based on available temperature and flow data, shifts in vegetation type, and changes in effective shade. The reaches were subdivided into elements that increase the spatial resolution of the model; the average element length was 0.34 miles. The water temperature and flow data collected in 2012 from Fortine Creek and three tributaries (i.e., Deep, Edna, and Swamp Creeks), along with channel measurements, irrigation data, and climate data (**Section 5.3**), were used to calibrate and validate the model. The difference between observed and modeled maximum stream temperatures for the calibration and validation averaged 1.3°F and 2.2°F, respectively, which meets the project criteria and indicates the model provides a reasonable approximation of maximum daily temperatures in Fortine Creek. While the influence of Fortine Creek tributaries was evaluated, assessing the human influences on tributary water temperatures was outside of the scope of this project because they are not identified as impaired and evaluating influences on riparian shade and streamflow would require a similar level of effort and resources as evaluating Fortine Creek.

An existing condition scenario and seven additional scenarios were modeled: two of the additional scenarios were developed to evaluate model sensitivity to streamflow and shade, three were to investigate the influence of human activities that affect riparian shade and streamflow on existing temperatures in Fortine Creek, and two were developed to evaluate stream temperatures under low streamflow conditions (**Table 5-3**). Although channel width and depth can influence stream temperatures, the existing channel dimensions were not changed for any of the scenarios because the existing dimensions are variable and field data are limited; altering channel width and depth would increase the complexity of the model and increase uncertainty in the output. The following sections describe all but the sensitivity-related modeling scenarios. In general, those scenarios showed that Fortine Creek is much more sensitive to changes in shade than streamflow. A more detailed report of those scenarios as well as the development and results of the QUAL2K model are included in **Appendix B**.

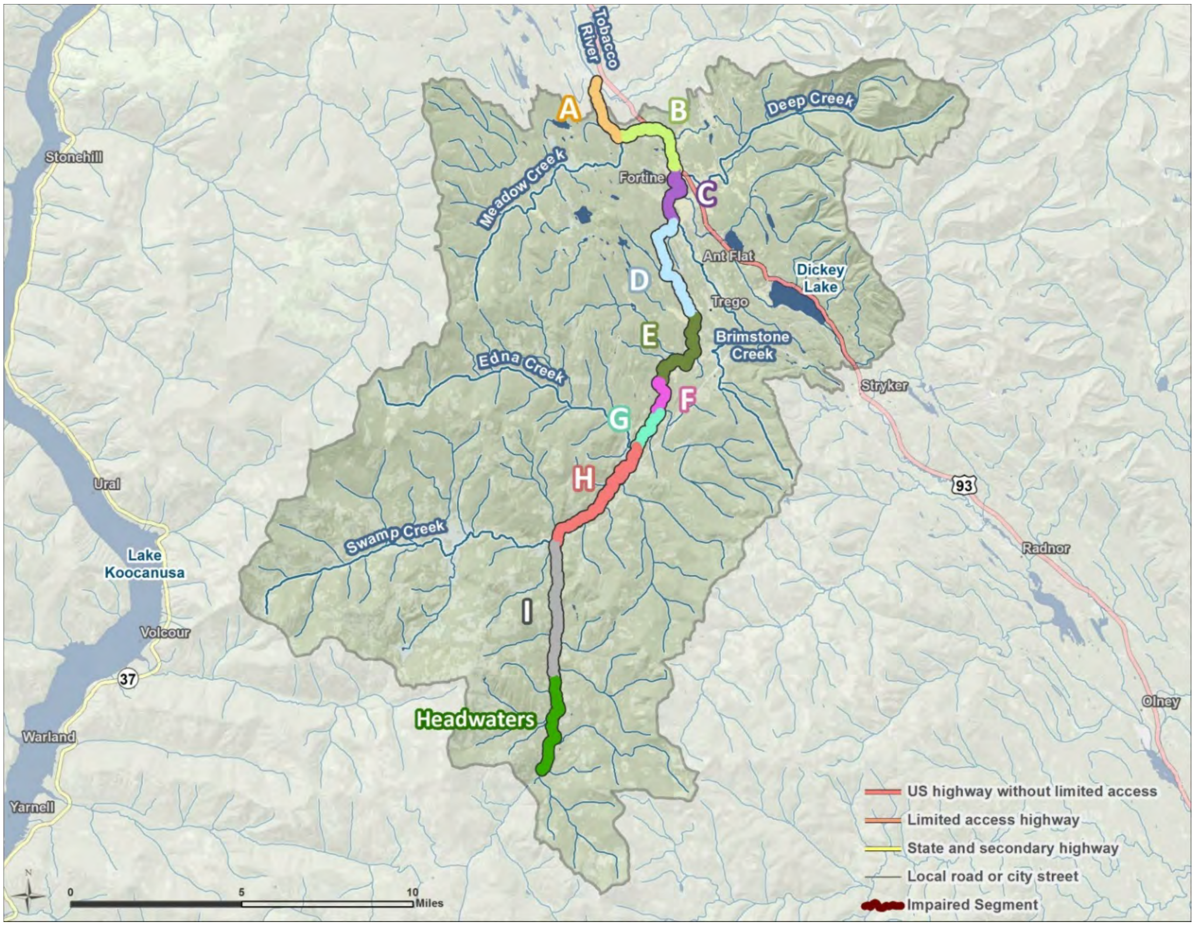

Figure 5-5. Model segmentation along Fortine Creek

Table 5-3. Fortine Creek QUAL2K model scenarios and summary of inputs

Scenario	Summary
1 - Existing Condition (baseline)	Existing condition scenario from which to test model sensitivity and management induced changes to streamflow and riparian shade. Based on current streamflow, climate, and shade conditions.
2 – No Withdrawals (sensitivity analysis)[1]	Existing condition without water withdrawals. To test the sensitivity of the model to water withdrawals and not intended for management purposes.
3 - Maximum Shade (sensitivity analysis)[1]	Existing condition with all vegetation communities within the 150 foot buffer along each side of the stream transformed to "high density trees" with the exception of roads, railroads, and areas dominated by hydrophytic shrubs[2]. To test the sensitivity of the model to shade and not intended for management purposes.
4 – Improved Shade	Existing condition with all vegetation communities, with the exception of hydrophytic shrubs[2], roads, and railroads transformed to medium density trees within 50 feet of the streambanks. Existing medium density and high density trees were retained and existing conditions vegetation was retained beyond the 50-foot buffer. To simulate achievement of all reasonable land and soil conservation practices.
5 – Improved Water Management	Existing condition with withdrawals reduced by 15%. To simulate achievement of all reasonable water conservation practices.

Table 5-3. Fortine Creek QUAL2K model scenarios and summary of inputs

Scenario	Summary
6 – Naturally Occurring	Existing condition scenario with improved riparian vegetation in a 50-foot buffer and a 15 percent reduction of water withdrawals. This is to simulate full standards attainment via the use of all reasonable land, soil, and water conservation practices.
7 – Low Flow Existing Condition	Low flow existing condition scenario. To simulate stream temperatures on a drier year than the existing condition (Scenario 1).
8 – Low Flow Naturally Occurring	Existing condition scenario with improved riparian vegetation in a 50-foot buffer and a 15 percent reduction of water withdrawals. To simulate full standards attainment via the use of all reasonable land, soil, and water conservation practices relative to the low flow existing condition (Scenario 7).

[1]This scenario was conducted for sensitivity analysis and is discussed in **Appendix B** but results are not presented in this section.

[2]Hydrophytic shrubs represent stands of willow/alder that are at or near their potential and not anticipated to attain great height at maturity. They were identified based on a combination of aerial photographs and field work.

5.5.1.1 Existing Condition Scenario (Baseline)

The existing condition scenario represents stream temperatures under existing conditions and is based on stream and climate data collected in August 2012, as described in **Section 5.3.2**. The existing condition scenario is used as a basis for comparison for all other scenarios (except 7 and 8, which are based on low flow conditions).

Under the existing condition scenario, maximum daily temperatures range from 59.4°F near the headwaters to 69.6°F almost 9 miles upstream from the mouth (**Figure 5-6**), which is near logger FRTNC-T6 and the same area where maximum temperatures were measured. Temperatures generally increase in a downstream direction with the sharpest increase between loggers FRTNC-T4 and FRTNC-T6 (around river miles 10 and 20) and then reset somewhat by decreasing by 2 or more degrees Fahrenheit downstream of FRTNC-T6 near river mile 5.6, which is where Deep Creek flows into Fortine Creek and contributes much cooler water (**Figure 5-2**).

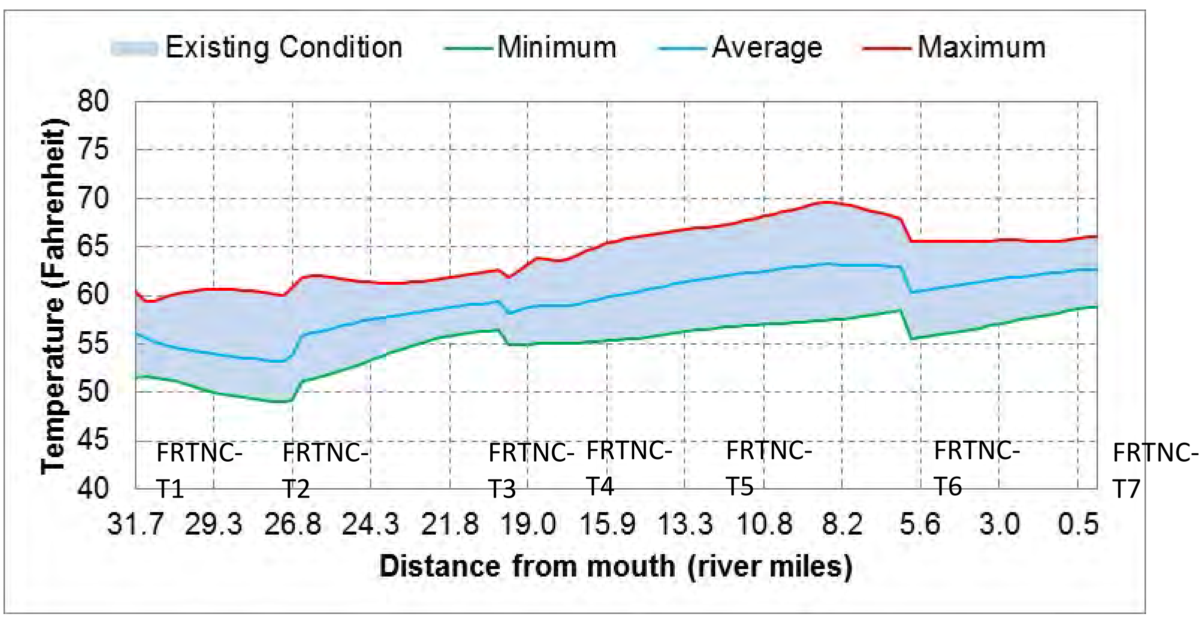

Figure 5-6. Modeled temperatures for the Fortine Creek existing condition scenario.

5.5.1.2 Improved Shade Scenario

For the improved shade scenario, the effective shade inputs to the model were set to represent the target shade condition. Since the target is a 50 foot buffer of medium density trees or any vegetation providing equivalent effective shade, the effective shade generated by a 50 foot buffer of medium density trees along Fortine Creek was calculated using the Shade Model (discussed in **Section 5.3.2.3**) and averaged for each of the nine model reaches (**Table 5-4**). Water, roads, railroads, and hydrophytic shrubs were excluded from the changes in the Shade Model. Hydrophytic shrubs was the term generally applied to stands of willow/alder that are at or near their potential and not anticipated to attain great height at maturity. They were identified based on a combination of aerial photographs and field work and determined to be all shrubs upstream of Edna Creek, which is by logger FRTNC-T3 and river mile 20. For reference to **Table 5-4**, this includes all of model segments H and I. Based on this scenario, the maximum daily stream temperature is very sensitive to improvements in riparian shade. Because the level of existing shade is variable among the reaches, the amount of improvement needed to meet the target and simulated by this scenario is also variable by reach and ranged from 1% in reach F to 18% in reach B (**Table 5-4**). By averaging all reaches, the existing shade is 56% and that needs to be improved to an average of 66%.

Table 5-4. Comparison of effective shade between the existing condition and improved shade scenario

Model Segment	Current Conditions (Existing Condition Scenario)	Improved Shade Scenario
I (near headwaters)	82%	86%
H	55%	62%
G	47%	61%
F	73%	74%
E	48%	60%
D	52%	61%
C	49%	63%
B	42%	60%
A (mouth)	53%	63%
Average	56%	66%

This scenario resulted in maximum daily temperatures ranging from 57.1°F to 66.3°F. **Table 5-5** presents the results at the temperature logger sites and **Figure 5-7** presents the continuous results along Fortine Creek. With the exception of a 0.3°F decrease in the uppermost 0.2 miles of Fortine Creek, maximum daily temperatures decrease relative to the existing condition scenario from 1.4°F to 3.5°F (**Figure 5-7**). Meeting the shade target caused an average decrease in the maximum daily temperature of 2.6°F from the existing condition scenario. The maximum decrease was in the lower watershed from logger T5 to the mouth and the smallest change was near the headwaters. The improved shade scenario indicates that human changes to the riparian vegetation are a significant source of temperature impairment.

Table 5-5. Comparison of model results between existing and improved shade scenarios

Daily temperature	Source	FRTNC-						
		T1	T2	T3	T4	T5	T6	T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	58.1	58.0	60.5	62.4	63.6	64.8	62.7
	Difference	**-1.4**	**-2.7**	**-2.0**	**-1.7**	**-3.4**	**-3.4**	**-3.4**

Notes: Results are rounded to the nearest one-tenth of a degree and the difference (bolded) is calculated as the QUAL2K result minus observed.

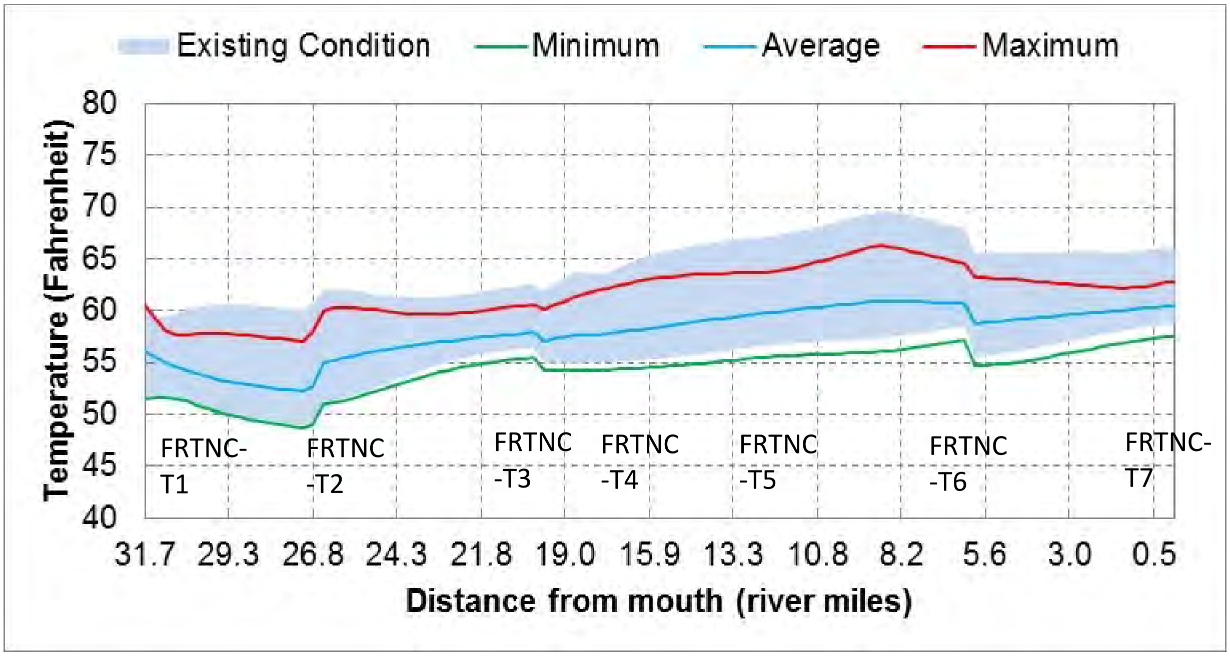

Figure 5-7. Comparison of modeled temperatures between the improved shade and existing condition scenarios.

5.5.1.3 Improved Water Management Scenario

Because the naturally occurring condition referenced in the temperature standard includes the use of all reasonable water conservation practices (Administrative Rules of Montana (ARM) 17.30.602(17)), an improved water management scenario was conducted to evaluate the effect that water conservation measures resulting in more instream flow would have on temperatures in Fortine Creek.

The irrigation withdrawals are most concentrated near Edna Creek and then occur periodically all the way to the mouth of Fortine Creek, with the largest withdrawal (3 cfs) occurring downstream of Brimstone Creek (**Figure B-9**, **Appendix B**). In this scenario, the 15 potentially significant irrigation withdrawals (which were collectively estimated to withdraw 6.24 cfs daily; see **Appendix B)** were reduced by 15% within the model and that savings of 0.94 cfs (6.24 * 0.15 = 0.94) was allowed to remain in the stream. The Natural Resources Conservation Service Irrigation Guide (Natural Resources Conservation Service, 1997) states that improving an existing irrigation system often increases water application efficiency by more than 30% and installing a new system typically adds an additional 5% to 10% savings. These improvements in efficiency could be used to grow different crops, expand production, or withdraw 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.

However, 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), so 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 instream. Considering the statistics presented above from the NRCS Irrigation Guide and other sources that evaluated efficiency improvements for different irrigation practices (Negri and

Brooks, 1990; 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 Fortine 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.

Under the improved water management scenario, improving water use efficiency and withdrawing 15% less water causes a negligible decrease in temperatures along Fortine Creek that does not start until between loggers FRTNC-T2 and FRTNC-T3 (**Table 5-6**). The reason for such a small change is likely because the 0.94 cfs left instream for this scenario is based on 15% less water being withdrawn at 15 locations that span 25 stream miles over which streamflow increases from approximately 10 cfs to almost 60 cfs. The daily maximum temperatures are almost identical to the existing condition scenario with modeled differences typically only at the hundredths place; they range from 59.4°F to 69.6°F. The change in maximum daily temperatures relative to the existing condition scenario ranged from a decrease of 0.06°F to an increase of 0.02°F, with an average decrease of 0.02°F. The largest decrease in daily maximum temperatures occurs between loggers FRTNC-T5 and FRTNC-T6 near Brimstone Creek and river mile 9.0, which is where the largest withdrawal is located. The results from this scenario indicate consumptive water usage is generally having a very small effect on water temperatures and is a much smaller source than shade.

Table 5-6. Comparison of model results between the existing and improved water management scenario

Daily temperature	Source	FRTNC-						
		T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	59.5	60.8	62.5	64.1	67.0	68.1	66.1
	Difference	**0**	**0**	**-0.001**	**-0.01**	**-0.02**	**-0.02**	**-0.04**

Notes: Results are rounded to the nearest one-tenth of a degree and the difference (bolded) is calculated as the QUAL2K result minus observed. For this scenario only, the differences are reported to greater decimal places because the change is so small.

5.5.1.4 Naturally Occurring Scenario (Full Application of BMPs with Current Land Use)

The naturally occurring scenario represents Fortine Creek water temperatures when all reasonable land, soil, and water conservation practices are implemented (Administrative Rules of Montana (ARM) 17.30.602). The naturally occurring scenario is a combination of the improved shade and water management scenarios. Although water conservation measures resulting in additional instream flow will only cause a slight decrease in maximum daily stream temperatures relative to improvements in shade, the conditions applied in the improved water management scenario were included because water conservation is a component of the naturally occurring condition and DEQ wanted to evaluate the effect of improvements to both shade and streamflow (via irrigation efficiency).

Table 5-7 presents the results at the temperature logger sites and **Figure 5-8** presents the continuous results along Fortine Creek. The naturally occurring scenario maximum daily temperatures ranged from 57.1°F to 66.3°F, with an average of 61.8°F. Therefore, as previously stated, with the exception of a 0.6-mile section where the naturally occurring temperature is up to 66.3°F and human sources cannot increase the temperature above 67.0°F, an increase of 1°F is allowed from human sources. Because this is such a small portion of Fortine Creek, which is 33.5 miles, the one degree allowable change will be the focus of discussion in most of this section.

The naturally occurring scenario results indicate there is the potential for significant reductions in stream temperatures relative to the existing condition: the potential temperature decreases from this scenario as compared to the existing condition scenario ranged from 0.3°F to 3.5°F, with an average decrease of 2.6°F (**Figure 5-9**). The 0.3°F decrease is the only change less than 1.4°F and occurs at the most upstream element, which represents approximately 0.2 miles of stream (see white dot on **Figure 5-10**). Like the shade scenario, the maximum decrease was in the lower watershed downstream of site FRTNC-T5 near Trego to the mouth and the smallest change was near the headwaters and between Swamp and Edna Creeks (i.e., between sites FRTNC-T2 and FRTNC-T3 at river mile 25) (**Figure 5-10**).

Table 5-7. Comparison of model results between the existing and naturally occurring scenario

Daily temperature	Source	FRTNC-						
		T1	T2	T3	T4	T5	T6	T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	58.1	58.0	60.5	62.4	63.6	64.8	62.7
	Difference	**-1.4**	**-2.8**	**-2.0**	**-1.7**	**-3.4**	**-3.4**	**-3.4**

Notes: Results are rounded to the nearest one-tenth of a degree and the difference (bolded) is calculated as the QUAL2K result minus observed.

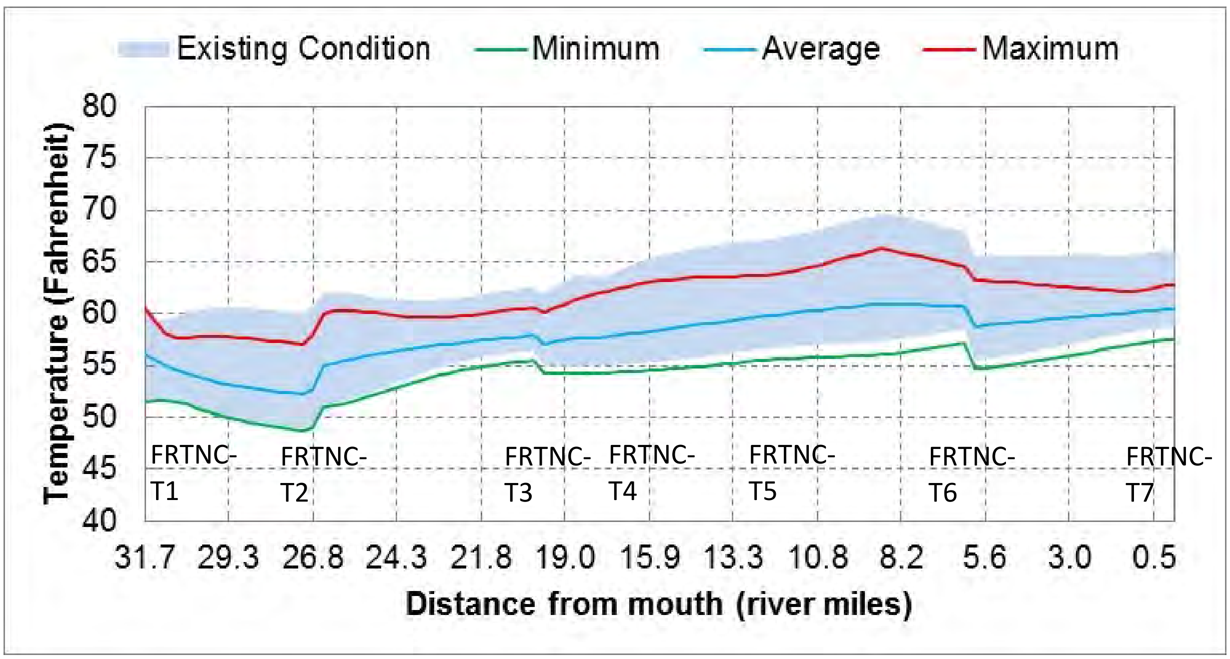

Figure 5-8. Comparison of modeled temperatures between the naturally occurring and existing condition scenarios.

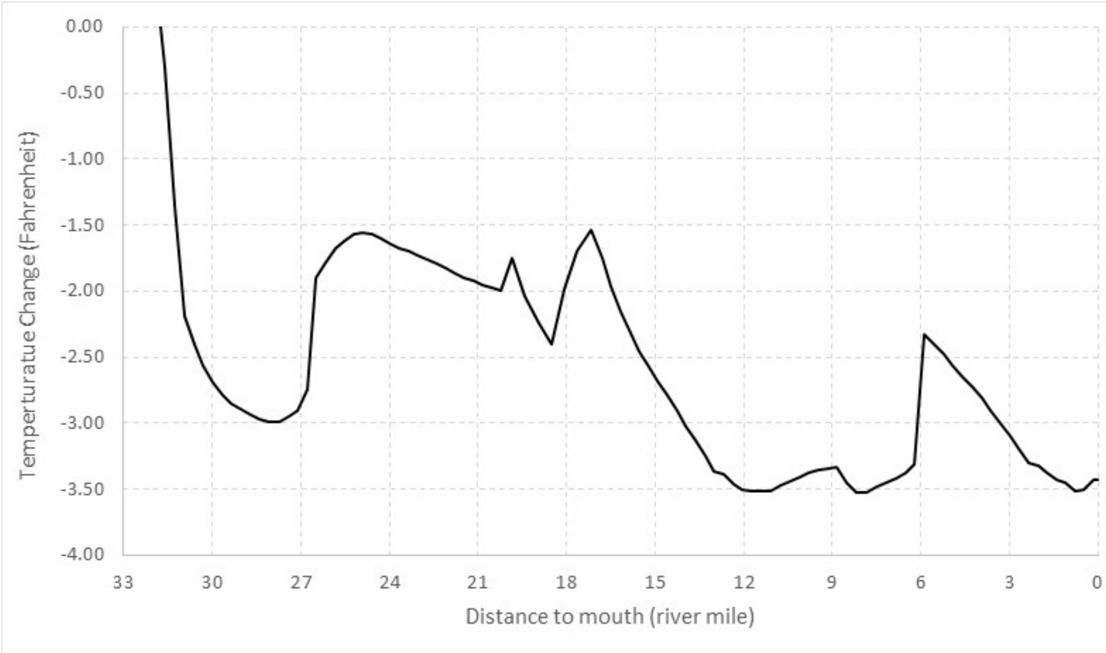

Figure 5-9. Temperature difference between the naturally occurring and existing condition scenarios

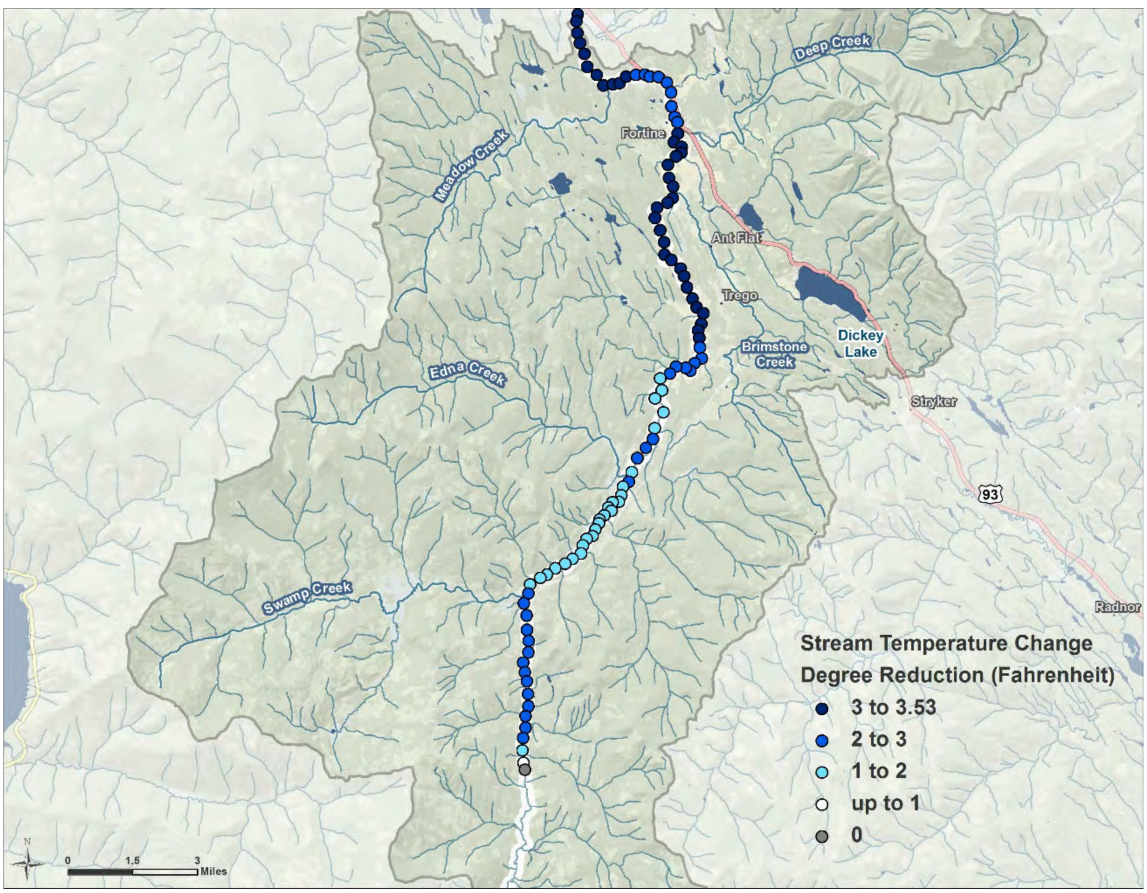

Figure 5-10. Temperature reductions that can be obtained under naturally occurring conditions (relative to the existing condition scenario)

5.5.1.5 Low Flow Existing Condition Scenario (Alternative Baseline)

Because streamflow conditions in August 2012 that were used to develop the existing condition scenario were well above the August average (approximately the 87th percentile flow for that day) and a goal of the model is to evaluate stream temperatures during hot, dry conditions when aquatic life are most likely to be stressed, an alternative baseline scenario was developed to represent existing temperatures during a year with much less flow. This scenario uses existing shade, channel, and climate conditions (which were applied in the existing condition scenario) but flow to Fortine Creek was reduced by 56 percent, which is estimated to be the 25th percentile flow. This reduction is based upon the low flow analysis for August 10 at the nearby Tobacco River USGS gage 12301300 (as discussed in **Appendix B**). Using the streamflow data from the gage for August 10, 2012 (the model calibration date), the flow would need to be 56% less to be at the 25th percentile flow for that day. Therefore, no measurements were used directly from the stream gage but instead its long term flow record was used to estimate the reduction to apply to measured flows in Fortine Creek.

Since the amount of water in the stream channel affects its ability to buffer incoming solar radiation, and less water will heat up faster, the low flow existing condition scenario results in warmer water temperatures along all of Fortine Creek relative to the existing condition scenario (**Section 5.5.1.1**). Maximum daily temperatures range from 60.5°F near the headwaters to 77.5°F several miles upstream from the mouth. Compared to the existing condition scenario, daily maximum temperatures at the logger sites increase between 1.2° F and 8.0° F (river mile-weighted average increase of 5.1° F). Therefore, the results of the low flow existing condition scenario indicate that stream temperatures would be quite a bit warmer during years with less streamflow. Note, this scenario is an alternative baseline and does not reflect any changes in land management; therefore, it should not be compared to any of the previously discussed scenarios when evaluating impairment or the potential decreases in temperature associated with improvements in shade/water management.

5.5.1.6 Naturally Occurring Low Flow Condition Scenario

The naturally occurring low flow scenario is equivalent to the naturally occurring condition scenario in regards to improvements in shade and water management but differs in that those changes were applied using the low flow existing condition scenario as the starting point. This scenario is intended to represent application of all reasonable land, soil, and water conservation practices during low flow conditions.

Similar to the naturally occurring condition scenario relative to the existing condition, this scenario results in cooler water temperatures along Fortine Creek; however, the decrease in maximum temperatures are all greater in magnitude. This means that under lower streamflows than measured in 2012, improvements in shade and streamflow have a more pronounced effect. **Table 5-8** presents the results at the temperature logger sites and **Figure 5-11** presents the continuous results along Fortine Creek. The naturally occurring low flow scenario maximum daily temperatures ranged from 59.0°F to 73.1°F, with an average of 65.5°F. Because the naturally occurring temperature under low flow conditions in portions of Fortine Creek is greater than 66.5°F, the allowable human-caused increase in temperature for those areas is 0.5°F (instead of 1.0°F). This applies from logger FRTNC-T4 downstream, which is about 17 miles upstream from the mouth. Relative to the low flow existing condition scenario, daily maximum temperatures decrease between 1.7°F and 5.4°F (river mile-weighted average decrease of 3.9°F).

Table 5-8. Comparison of model results between the low flow existing condition and low flow naturally occurring scenarios

Daily temperature	Source	FRTNC-						
		T1	T2	T3	T4	T5	T6	T7
Maximum	Existing	62.2	64.4	67.1	69.3	73.5	73.5	72.9
	Scenario	59.7	60.6	64.2	66.9	68.4	68.5	68.3
	Difference	**-2.5**	**-3.8**	**-2.9**	**-2.6**	**-5.1**	**-5.0**	**-4.6**

Notes: Results are rounded to the nearest one-tenth of a degree and the difference (bolded) is calculated as the QUAL2K result minus observed.

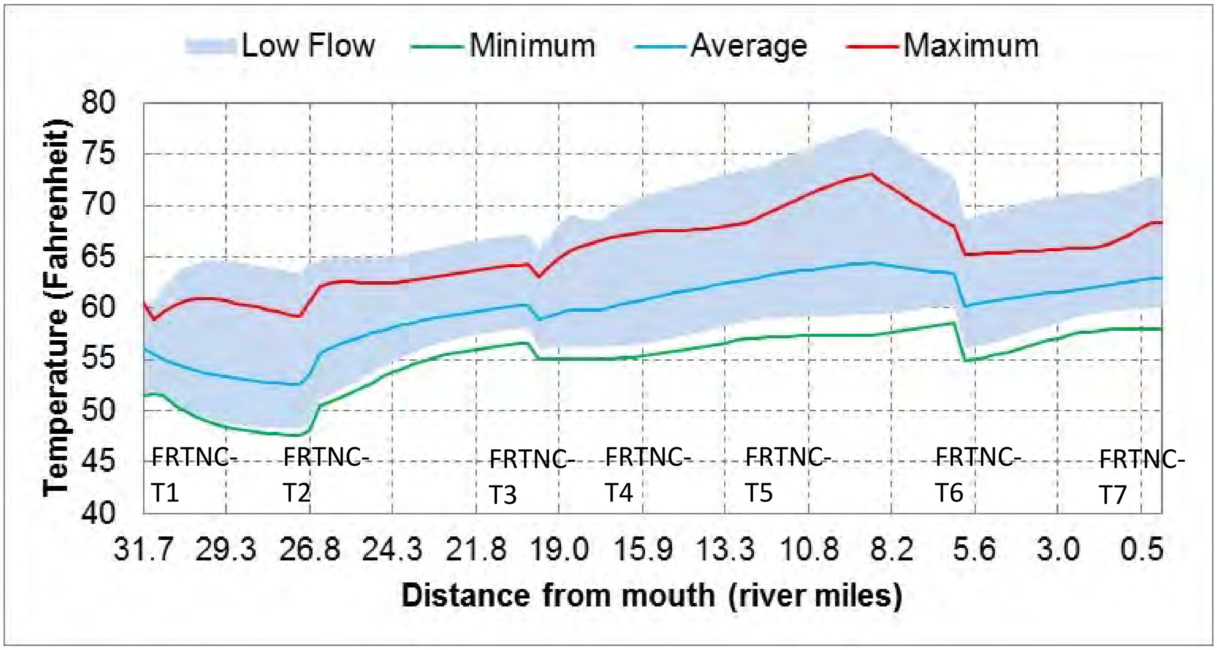

Figure 5-11. Comparison of modeled temperatures between the low flow naturally occurring and low flow existing condition scenarios.

5.5.2 Scenario Summary

Scenarios representing increased shading (i.e., improved shade and naturally occurring scenarios) showed decreased water temperatures by more than 1.0°F at all of the logger sites and at all but a 0.2-mile section near the headwaters, as compared to the existing condition. The scenario representing improvements in water management showed such small changes in water temperatures that results for the improved shade and naturally occurring condition scenario were almost identical.

Under existing conditions, reductions in maximum daily water temperatures ranging from 1.4°F to 3.5°F are necessary to meet the temperature water quality standard. The low flow existing condition scenario indicates maximum temperatures throughout Fortine Creek will be quite a bit higher during years with lower streamflow than 2012, resulting in a smaller allowable human-caused change in temperature and the need for greater reductions. Under low flow conditions, like those simulated by the low flow existing condition scenario, reductions in maximum daily water temperatures ranging from 1.7°F to 5.4°F are necessary to meet the temperature water quality standard.

A comparison of maximum daily temperatures at each logger for all of the scenarios is presented in the following figures: **Figures 5-12** and **5-13** summarize all of the management scenario results in maximum daily temperature and the temperature difference relative to the existing condition, respectively. **Figures 5-14** and **5-15** summarize the maximum daily temperature for just the existing condition and naturally occurring scenario results and the temperature difference between those scenarios, respectively.

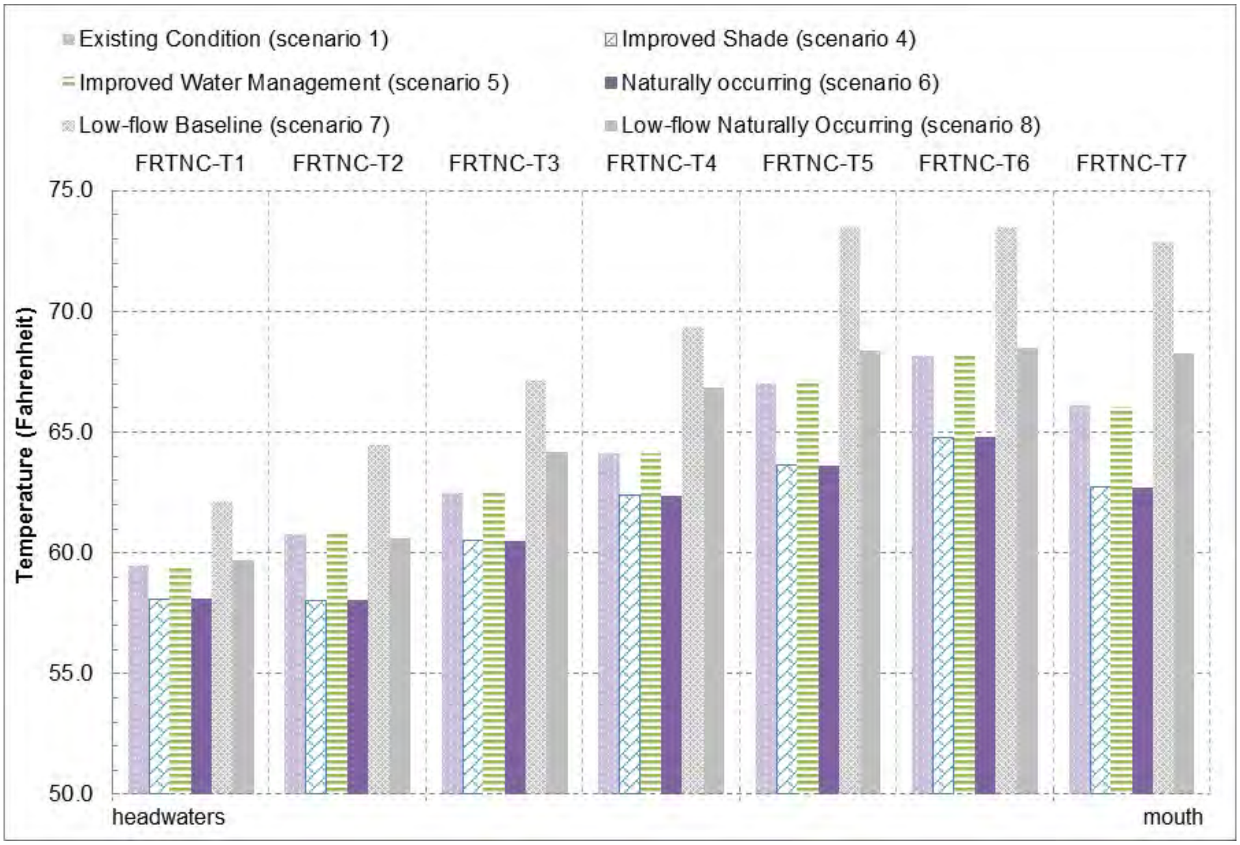

Figure 5-12. Maximum daily water temperature along Fortine for each scenario

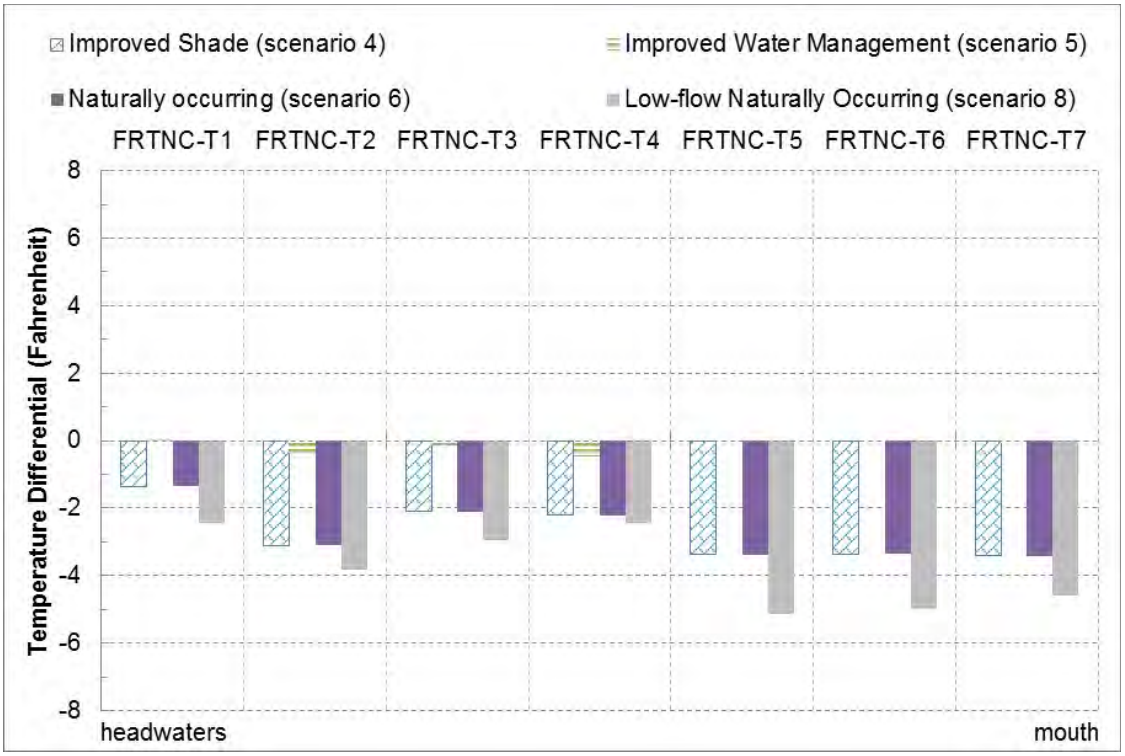

Figure 5-13. Comparisons to the existing condition scenarios (shown as the difference in simulated maximum daily water temperatures). The low flow scenario is compared to the low flow existing.

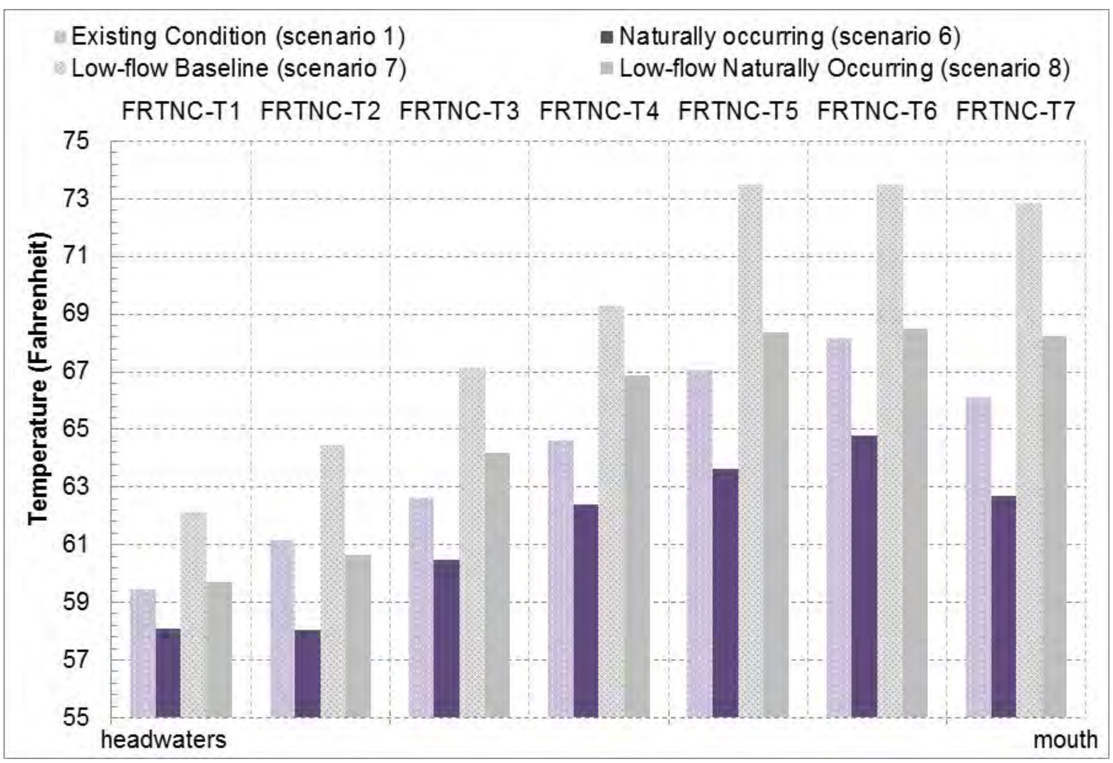

Figure 5-14. Maximum daily temperature along Fortine Creek for both existing condition scenarios and their respective naturally occurring scenarios

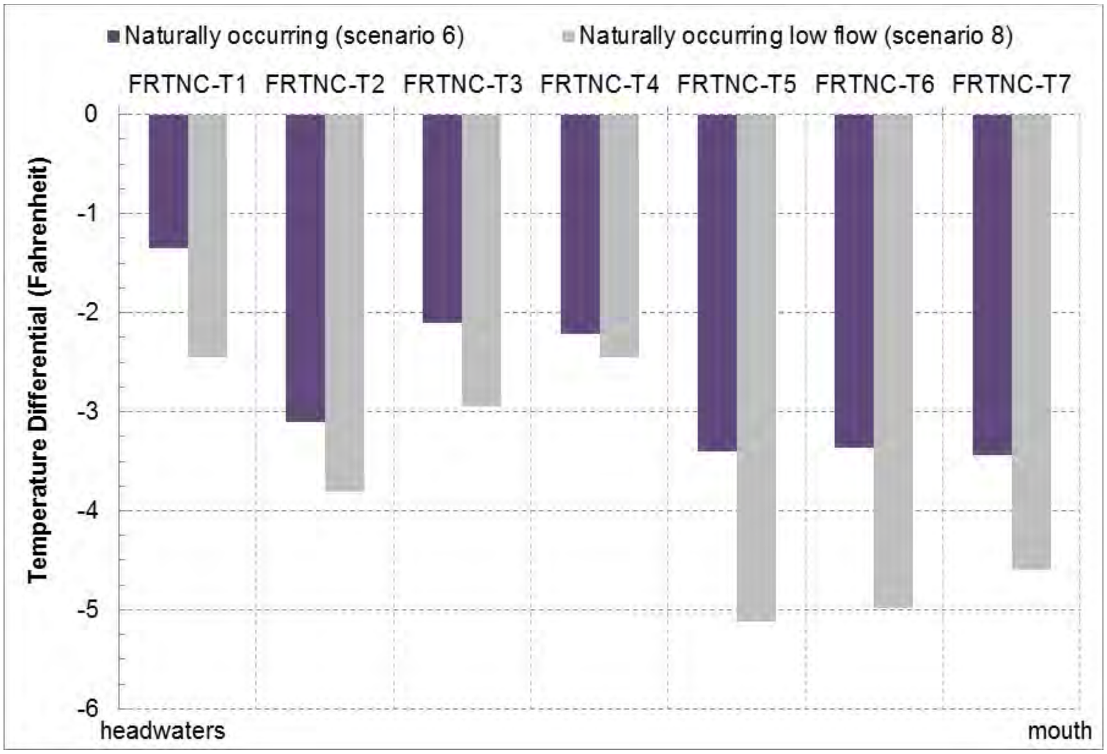

Figure 5-15. Temperature difference between both naturally occurring scenarios and their respective existing condition scenarios (as simulated maximum daily water temperatures)

5.5.3 QUAL2K Model Assumptions

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

- Fortine Creek can be divided into distinct reaches, each considered homogeneous for shade, flow, and channel geometry characteristics. Monitoring site locations were selected to be representative of reaches of Fortine Creek.
- Stream meander and subsurface flow paths (both of which may affect depth-velocity and temperature) are inherently represented during the estimation of various parameters (e.g., stream slope, channel geometry, and Manning's roughness coefficient) for each reach.
- Weather conditions at the Eureka remote automatic weather stations (RAWS), which were elevation-corrected, are representative of local weather conditions along Fortine Creek.
- Adjustments made to streamflow for the low flow existing condition scenario adequately represent existing conditions on a much drier summer than 2012.
- Shade Model results are representative of riparian shading along reaches of Fortine Creek.
- All of the cropland associated with water rights is fully irrigated. No field measurements of irrigation withdrawals or returns were available. Application of some water conservation measures resulting in a 15% decrease in the assumed water withdrawn is reasonable and consistent with the definition of the naturally occurring condition.
- The effective shade provided by a 50 foot buffer of medium density trees 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 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 earlier, the temperature standard for Fortine Creek 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 Fortine Creek relative to naturally occurring temperatures is depicted in **Figure 5-16**. As stated in **Section 5.5.1.4**, maximum daily temperatures in Fortine Creek during the naturally occurring scenario are generally less than 66°F, which means the allowable increase caused by human sources during the hottest part of the summer is typically 1.0°F. However, as indicated by the low flow naturally occurring scenario (**Section 5.5.1.6**), water temperatures during low flow years are expected to be greater than 66.5°F from logger FRTNC-T4 downstream, meaning the allowable human-induced temperature change under those conditions is 0.5°F.

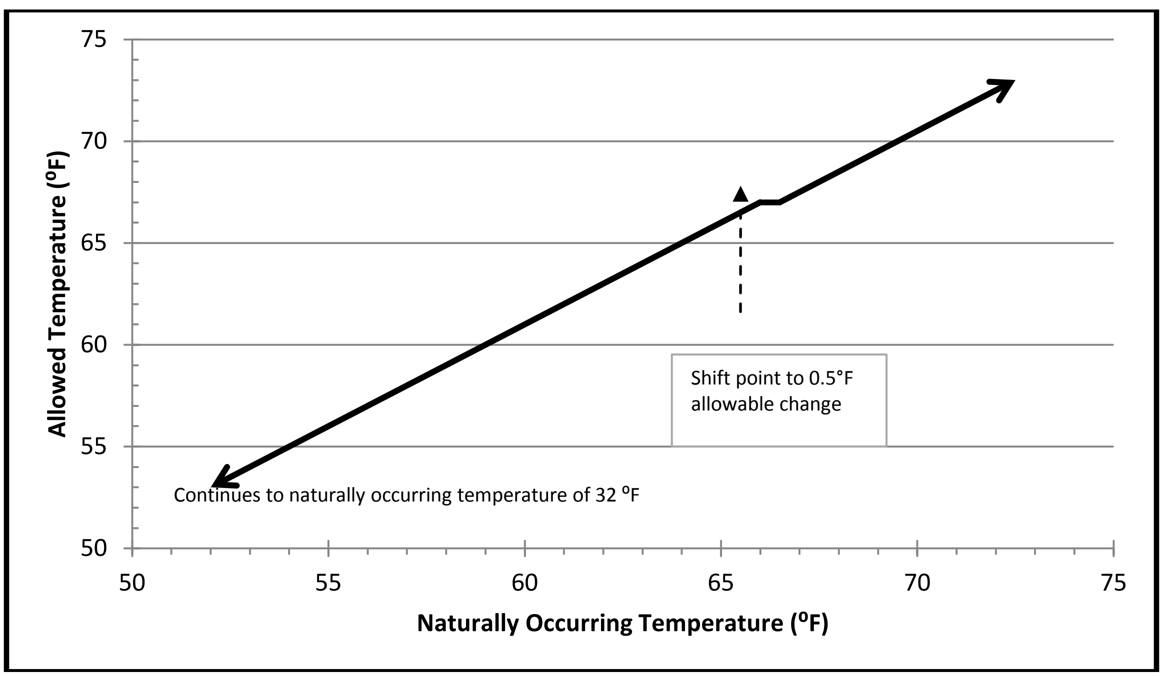

Figure 5-16. Line graph of the temperature standard that applies to Fortine Creek

For any naturally occurring temperature over 32°F (i.e., water's freezing point), the allowable instantaneous thermal total maximum load (kcal/per second) can be calculated using the standard to identify the allowable human-caused increase (stated above and shown in **Figure 5-16**) 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)
28.3 = conversion factor

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 (which is 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 and width/depth 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 ratio, 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. Example instantaneous TMDLs 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 for Fortine Creek

The example TMDLs expressed as an instantaneous load are presented in **Table 5-9** and the surrogate TMDL and allocations are presented in **Table 5-10**. The example TMDLs are a direct translation of the water quality standard into a thermal load. There are no point sources and the entire allowable load is allocated to natural and human sources that influence temperature. The example TMDLs are based on the modeled improved shade scenario/naturally occurring scenario maximum daily temperature at the mouth during summer and the modelled low flow naturally occurring maximum daily temperature at the mouth.

The naturally occurring temperature (i.e., TMDL basis) at the mouth based on existing conditions is 62.7°F, which means there is an allowable human-caused increase of 1.0°F and the allowable temperature would be 63.7°F. The maximum daily temperature at the mouth under the existing condition scenario was 66.1°F (which is actually 3.5°F less the measured maximum daily temperature at that location in 2012). The calculations for the existing load and example TMDL based on existing conditions and following **Equation 5-1** are as shown below. Note, the existing flow measured at the mouth (logger FRTNC-T7) is 59.3 cfs.

Existing Conditions TMDL = (((62.7 + 1.0) – 32) * 5/9) * 59.3 * 28.3 = 29,555 kcal/second
Existing Load = ((66.1 – 32) * 5/9) * 59.3 * 28.3 = 31,792 kcal/second

In comparison, the low flow naturally occurring temperature (i.e., TMDL basis) at the mouth based on low flow existing conditions is 68.3°F, which means there is an allowable human-caused increase of 0.5°F and the allowable temperature would be 68.8°F. The maximum daily temperature at the mouth under the low flow existing condition scenario was 72.9°F (which is 3.3°F more the measured maximum daily temperature at that location in 2012). The calculations for the low flow existing load and example TMDL based on low flow existing conditions and following **Equation 5-1** are as shown below. Note, the low flow value for the mouth is 26.1 cfs (based on reducing 59.3 cfs by 56%).

Low Flow Existing Conditions TMDL = (((68.3 + 0.5) – 32) * 5/9) * 26.1 * 28.3 = 15,101 kcal/second
Low Flow Existing Load = ((72.9 – 32) * 5/9) * 26.1 * 28.3 = 16,783 kcal/second

The surrogate TMDL contains allocations to temperature-influencing factors that will result in standards attainment when met. Because there are no point sources, there is no wasteload allocation. 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 5-9. Example Instantaneous Temperature TMDLs and Allocation for Fortine Creek at the mouth

TMDL Example	Source Type	Modeled Existing Load (kcal/sec)	TMDL/Load Allocation (kcal/sec)[1]	Percent Reduction Needed
Existing Conditions (based on 2012 data)	Natural and human sources that influence temperature	31,792	29,555	7%
Low Flow Existing Conditions	Natural and human sources that influence temperature	16,783	15,101	10%

[1]This can be converted to a daily load by multiplying by 86,400 (i.e., 29,555 kcal/sec * 86,400 = 2,553,552,000 kcal/day)

Table 5-10. Surrogate Temperature TMDL and Allocations for Fortine Creek

Source Type	Surrogate Allocation
Land uses and practices that reduce riparian health and shade provided by near-stream vegetation along Fortine Creek.	• Improve to and maintain a 50 foot buffer with medium density trees or any vegetation providing equivalent effective shade

Table 5-10. Surrogate Temperature TMDL and Allocations for Fortine Creek

Source Type	Surrogate Allocation
Land uses and practices that result in the overwidening of the stream channel such that widths are increased, depths are decreased, and thermal loading is accelerated	No increase in average width or width/depth ratios due to human-caused sources: • Where bankfull width ≤ 30 feet, a width/depth ratio ≤ 21 • Where bankfull width > 30 feet: a width/depth ratio ≤ 35
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, channel width, and instream flow.**

5.6.2.1 Meeting Temperature Allocations

Since riparian shade is the primary source of the impairment, improving the effective shade will be the primary mechanism for implementing and achieving the TMDL. DEQ realizes that re-establishment of a riparian overstory and meeting the effective shade target will likely take a long time. In many instances, current management practices are meeting the intent of the allocations, and the commitment to improving water quality needs to be maintained so that the existing riparian vegetation can continue to mature. The targets and allocations represent the desired conditions that would be expected in most areas along the stream, but as discussed relative to shade, width/depth ratios, 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.

Because the improved shade scenario and naturally occurring scenario yielded almost identical results, the numeric TMDL can be met without changes in water use. These results also indicate that there may no longer be a low flow alterations impairment on Fortine Creek, and that should be investigated. However, because no on-the-ground assessment was conducted of the irrigation network, using irrigation BMPs may have a larger effect during years with lower streamflow, and as part of the implicit MOS, the surrogate TMDL does contain an allocation to apply all reasonable water conservation practices. Water users in the Fortine Creek watershed are encouraged to work with the USDA 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 Fortine Creek.

For both the numeric and surrogate TMDLs, the intent and measure of success for all allocations is to follow all reasonable land, soil, and water conservation practices. Future evaluations of TMDL implementation and impairment status will not only assess conservation practices in the watershed but will also use adaptive management (as described in **Section 5.8** and **7.2**) to determine if targets applied within this document are still appropriate.

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 Fortine 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 for Fortine Creek was based on the August solar path, which is typically the hottest month of the year.
- Although the maximum daily temperature was the focus for 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. Scenario results for daily temperature minimum and mean are presented in **Appendix B**.
- 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.

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 Fortine Creek investigated stream temperatures during summer when effects of increased water temperatures are most likely to have a detrimental effect on aquatic life. Additionally, low flow scenarios were developed to represent stream temperatures under more critical conditions than those observed in 2012 and how stream temperatures under those conditions would respond to implementation of all reasonable land, soil, and water conservation practices. Under the low flow scenarios, the channel dimensions were not changed in the model, which is a conservative assumption since channel wetted width frequently becomes narrower under low flow conditions.
- Despite the modest improvement in stream temperature that could be obtained by implementing conservation measures to leave additional water instream, the source assessment and allocations address consumptive use as a potential human source and recommend the use of all reasonable water conservation measures.
- Compliance with 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) (ATKINS, 2012) and adhering to DEQ sampling protocols (Montana Department of Environmental Quality, 2005b; 2005a). A QAPP was also completed for the QUAL2K model (Tetra Tech, Inc., 2012), 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 5.5.2** but are further detailed within the model report in **Appendix B**.

The largest source of uncertainty is regarding the targets and conditions used to represent the naturally occurring condition. The target for width/depth ratio was developed as part of the sediment TMDL process for the Tobacco watershed (Montana Department of Environmental Quality, 2011) and is based on reference data. 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, communication with stakeholders, and best professional judgment. It was selected to be conservative yet achievable, and 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. Since no information is known regarding current irrigation practices within the watershed, there is also uncertainty regarding current conservation practices and the potential for improvement. This uncertainty is the reason there is no numeric target for improving instream flow and no numeric allocation. 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. Although this uncertainty within the model results in error bars around the modeled temperatures for each scenario, the magnitude of temperature increase caused by human sources still exceeds the allowable change for most of Fortine Creek. 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 current weather conditions, which inherently accounts for any global climate change to date. The low flow scenarios were developed to evaluate temperatures when streamflow is at approximately the 25th percentile, which may be an indication of temperatures under future climate conditions, but because of the complexities in predicting future air temperatures and precipitation, it was not intended to be a climate change scenario. 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 NUTRIENTS TMDL COMPONENTS

This section focuses on nutrients (total nitrogen [TN], and total phosphorus [TP] forms) as a cause of water quality impairment in the Tobacco TMDL Planning Area (TPA). It includes 1) nutrient impairment of beneficial uses; 2) specific stream segments of concern; 3) currently available data on nutrient impairment assessment in the watershed, including target development and a comparison of existing water quality targets; 4) quantification/description of nutrient sources based on recent studies; and 5) identification and justification for nutrient TMDLs and TMDL allocations.

6.1 EFFECTS OF EXCESS NUTRIENTS ON BENEFICIAL USES

Nitrogen and phosphorus are natural background chemical elements required for the healthy and stable functioning of aquatic ecosystems. Streams in particular are dynamic systems that depend on a balance of nutrients, which is affected by nutrient additions, consumption by autotrophic organisms, cycling of biologically fixed nitrogen and phosphorus into higher trophic levels, and cycling of organically fixed nutrients into inorganic forms with biological decomposition. Additions from natural landscape erosion, groundwater discharge, and instream biological decomposition maintain a balance between organic and inorganic nutrient forms. Human influences may alter nutrient cycling pathways, causing damage to biological stream function and water quality degradation.

Excess nitrogen in the form of dissolved ammonia (which is typically associated with human sources) can be toxic to aquatic life. Elevated nitrates in drinking water can inhibit normal hemoglobin function in infants. Besides the direct effects of excess nitrogen, elevated inputs of nitrogen and phosphorus from human sources can accelerate aquatic algal growth to nuisance levels. Respiration and decomposition of excessive algal biomass depletes dissolved oxygen, which can kill fish and other forms of aquatic life. Nutrient concentrations in surface water can lead to blue-green algae blooms (Priscu, 1987), which can produce toxins lethal to aquatic life, wildlife, livestock, and humans.

Aside from toxicity, nuisance algae can shift the macroinvertebrate community structure, which may then affect fish that feed on macroinvertebrates (U.S. Environmental Protection Agency, 2010). Additionally, changes in water clarity, fish community structure, and aesthetics can harm recreational uses, such as fishing, swimming, and boating (Suplee et al., 2009). Nuisance algae can increase treatment costs of drinking water or pose health risks if ingested in drinking water (World Health Organization, 2003).

6.2 STREAM SEGMENT OF CONCERN

There is one waterbody segment in the Tobacco TPA that is on the 2014 Montana 303(d) List for nutrient impairment: Lime Creek (**Figure 6-1** and **Table 6-1**).

Deep Creek and Fortine Creek (**Appendix A**, **Table A-1**) are on the 2014 303(d) List as impaired by excess algal growth, which is a non-pollutant impairment that may be associated with excess nutrients. They are not addressed within this document but in water column and algal sampling conducted by DEQ in 2007/2008, all values were below the nutrient targets. It is recommended that the impairment listing for excess algal growth be re-evaluated in the future and additional data collected, if necessary.

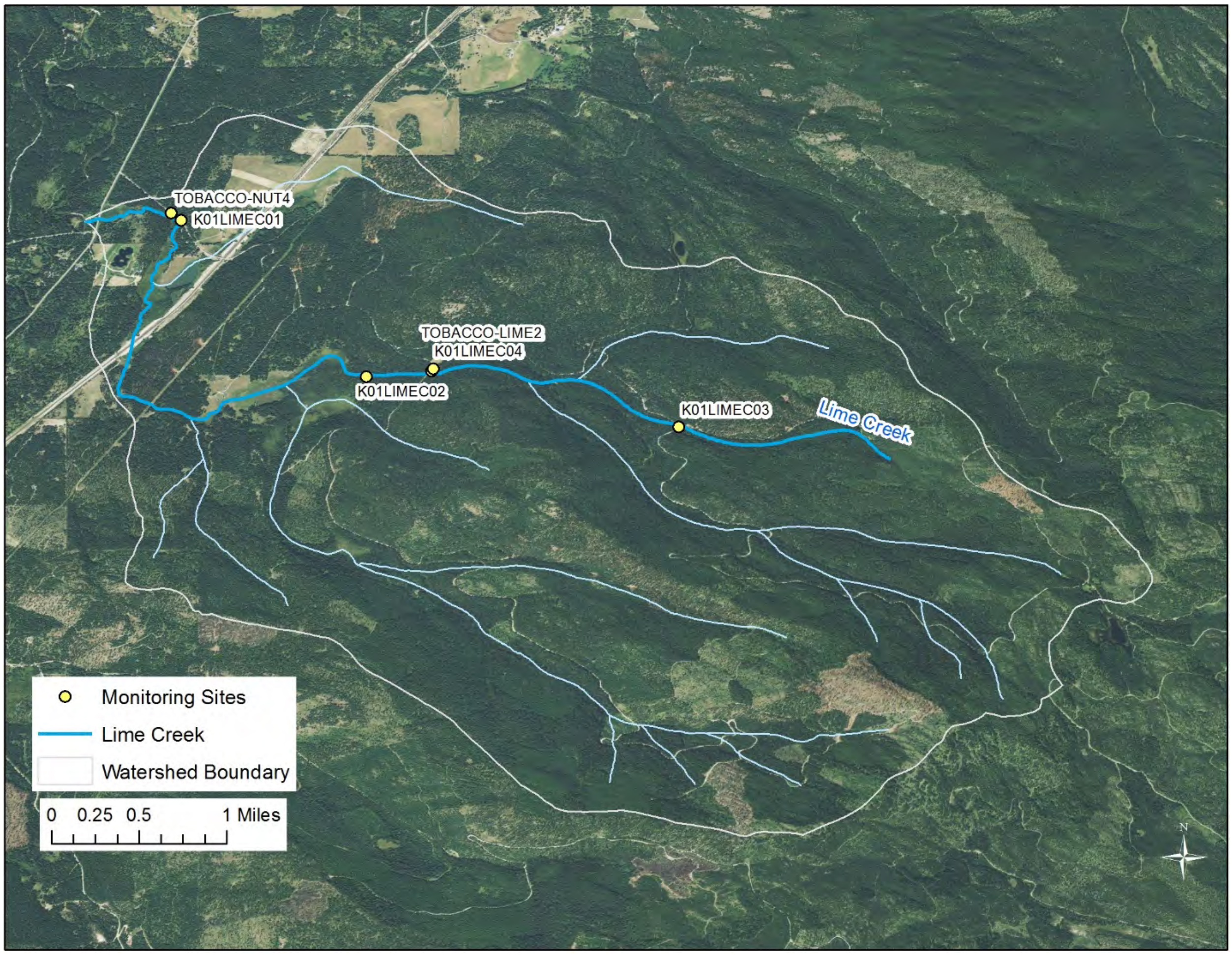

Figure 6-1. 2013 National Agricultural Imagery Program (NAIP) aerial imagery of Lime Creek watershed showing water quality monitoring locations.

Table 6-1. Waterbody segment information for Lime Creek.

Stream Segment	Waterbody ID
LIME CREEK, Headwaters to Mouth (Fortine Creek)	MT76D004_050

6.3 Information Sources and Assessment Methods

To assess nutrient conditions for TMDL development, Department of Environmental Quality (DEQ) compiled nutrient data and undertook additional monitoring. The following data sources represent the primary information used to characterize water quality.

1) **TMDL Sampling:** DEQ and Environmental Protection Agency (EPA) conducted water quality sampling in 2007/2008 and 2012/2013 to update impairment determinations and assist with the development of nutrient TMDLs. Sample locations were generally such that they provided a comprehensive upstream to downstream view of nutrient levels. All data used in TMDL development were collected during the growing season for the Northern Rockies Level III Ecoregion (July 1 – September 30). Benthic algae samples were collected and analyzed for chlorophyll-*a* and ash-free dry mass (AFDM). Macroinvertebrate and periphyton samples were also collected.

2) **DEQ Assessment File:** This file contains information used to make the existing nutrient impairment determination.

Nutrient data used for impairment assessment purposes and TMDL development are included in **Appendix C**. Other nutrient data from the watershed is publicly available through EPA's STOrage and RETrieval database (STORET) and DEQ's EQuIS water quality databases.

Additional sources of information used to develop TMDL components include the following:

- Streamflow data
- Geographic Information System (GIS) data layers
- Forest Service grazing allotment information
- Land-use information

The above information and water quality data are used to compare existing conditions to waterbody restoration goals (targets), to assess nutrient pollutant sources, and to help determine TMDL allocations. Field data sheets were reviewed to rule out irregularities in collection methods or sample Quality Assurance (QA)/Quality Control (QC). Laboratory methods and QA/QC criteria were also reviewed to ensure these values were accurate. Nothing was found to indicate that any results were anomalous.

6.4 Water Quality Targets

TMDL water quality targets are numeric indicator values used to evaluate whether water quality standards have been met. These are discussed further in **Section 4.0**. This section presents nutrient water quality targets and compares them with recently collected nutrient data for Lime Creek following DEQ's assessment methodology (Suplee and Sada de Suplee, 2011). To be consistent with DEQ's draft assessment methodology, and because of improvements in analytical methods, only data from the past 10 years are included in the review of existing data.

6.4.1 Nutrient Water Quality Standards

Montana's water quality standards for nutrients (nitrogen and phosphorous) are narrative and are addressed via narrative criteria. Narrative criteria require state surface waters to be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: 1) produce conditions that create concentrations or combinations of material toxic or harmful to aquatic life, and 2) create conditions that produce undesirable aquatic life (Administrative Rules of Montana (ARM) 17.30.637(1)(d-e)). DEQ is currently developing numeric nutrient criteria for TN and TP that will be established at levels consistent with narrative criteria requirements. These draft numeric criteria are the basis for the nutrient TMDL targets and are consistent with EPA's guidance on TMDL development and federal regulations.

6.4.2 Nutrient Target Values

Nutrient water quality targets include nutrient concentrations in surface waters and measures of benthic algae (a form of aquatic life that at elevated concentrations is undesirable) chlorophyll-*a* concentrations and AFDM. The target concentrations for nitrogen and phosphorus are established at levels believed to prevent the harmful growth and proliferation of excess algae. Since 2002, DEQ has conducted a number of studies in order to develop numeric criteria for nutrients (N and P forms). DEQ is developing draft numeric nutrient standards for TN and TP, and an assessment method that includes chlorophyll-*a* and AFDM based on 1) public surveys defining what level of algae was perceived as "undesirable" (Suplee et al., 2009) and 2) the outcome of nutrient stressor-response studies that determine nutrient concentrations that will maintain algal growth below undesirable and harmful levels (Suplee and Watson, 2013). Although dissolved fractions of phosphorus and nitrogen do not have draft numeric nutrient criteria because uptake by aquatic organisms can make their concentrations highly variable, DEQ has determined that nitrate is an important constituent to evaluate in conjunction with TN and TP (Suplee and Watson, 2013).

Nutrient targets for TN and TP (which are also draft numeric criteria), chlorophyll-*a*, and AFDM are based on Suplee and Watson (2013) and can be found in **Table 6-2**. The NO_3+NO_2 target is based on research by DEQ (Suplee and Watson, 2013) and can also be found in **Table 6-2**. DEQ has determined that the values for NO_3+NO_2, TN, and TP provide an appropriate numeric translation of the applicable narrative nutrient water quality standards based on existing water quality data for Lime Creek. The target values are based on the most sensitive uses; therefore, the nutrient TMDLs are protective of all designated uses. When the draft criteria for TN and TP become numeric standards they will be in DEQ's DEQ-12 circular.

The nutrient target suite for streams in the Northern Rockies Level III Ecoregion also includes two biometric indicators: macroinvertebrates and diatoms. For macroinvertebrates, the Hilsenhoff Biotic Index (HBI) score) is used. The HBI value increases as the amount of pollution tolerant macroinvertebrates in a sample increases; the macroinvertebrate target is an HBI score equal to or less than 4.0 (Suplee and Sada de Suplee, 2011) (**Table 6-2**). Benthic diatoms, or periphyton, are a type of algae that grow on the stream bottom, and there are certain taxa that tend to increase as nutrient concentrations increase. The diatom target is a periphyton sample with a ≤51% probability of impairment by nutrients (Suplee and Sada de Suplee, 2011) (**Table 6-2**).

Because numeric nutrient chemistry is established to maintain algal levels below target chlorophyll-*a* concentrations and AFDM, target attainment applies and is evaluated during the summer growing season (July 1–September 30 for the Northern Rockies Level III Ecoregion) when algal growth will most likely affect beneficial uses. For data evaluation, samples collected ten days on either side of the growing season may also be included (Suplee and Watson, 2013). Targets listed here have been established specifically for nutrient TMDL development in the Tobacco TPA and may or may not be applicable to streams in other TMDL project areas. The applicable target values in **Table 6-2** will be used to develop TMDLs. See **Section 7.1.3** for the adaptive management strategy as it relates to nutrient water quality targets.

Table 6-2. Nutrient Targets for the Tobacco Project Area.

Parameter	Northern Rockies Level III Ecoregion Target Value
Nitrate+Nitrite (NO_3+NO_2)[(1)]	≤ 0.10 mg/L
Total Nitrogen (TN)[(2)]	≤ 0.275 mg/L
Total Phosphorus (TP)[(2)]	≤ 0.025 mg/L
Chlorophyll-*a*[(2)]	≤ 125 mg/m^2
Ash Free Dry Mass (AFDM)	≤ 35 g/m^2
Hilsenhoff's Biotic Index (HBI)[(3)]	< 4.0
Periphyton[(3)]	< 51%

[(1)] Value is from Suplee (Suplee, Michael W., personal communication 11/14/2013)
[(2)] Value is from Suplee and Watson(2013).
[(3)] Value is from Suplee and Sada de Suplee (2011).

6.4.3 Existing Conditions and Comparison to Targets

To evaluate whether attainment of nutrient targets has been met, the existing water quality conditions in each waterbody segment are compared to the water quality targets in **Table 6-2** using the methodology in the DEQ draft guidance document "2011 Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nitrogen and Phosphorus Levels" (Suplee and Sada de Suplee, 2011). This approach provides DEQ with updated impairment determinations used for TMDL development. Because the original impairment listings are based on old data or were listed before developing the numeric criteria, each stream segment will be evaluated for impairment from nitrate, TN, and TP using data collected within the past 10 years. Additionally, nutrient samples collected prior to 2005 were analyzed for Total Kjeldahl Nitrogen (TKN), which has since been replaced by DEQ with Total Persulfate Nitrogen as the preferred analytical method for total nitrogen; samples analyzed for TKN may have a high bias (Rus et al., 2013) and are excluded from the data review.

The assessment methodology uses two statistical tests (Exact Binomial Test and the One-Sample Student's T-test for the Mean) to evaluate water quality data for compliance with established target values. In general, compliance with water quality targets is not attained when nutrient chemistry data shows a target exceedance rate of >20% (Exact Binomial Test), when mean water quality nutrient chemistry exceeds target values (Student T-test), or when a single chlorophyll-*a* value exceeds benthic algal target concentrations (125 mg/m^2 or 35 g Ash Free Dry Weight/m^2). Where water chemistry and algae data do not provide a clear determination of impairment, or where other limitations exist, macroinvertebrate and periphyton biometrics are considered in further evaluating compliance with nutrient targets. Lastly, inherent to any impairment determination is the existence of human sources of pollutant loading. Human-caused sources of nutrients must be present for a stream to be considered impaired. To ensure a higher degree of certainty for removing an impairment determination and making any new impairment determination, the statistical tests are configured differently for an unlisted nutrient form than for a listed nutrient form. This can result in a different number of allowable exceedances for nutrients within a single stream segment. Such tests help assure that assessment reaches do not vacillate between listed and delisted status by the change in results from a single additional sample. When applying the T-test for assessment and sample values were below detection limits, one-half the detection limit was used.

6.4.3.2 Lime Creek (MT76D004_050)

Lime Creek is on the 2014 303(d) List as impaired for total phosphorus and total nitrogen. Chlorophyll-*a*, a non-pollutant response variable, is also listed as impaired on the 2014 303(d) List. Lime Creek flows 4.9 miles from its headwaters until the confluence with Fortine Creek. It was originally listed in 2006 as impaired because of excess nutrients associated with grazing and timber harvest.

Summary nutrient data statistics for Lime Creek are provided in **Table 6-3**. Thirteen nutrient samples were collected between 2003 and 2013, although one nitrogen value was excluded from this assessment because it was for TKN. NO_3+NO_2 values ranged from <0.005 to 0.020 mg/L with no samples exceeding the target. TN values ranged from < 0.04 to 0.91 mg/L with two samples exceeding the TN target of 0.275 mg/L. TP values ranged from <0.003 to 0.024 mg/L with no samples exceeding the TP target of 0.025 mg/L. From the three algal samples, all three chlorophyll-*a* values were below the target but one of the samples had an AFDM value that was well over the AFDM target. Two of the four macroinvertebrate samples exceeded the HBI target and three of the five periphyton samples exceeded the target. **Figure 6-2** shows stream conditions near the mouth in August 2012 when the AFDM, periphyton, and macroinvertebrate targets were all exceeded; both aquatic plants and filamentous algae are common in the channel.

Figure 6-2. August 23, 2012 site photo at K01LIMEC01 with algal rock example in inset.

Table 6-3. Nutrient Data Summary for Lime Creek. Bold values indicate target exceedance.

Nutrient Parameter	Sample Timeframe	Sample Size	Min[1]	Max	Median
NO_3+NO_2, mg/L	2003-2013	13	<0.005	0.020	0.005
TN, mg/L	2003-2013	12	<0.04	**0.91**	0.10
TP, mg/L	2003-2013	13	<0.003	0.024	0.007
Chlorophyll-*a*, mg/m^2	2012	3	<50[2]	1.1	<50[2]
AFDM, g/m^2	2012	3	<35[2]	**118**	<35[2]
Macroinvertebrate HBI	2003-2012	4	1.9	**4.6**	3.6
Periphyton	2003-2012	5	25	**68**	**57**

[1] Values preceded by a "<" symbol are detection limits for that parameter. The actual sample value was below the detection limit.

[2] Visually estimated to be less than 50 mg/m2 for chlorophyll-*a* and less than the AFDM target

Based on the assessment results (**Table 6-4)** Lime Creek is impaired for TP and TN. The TN target exceedances and the failure to meet targets for AFDM, macroinvertebrates, and periphyton collectively indicate excess nutrients are impairing aquatic life in Lime Creek. Although there were no exceedances of the TP target, because Lime Creek is currently listed for impairment by TP and the biological data indicate nutrient impairment, TP will be retained as an impairment cause. There could be a lack of TP target exceedances because biota are consuming nutrients, which decreases the nutrient concentrations. Therefore, TMDLs will be developed for TN and TP. The TN TMDL will address the chlorophyll-*a* impairment. However, because none of the water samples exceeded the TP target, additional water column and biological sampling is recommended to help refine the impairment cause(s) and sources.

Table 6-4. Assessment Method Evaluation Results for Lime Creek

Nutrient	Sample Size	Target Value (mg/L)	Target Exceed -ances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	Peri-phyton	TMDL Required ?
NO_3+NO_2	13	0.10	0	PASS	PASS					NO
TN	12	0.275	2	**FAIL**	PASS	Pass	**Fail**	**Fail**	**Fail**	**YES**
TP	13	0.025	0	PASS	PASS					**YES**

6.5 Source Assessment

This section summarizes the source assessment approach and findings for Lime Creek.

6.5.1 Source Assessment Approach

Based on a review of water quality data, geographic information, discussions with stakeholders, and project reports and narratives, potential human sources of nutrient loading to Lime Creek include livestock grazing, residential development, and timber harvest. These are all nonpoint sources, meaning they are dispersed across the landscape and do not originate from a discrete source, such as a pipe (i.e., point source). Lime Creek watershed does not have any permitted point sources of nutrients. Nutrient sources therefore consist primarily of 1) natural sources derived from airborne deposition, vegetation, soils, and geologic weathering; and 2) human-caused nonpoint sources (i.e., grazing, development, and timber harvest).

Because there are no point sources and nonpoint source categories are intermixed within each watershed, the source assessment approach focuses on using monitoring data collected between 2003 and 2013 to evaluate spatial patterns and identify the most probable nutrient sources. Since all water quality data were collected during the growing season (i.e., July 1 – September 30), the source characterization focuses mainly on sources and mechanisms that influence nutrient contributions during this period. Synoptic sampling data (from multiple sites on the same day) as well as other sources such as DEQ assessment files, GIS land use data, and personal communication with land managers were also used for the source assessment.

6.5.2 Source Categories

As stated above, there are no permitted point sources of nutrients in the Lime Creek watershed; the potential sources of nutrients are livestock grazing, residential development, timber harvest, and natural background. A brief summary of each potential source category is described below with additional information about Lime Creek in the section that follows.

Livestock Grazing

Cattle grazing occurs on public and private land in the Lime Creek watershed. Although cattle do not tend to graze along the valley bottom during the growing season, there are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include: the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas, breakdown of excrement and loading via surface and subsurface pathways, delivery from grazed forest and rangeland during the growing season, transport of fertilizer applied in late spring via overland flow and groundwater, and the increased mobility of phosphorus caused by irrigation-related saturation of soils in pastures (Green and Kauffman, 1989). Typically, pasture is managed for hay production during the summer, and for grazing feed during the fall and spring. Hay pastures are fairly thickly vegetated in the summer but less so in the fall through spring. During the winter grazing period (October – May), trampling and consumption reduces biomass at a time of the year when it is already low. Details regarding grazing on USFS land were provided by the Kootenai National Forest [1].

Residential Development
There is some residential development near the mouth of Lime Creek. Developed areas can contribute nutrients to the watershed by runoff from impervious surfaces, deposition by machines/automobiles, application of fertilizers, increased irrigation on lawns, and septic systems. Septic systems, even when operating as designed can contribute nutrients to surface water through subsurface pathways. The amount of nutrients that a given septic system contributes to a waterbody is dependent upon its discharge, soils, and distance from the waterbody. The number and location of septic systems in the watershed was estimated based on the Structures and Address Framework, which is part of the Montana Spatial Data Infrastructure (Montana State Library, 2014).

Timber Harvest
The Lime Creek watershed is predominantly on land managed by the Kootenai National Forest and it is heavily timbered. Timber harvest inevitably causes some measure of downstream effects that may or may not be significant over time. Changes in land cover will change the rate at which water evapotranspires and thus the water balance, in that the distribution of water between base flow and runoff will change. Disturbances of the ground surface may also disrupt the hydrological cycle. The combination of these changes can alter water yield, peak flows and water quality (Jacobson 2004). Changes in biomass uptake and soil conditions will affect the nutrient cycle. Nutrient uptake by biomass is greatly reduced after timber harvest, leaving more nutrients available for runoff. Elevated nitrate concentrations also result from increased leaching from the soil as mineralization is enhanced. This increase generally only lasts up to two or three years before returning to pre-harvest levels (Feller and Kimmins, 1984; Likens et al., 1978; Martin and Harr, 1989). Therefore, the source assessment of timber harvest focuses on relatively recent harvest data. A summary of timber harvest sales that have occurred on USFS land in the Lime Creek watershed since 2007 was provided by the Kootenai National Forest[2].

Natural Background
Because potential human sources are dispersed throughout the watershed, natural background loading was estimated by using the median growing season concentration from the DEQ reference nutrient dataset for each pollutant in the Level III Northern Rockies ecoregion (as described in Suplee and Watson, 2013): TN = 0.039 mg/L and TP = 0.005 mg/L. These values are based on samples collected from 22 sites: there are 76 TN samples and 81 TP samples.

The effect of wildlife grazing and waste on nutrient loading is considered part of the natural background load. The contribution of wildlife was not evaluated during this project and may be greater in more heavily used areas of the watershed, however, wildlife were assumed to contribute a minimal nutrient load relative to livestock. Forest fires are also considered part of natural background. Based on USFS GIS data, no wildfires have occurred in the Lime Creek watershed since the early 1900s.

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[1] E-mail from Ellen Sullivan, Range Manager, Rexford Ranger District, Kootenai National Forest to Lisa Kusnierz, EPA on February 6, 2014.
[2] E-mails from Patti Wardensky, Kootenai National Forest and D5 Facts Coordinator, Kootenai National Forest, to Lisa Kusnierz, EPA on June 9, 2014.

6.5.3 Lime Creek Source Assessment

The source assessment discussion for Lime Creek contains an overview of the land use distribution relative to potential sources in the watershed followed by an analysis and discussion of the water quality data.

Overview of Land Uses and Potential Sources

Lime Creek watershed is almost entirely (92%) within the Kootenai National Forest, and most of that land is part of the Trego Grazing Allotment (hatched area in **Figure 6-3**). Upstream of the railroad tracks, the permit for the allotment allows for 40 cow/calf pairs with a season of use from June 5 through September 30. Within the allotment downstream of the railroad tracks, the season of use is the same as the rest of the allotment but the permit only allows 10 cow/calf pairs. Stream access within the allotment is limited to one main crossing where a power line crosses the stream approximately 0.4 miles upstream of the railroad ("cattle access" in **Figure 6-3**) and some sporadic access points that only receive occasional use[3]. Within the allotment, salt must be located at least ¼ mile from streams and riparian areas, and streambank stability issues should be identified and problem areas should be protected. As a result of the goal of identifying and addressing problem areas, exclosure fencing was added to a riparian meadow between Fortine Creek Road and Lime Creek Road that is downstream of site TOBACCO-NUT4 and the fencing was recently repaired and improved.

Based on information provided by the Kootenai National Forest[4], timber harvest has occurred on approximately 758 acres since 2007. Of that, 654 acres (86%) were harvested for improvement and 104 acres (14%) were harvested for regeneration. Most timber sales occurred in 2007, and the most recent sales were in 2010 and encompassed 126 acres. However, the entire harvest was not necessarily completed during the same year as the sale was approved; most of the harvest activities were not documented as complete until the 2013 fiscal year. The goal of improvement harvest is to remove excess or diseased trees to make the stand more manageable. The USFS considers it an intermediate level of disturbance that is not anticipated to cause water quality effects. Regeneration harvest is more intensive and it involves removal of most to all existing trees. Regeneration harvest that has occurred since 2007 is on 1.8% of the USFS land within the watershed (i.e., 104 acres out of 5882 acres). In areas where regeneration harvest has occurred, the USFS must certify or be very close to certifying regeneration within five years of project completion. Based on the aerial image from 2013 shown in **Figure 6-1** as well as a timber harvest map associated with the USFS Trego Project (**Appendix A, Figure A-9**), timber harvest has been scattered throughout the public land, and there has also been some on private land.

As shown on the source assessment map (**Figure 6-3**), the private land is in the lower watershed and primarily clustered near the mouth of Lime Creek. There is some residential development on the private land, as indicated by the septic systems on **Figure 6-3.** Based on GIS data (Monta**na State Library 2014)**, there are seven septic systems in the watershed. Based on 2013 land cover data (Montana Natural Heritage Program, 2013) and Montana Department of Natural Resource water rights information (Montana Department of Natural Resources and Conservation, Water Resources Division, 2013), there is also grazing and pasture on the private land, as well as livestock access to Lime Creek and flood and sprinkler irrigation.

[3] E-mail from Ellen Sullivan, Range Manager, Rexford Ranger District, Kootenai National Forest to Lisa Kusnierz, EPA on February 6, 2014.

[4] E-mails from Patti Wardensky, Kootenai National Forest and D5 Facts Coordinator, Kootenai National Forest, to Lisa Kusnierz, EPA on June 9, 2014.

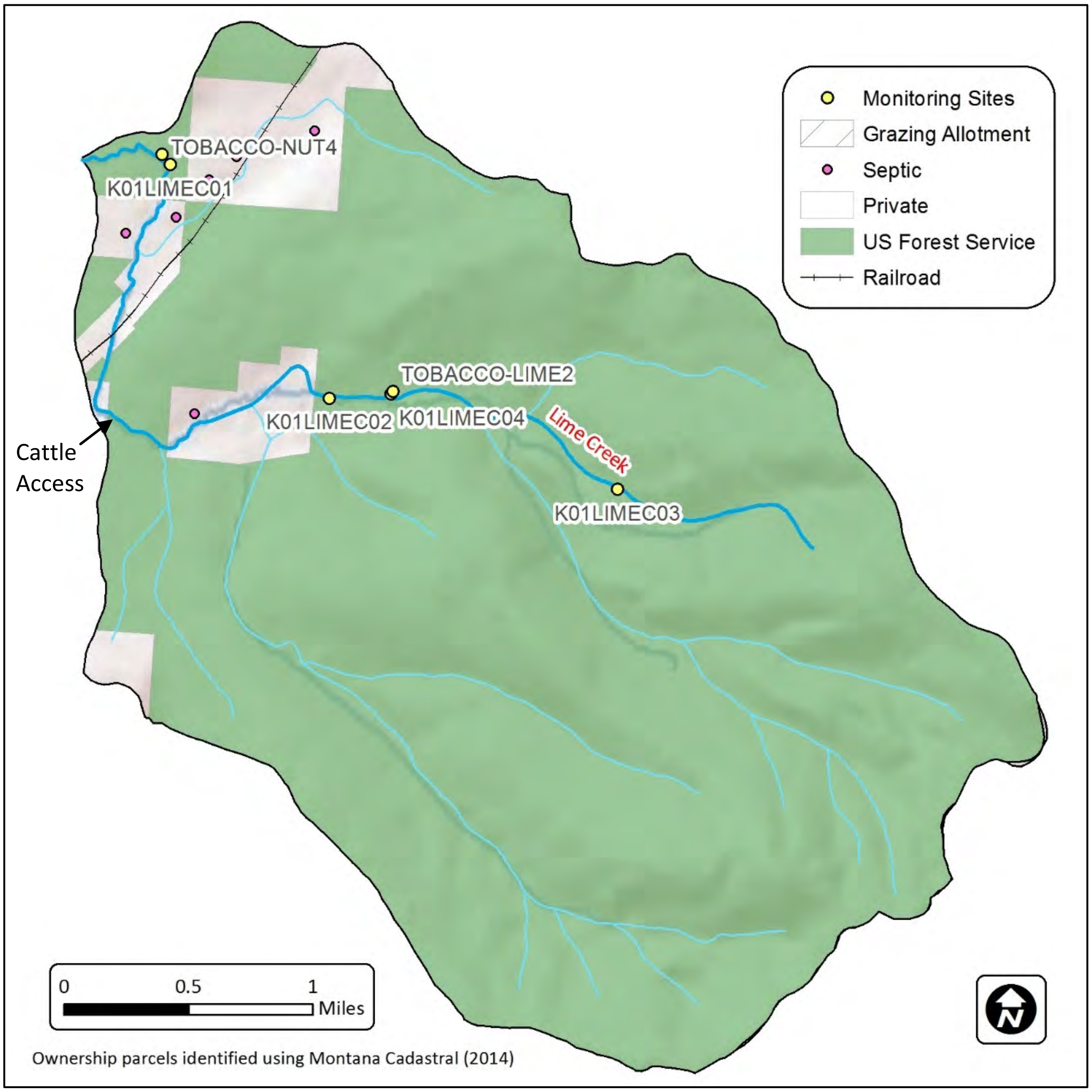

Figure 6-3. Source assessment map for Lime Creek.

Data Analysis

As shown in **Figure 6-3**, the water quality monitoring sites are dispersed from upper Lime Creek to the mouth. All samples collected between 2003 and 2008 were collected near the mouth, which is useful for evaluating impairment status and examining if there is a relationship between nutrient concentrations and flow but does not help with evaluating loading. However, data collected in 2012/2013 represent approximately two thirds of the samples and were collected at three sites over three sampling dates, which allows for comparison of samples collected at multiple sites on the same day (i.e., synoptic data).

Both TN target exceedances occurred during the same sampling event in July 2012, which was the sampling event with the highest streamflow. This indicates nutrient loading may be associated with streamflow, however, no flow-related trends are apparent for TP or for TN for any of the other sampling events. Therefore, more synoptic data collected under varying flow conditions would be helpful in further investigating if there is a relationship between nutrient loading and flow.

Although there is no clear relationship between flow and nutrient concentrations, the synoptic sample data consistently show a trend for both TP and TN of increasing concentrations near the mouth at site K01LIMEC01 (**Figures 6-4** and **6-5**, respectively). The highest TN value and the highest TP values were in samples collected at K01LIMEC01. Additionally, all but one of the exceedances of biological targets occurred near the mouth. This suggests that the nutrient sources are primarily in the mixed use area that contains private land and the lower part of the Trego grazing allotment. However, the data also indicate nitrogen loading farther up in the watershed: for all three sample events, TP concentrations were the same at the upper two sites, but for two of the three events, the TN concentration increased between the upper and middle site (i.e., K01LIMEC03 and K01LIMEC04). Also, one of the TN target exceedances occurred at the middle site (K01LIMEC04), which only has USFS land upstream of it.

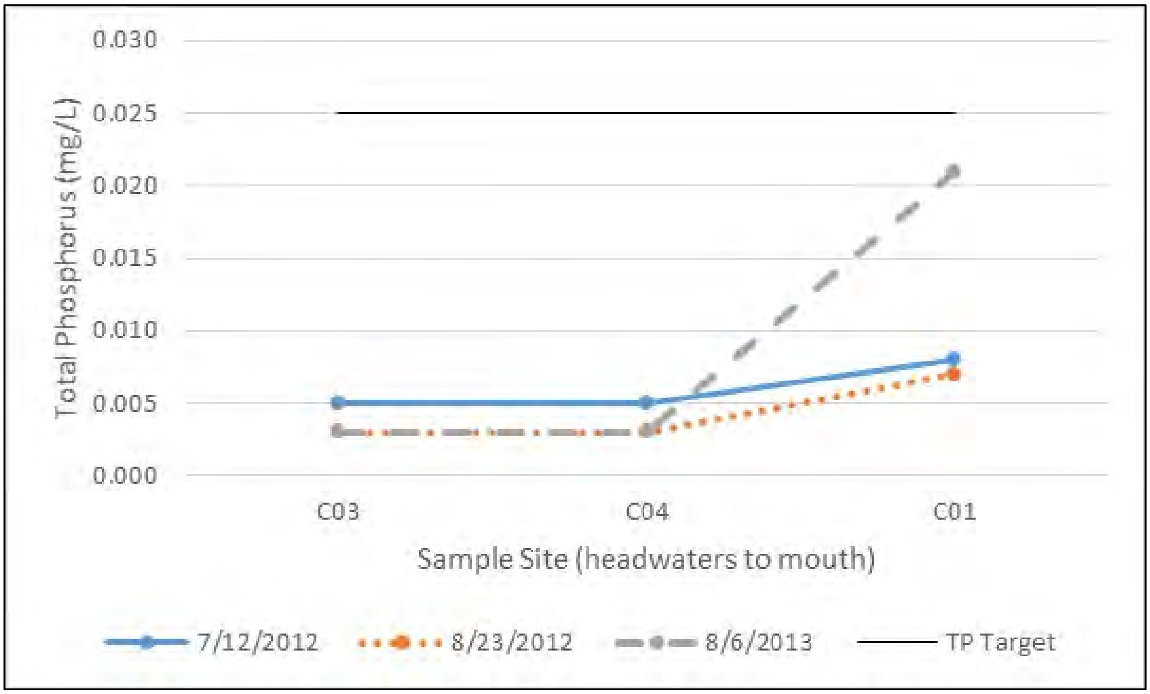

Figure 6-4. Lime Creek synoptic total phosphorus data collected in 2012/2013.

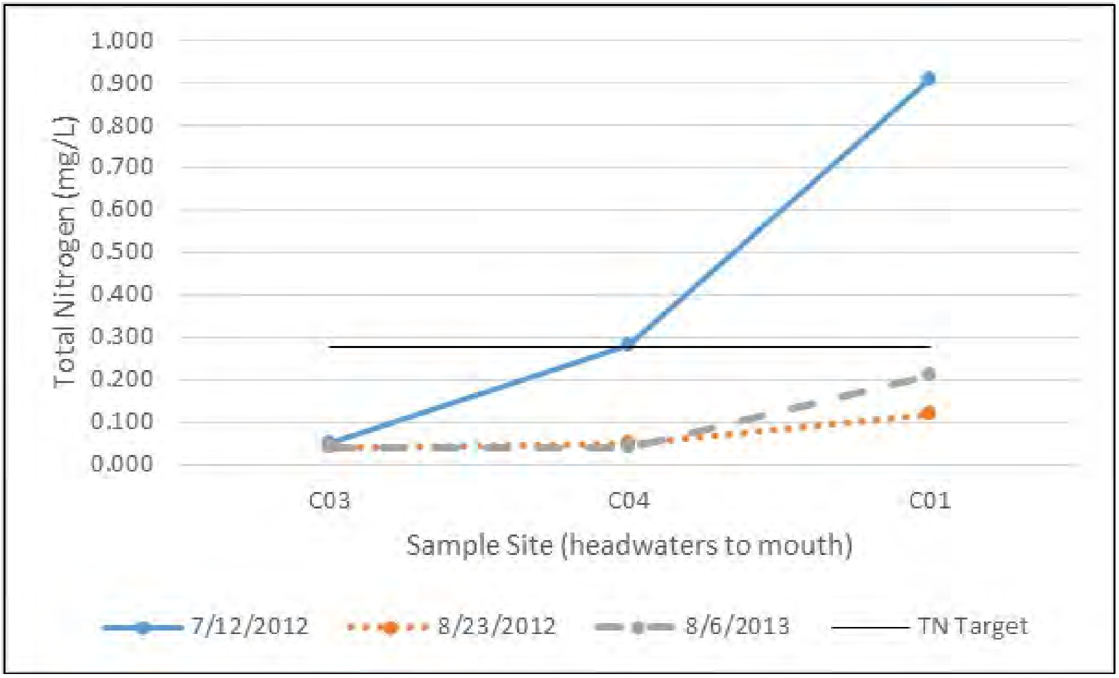

Figure 6-5. Lime Creek synoptic total nitrogen data collected in 2012/2013.

Summary

Overall, the data indicate grazing and/or timber harvest on USFS land in the mid-watershed is a source of nitrogen loading (**Figure 6-3**) but that most nutrient loading is occurring in the mixed use area in the lower watershed. The lower part of Lime Creek does have some access points for livestock, including the primary access within the allotment, which increases the potential for nutrient loading. The most probable nutrient sources along the lower section of Lime Creek are grazing and residential development. However, timber harvest is also potentially a source, as well as grazing in the upper part of the allotment, because Magnesia Creek is a tributary that extends into the upper watershed but flows into Lime Creek in the section of private land downstream of site K01LIMEC02 (**Figure 6-3**). Additional evaluation of sources along the stream as well as additional monitoring locations in the lower watershed are recommended to refine the source assessment.

6.6 TMDL and Allocation Overview

As stated above TMDLs will be developed for Lime Creek for TP and TN. Because streamflow varies seasonally, TMDLs are not expressed as a static value, but as an equation of the appropriate target multiplied by flow as shown in **Equation 6-1**. As flow increases, the allowable load (TMDL) increases as shown by the TP TMDL example in **Figure 6-6.** Like the water quality targets, the TMDLs are applied only to the summer growing season (July 1st through Sept 30th). An example TMDL is presented for each nutrient based on measured flows. Along with each TMDL example, monitoring data are used to calculate the existing load and then compare that to the allowable load (TMDL) to calculate the percent reduction in loading needed to meet the TMDL. For the existing load, the highest growing season concentration is used, but the range of reductions necessary based on all growing season sampling data is also discussed. The actual reductions needed may be greater than the load reductions provided in this section because the reduction estimates are based on measured loads, which may differ from loading inputs because algae and other primary producers in streams regularly consume nutrients and alter instream concentrations.

Equation 6-1: TMDL (lbs/day) = (X) (Y) (k)

X = water quality target in mg/L (TN = 0.275 mg/L, TP = 0.025 mg/L)
Y = streamflow in cubic feet per second (cfs)
k = conversion factor of 5.4

Because a simple approach was used for the source assessment and all sources are nonpoint, the TMDL allocations for each stream are broken into a load allocation to natural background and a composite load allocation to all human-caused nonpoint sources. Therefore, the equation for both nutrient TMDLs is as follows: **TMDL = LA $_{\textbf{Natural Background}}$ + LA $_{\textbf{Human Sources}}$**

The LA $_{\text{Human Sources}}$ is calculated by subtracting the LA $_{\text{Natural Background}}$ from the TMDL. Because there are no point sources, the wasteload allocation (WLA) is 0. The nutrient TMDLs include an implicit margin of safety (MOS), which is based on conservative assumptions as described in **Section 6.6.8.3**.

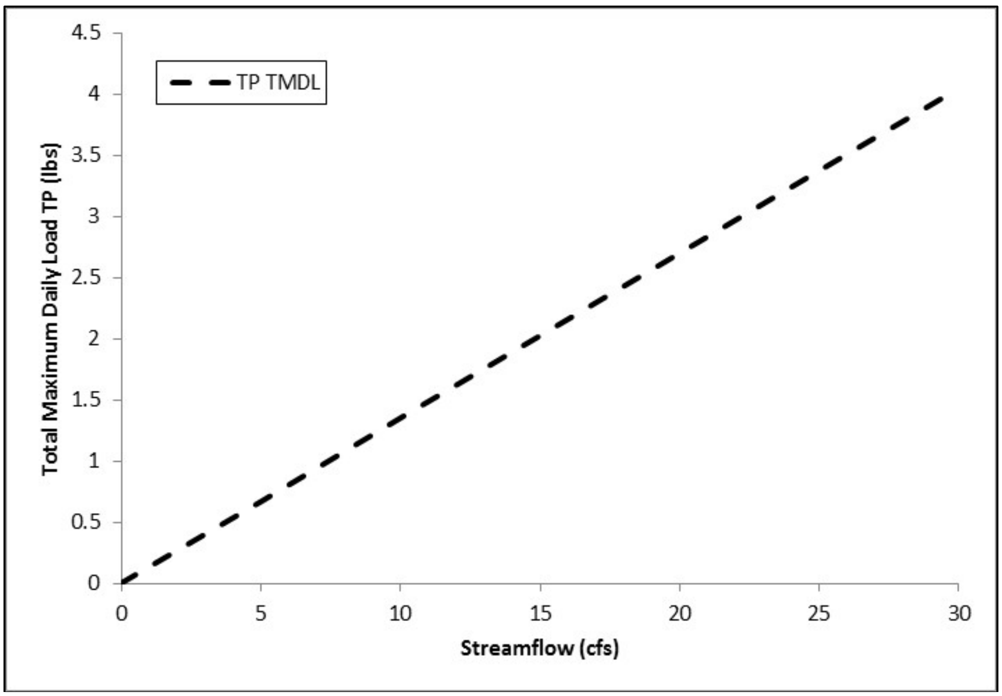

Figure 6-6. Example TMDL for TP for streamflow ranging from 0 to 30 cfs.

6.6.1 Meeting Allocations

Allocations are intended to be met by implementation of additional BMPs. It is important to recognize that the first critical step toward meeting the nutrient allocations involves applying and/or maintaining the land management practices or BMPs that will reduce nutrient loading. Once these actions have been completed at a given location, the landowner or land manager will have taken action consistent with the intent of the nutrient allocation for that location. For many nonpoint source activities, it can take several years to achieve the full load reduction at the location of concern, even though full BMP implementation is in effect. For example, it may take several years for riparian areas to fully recover and decrease nutrient loading after implementing grazing BMPs. It is also important to apply proper BMPs and other water quality protection practices for all new or changing land management activities to limit any potential increased nutrient loading.

Progress towards TMDL and individual allocation achievement can be gauged by BMP implementation and improvement in or attainment of water quality targets defined in **Section 6.4.2**. Any effort to calculate loads and percent reductions for purposes of comparison to TMDLs and allocations in this document should be accomplished via the same methodology used to develop the loads and percent reductions presented within this document.

6.6.2 Lime Creek TMDLs and Allocations

Total Nitrogen TMDL

Based on the samples that exceeded the target, TN load reductions of 2% and 70% are needed. For all other samples, no reductions are needed to meet the TMDL. This indicates that Lime Creek is typically meeting the TN TMDL and only minor adjustments to land management practices are needed to meet the TMDL. Based on recent monitoring data, load reductions are primarily needed in the lower watershed near the mouth but some excess loading is also occurring in the mid-watershed, likely as a result of grazing and/or timber harvest.

As described above, the TMDL will be composed of two load allocations: one to natural background sources and the other to all human sources (i.e., grazing, development, and timber harvest). **Table 6-5** shows an example TN TMDL using monitoring data from July 2012 collected near the mouth at K01LIMEC01, which is when the highest TN concentration was measured. The example follows **Equation 6-1** as shown below. Because excess TN is contributing to excess algal growth, the TN TMDL will address the chlorophyll-*a* impairment.

*Following **Equation 6-1**: TMDL = (0.275 mg/L) (4.8 cfs) (5.4) = 7.13 lbs/day*

Table 6-5. Example TN TMDL and allocations for Lime Creek.

Allocation	Source Category	Current Load (lbs/day)[1]	% Reduction Needed	Allocation (lbs/day)	Rationale/Assumptions
Load Allocation	Natural Background	1.01	0%	1.01	Assumes a natural background concentration of 0.039 mg/L TN, which is the median growing season TN concentration from the DEQ reference dataset for the Northern Rockies ecoregion
	All other nonpoint sources (e.g., grazing, development, timber harvest)	22.58	73%	6.12	The load was calculated by subtracting the natural background load from the measured load.
TMDL	**All Sources**	23.59	70%	7.13	Total allowable load and reduction needed based on sample data

[1]Based on a measured TN concentration of 0.91 mg/L and flow of 4.8 cfs on July 12, 2012 at site K01LIMEC01

Total Phosphorus TMDL

The example TP TMDL and load allocations to natural background and all human sources are summarized in **Table 6-6**. Current loading based on the highest measured TP concentration is also presented in **Table 6-6**, but because the measured existing loads are less than the example TMDL, no reduction is necessary to meet the water quality target. As discussed previously, nutrient uptake by algae and other primary producers may decrease nutrient loads, which can make it appear as though there is not a nutrient problem when there actually is. The target exceedance of AFDM, which is a measure of excessive algal growth, along with elevated periphyton and HBI scores all indicate excess nutrient loading to the stream. Determining the precise cause(s) of these target exceedances and the role of phosphorus warrants further study, but reducing nutrient loading to address excessive algal growth is still considered necessary to address the nutrient impairment. Reductions may be achieved through a variety of water quality planning and implementation actions as discussed in **Section 7.0.**

Table 6-6. Example TP TMDL and allocations for Lime Creek.

Allocation	Source Category	Current Load (lbs/day)[1]	% Reduction Needed	Allocation (lbs/day)	Rationale/Assumptions
Load Allocation	Natural Background	0.019	0%	0.019	Assumes a natural background concentration of 0.005 mg/L TP, which is the median growing season TP concentration from the DEQ reference dataset for the Northern Rockies ecoregion
	All other nonpoint sources (e.g., grazing, development, timber harvest)	0.072	0%	0.076	The load was calculated by subtracting the natural background load from the measured load.
TMDL	**All Sources**	**0.091**	**0%**	**0.095**	Total allowable load and reduction needed based on sample data

[1]Based on a measured TP concentration of 0.024 mg/L and flow of 0.7 cfs on August 12, 2003 at site K01LIMEC01

6.7 Seasonality and Margin of Safety

TMDL documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and load allocations. TMDL development must also incorporate a margin of safety to account for uncertainties between pollutant sources and the quality of the receiving waterbody, and to ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses.

6.7.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development and throughout this plan seasonality is an integral consideration. Specific examples of how seasonality has been addressed within this document include:

- Water quality targets and subsequent allocations are applicable for the summer-time growing season (July 1st – Sept 30th), to coincide with seasonal algal growth targets.
- Nutrient data used to determine compliance with targets and to establish allowable loads was collected during the summer-time period to coincide with applicable nutrient targets.

6.7.2 Margin of Safety

A margin of safety is a required component of TMDL development. The margin of safety accounts for the uncertainty about the pollutant loads and the quality of the receiving water and is intended to protect beneficial uses in the face of this uncertainty. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (U.S. Environmental Protection Agency, 1999a). This plan addresses MOS implicitly in a variety of ways:

- Static nutrient target values (e.g., 0.275 mg/L TN and 0.025 mg/L TP) were used to calculate allowable loads (TMDLs). Allowable exceedances of nutrient targets were not incorporated into the calculation of allowable loads, thereby adding a MOS to established allocations.
- Target values were developed to err on the conservative side of protecting beneficial uses.
- Seasonality (discussed above) and variability in nutrient loading were considered.

An adaptive management approach was used to evaluate target attainment and allow for refinement of load allocation, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development.

6.8 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, nutrient targets, source assessment, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. However, mitigation and reduction of uncertainties through adaptive management approaches are key components of ongoing TMDL implementation and evaluation. The process of adaptive management is predicated on the premise that TMDL targets, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood. Uncertainty is inherent in both the water quality-based and model-based modes of assessing nutrient sources and needed reductions. The main sources of uncertainty are summarized below.

Water Quality Conditions

It was assumed that sampling data for Lime Creek are representative of conditions in Lime Creek. The measured TP values were below the target but because of previous impairment determinations; exceedances of the chlorophyll-*a*, periphyton, and HBI targets; and the uncertainty in nutrient limitation and uptake within the stream the TP impairment determination was retained. As a result, a TP TMDL was established although data indicate the TP target is being attained. Future monitoring as discussed in **Section 7.0** should help reduce the uncertainty regarding data representativeness, clarify whether or not TP has a role in causing excess algal growth in Lime Creek, improve the understanding of the effectiveness of BMP implementation, and increase the understanding of the loading reductions needed to meet the TMDLs.

Source Assessment

Because of the mixed land uses upstream of where most of the target exceedances occurred, there is a substantial amount of uncertainty regarding the source assessment and whether a single source category or combination of sources are causing the nutrient impairment. Additional monitoring and source assessment work is recommended to better identify the source(s) of excess nutrients and if there are specific problem areas. A riparian exclosure downstream of K01LIMEC01 within the Trego allotment was recently improved, and there may be other grazing-related improvements that can be made on both public and private land.

There may be some failing systems, and depending on their proximity or connectivity to surface water, they could be point sources of nutrient loading. However, a completely failing system has obvious symptoms and will be addressed quickly, and a partially failing system will likely result in similar loading as a functioning system, unless it is in close proximity to surface water. This source could be investigated further, particularly in segments with nearby septic systems and elevated nutrient concentrations that cannot be explained by other sources.

Despite the uncertainty associated with the loading contributions from the various nonpoint sources in the watershed, based on the literature and field observations there is a fairly high level of certainty that improvements in land management practices discussed in this document will reduce nutrient loading sufficiently to meet the TMDLs.

7.0 Water Quality Improvement Plan and Monitoring Strategy

7.1 Purpose of Improvement and Monitoring Strategy

This section describes an overall strategy and specific on-the-ground measures designed to restore water quality beneficial uses and attain water quality standards for nutrients and temperature in the Tobacco TMDL Planning Area streams. The strategy includes general measures for reducing loading from each identified significant pollutant source. Effective monitoring is integral to these implementation measures and the foundation of an adaptive management approach. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities, the amount of pollutant load reduction (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.

This section should further assist stakeholders in developing a watershed restoration plan (WRP) that will provide more detailed information about restoration goals and monitoring plans within the Tobacco River watershed. The WRP may also encompass broader goals than the water quality improvement strategy outlined in this document. The intent of the WRP is to serve as a locally organized “road map” for watershed activities, prioritizing types of projects, sequences of projects, and funding sources towards achieving local watershed goals. Within the WRP, local stakeholders identify and prioritize streams, tasks, resources, and schedules for applying best management practices (BMPs). As restoration efforts and results are assessed through watershed monitoring, this strategy should be adapted and revised by stakeholders based on new information and ongoing improvements.

7.2 Role of DEQ, Other Agencies, and Stakeholders

The Montana Department of Environmental Quality (DEQ) does not implement TMDL pollutant-reduction projects for nonpoint source activities, but may provide technical and financial assistance for stakeholders interested in improving their water quality. Successful implementation of TMDL pollutant-reduction projects requires collaboration among private landowners, land management agencies, and other stakeholders. DEQ will work with participants to use the TMDLs as a basis for developing locally-driven WRPs, administer funding specifically to help support water quality improvement and pollution prevention projects, and help identify other sources of funding.

Because most nonpoint source reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers work collaboratively with local and state agencies to achieve water quality restoration goals and to meet TMDL targets and load reductions. Specific stakeholders and agencies that will likely be vital to restoration efforts for streams discussed in this document include:

- Lincoln Conservation District
- Flathead Conservation District
- Kootenai River Network (KRN)
- U.S. Forest Service (USFS)
- Natural Resources and Conservation Service (NRCS)
- U.S. Fish & Wildlife Service (USFWS)
- U.S. Environmental Protection Agency (EPA)
- Montana Department of Natural Resources and Conservation (DNRC)

- Montana Fish, Wildlife and Parks (FWP)
- Montana Department of Environmental Quality (DEQ)
- Plum Creek Timber Company
- Montana Trout Unlimited
- Burlington Northern Santa Fe (BNSF) Railway
- Montana Water Center (at Montana State University)
- University of Montana Watershed Health Clinic
- Montana Aquatic Resources Services
- Montana State University Extension Water Quality Program

7.3 Adaptive Management and Uncertainty

The implementation goals and monitoring strategy presented in this section provide a starting point for the development of more detailed planning efforts regarding restoration and monitoring needs; it does not assign monitoring responsibility. Recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate plans to meet the water quality improvement goals outlined in this document.

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, water quality is improving, or if revisions to current goals are necessary. This aligns with an adaptive management approach that is incorporated into DEQ's assessment and water quality impairment determination process. The Watershed Protection Section administers and monitors TMDL implementation and works with local watershed groups to identify waterbodies where there have been sufficient activities to warrant an evaluation of current stream conditions.

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 7-1** below in their technical guide as a visual explanation of the iterative process of adaptive management (Williams et al., 2009).

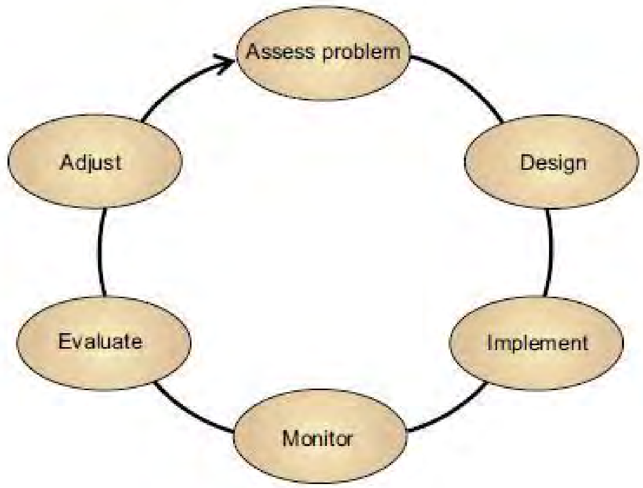

Figure 7-1. Diagram of the adaptive management process

Funding for future implementation and 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, DEQ will conduct a formal evaluation of the waterbody's impairment status and determine whether TMDL targets and water quality standards are being met.

7.4 Water Quality Restoration and Monitoring Objectives

The water quality restoration objective for the Tobacco TMDL Planning Area is to reduce pollutant loads as identified throughout this document as well as the 2011 "Tobacco Planning Area Sediment TMDLs and Framework Water Quality Improvement Plan" (Montana Department of Environmental Quality, 2011) in order to meet the water quality standards and TMDL targets for full recovery of beneficial uses for all impaired streams. Meeting the nutrient and temperature TMDLs provided in this document will achieve this objective for these pollutant-impaired streams. Based on the assessment provided in this document, the TMDLs can be achieved through proper implementation of appropriate BMPs.

Specific objectives for watershed restoration activities should be identified by local watershed groups and other stakeholders through the development of a watershed restoration plan (WRP). A WRP can provide a framework strategy for water quality restoration and monitoring in the Tobacco TMDL Planning Area, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document, as well as other water quality issues of interest to local communities and stakeholders. WRPs identify considerations that should be addressed during TMDL implementation and should assist stakeholders in developing a more detailed adaptive plan in the future. A locally developed WRP will provide more detailed information about restoration goals and spatial considerations but may also encompass broader goals than this framework includes. A WRP would serve as a locally organized "road map" for watershed activities, sequences of projects, prioritizing of projects, and funding sources for achieving local watershed goals, including water quality improvements. The WRP is intended to be a living document that can be revised based on new information related to restoration effectiveness, monitoring results, and stakeholder priorities.

The KRN is working with members and local stakeholders to develop a WRP for the Kootenai River basin, which includes streams in the Tobacco TMDL Planning Area. If other organizations are interested in the WRP planning and development process, they should coordinate efforts with KRN to ensure a comprehensive and effective implementation process. Additional information can be found on the KRN website at: www.kootenairivernetwork.org.

The EPA requires nine minimum elements for a WRP. A complete description can be found at http://www.epa.gov/region9/water/nonpoint/9elements-WtrshdPlan-EpaHndbk.pdf and are summarized here:

1. Identification of the causes and sources of pollutants
2. Estimated load reductions expected based on implemented management measures
3. Description of needed nonpoint source management measures
4. Estimate of the amounts of technical and financial assistance needed
5. An information/education component
6. Schedule for implementing the nonpoint source management measures
7. Description of interim, measurable milestones
8. Set of criteria that can be used to determine whether loading reductions are being achieved over time
9. A monitoring component to evaluate effectiveness of the implementation efforts over time

This document and the 2011 sediment TMDL document provide, or can serve as an outline, for many of the required elements. Water quality goals for temperature and nutrients are detailed in **Sections 5.0** and **6.0**, respectively. These goals include water quality and habitat targets as measures for long-term effectiveness monitoring. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of waterbodies in the Tobacco TMDL Planning Area. It is presumed that meeting all water quality and habitat targets will achieve the water quality goals for each impaired waterbody.

7.5 Overview of Management Recommendations

TMDLs were completed for nutrients on Lime Creek and for temperature on Fortine Creek in this document. The 2011 document (Montana Department of Environmental Quality, 2011) contains sediment TMDLs for Deep, Edna, Fortine, Lime, Sinclair, Swamp, and Therriault Creeks, and the Tobacco River. Other streams in the project area may be in need of restoration or pollutant reduction, but insufficient information about them precludes TMDL development at this time. The following sub-sections describe some generalized recommendations for implementing projects to achieve the TMDLs in this document. Details specific to each stream and related impairments are found within **Sections 5.0** and **6.0**.

In general, restoration activities can be separated into two categories: active and passive. Passive restoration allows natural succession to occur within an ecosystem by removing a source of disturbance. Fencing off riparian areas from cattle grazing is a good example of passive restoration. Active restoration, on the other hand involves accelerating natural processes or changing the trajectory of succession. For example, historic placer mining often resulted in the straightening of stream channels and piling of processed rock on the streambank. These impacts would take so long to recover passively that active restoration methods involving removal of waste rock and rerouting of the stream channel would likely be necessary to improve stream and water quality conditions. In general, passive restoration is preferable for temperature and nutrient problems because it is generally more cost effective, less labor intensive, and will not result in short term increase of pollutant loads as may occur from active restoration activities. However, in some cases active restoration is the only feasible mechanism for achieving desired goals; these activities must be assessed on a case by case basis (Nature Education, 2013).

7.5.1 Temperature Restoration Approach

The goal of the temperature restoration approach is to reduce water temperatures where possible to be consistent with naturally occurring conditions. The most significant mechanism for reducing water temperatures in Fortine Creek is increasing riparian shade. Other factors that will help are: using water conservation measures to maximize water left in the stream, improving overwidened portions of the stream, and maintaining conditions where Fortine Creek is currently meeting the temperature targets. General recommendations for each of the main temperature-influencing factors are discussed below. Further details on implementation strategies and recommendations for specific sources of pollutants can be found in Section 6.2 of the "Tobacco Planning Area Sediment TMDLs and Framework Water Quality Improvement Plan" (Montana Department of Environmental Quality, 2011).

7.5.1.1 Riparian Shade

Increases in shade can be accomplished through the restoration and protection of shade-providing vegetation within the riparian corridor. This type of vegetation can also have the added benefit of improving streambank stabilization to reduce bank erosion, slowing lateral stream migration, and providing a buffer to prevent pollutants from upland sources from entering the stream. In some cases, this can be achieved by limiting the frequency and duration of livestock access to the riparian corridor, or through other grazing related BMPs such as installing water gaps or off-site watering. Other areas may require planting, active bank restoration, and protection from browse to establish vegetation. **Figure 5-10** shows where restoration activities may most effectively reduce stream temperatures.

7.5.1.2 Channel Morphology

Recovery of stream channel morphology in most cases will occur slowly over time and is closely linked to implementation of the Fortine Creek sediment TMDL, which should focus on improving riparian condition and stabilizing streambanks. There may be discrete locations or portions of reaches that demand a more rapid intervention through active physical restoration, but size, scale, and cost of restoration in most cases are limiting factors to applying this type of remedy.

7.5.1.3 Water Management and Irrigation

Understanding irrigation water, groundwater, and surface water interactions is an important part of understanding how irrigation practices will affect streamflow during specific seasons. Some irrigation practices in western Montana are based on flood irrigation methods. Occasionally head gates and ditches leak, which can decrease the amount of water in diversion flows. The following recommended activities could potentially result in notable water savings along Fortine Creek:

- Install upgraded head gates for more exact control of diversion flow and to minimize leakage when not in operation
- Develop more efficient means to supply water to livestock
- Determine necessary diversion flows and timeframes that would reduce over watering and improve forage quality and production
- Where appropriate, redesign or reconfigure irrigation systems
- Upgrade ditches (including possible lining, if appropriate) to increase ditch conveyance efficiency

Some water from spring and early summer flood irrigation likely returns as cool groundwater to the streams during the heat of the summer. These critical areas could be identified so that they can be preserved as flood irrigation areas. Other irrigated areas which do not contribute to summer groundwater returns to the river should be identified as areas where year round irrigation efficiencies could be more beneficial than seasonal management practices. Winter baseflow should also be considered during these investigations.

It is unknown to what extent instream flow in Fortine Creek could be increased. If increases in instream summer flows are possible, they can be achieved through a thorough investigation of water use practices and water conveyance infrastructure, and a willingness and ability of local water users to keep more water in the stream. The improved water management scenario in this document uses a 15% reduction in withdrawals as an example to demonstrate potential impacts on temperature. As discussed in **Section 5.0**, changes in water management resulting in increased instream flows is anticipated to be more important during low flow years, which means a drought management plan may be beneficial for water users to develop. However, this TMDL document cannot, nor is it intended to, prescribe limitations on individual water rights owners and users. Local water users should work collectively and with local, state, and federal resource management professionals to review water use options and available assistance programs.

The above approaches give only the broadest description of activities to help reduce water temperatures. The temperature assessment described in **Section 5.0** looked at possible scenarios based on limited information at the watershed scale. Those scenarios showed that improvements in stream temperatures can primarily be made by improvements to riparian shade. It is strongly encouraged that resource managers and land owners continue to work to identify all potential areas of improvement through monitoring and develop projects and practices to reduce stream temperatures in Fortine Creek.

7.5.2 Nutrients Restoration Approach

The goal of the nutrient restoration strategy is to reduce nutrient inputs to Lime Creek by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, and limiting the transport of nutrients from rangeland, cropland, and harvested and developed areas. The source assessment conducted to support TMDL development (**Section 6.5**) can help provide a starting point for where most loading is occurring but additional analysis and source identification will likely be required to identify site-specific delivery pathways and to develop a detailed restoration plan. General recommendations by the major potential nutrient source categories discussed below. Further details on implementation strategies and recommendations for specific sources of pollutants can be found in Section 6.2 of the “Tobacco Planning Area Sediment TMDLs and Framework Water Quality Improvement Plan” (DEQ, 2011).

7.5.2.1 Agriculture

Cropland filter strip extension, vegetative restoration, and long-term filter area maintenance are vital BMPs for agricultural areas. Grazing systems with the explicit goal of increased post-grazing vegetative ground cover are needed to address the same nutrient loading from rangelands. Grazing prescriptions that enhance the filtering capacity of riparian filter areas offer a second tier of controls on the sediment content of upland runoff. Grazing and pasture management adjustments should consider:

- The timing, frequency, and duration of near-stream grazing
- The spacing and exposure duration of on-stream watering locations

- Provision of off-stream watering areas to minimize near-stream and riparian habitat damage
- Active reseeding and rest rotation of locally damaged vegetation stands
- Improved management of irrigation systems
- Incorporation of streamside vegetation buffer to irrigated croplands and animal feeding areas

In general, these are sustainable grazing and cropping practices that can reduce nutrient inputs while meeting production goals. The appropriate combination of BMPs will differ according to landowner preferences and equipment but are recommended as components of a comprehensive plan for farm and ranch operators. Sound planning combined with effective conservation BMPs should be sought whenever possible. Assistance from resource professionals from various local, state, and federal agencies or non-profit groups is widely available in Montana. The local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?service=page/CountyMap&state=MT&stateName=Montana&stateCode=30) and county conservation district offices (http://lincolncd.org/ or http://macdnet.org/) are geared to offer both planning and implementation assistance.

7.5.2.2 Forestry and Timber Harvest

Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (Montana State University Extension Service, 2001) and the Montana Streamside Management Zone (SMZ) Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e., within 50 feet of a waterbody), the riparian protection principles behind the law can be applied to numerous land management activities (i.e., timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. The DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

7.5.2.3 Residential Development

There are multiple sources and pathways of pollution to consider in residential and urban areas. Relative to Lime Creek, the most likely sources of nutrients associated with development are destruction of riparian areas, fertilizer usage, and septic systems.

Substantially degraded riparian areas do not effectively filter pollutants from upland runoff. Riparian areas that have been converted to lawns or small acreage pastures for domestic livestock may suffer from increased contributions of nutrients, sediment, and bacteria, as well as increased summer stream temperatures, increased channel erosion, and greater damage to property from flooding (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012). DEQ encourages the consideration of adopting local zoning or regulations that protect the functions of floodplains and riparian and wetland areas where future growth may occur. Requirements for protecting native vegetation riparian buffers can be an effective mechanism for maintaining or improving stream health.

Local outreach activities to inform new residential property owners of the effects of riparian degradation may also prevent such activities from occurring, including providing information on: appropriate fertilizer application rates to lawns and gardens, regular septic system maintenance, preserving existing riparian vegetation, native vegetation for landscaping, maintaining a buffer to protect riparian and wetland areas, and practices to reduce the amount of stormwater originating from developed property. Nutrient loading values for septic systems vary depending on soil type and distance to the nearest stream, but septic systems should already have minimum design/installation requirements, which should serve as a basic BMP. Older systems should be upgraded and all new systems should meet these minimum requirements. Montana's Nonpoint Source Management Plan contains suggested BMPs to address the effects of residential and urban development, and also contains an appendix of setback regulations that have been adopted by various cities and counties in Montana (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012; Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012). Planning guides and informational publications related to wetlands and native plant species in Montana can be found on DEQ's Wetlands Conservation website at: http://deq.mt.gov/wqinfo/Wetlands/default.mcpx.

7.6 Future Monitoring Guidance

General objectives for future monitoring in the Tobacco TMDL Planning Area include:

- Strengthen the spatial understanding of pollutant 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 characterizations made in TMDL development
- Gather consistent information among agencies and watershed groups that is comparable to the established water quality targets and allows for common threads in discussion and analysis. Consult with DEQ on up to date monitoring parameters.
- Expand the understanding of streams and nonpoint source pollutant loading throughout the Tobacco TMDL Planning Area beyond those where TMDLs have been developed and address issues
- Track restoration projects as they are implemented and assess their effectiveness toward meeting project goals and water quality targets

7.6.1 Strengthening Source Assessment

In the Tobacco TMDL Planning Area, the identification of pollutant sources was conducted largely through a review and analysis of available data, field notes, assessments of aerial photographs, discussion with stakeholders, the incorporation of Geographic Information System (GIS) information, and the review of published scientific studies. Limited field-verification of the available data was able to be conducted. In many cases, assumptions were made based on known conditions in a part of a watershed and extrapolated throughout the watershed. 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 from each of the discussed streams and subwatersheds. Strategies for strengthening source assessments for each of the pollutant categories are outlined below.

Temperature

- Field surveys to better identify and characterize riparian area conditions and potential for improvement
- Identification and prioritization of areas for improvement in shading along Fortine Creek, particularly in the lower portions where there is the greatest potential for temperature decreases from improved riparian shading
- 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 the Fortine Creek watershed
- Assessment of irrigation practices and other water use in the Fortine Creek watershed 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

Nutrients

- A better understanding of nutrient concentrations in groundwater (as well as the sources), particularly near the mouth of Lime Creek
- A better understanding of cattle grazing practices on public and private land, and identification of areas where management practices are fully functioning and those where practices could be improved
- A better understanding of septic system contributions to nutrient loads, specifically in the lower portion of Lime Creek
- Additional sampling in lower Lime Creek where land uses are mixed to help better evaluate the contribution from different source areas and types

7.6.2 Increasing Available Data

Data are often limited depending on the stream and pollutant of interest. 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

Temperature investigation for Fortine Creek included seven temperature loggers in the mainstem and two additional loggers in tributaries, deployed in the summer of 2012. This information was supplemented by USFS data from three loggers also deployed in 2012 (i.e., one in Fortine and two in tributaries). Some additional data were collected from 2003 through 2005. 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 Fortine Creek. In addition, 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 Fortine Creek and its major tributaries is recommended.

Nutrients

Water quality sampling occurred between 2003 and 2008 near the mouth of Lime Creek. However, the majority of samples used in this analysis were collected between 2012 and 2013 at three sampling locations over three sampling dates in order to best delineate nutrient sources. Data suggest that nutrient loading may be associated with streamflow but more synoptic data collected under varying flow conditions would be helpful in further investigating this relationship. In addition, current data show a trend of increasing nutrient concentrations near the mouth of Lime Creek. Additional data will improve source identification for more targeted restoration activities.

7.6.3 Consistent Data Collection and Methodologies

Data has been collected throughout the Tobacco TMDL Planning Area 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 be 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. Consult with DEQ prior to future monitoring efforts, as there may be updated monitoring protocols. Improved communication between agencies and stakeholders will further improve accurate and efficient data collection.

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.

Temperature

Consistency in temperature data collection is not as significant for what is collected as much as how and where it is collected. 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.

Nutrients

For those watershed groups and/or government agencies that monitor water quality, it is recommended that the same analytical procedures and reporting limits are used (**Table 7-1**) so that water quality data may be compared to TMDL targets. In addition, stream discharge should be measured at time of sampling.

Table 7-1. DEQ Nutrient Monitoring Parameter Requirements

Parameter*	Preferred method	Alternate method	Required reporting limit (ppb)	Holding time (days)	Bottle	Preservative
Total Persulfate Nitrogen (TPN)	A4500-NC	A4500-N B	40	28	250mL high-density polyethylene (HDPE)	≤6°C (7d HT); Freeze (28d HT)
Total Phosphorus as P	EPA-365.1	A4500-P F	3			H2S04, ≤6°C of Freeze
Nitrate-Nitrite as N	EPA-353.2	A4500-N03 F	10			
Chlorophyll-*a*	A 10200 H	n/a	n/a	21(pH≥	Filter	Freeze

Table 7-1. DEQ Nutrient Monitoring Parameter Requirements

Parameter*	Preferred method	Alternate method	Required reporting limit (ppb)	Holding time (days)	Bottle	Preservative
Ash-Free Dry Mass	A 10300 C(5)	n/a	n/a			
Periphyton	PERI-1/PERI-1mod	n/a	n/a	n/a	50 cm^3 centrifuge tube	Formalin (40% formaldehyde solution)
Macroinvertebrates	EMAP	n/a	n/a	n/a	1L Acid-washed high-density polyethylene (HDPE)	Ethanol

*Preferred analytical methods and required reporting limits may change in the future (e.g., become more stringent); consult with DEQ prior to any monitoring effort in order to ensure you use the most current methods.

7.6.4 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 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 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.

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, pre and post riparian vegetation monitoring will be important to track the abundance, distribution, and health of riparian vegetation as well as its impact on stream shading and ultimately reductions in low flow temperatures.

7.6.5 Watershed Wide Analyses

Recommendations for monitoring in the Tobacco TMDL Planning Area should not be confined to only those streams addressed within this document. The water quality targets presented in this document are applicable to all streams in the watershed, and the absence of a stream from the state's impaired waters list does not necessarily imply that the stream fully supports all beneficial uses. Furthermore, as conditions change over time and land management changes, consistent data collection methods throughout the watershed will allow resource professionals to identify problems as they occur, and to track improvements over time.

7.7 Potential Funding and Technical Assistance Sources

Prioritization and funding of restoration or water quality improvement projects is integral to maintaining restoration activities and monitoring project successes and failures. Several government agencies and also a few non-governmental organizations fund or can provide assistance with watershed or water quality improvement projects or wetlands restoration projects. Below is a brief summary of potential funding sources and organizations to assist with TMDL implementation.

7.7.1 Section 319 Nonpoint Source Grant Program

DEQ issues a call for proposals every year to award Section 319 grant funds administered under the federal Clean Water Act. The primary goal of the 319 program is to restore water quality in waterbodies whose beneficial uses are impaired by nonpoint source pollution and whose water quality does not meet state standards. 319 funds are distributed competitively to support the most effective and highest priority projects. In order to receive funding, projects must directly implement a DEQ-accepted watershed restoration plan and funds may either be used for the education and outreach component of the WRP or for implementing restoration projects. The recommended range for 319 funds per project proposal is $10,000 to $30,000 for education and outreach activities and $50,000 to $300,000 for implementation projects. All funding has a 40% cost share requirement, and projects must be administered through a governmental entity such as a conservation district or county, or a nonprofit organization. For information about past grant awards and how to apply, please visit http://deq.mt.gov/wqinfo/nonpoint/319GrantInfo.mcpx.

7.7.2 Future Fisheries Improvement Program

The Future Fisheries grant program is administered by FWP and offers funding for projects that focus on habitat restoration to benefit wild and native fish. Anyone ranging from a landowner or community-based group to a state or local agency is eligible to apply. Applications are reviewed annually in December and June. Projects that may be applicable to the Tobacco TMDL Planning Area include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats. For additional information about the program and how to apply, please visit http://fwp.mt.gov/fishAndWildlife/habitat/fish/futureFisheries/.

7.7.3 Watershed Planning and Assistance Grants

The DNRC administers Watershed Planning and Assistance Grants to watershed groups that are sponsored by a conservation district. Funding is capped at $10,000 per project and the application cycle is quarterly. The grant focuses on locally developed watershed planning activities; eligible activities include developing a watershed plan, group coordination costs, data collection, and educational activities. For additional information about the program and how to apply, please visit http://dnrc.mt.gov/cardd/LoansGrants/WatershedPlanningAssistance.asp.

Numerous other funding opportunities exist for addressing nonpoint source pollution. Additional information regarding funding opportunities from state agencies is contained in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and

Assistance Division, Water Quality Planning Bureau, 2012) and information regarding additional funding opportunities can be found at http://www.epa.gov/nps/funding.html.

7.7.4 Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is administered by NRCS and offers financial (i.e., incentive payments and cost-share grants) and technical assistance to farmers and ranchers to help plan and implement conservation practices that improve soil, water, air and other natural resources on their land. The program is based on the concept of balancing agricultural production and forest management with environmental quality, and is also used to help producers meet environmental regulations. EQIP offers contracts with a minimum length of one year after project implementation to a maximum of 10 years. Each county receives an annual EQIP allocation and applications are accepted continually during the year; payments may not exceed $300,000 within a six-year period. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

7.7.5 Montana Partners for Fish and Wildlife

Montana Partners for Fish and Wildlife is a program under the U.S. Fish & Wildlife Service that assists private landowners to restore wetlands and riparian habitat by offering technical and financial assistance. For additional information about the program and to find your local contact for the Kootenai River watershed, please visit: http://www.fws.gov/mountain-prairie/pfw/montana/.

7.7.6 Wetlands Reserve Program

The Wetlands Reserve Program is a voluntary conservation program administered by the NRCS that offers landowners the means to restore, enhance, and protect wetlands on their property through permanent easements, 30 year easements, or Land Treatment Contracts. The NRCS seeks sites on agricultural land where former wetlands have been drained, altered, or manipulated by man. The landowner must be interested in restoring the wetland and subsequently protecting the restored site. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/mt/programs/easements/wetlands/

7.7.7 Montana Wetland Council

The Montana Wetland Council is an active network of diverse interests that works cooperatively to conserve and restore Montana's wetland and riparian ecosystems. Please visit their website to find dates and locations of upcoming meetings, wetland program contacts, and additional information on potential grants and funding opportunities: http://deq.mt.gov/wqinfo/wetlands/wetlandscouncil.mcpx.

7.7.8 Montana Natural Heritage Program

The Montana Natural Heritage Program is a valuable resource for restoration and implementation information including maps. Wetlands and riparian areas are one of the 14 themes in the Montana Spatial Data Infrastructure. The Montana Wetland and Riparian Mapping Center (found at: http://mtnhp.org/nwi/) is creating a statewide digital wetland and riparian layer as a resource for management, planning, and restoration efforts.

7.7.9 Montana Aquatic Resources Services, Inc.

Montana Aquatic Resources Services, Inc. (MARS) is a nonprofit organization focused on restoring and protecting Montana's rivers, streams and wetlands. MARS identifies and implements stream, lake, and wetland restoration projects, collaborating with private landowners, local watershed groups and conservation districts, state and federal agencies, and tribes. For additional information about the program, please visit http://montanaaquaticresources.org

8.0 Public Participation

Stakeholder and public involvement is a component of TMDL planning supported by Environmental Protection Agency (EPA) guidelines and required by Montana state law (Montana Code Annotated (MCA) 75-5-703 and 704) which directs DEQ to consult with a watershed advisory group 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 Tobacco TMDL Planning Area (TPA).

8.1 Participants and Roles

This project was a collaborative effort between Montana DEQ and the U.S. EPA. Throughout completion of the Tobacco planning area temperature and nutrient TMDLs, DEQ and EPA worked with stakeholders to keep them apprised of project status and solicited input from the Tobacco TMDL watershed advisory group. A description of the participants in the development of the temperature and nutrient TMDLs in the Tobacco TPA and their roles is contained below.

Montana Department of Environmental Quality
Montana state law (Montana Code Annotated (MCA) 17-5-703) directs DEQ to develop all necessary TMDLs. DEQ 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 worked with other state and federal agencies to gather data and conduct technical assessments. DEQ also partnered with the Kootenai River Network, a non-profit organization, to collect data and coordinate local outreach activities for this project.

United States 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. Project management support was provided by the EPA Regional Office in Helena, MT, including overseeing contractors hired for data collection, analysis, and modeling; communicating with the Tobacco TMDL Watershed Advisory Group and other stakeholders; writing the majority of this document; and providing technical review.

Kootenai River Network
The Kootenai River Network (KRN) was a major partner during this project. The KRN is a non-profit organization whose primary purpose is to foster communication and implement collaborative processes among private and public interests in the Kootenai River watershed and basin. They strive to improve resource management practices and restore water quality and aquatic resources in the basin. Membership in the KRN includes representatives from the U.S. Fish and Wildlife Service; Natural Resources Conservation Service; Montana Fish, Wildlife and Parks; Lincoln Conservation District; and Plum Creek Timber Company; among other organizations.

Conservation Districts
Majority of the Tobacco TMDL Planning Area falls within Lincoln County; however a small portion of the Lime Creek drainage is located in Flathead County. Therefore, DEQ and EPA provided both the Lincoln

Conservation District and the Flathead Conservation District with consultation opportunity during development of the temperature and nutrient TMDLs. This included opportunities to provide comment during the various stages of TMDL development, and an opportunity for participation in the advisory group described below.

Tobacco TMDL Watershed Advisory Group

The Tobacco TMDL Watershed Advisory Group consisted of selected resource professionals who possess a familiarity with water quality issues and processes in the Tobacco River watershed, and also representatives of applicable interest groups. All members were solicited to participate and work with DEQ and EPA and the Lincoln and Flathead conservation districts in an advisory capacity per Montana state law (Montana Code Annotated (MCA) 17-5-703 and 704). DEQ and EPA requested participation from the interest groups defined in MCA 75-5-704 and included local city and county representatives, livestock-oriented and farming-oriented agriculture representatives, conservation groups, watershed groups, state and federal land management agencies, and representatives of recreation and tourism interests.

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. Typically, draft documents were released to the advisory group for review under a limited timeframe, and their comments were then compiled and evaluated. Final technical decisions regarding document modifications resided with DEQ and EPA.

Communications with the advisory 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.

8.2 Response to Public Comments

Upon completion of a 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 public comment, and DEQ addresses and responds to all formal public comments.

The formal public comment period for the "Tobacco Planning Area Nutrient and Temperature TMDLs and Water Quality Improvement Plan" was initiated on July 14, 2014 and closed on August 12, 2014. Electronic copies of the draft document were made available at the Eureka public library and at the State Library in Helena, MT. No public comments were received on this document.

A public informational meeting was held in Eureka, MT on July 23, 2014. DEQ and EPA provided an overview of the document, answered questions, and solicited public input and comment on the TMDLs. The announcement of both the public comment period and the public meeting was distributed to the Tobacco TMDL Watershed Advisory Group, which included the KRN and Lincoln and Flathead conservations districts; the Statewide TMDL Advisory Group; and other identified interested parties via e-mail. Notice of the meeting was posted on the DEQ webpage and DEQ wiki, and also advertised in the Daily Interlake, Missoulian, and Tobacco Valley News newspapers.

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APPENDIX A – MAPS AND TABLES

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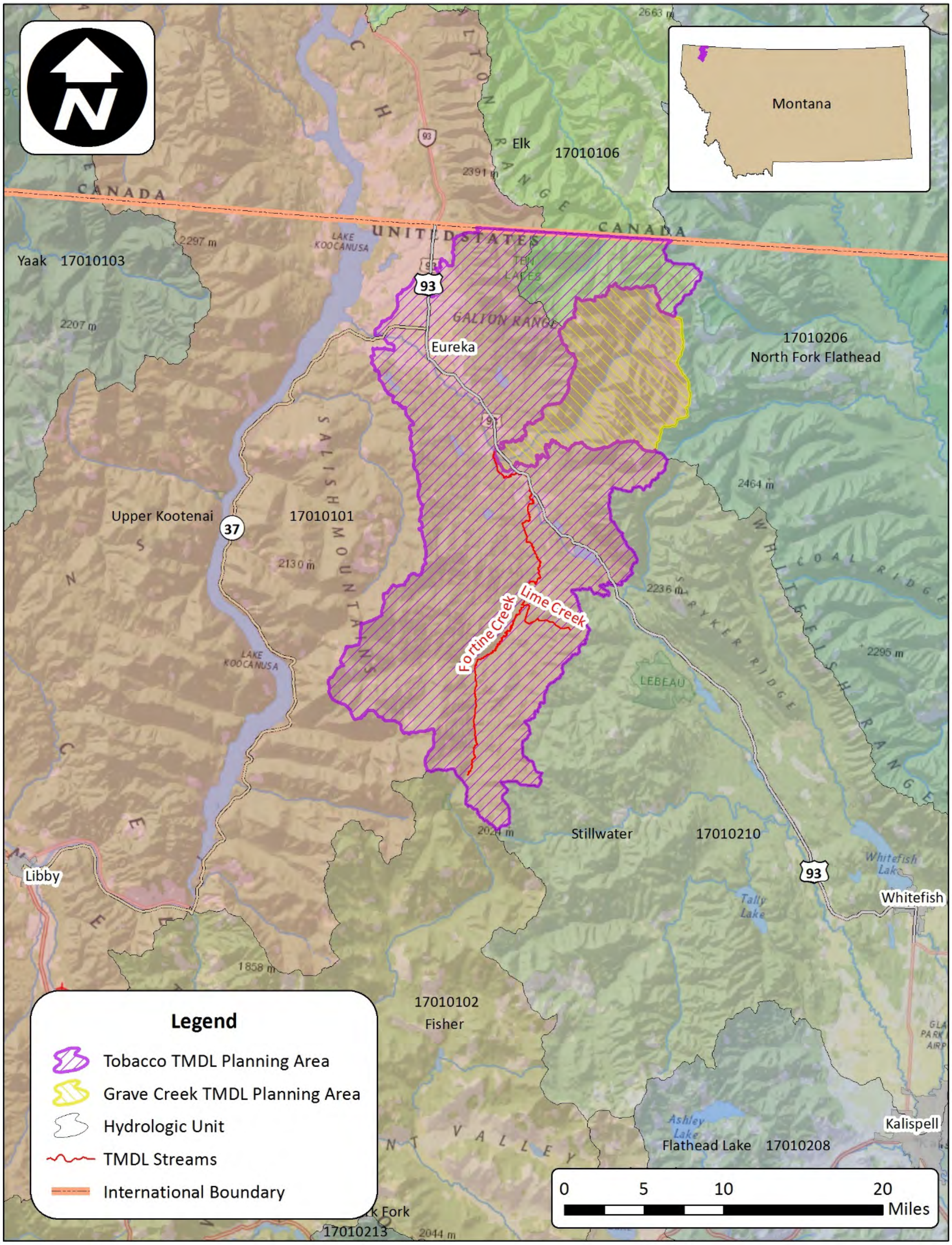
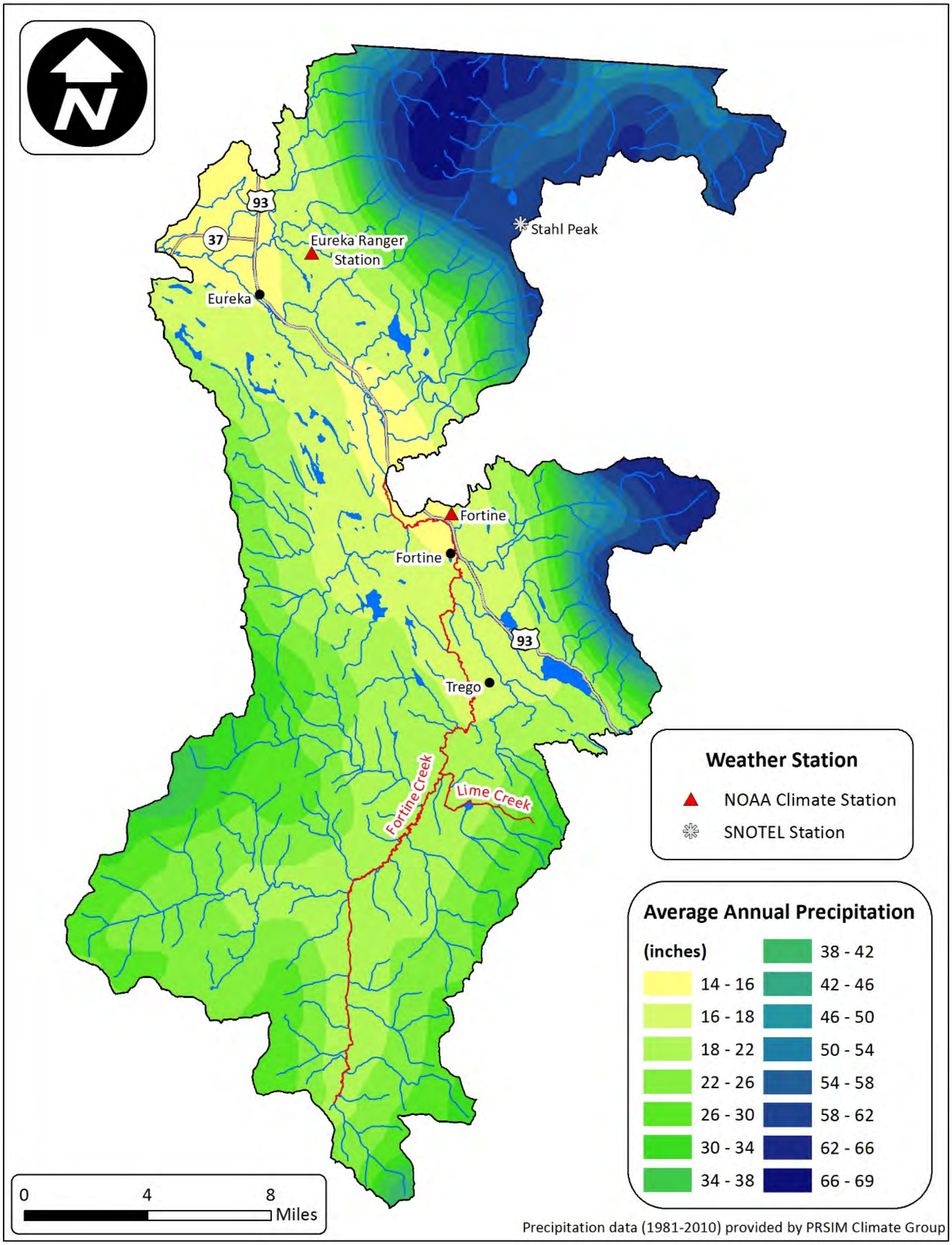


Map A-1. General location of the Tobacco TMDL Planning Area

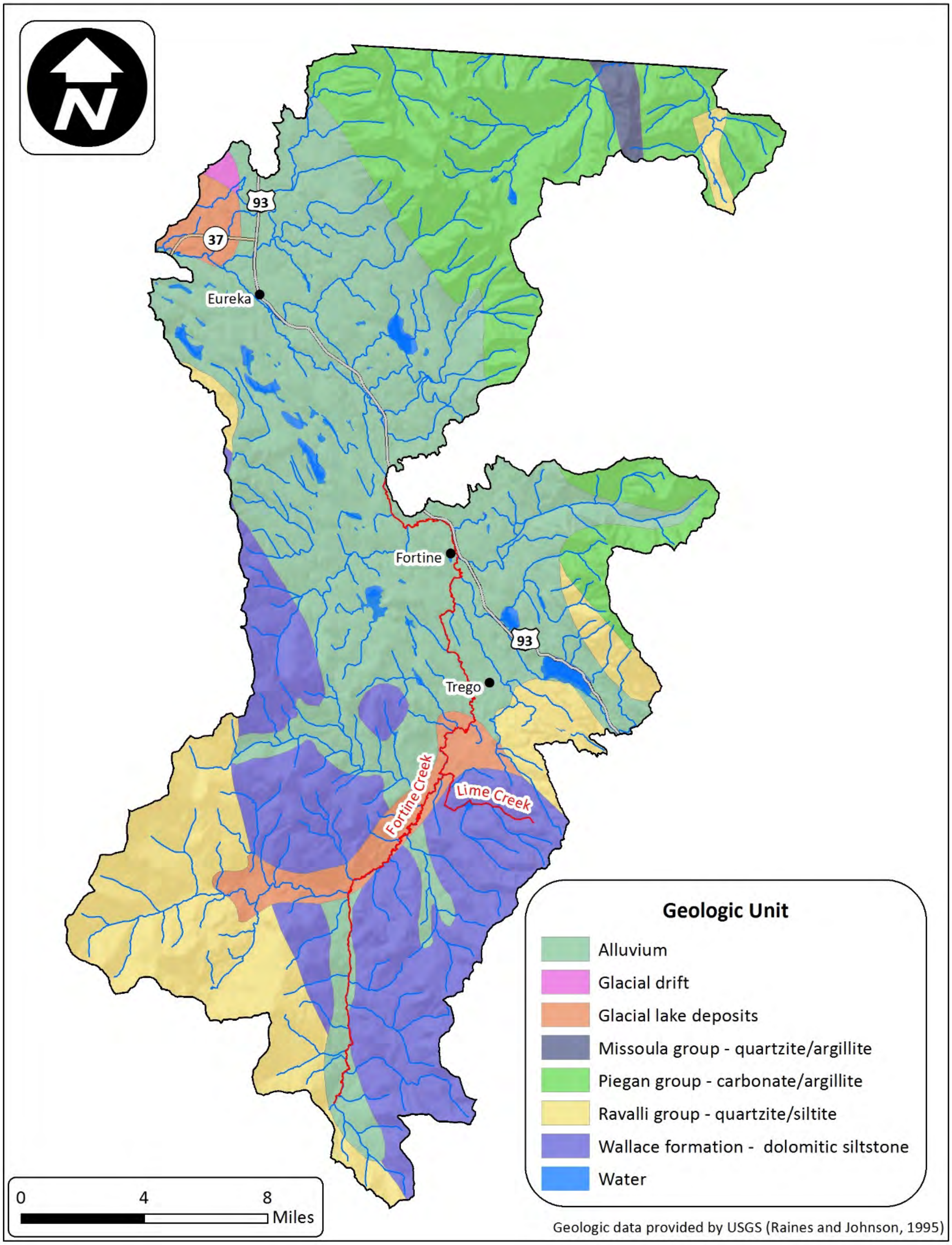
Table A-1. 2014 Impaired Waterbodies, Impairment Causes, Impaired Uses, and Impairment Cause Status in the Tobacco TMDL Planning Area[1].

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impaired Use(s)	Impairment Cause Status
Fortine Creek, headwaters to mouth (Grave Creek)	MT76D004_020	Alteration in streamside or littoral vegetative covers	Non-pollutant	Aquatic Life	Addressed by sediment TMDL established in 2011 and also in this document
		Excess algal growth	Non-pollutant	Aquatic Life, Primary Contact Recreation	Discussed in document; Follow up work recommended
		Low flow alterations	Non-pollutant	Aquatic Life, Primary Contact Recreation	Discussed in document; Follow up work recommended
		Sediment/siltation	Sediment	Aquatic Life	Sediment TMDL established in 2011
		Temperature	Temperature	Aquatic Life	Temperature TMDL contained in this document
Lime Creek, headwaters to mouth (Fortine Creek)	MT76D004_050	Alteration in streamside or littoral vegetative covers	Non-pollutant	Aquatic Life	Addressed by sediment TMDL established in 2011 and also in this document
		Chlorophyll-*a*	Non-pollutant	Aquatic Life, Primary Contact Recreation	Addressed by TN TMDL in this document
		Total Nitrogen (TN)	Nutrients	Aquatic Life	TN TMDL contained in this document
		Total Phosphorus (TP)	Nutrients	Aquatic Life	TP TMDL contained in this document
		Sediment/siltation	Sediment	Aquatic Life	Sediment TMDL established in 2011
Deep Creek, headwaters to mouth (Fortine Creek)	MT76D004_080	Alteration in streamside or littoral vegetative covers	Non-pollutant	Aquatic Life	Addressed by sediment TMDL established in 2011 and also in this document
		Excess algal growth	Non-pollutant	Aquatic Life, Primary Contact Recreation	Discussed in document; Follow up work recommended
		Sediment/siltation	Sediment	Aquatic Life	Sediment TMDL established in 2011

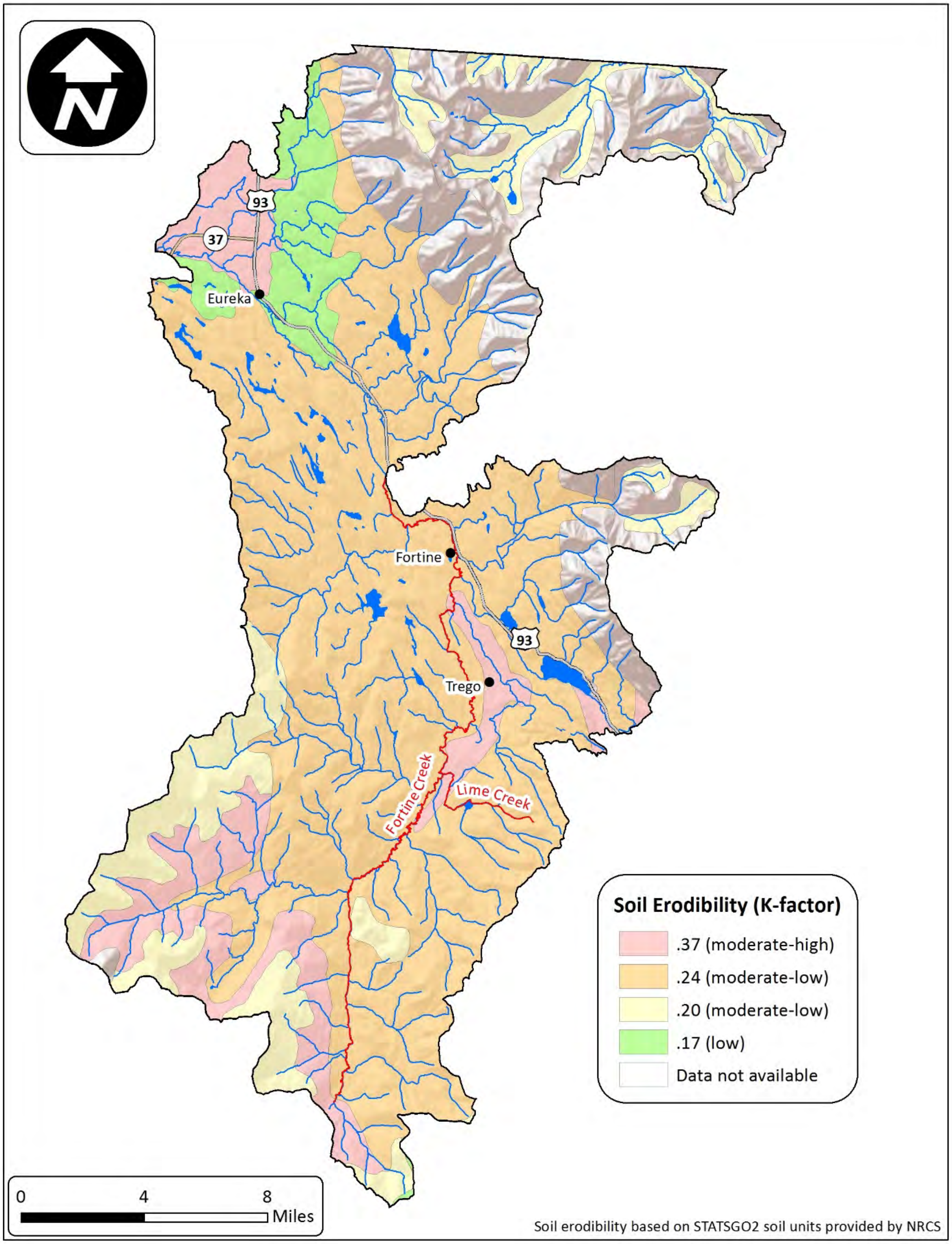
[1]This table includes all remaining impairments in the planning area but does not include waterbodies that only have sediment and/or non-pollutant causes that were addressed in the Grave Creek and Tobacco sediment TMDL documents (River Design Group, 2005; Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011).



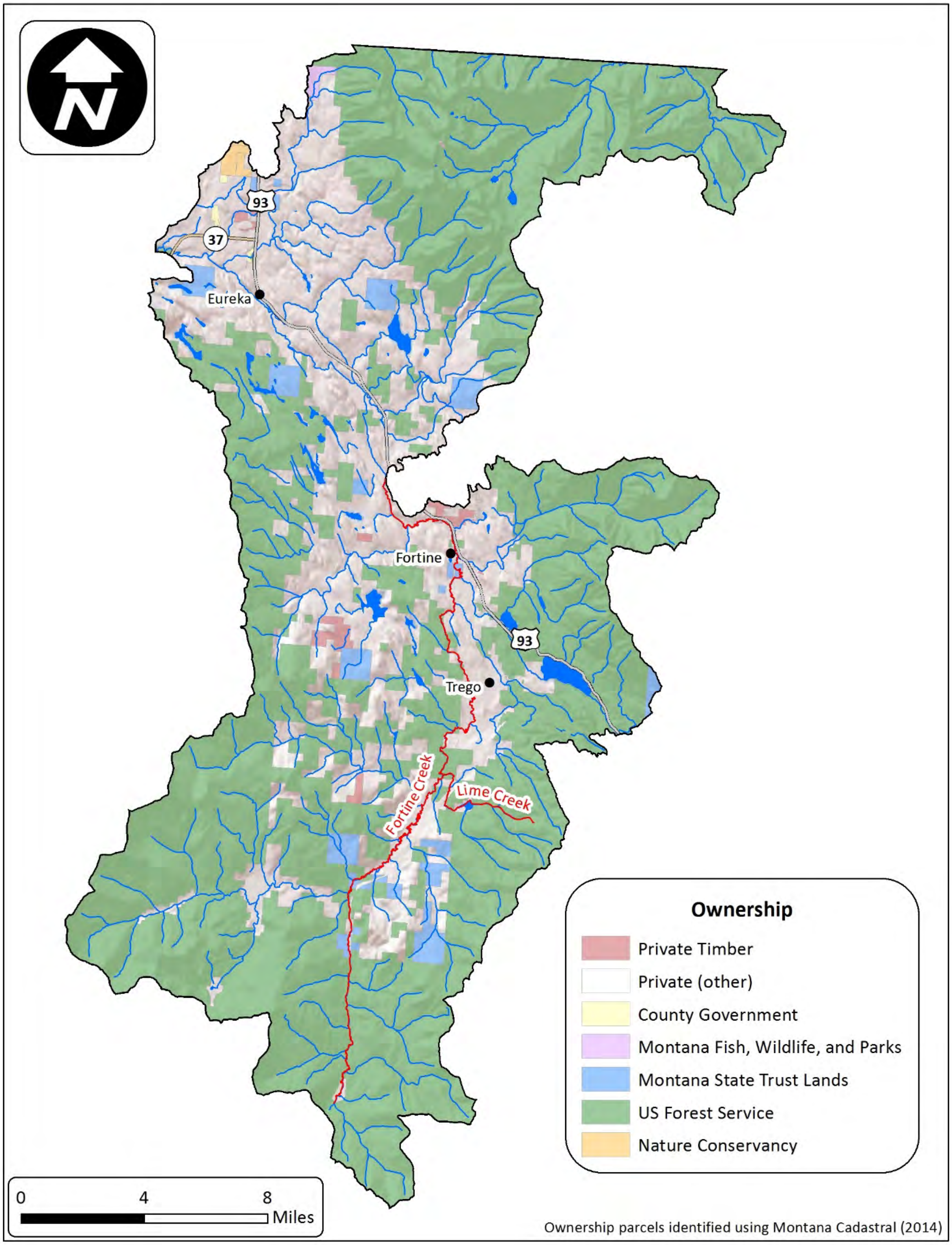
Map A-2. Average annual precipitation and weather stations in the Tobacco TMDL Planning Area



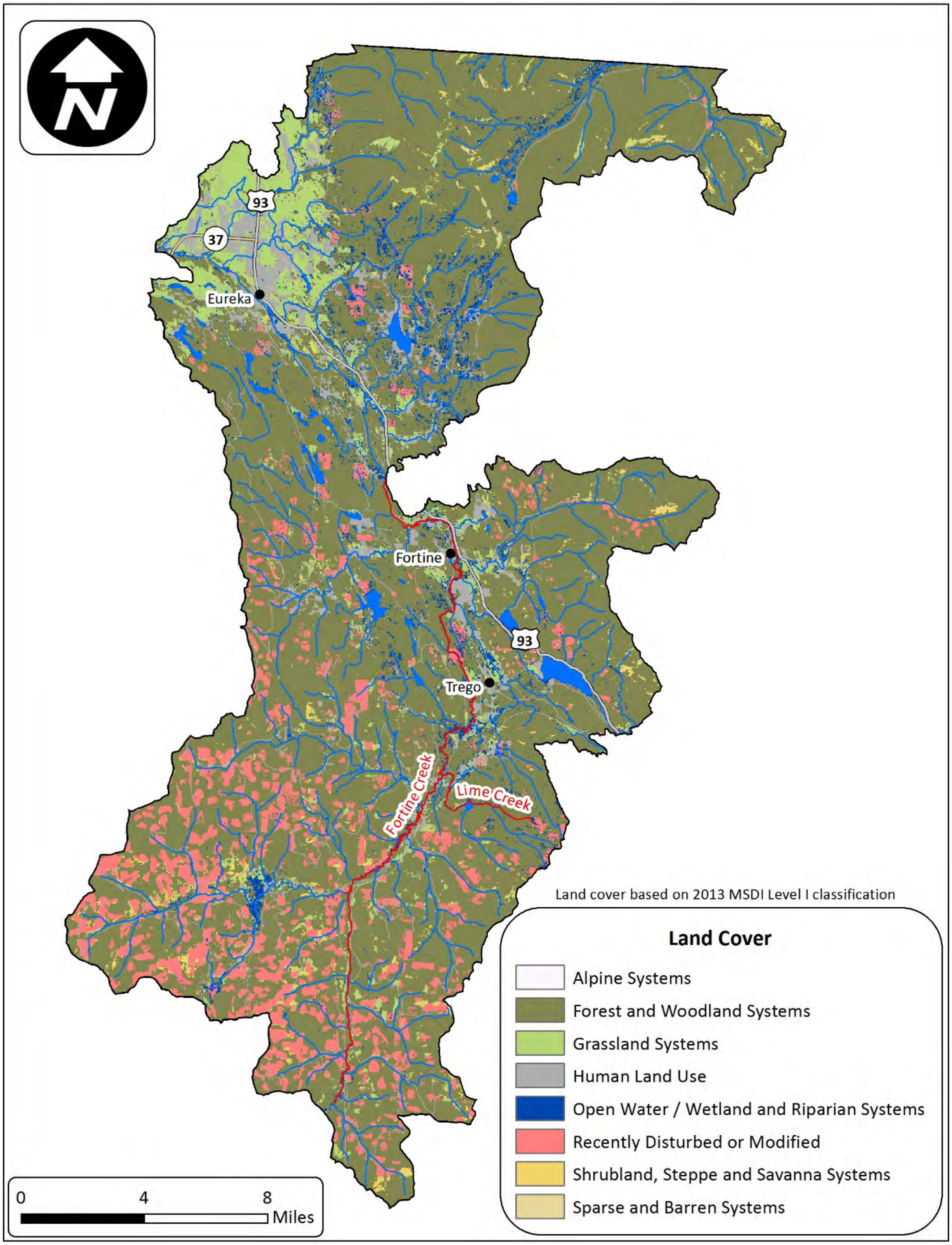
Map A-3. Geology of the Tobacco TMDL Planning Area



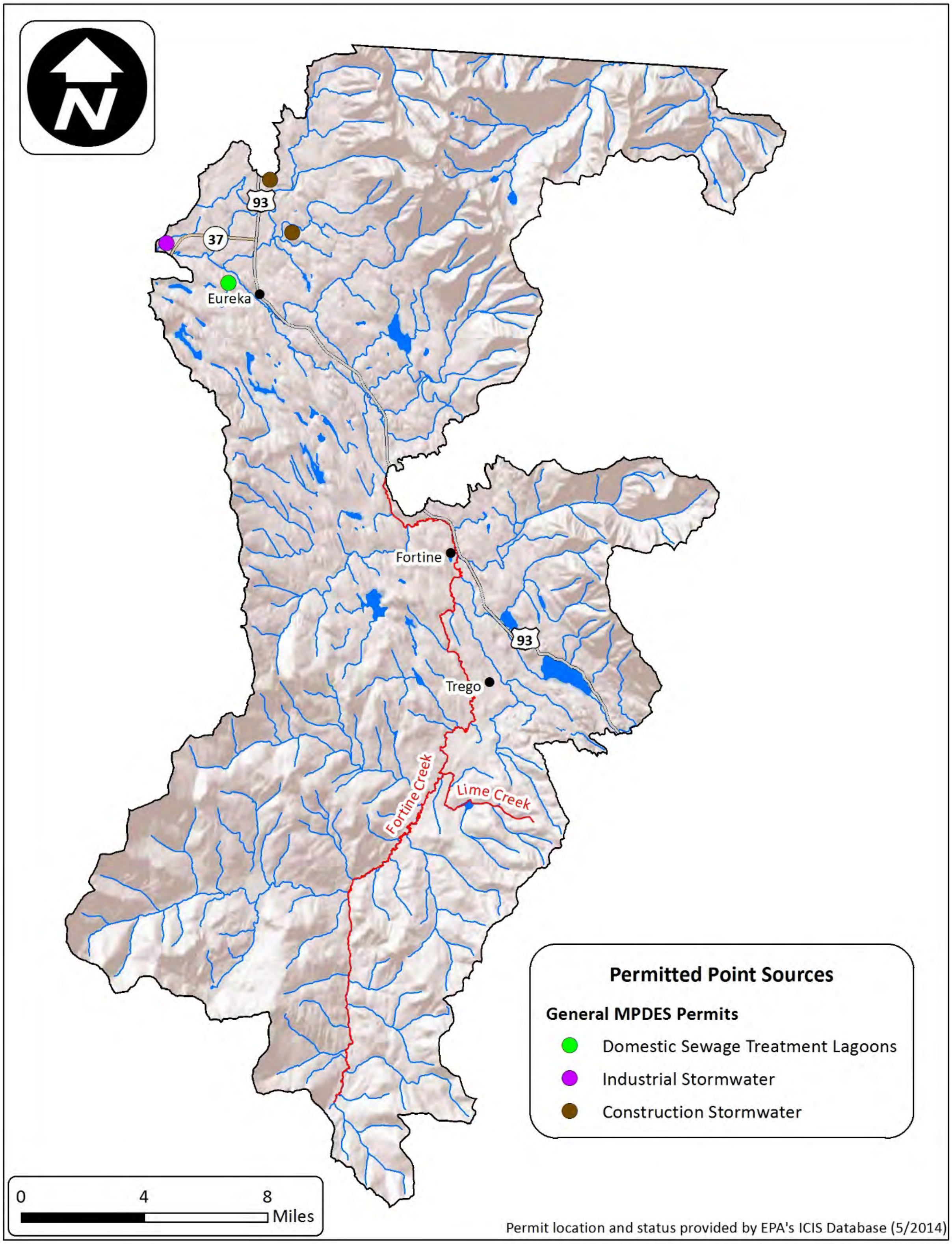
Map A-4. Soil Erodibility in the Tobacco TMDL Planning Area



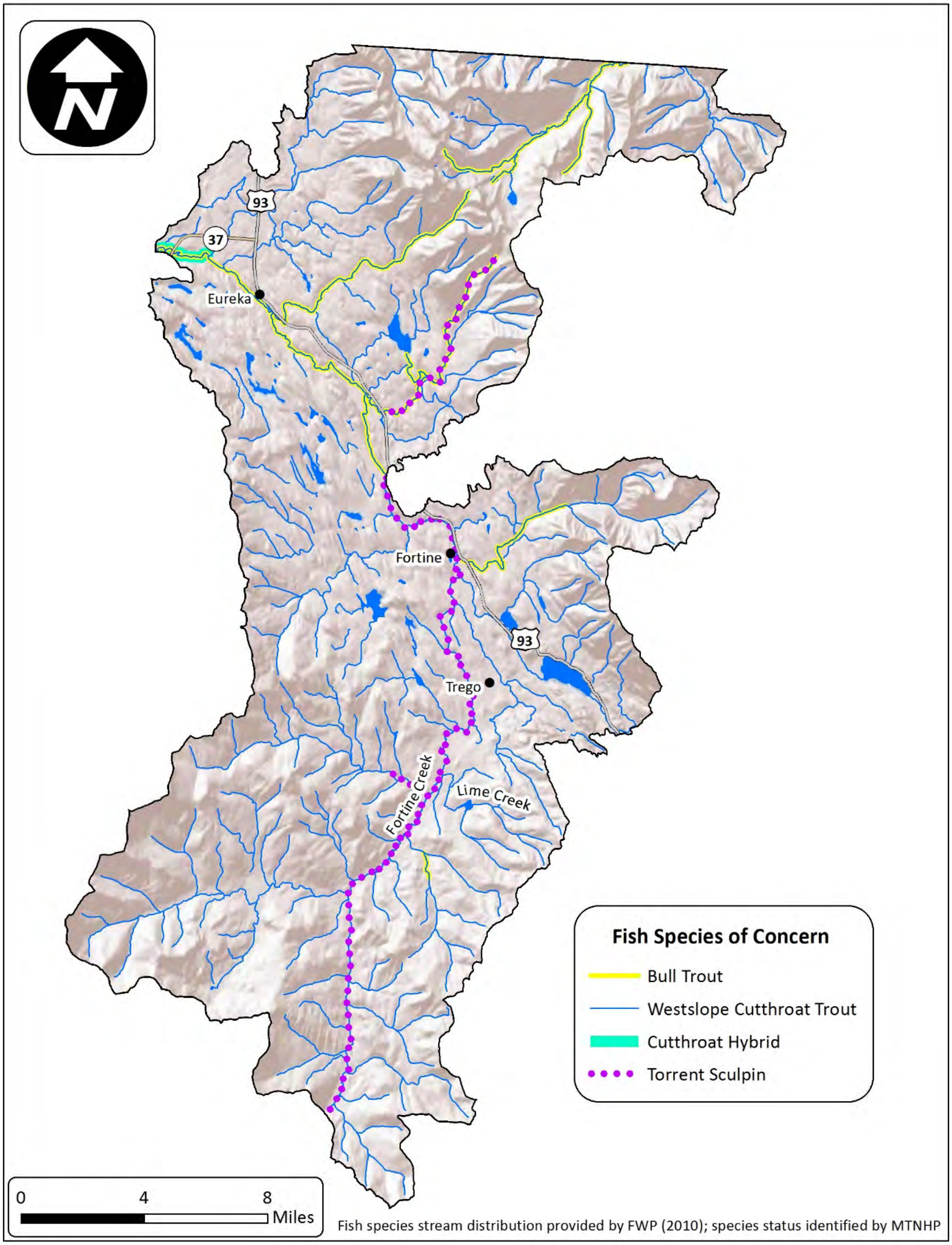
Map A-5. Land ownership in the Tobacco TMDL Planning Area



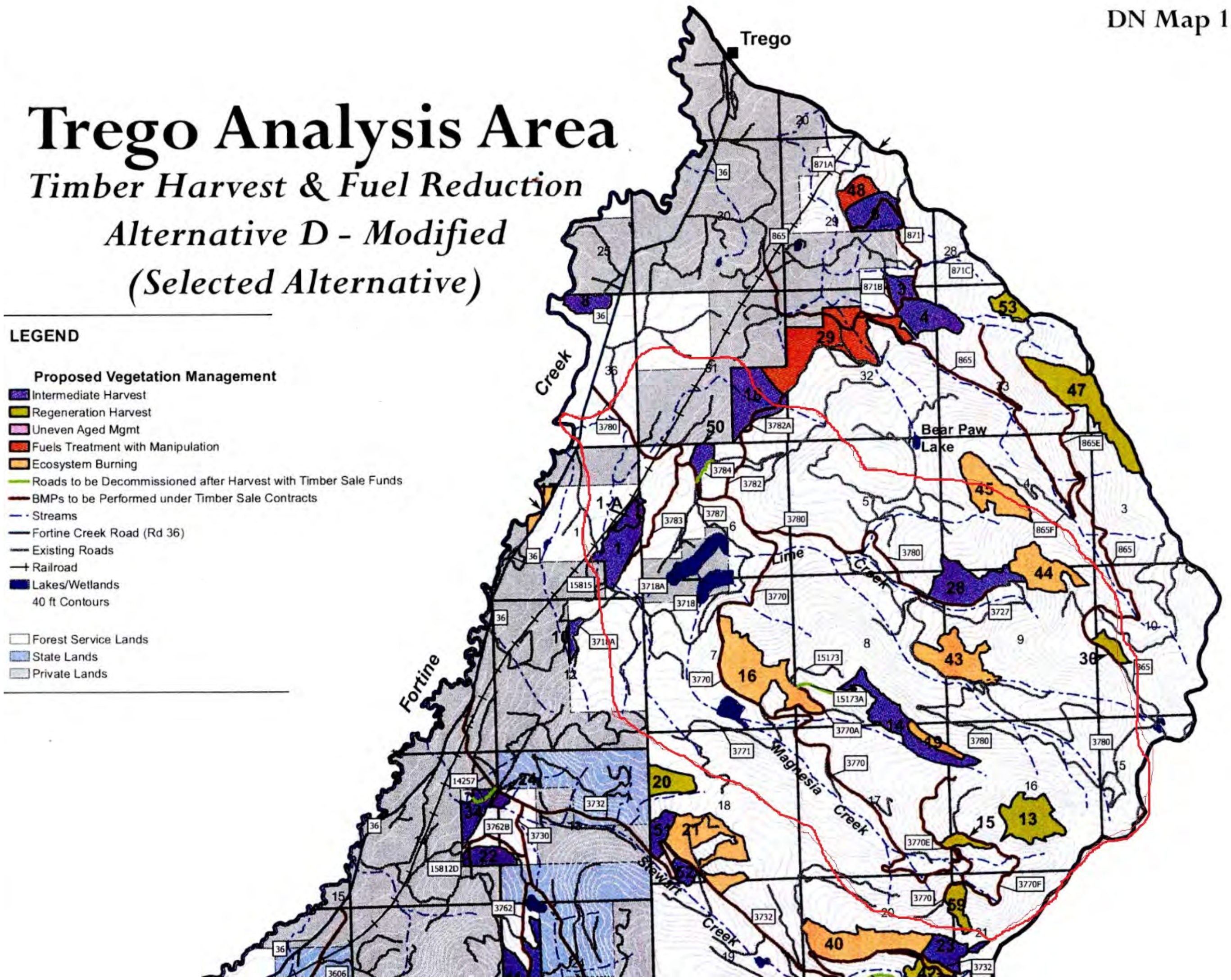
Map A-6. Types of land cover and land use in the Tobacco TMDL Planning Area



Map A-7. Locations of MPDES permitted point sources in the Tobacco TMDL Planning Area



Map A-8. Fish species of concern in the Tobacco TMDL Planning Area



Map A-9. Timber harvest that has occurred as part of the 2007 Trego Project. Red line is the approximate Lime watershed boundary. Base map provided by the Kootenai National Forest from the Trego Decision Notice and Finding of No Significant Impact, February 2007

Appendix A - References

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APPENDIX B – FORTINE CREEK QUAL2K MODEL REPORT

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Acronyms and Abbreviations

EPA	U.S. Environmental Protection Agency
DEQ	Montana Department of Environmental Quality
MRLC	Multi-Resolution Land Characteristics Consortium
NLCD	National Land Cover Dataset
QUAL2K	River and Stream Water Quality Model
RM	river mile
TMDL	total maximum daily load
TPA	TMDL Planning Area
USFS	U.S. Forest Service (U.S. Department of Agriculture)
USGS	U.S. Geological Survey (U.S. Department of the Interior)
WRCC	Western Regional Climate Center

Units of Measure

°C	degrees Celsius
°F	degrees Fahrenheit
cfs	cubic feet per second
MSL	mean sea level

EXECUTIVE SUMMARY

Fortine Creek is on the 2012 303(d) List as impaired because of elevated water temperatures. Data were collected in 2012 and a QUAL2K water quality model was then developed for Fortine Creek to evaluate the impairment status and the effect that human sources are having on stream temperatures. Eight scenarios (described below) were developed to evaluate model sensitivity and a range of potential watershed management activities. Scenarios 2 through 6 were based on existing conditions (Scenario 1). Scenario 8 was based on existing conditions during a low flow year (Scenario 7). Generally, small changes in shade or inflow had minimal effects on water temperatures while large increases in shade and large increases or decreases of inflows had considerable effects on water temperatures.

- Scenario 1 - Baseline: Existing condition (i.e., the calibrated model). This served as the baseline scenario from which to compare all other scenarios except 7 and 8.
- Scenario 2 – No withdrawals: Existing condition without water withdrawals. This scenario was performed to test the sensitivity of the model to water withdrawals and is not intended for management purposes.
- Scenario 3 – Maximum Shade: Existing condition with riparian vegetation in a 150-foot buffer at its maximum potential shade. This scenario was performed to test the sensitivity of the model to shade and is not intended for management purposes.
- Scenario 4 – Improved Shade: Existing condition scenario with riparian vegetation in a 50-foot buffer improved to the maximum extent practicable. This is to simulate standards attainment regarding soil and land conservation practices.
- Scenario 5 – Improved Water Management: Existing condition scenario with a 15 percent reduction of water withdrawals. This is to simulate standards attainment regarding water conservation practices.
- Scenario 6 – Naturally Occurring: Existing condition scenario with improved riparian vegetation in a 50-foot buffer and a 15 percent reduction of water withdrawals. This is to simulate full standards attainment via the use of all reasonable land, soil, and water conservation practices.
- Scenario 7 – Low Flow Baseline: A baseline low flow scenario with a 56 percent reduction of flow relative to Scenario 1. This is an altered existing condition scenario in which the baseline flow is reduced. This scenario is to simulate the existing condition on a drier year than that used to calibrate the model under Scenario 1. Besides flow, all inputs were identical to Scenario 1. This served as a low flow baseline scenario from which to compare Scenario 8.
- Scenario 8 – Low Flow Naturally Occurring: A low flow scenario with a 56 percent reduction of flow, improved vegetation in a 50-foot buffer to the maximum extent practicable, and a 15 percent reduction of water withdrawals. This is to simulate full standards attainment via the use of all reasonable land, soil, and water conservation practices on a drier year than that used for Scenario 6.

B1.0 INTRODUCTION

This appendix is based on a model report completed by Tetra Tech (Tetra Tech 2013) for a temperature model (QUAL2K) that was used to support TMDL development for Fortine Creek. Background information is provided in the following section (**Section B2.0**). A summary of model set up, calibration, and validation 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 STUDY AREA

Fortine Creek (MT76D004_020) is identified on the 2012 303(d) List as impaired by temperature. Fortine Creek is located in northwest Montana (**Figure B-1**) in the Northern Rockies ecoregion and the impaired segment flows for approximately 33.46 miles from its headwaters to its confluence with Grave Creek, forming the headwaters of the Tobacco River.

Most of the Fortine Creek watershed is managed by the U.S. Forest Service (USFS) as part of the Kootenai National Forest (**Figure B-1**). However, significant portions of the valley bottom along Fortine Creek are privately owned. The landscape is predominantly forested, with patches of mature forest interspersed with selective harvests and clearcuts at various stages of regrowth (**Figure B-2**). U.S. Route 93 bisects the watershed, running along Dickey Lake and Murphy Lake and through the town of Fortine.

B2.2 MONTANA TEMPERATURE STANDARD

The model results will be used to verify Fortine Creek is not meeting the temperature standard. For a waterbody with a use classification of B-1, such as Fortine Creek, 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 occurring[2] 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.

[1] Administrative Rules of the state of Montana 17.30.623(e).

[2] Administrative Rules of the state of Montana 17.30.602(17): "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. Conditions resulting from the reasonable operation of dams in existence as of July 1, 1971, are natural.”

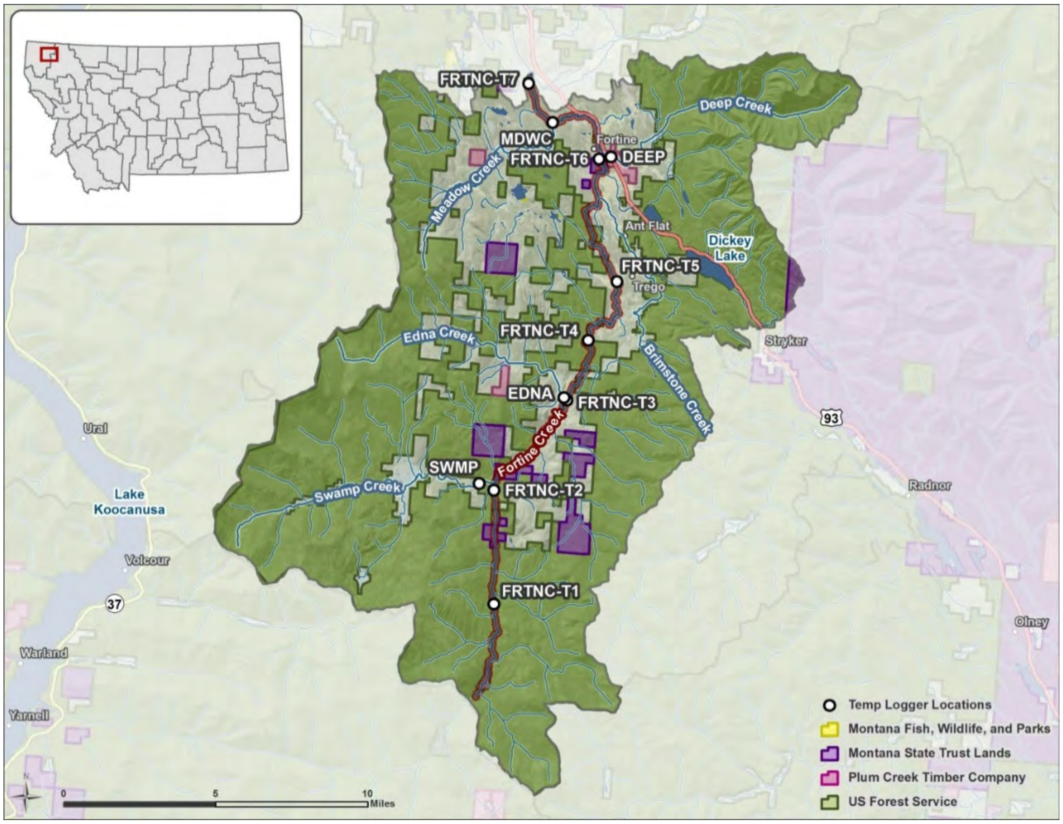


Figure B-1. Land ownership in the Fortine Creek watershed (NRIS, 2012)

Figure B-2. 2009 Aerial Imagery of Fortine Creek watershed (2009 NAIP; NRIS 2012)

B2.3 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, 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 the temperature in small streams (or those with reduced flows) can be changed more easily.

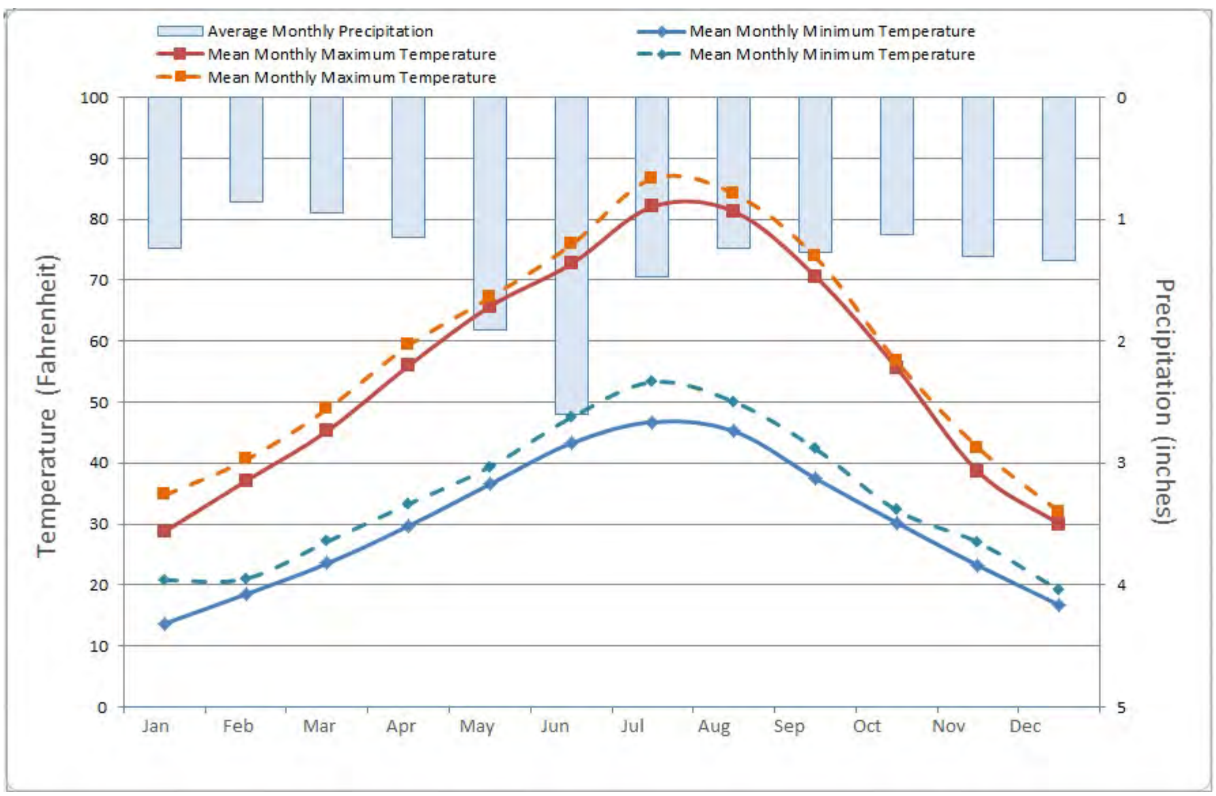
This section provides a summary of the available data pertaining to factors that could influence stream temperature in Fortine Creek and are necessary for model development: climate, shade, stream morphology, and hydrology. Point sources also have the potential to influence stream temperature but there are currently no permitted point sources to Fortine Creek (as of January 14, 2014).

B2.3.1 Climate

The nearest weather stations to the Fortine Creek watershed are located in Fortine, Montana (National Weather Service stations 243139 and 243142) at an elevation of 3,040 feet above mean seal level (MSL). These two stations represent one continuous, non-overlapping dataset, with station 243142 replacing station 243139 in October 2009. Average annual precipitation is 16.5 inches, with the greatest amounts falling in May and June (**Figure B-3**; Western Regional Climate Center 2012). Average maximum temperatures occur in July and August and are 82.1 °F and 81.3°F, respectively.

A Remote Automatic Weather Station (RAWS) is located in Eureka, Montana (National Weather Service station ID 240110) at 2,800 feet above MSL. This station records weather data hourly, which is preferable for QUAL2K model development, whereas stations 243139 and 243142 record data daily. Thus, Eureka hourly temperature data were used to develop the QUAL2K inputs. The Eureka RAWS data are also summarized in **Figure B-3**.

It should be noted the Eureka weather station is at an elevation of 2,800 above MSL, and Fortine Creek ranges in elevation from approximately 2,800 to 3,940 feet above MSL. Since elevation along Fortine Creek varies over a large range, temperature data were corrected for elevation differences between model segments and the Eureka RAWS (as described in **Section B3.5**).



Source: Monthly Summaries from 1950 to 2012 at Stations 243139 and 243142 as solid lines, and from 2001 to 2012 at the Eureka RAWS as dashed lines (precipitation not available) (NCDC 2012).

Figure B-3. Monthly average air temperatures and precipitation at weather stations near Fortine Creek

B2.3.2 Shade

Effective shade (which is referred to as shade hereafter) is defined as the fraction of solar radiation that is blocked by topography and vegetation. Shade measurements were collected on September 12 and 13, 2012, at eight monitoring locations along Fortine Creek using a Solar Pathfinder™ (**Figure B-4**). The data are summarized in **Table B-1** and accompanying field notes are in **Attachment B-3**. Hourly shade estimates based on the Solar Pathfinder™ measurements are available by request from DEQ or EPA but are not attached to this document due to file size.

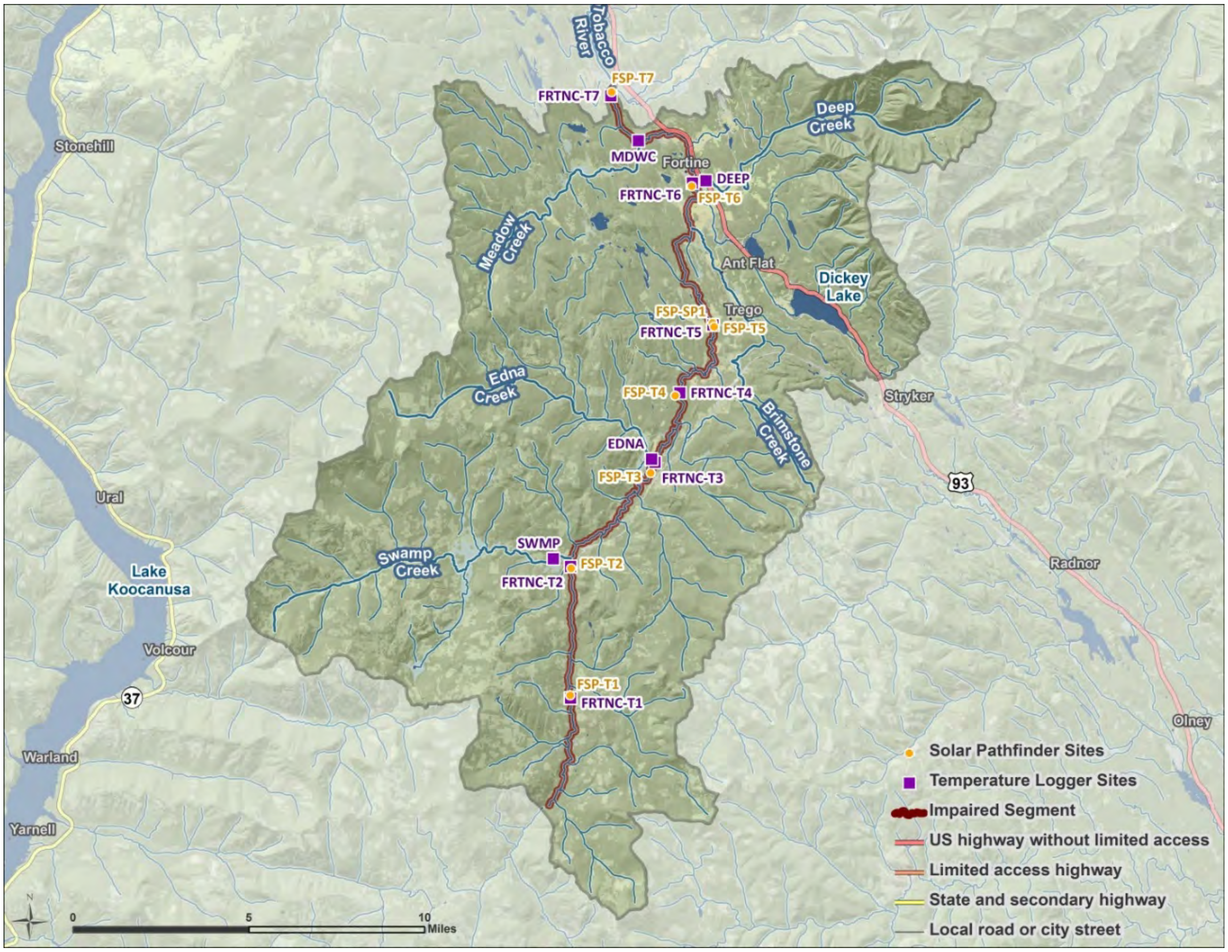


Figure B-4. 2012 EPA flow, shade, and continuous temperature monitoring sites

Table B-1. Average shade per site from Solar Pathfinder™ measurements

Site ID	Average daily shade (averaged across daylight hours)
FRTNC-T1	78%
FRTNC-T2	90%
FRTNC-T3	42%
FRTNC-T4	63%
FRTNC-T5	28%
FRTNC-T6	32%
FRTNC-T7	57%
FRTNC-SP1	10%

B2.3.3.1 Shade Modeling

An analysis of aerial imagery and field reconnaissance showed that shading along Fortine Creek was highly variable. Therefore, shade was also evaluated using the spreadsheet model Shadev3.0.xls. Shade version 3.0 is a riparian vegetation and topography model that computes the hourly shade for a single day (Washing 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, which is the distance between the edge of the first vegetation zone on the left and right bank.

Available Data

The application of the Shade Model to Fortine Creek relied upon field data collected in 2012 and the interpretation of these data. Based on the field data, several model inputs were obtained: tree/shrub height, overhang, wetted channel width, and bankfull width.

Riparian and Shade Inputs

To characterize shade along a stream, it is important to know the composition of the riparian vegetation because different forms of vegetation have varying degrees of potential to provide shade. To supplement the field data collected at the sites shown in **Figure B-4** and provide a longitudinally continuous data set of vegetation characteristics along Fortine Creek, vegetation communities between the shade monitoring sites were visually characterized based on aerial imagery (dated August 17, 2012; GoogleEarth 2012). Using GIS, vegetative communities observed in the aerial imagery that were within a 150 foot buffer of the stream centerline were classified as trees, shrubs, or herbaceous. Bare ground and roads were also identified during GIS analyses. Trees were further divided into the following classes based on percent canopy cover derived from the 2006 NLCD (**Figure B-5**):

- 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)

Based on the classification procedure described above, high density trees, medium density trees, shrubs, and herbaceous are all dominant cover types along Fortine Creek (**Table B-2**). Sparse trees, roads, and bare ground comprise only a small percentage of the riparian area.

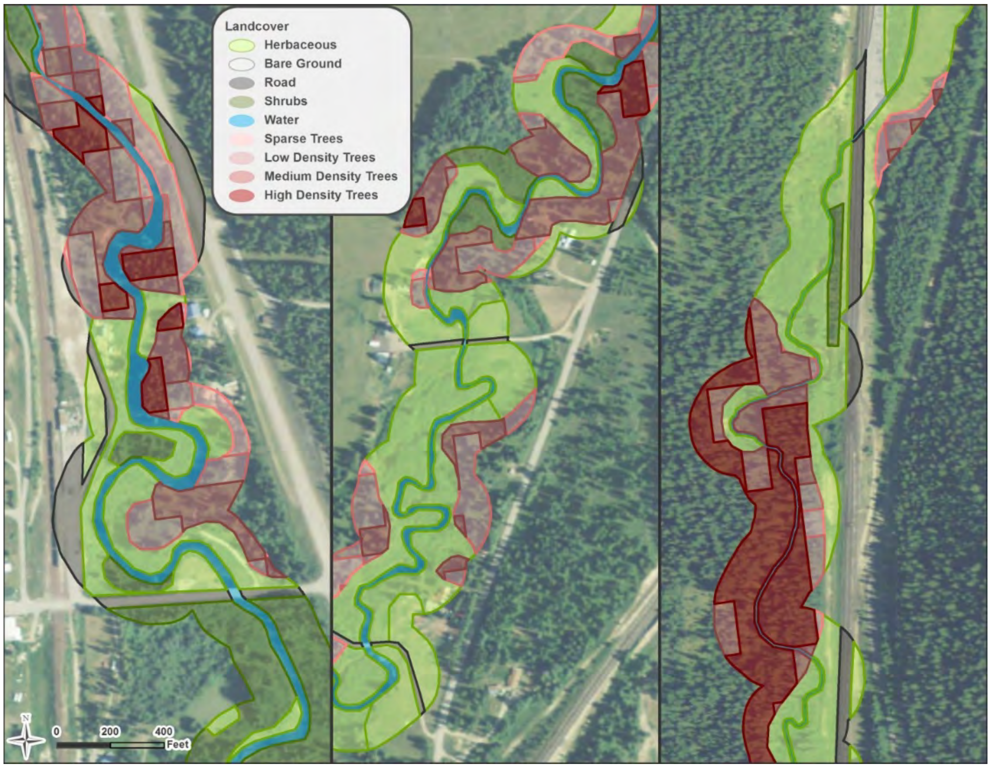


Figure B-5. Vegetation mapping examples for Fortine Creek

Table B-2. Land cover types in the Fortine Creek riparian zone

Land cover type	Area within 150ft Buffer (acres)	Relative Area within 150ft Buffer (percent)	Relative Area within 50ft Buffer (percent)
Bare ground	9.2	0.8%	0.4%
Herbaceous	225.8	18.6%	21.3%
Roads	32.5	2.7%	1.0%
Shrub	236.1	19.5%	25.1%
Sparse trees	50.1	4.1%	3.0%
Low density trees	105.4	8.7%	8.3%
Medium density trees	247.9	20.5%	20.6%
High density trees	304.6	25.1%	20.2%

The 2012 field notes and the above described vegetation mapping were used to develop a riparian description table with inputs needed for the Shade Model (**Table B-3**). Vegetation descriptions used the average value for tree/shrub height and overhang from field observation. Besides the riparian vegetation information summarized in **Table B-3**, other necessary inputs for the Shade Model are 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. Reach lengths within the model must be of equal intervals but the reaches in the field study were not at equal intervals and were very widely spaced. A uniform reach length interval of 30 meters (98 feet) was used as a model input. 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 below.

Table B-3. Vegetation input values for the Shade Model

Attribute	Value	Basis
Trees		
Height	23 meters (75 feet)	Average of field values across all Solar Pathfinder™ sites.
Density	Variable	2006 NLCD.
Overhang	2.3 meters (7.5 feet)	Estimated as 10% of height (Stuart 2012).
Shrubs		
Height	4 meters (13 feet)	Average of field values across all Solar PathfinderTM sites.
Density	90%	Ocular estimate based on aerial imagery.
Overhang	1 meter (3.3 feet)	Estimated as 25% of height (Shumar and de Varona 2009)
Herbaceous		
Height	1 meter (3.3 feet)	Estimated average based on site reconnaissance (September 2012).
Density	100%	Estimated average based on site reconnaissance (September 2012).
Overhang	0 meters	Estimated based on site reconnaissance (September 2012).

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 streambanks, 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.

Although the field work provided an estimate of the wetted width, an assessment along the entire stream was obtained 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.

B2.3.3.2 Shade Model Results

The current longitudinal effective shade profile generated from the Shade Model and the Solar Pathfinder™ measurements are presented in **Figure B-6.**

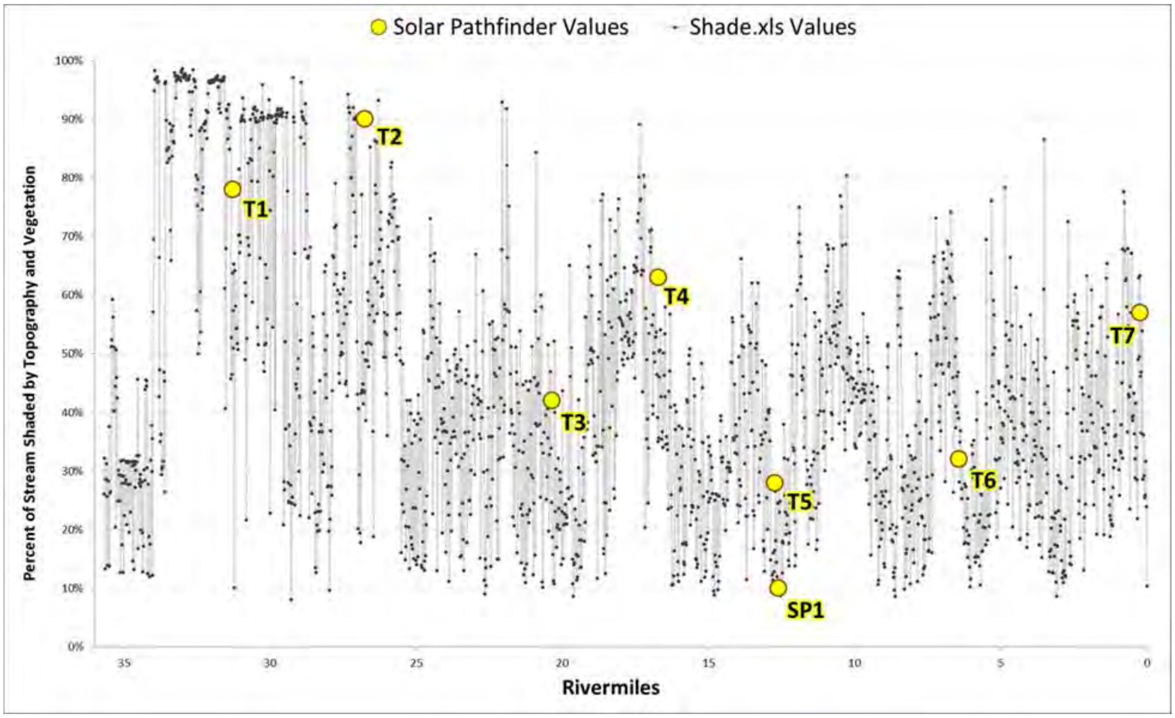


Figure B-6. Longitudinal estimates of observed and simulated effective shade along Fortine Creek

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:

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

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

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

where

P = model predicted values
O = observed values
n = number of samples

Shade model error statistics are provided in **Table B-4** and suggest a good fit between observed and predicted average effective shade values. The average absolute mean error is 7%. (i.e., the average error from the Shade Model output and Solar Pathfinder™ measurements was 7% daily average shade).

Table B-4. Fortine Creek Shade Model error statistics

Error Statistic	Formula	Result	Units
Mean Error (ME)	(1/N)*Σ(Pn-On)	6%	percent of percent shade
Average Absolute Mean Error (AME)	(1/N)*Σ|(Pn-On)|	7%	percent shade
Root Mean Square Error (RMSE)	[(1/N)*Σ(Pn-On)2]1/2	9%	percent of percent shade

B2.3.3 Stream Morphology

Stream morphology (channel pattern and geometry) departure from natural conditions might influence stream temperatures. Deteriorating stream channel morphology could reduce hyporheic flow, which is beneath and along the streambed where surface water and shallow groundwater mix, and can act as an effective stream temperature buffer. Additionally, channels that have been overwidened are less easily shaded and have a greater surface area, which can lead to an increased heat load to the stream (Poole and Berman 2001). Decreased stream depths from channel overwidening can also accelerate temperature increases.

Channel morphology measurements were taken in 2008 at three cross-sections each at five sites on Fortine Creek in support of sediment TMDL development (DEQ 2011). Additionally, bankfull and wetted width measurements were collected on September 12 and 13, 2012 at the locations evaluated for shade with Solar Pathfinder™ measurements (**Figure B-4**).

B2.3.4 Hydrology

No active U.S. Geological Survey (USGS) continuously recording gages are located on Fortine Creek. The closest such gage is 12301300, located downstream of Fortine Creek on the Tobacco River near Eureka, MT. EPA collected instantaneous flow measurements in 2012, during temperature data logger deployment and retrieval and during mid-season (**Table B-5**). Flow data were also collected by DEQ in support of other water quality studies in 2003, 2007, 2008, and 2012, and by the USFS for Deep Creek in 2011 and Edna and Fortine creeks in 2012 (**Tables B1-1** through **B1-4** in **Attachment B-1**). Locations of the flow measurements are shown in **Figure B-7**.

All available data were used to evaluate the water balance in Fortine Creek and to develop a pre-modeling understanding of the hydrology. However, only the 2012 data (primarily the August data) were relied upon for model inputs and hydrologic calibration. It should be noted that, compared to the historic period of record at the nearest continuous recording USGS gage (i.e., USGS 12301300, Tobacco River near Eureka MT), flows on August 10, 2012 were well above average and corresponded to the 87th percentile flow (**Figure B-8**).

Table B-5. 2012 EPA instantaneous flow measurements (cfs)

Date	FRTNC-T1	FRTNC-T2	SWMP [a]	FRTNC-T3	FRTNC-T4	FRTNC-T5	FRTNC-T6	DEEP b	FRTNC-T7
June 25, 2012	81.8	111.0	87.7	--	--	--	--	--	--
July 12, 2012	--	--	--	56.2	80.8	74.5	94.1	53.5	148.4
August 10, 2012	3.7	8.2	3.6	19.6	31.0	28.6	34.9	16.8	59.3
September 18, 2012	1.6	4.2	1.4	11.0	16.6	14.3	17.1	7.9	23.2

[a.] Site is located on Swamp Creek, a tributary to Fortine Creek.
[b.] Site is located on Deep Creek, a tributary to Fortine Creek.

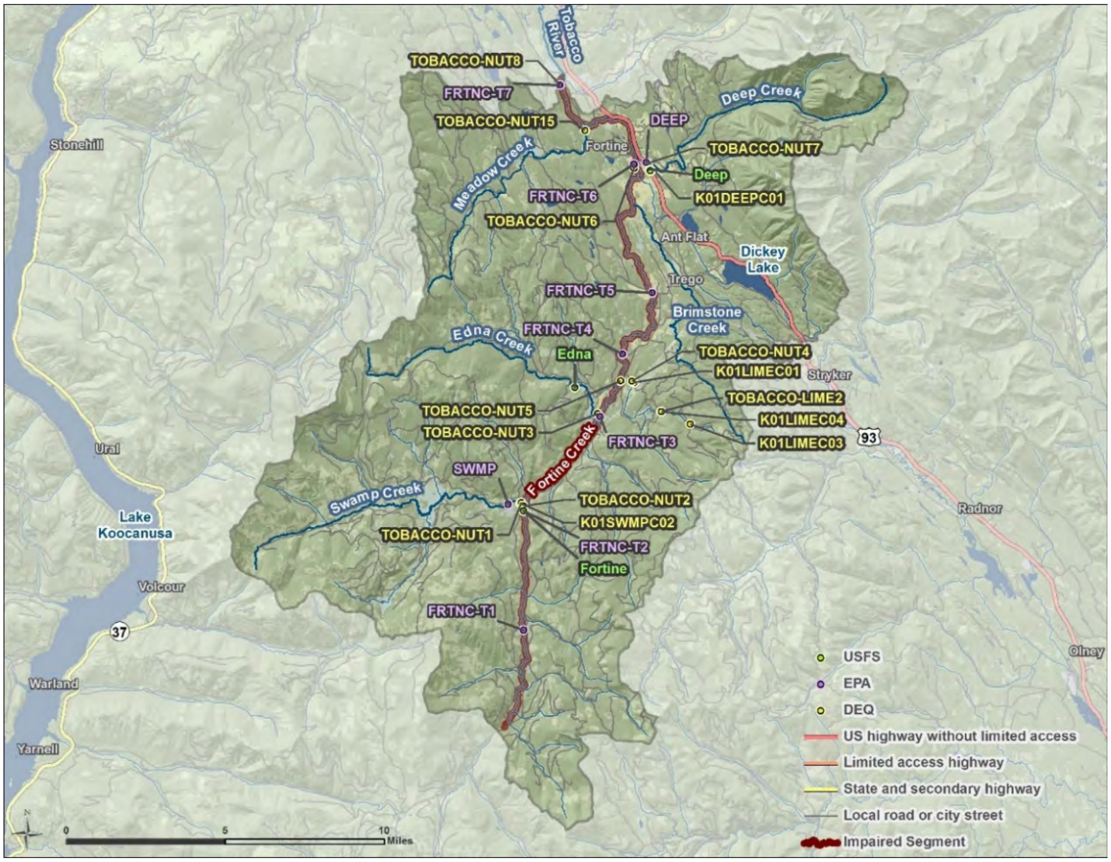


Figure B-7. All monitoring sites with recent instantaneous flow measurements

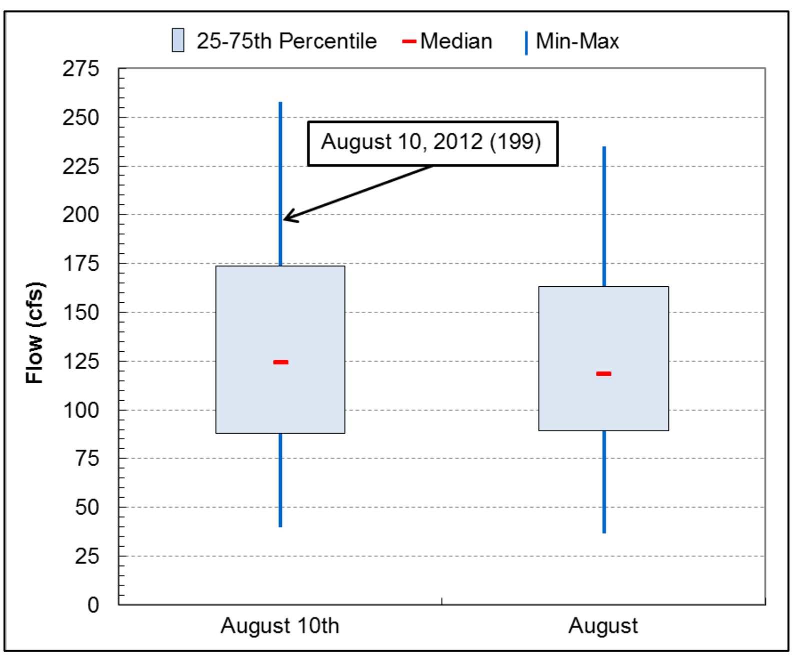
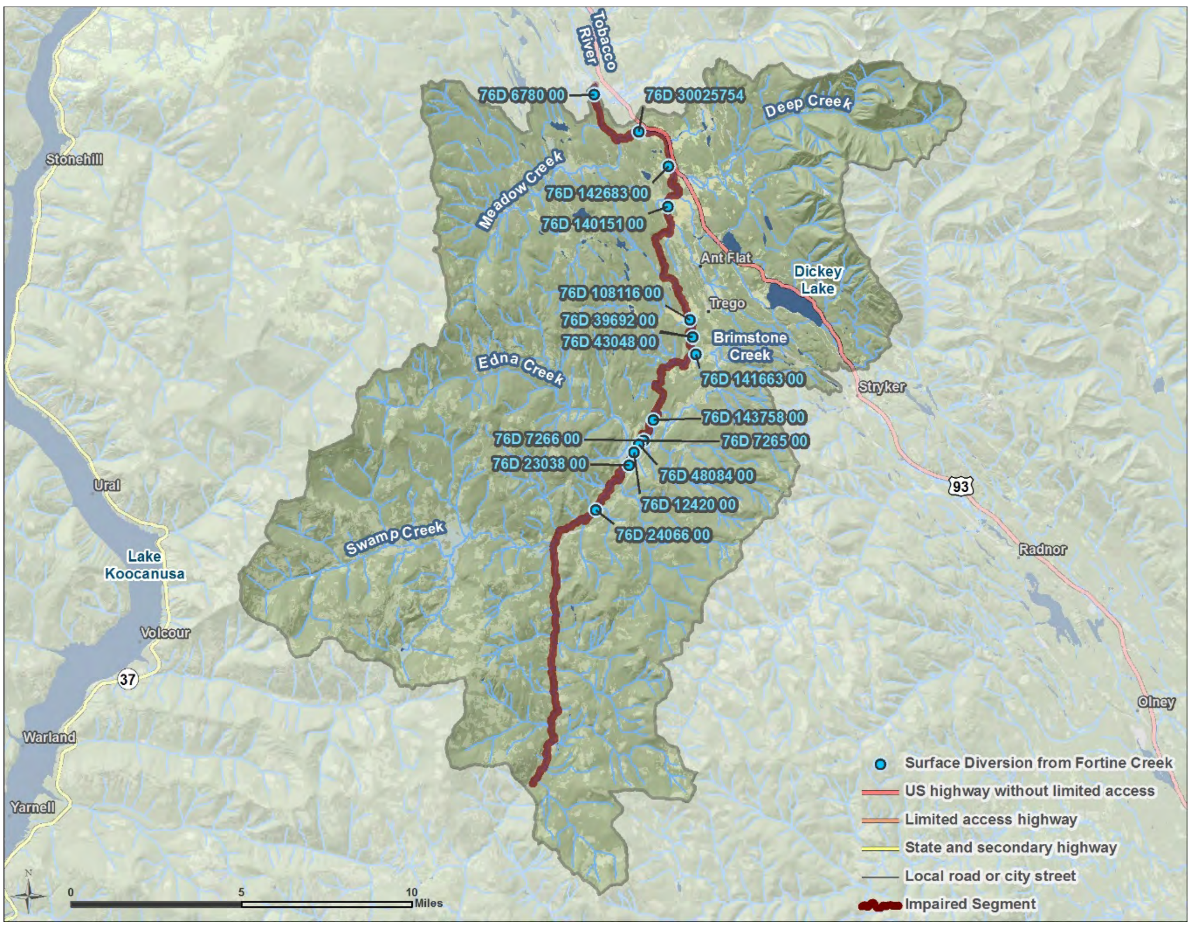


Figure B-8. Average discharge (cfs) at nearby USGS gage 12301300 (WY 1959 – 2012)

B2.3.4.1 Hydrologic Modification

Based on review of aerial photographs and online water rights data (ftp://nris.mt.gov/dnrc), there are 697 surface and groundwater diversions in the Fortine Creek watershed that support a variety of uses. "Points of diversion" and "places of use" spatial data were obtained from the Montana Natural Resource Information System (NRIS 2012). Of the 697 diversions in the Fortine Creek watershed, 31 were directly from Fortine Creek. Of those, only 15 appear to constitute potentially significant withdrawals (**Figure B-9** and **Table B-6**) because the remainder are for direct livestock access to Fortine Creek. Withdrawals were not field-verified.

It is estimated that up to 6.24 cfs may be withdrawn from Fortine Creek on a daily basis during July and August (**Table B-6**). This amount was estimated using the Irrigation Water Requirements program developed by the U.S. Department of Agriculture for estimating crop irrigation requirements (Dalton 2003). Most daily withdrawals are close to or less than 0.5 cfs but one just downstream of Brimstone Creek is estimated to be 3 cfs (76D 140151 00). This method assumes that the entire crop area associated with the withdrawal is irrigated.



Source of "points of diversion" data: NRIS 2012.

Figure B-9. Potentially significant surface and groundwater diversions along Fortine Creek and point sources in the Fortine Creek watershed

Table B-6. Potentially significant points of diversion from Fortine Creek (NRIS 2012)

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)
76D 7266 00	Domestic	--	Pu	0	0.04	1.5	--	0.04
76D 143758 00	Domestic	--	Pu	0	0.04	1.5	--	0.04
76D 48084 00	Domestic	--	Pu	0.5	0.02	1.5	497	0.01
76D 43048 00	F&W	--	Pu	18	0.44	5.15	17,907	0.21
76D 30025754	F&W	--	IG	0	0.03	24.2	--	0.03
76D 142683 00	Industrial	--	Pi	0	0.60	217.73	--	0.60
76D 6780 00	Irrigation	F	H	39	1.48	162.5	38,799	0.46
76D 108116 00	Irrigation	S	Pu	44	0.49	95.5	43,774	0.52
76D 7265 00	Irrigation	S	Pu	7	0.12	15.75	6,964	0.08
76D 140151 00	Irrigation	S	Pu	263	3.34	900	261,647	3.09
76D 141663 00	Irrigation	S	Pu	2	0.01	2	1,990	0.02
76D 12420 00	Irrigation	F	H	49	1.86	215.6	48,748	0.58
76D 23038 00	Irrigation	S	Pu	4.5	0.17	6	4,477	0.05
76D 24066 00	Irrigation	S	Pu	4	0.15	17.6	3,979	0.05
76D 39692 00	Irrigation	S	Pu	38	0.64	86	37,804	0.45
Total Withdrawal				**469**				**6.24**

Notes: F = flood; F&W = fish and wildlife; H = headgate; IG= infiltration gallery; PI = pipeline; Pu = pump; S = sprinkler.

[a.] The daily volume applied was estimated using the USDA Irrigation Water Requirements program.

[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.

B2.4 Stream Temperature Data

Continuous temperature data is necessary for QUAL2K model development. Continuous temperature data have been collected in the Fortine Creek watershed by EPA, USFS, and the Montana Department of Fish, Wildlife and Parks (FWP). EPA collected continuous temperature data at seven sites along Fortine Creek and at two tributary sites (the mouth of Swamp and Deep creeks) in support of this modeling effort (**Figure B-10**). Monitoring sites were also proposed for Edna and Meadow creeks, but access could not be obtained near the mouth of Edna Creek and the mouth of Meadow Creek had insufficient flow. Data loggers recorded temperatures every one-half hour for two months between June 25 or July 12, 2012[3] and September 18, 2012. The USFS also collected continuous temperature data in 2012; loggers were deployed at one site in Fortine Creek (located in close proximity to EPA site FRTNC-T4) and Deep and Edna creeks[4] (**Figure B-10**) from June 15 to September 10. Additionally, FWP coordinated with DEQ to collect continuous temperature data at four locations in Fortine Creek in 2004 and 2005. The FWP logger sites extended from near Trego (and EPA site FRTNC-T5) to the mouth (**Figure B-10**).

[3] Temperature loggers were deployed on July 12, 2012 at the following sites because instream flow was too high to deploy loggers on June 25, 2012: FRTNC-T3, FRTNC-T4, FRTNC-T5, FRTNC-T6, DEEP, and FRTNC-T7.

[4] USFS's Deep and Edna creeks' loggers recorded extremely elevated temperatures prior to June 14, 2012 and after September 10, 2012. USFS Fortine Creek logger recorded extremely elevated temperatures prior to August 1, 2012 and after September 10, 2012. The high temperatures indicate the loggers were likely exposed to ambient air.

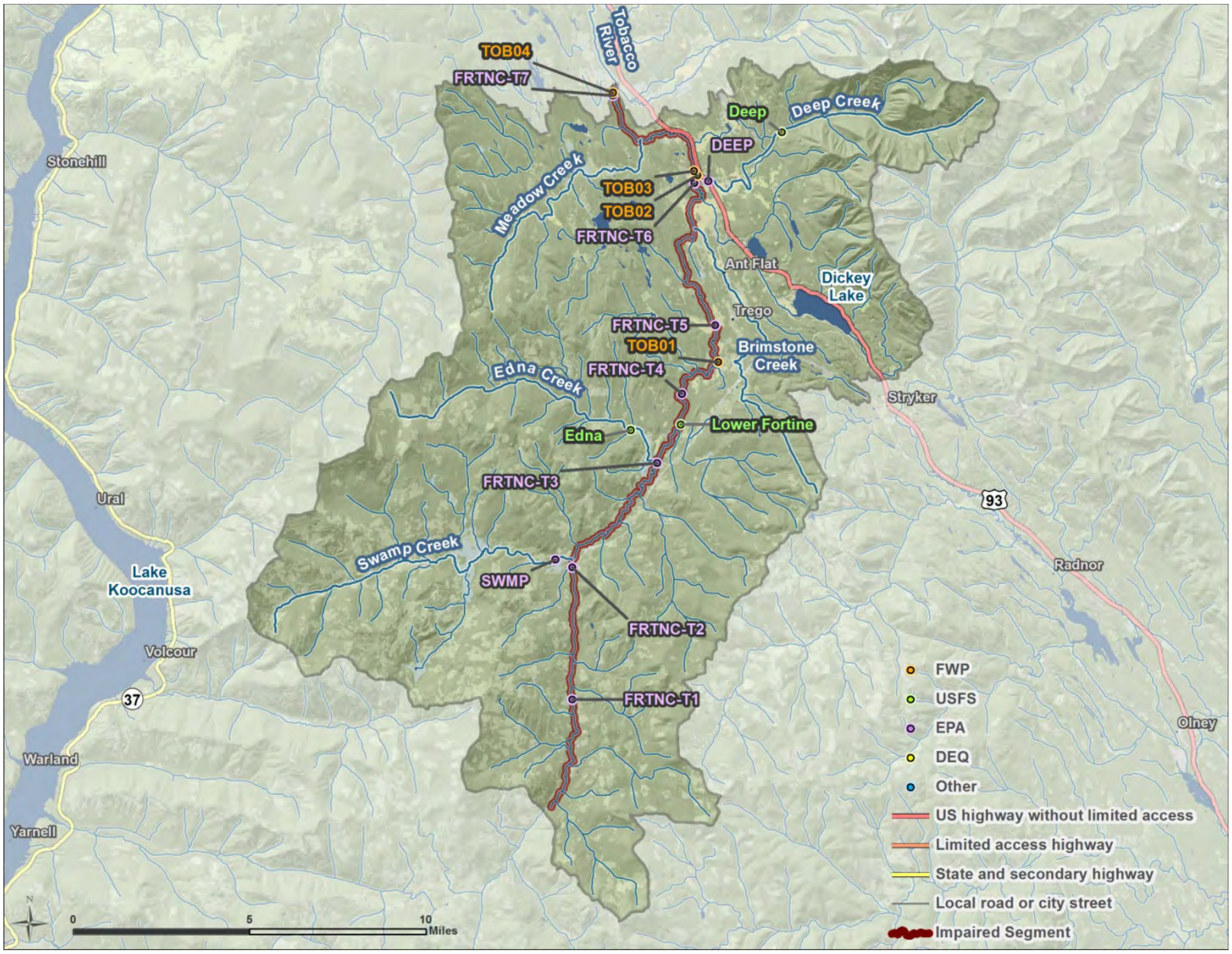


Figure B-10. Temperature loggers in the Fortine Creek watershed

A summary of the continuous temperature data collected by EPA and the USFS in 2012 is provided in **Figure B-11**. Median temperatures in Fortine Creek ranged from approximately 53°F to approximately 63°F with a general increasing trend from the headwaters to the mouth. The exception to this trend is site FRTNC-T6 where the highest median temperature was recorded. Maximum daily temperatures in Fortine Creek ranged from approximately 62°F to approximately 75°F (**Table B-7**). Unlike the median temperatures, a general trend of increasing maximum temperatures in a downstream direction does not hold true (**Figure B-12**). The highest maximum temperatures were recorded at FRTNC-T6. It appears that Swamp Creek (SWMP) have a warming influence on Fortine Creek, Edna Creek has no negligible influence, and Deep Creek has a cooling influence. In 2012, the warmest temperatures were detected on July 13 and August 7 and the warmest weeks were the second week of July and the first and second weeks of August (**Table B-7**).

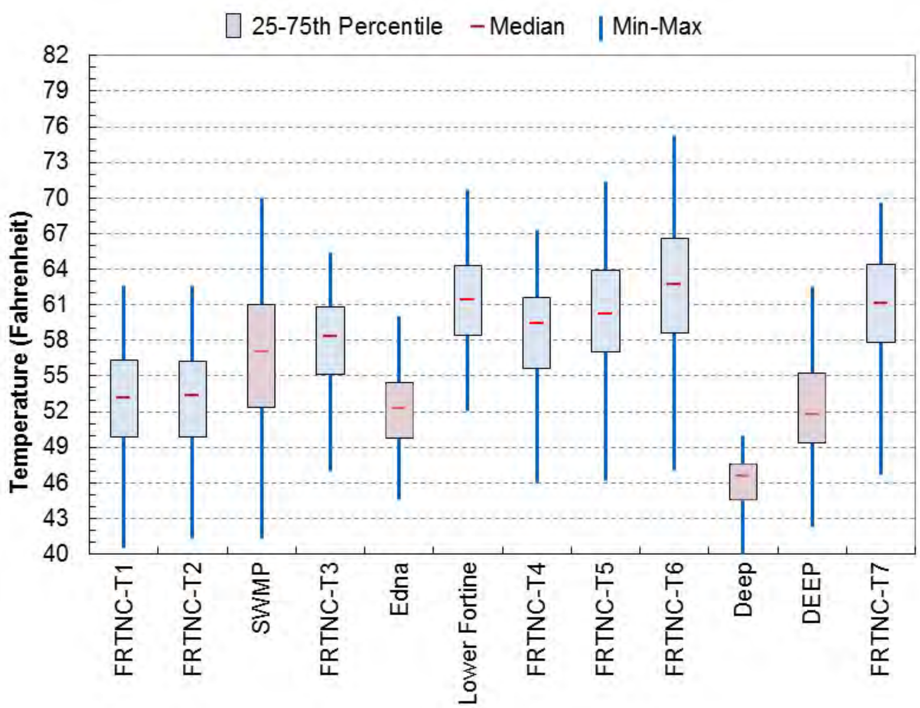


Figure B-11. Box-and-whisker plots of summer 2012 EPA and USFS continuous temperature data[5]

Table B-7. Maximum and maximum weekly maximum temperatures in Fortine Creek, 2012

Temperature logger site	Maximum temperatures a		Maximum weekly maximum temperature b	
	Temperature (°F)	Date	Temperature (°F)	Date
FRTNC-T1	62.6	August 7	61.0	August 5-11
FRTNC-T2 c	62.6	July 13	60.5	August 11-17
FRTNC-T3	65.4	July 13	63.4	July 12-18
Lower Fortine [d]	70.7	August 7	68.9	August 7-13
FRTNC-T4	67.3	August 7	65.8	August 7-13
FRTNC-T5	71.4	August 7	69.2	August 5-11
FRTNC-T6	75.3	July 13	72.4	July 25-31
FRTNC-T7	69.6	August 7	68.0	August 6-12

[a.] Maximum of recorded one-half hourly temperatures.
[b.] Mean of daily maximum water temperatures measured over the warmest consecutive seven-day period.
[c.] Logger FRNTC-T2 was probably exposed to ambient air from July 24, 2012 to mid-day August 10, 2012 when the logger was re-positioned. The data presented in this table are limited to a subset of the monitored temperatures from June 25, 2012 through July 23, 2012 and August 11, 2012 through September 18, 2012.
[d.] USFS's Fortine Creek logger recorded extremely elevated temperatures prior to August 1, 2012 and after September 10, 2012. The logger was likely exposed to ambient air. The data presented in this table are limited to a subset of the monitored temperatures from August 1 through September 10, 2012.

[5] Due to possible logger exposure to ambient air, the data presented in Figure B-11 are limited to a subset of the monitored temperatures from June 15 through September10, 2012 for the loggers in Deep and Edna creeks and from August 1 through September 10, 2012 for Fortine Creek. Also, EPA logger FRNTC-T2 was possibly out of water from July 24 through mid-day August 10, 2012; these data are excluded from Figure B-11.

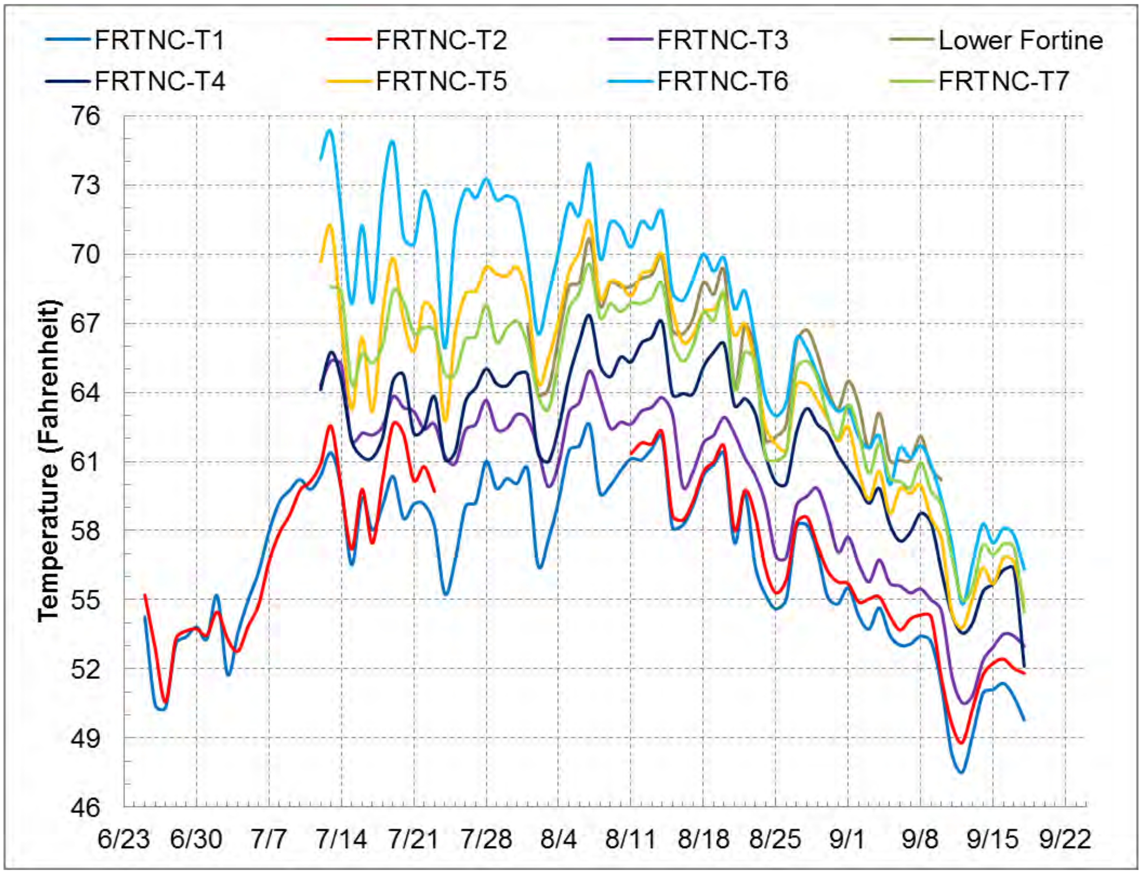


Figure B-12. Daily maximum temperatures, Fortine Creek and tributaries, June 25 or July 12 to September 18, 2012 (EPA sites) and August 1 to September 10, 2012 (USFS site)

The FWP data are discussed and presented separately from the EPA and USFS temperature data because they were collected during a different time period (i.e., 2004 and 2005). Although climatic and flow conditions were likely different in 2004/2005 as compared to 2012, the FWP logger data show a similar downstream trend as the 2012 data collected within the same portion of Fortine Creek (i.e., near Trego to the mouth): temperatures increased slightly until Deep Creek, which is between TOB02 and TOB03, which appears to have a cooling effect on temperatures in Fortine Creek (**Figures B-13** and **B-14)**. Comparing **Figure B-12** to **Figure B-13**, maximum temperatures measured in 2004/2005 were in the mid to upper 70s at several sites and higher than in 2012.

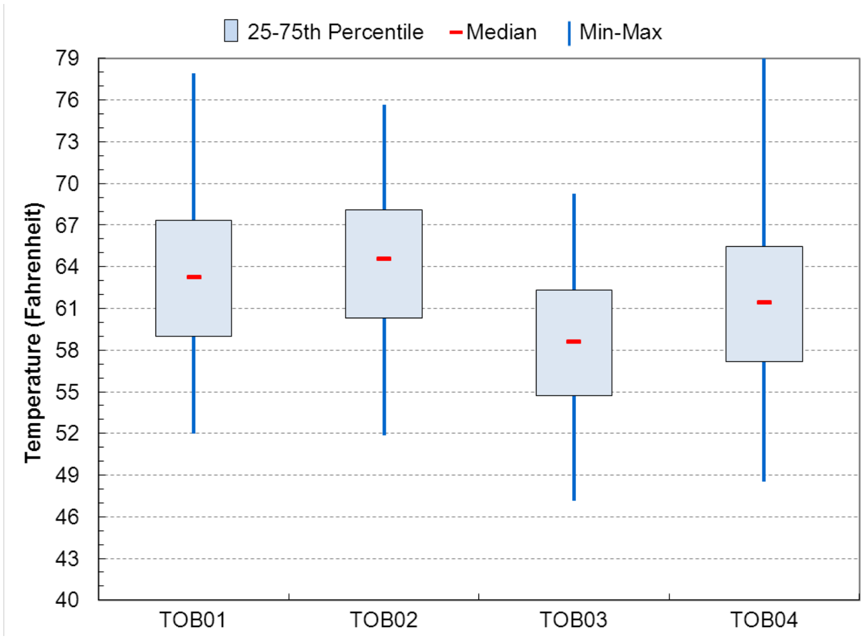


Figure B-13. Box-and-whiskers plots of FWP temperature data, 2004-2006[6]

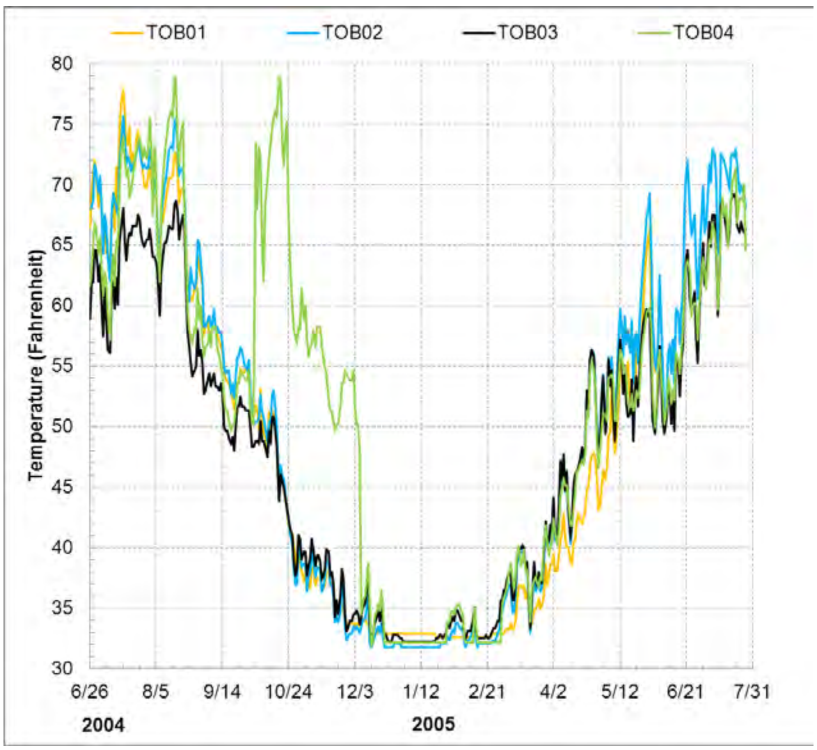


Figure B-14. Daily maximum temperatures along Fortine Creek, June 26, 2004 to July 27, 2005

[6] The FWP data shown in this figure are from roughly the same days per year as the EPA/USFS data shown in Figure B-12. TOB01 data are from July 5 to September 18, 2004. TOB02 and TOB04 data are from June 26 to September 18, 2004 and June 25 to July 27, 2005. TOB03 data are from June 26 to September 18, 2004 and June 25 to September 18, 2005.

B3.0 MODEL SETUP

A QUAL2K model was used to simulate temperatures in Fortine 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 simulating hydraulics and water quality conditions of small rivers and creeks. It is a one-dimensional uniform flow model with the assumption of a completely mixed system for each computational element. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. 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).

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

The following subsections describe the process that was used to setup the QUAL2K model for Fortine Creek.

B3.1 CHANNEL FLOW-PATH

The QUAL2K model for Fortine Creek was developed for the 31.7-miles of the stream from the confluence with the Tobacco River upstream to site FRTNC-T1, which is near the headwaters (**Figure B-1**). This segment was delineated using the National Hydrography Dataset, which includes multiple named tributaries to Fortine Creek that were explicitly modeled as point sources: Deep Creek (river mile [RM] 6.0), Edna Creek (RM 19.6), and Swamp Creek (RM 26.4). All other tributaries were implicitly modeled as part of the net diffuse flow.

B3.2 STREAM SEGMENTATION

Segmentation refers to discretization of a waterbody into smaller computational units (e.g., reaches and elements). Segmentation into reaches allows for representation of stretches of the river that have constant hydraulic characteristics (e.g. slope, bottom width). Each reach is further divided into elements that are the fundamental computational units in QUAL2K. The number of elements is determined on the basis of the estimated velocity/computational time step to ensure the containment of the heat load calculation within each element per time step.

Fortine Creek was divided into nine linked reaches from the mouth to the headwaters (**Figure B-15**) identified as A, B, C, D, E, F, G, H, and I. The segmentation locations were selected on the basis of available diurnal temperature and flow data (available at the EPA and USFS sample sites), changes in vegetation, and changes in effective shade. Each of the nine linked reaches was further subdivided into elements. The element length was selected to be short enough to increase the spatial resolution and long enough to support model stability; the average element length was 0.34 miles (550 meters).

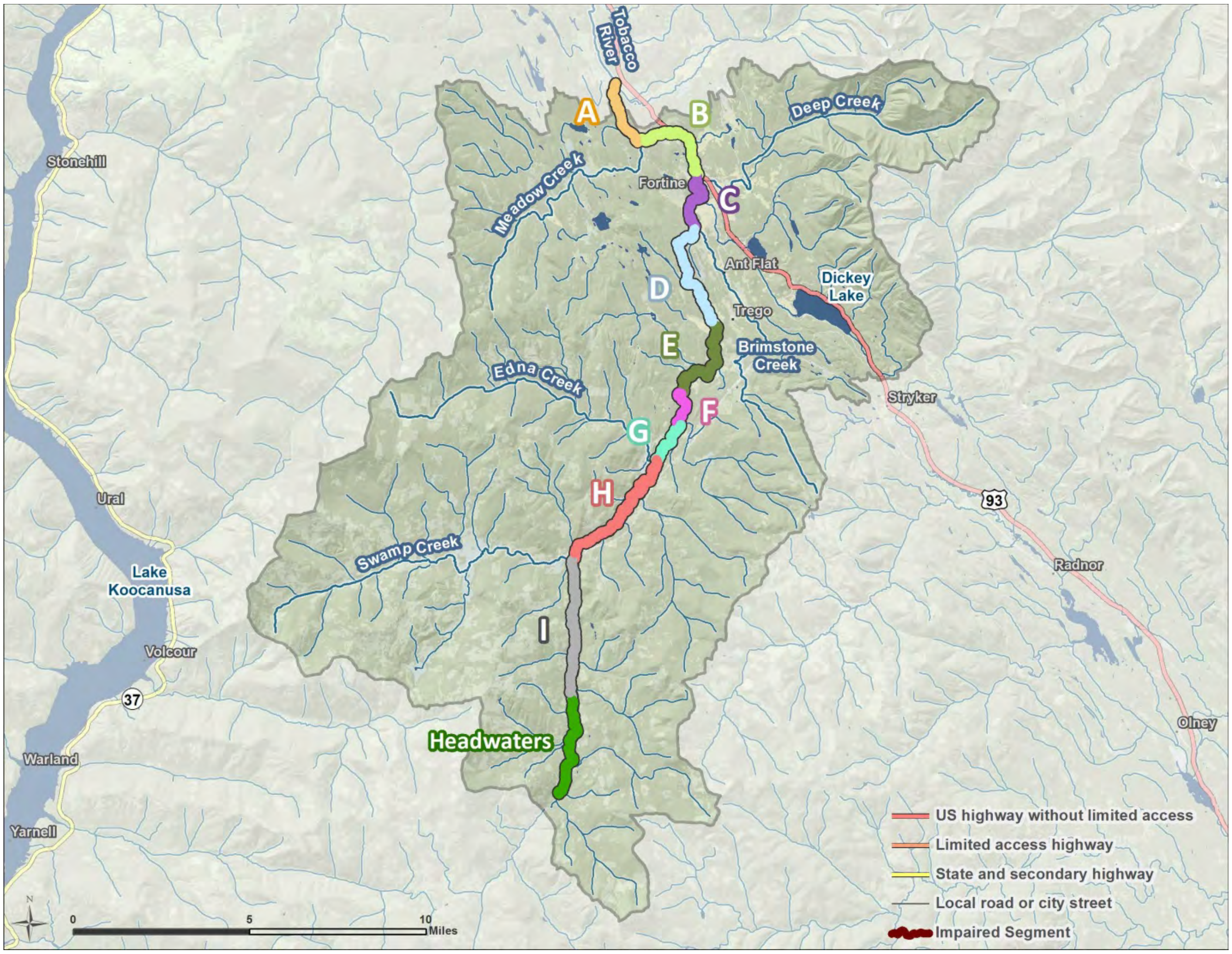


Figure B-15. Model segmentation along Fortine Creek

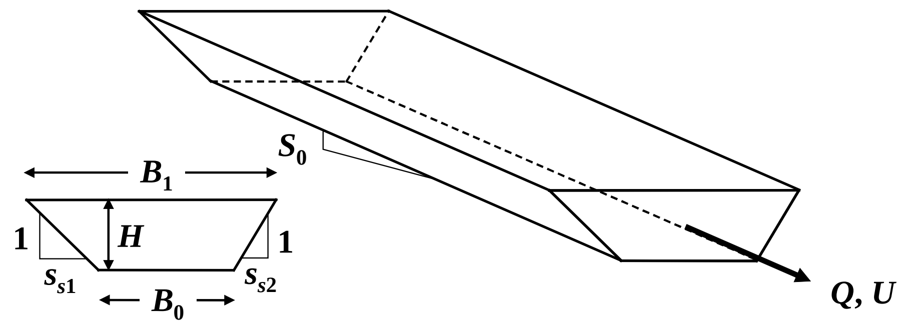
B3.3 CHANNEL GEOMETRY

The channel geometry data that was input into QUAL2K was derived from EPA field work. The model inputs and assumptions are presented in **Attachment B-2** (and the original field data are available upon request). Manning's n was calculated for each segment using site photographs and equations[7] presented in Marcus et al. (1992). Channel slopes were calculated for each model reach as the geometric mean of slopes calculated at each node of the Shade Model (i.e., every 98 feet [30 meters] along Fortine Creek). Stream bottom width and the sides of the trapezoidal cross-section assumed for modeling (**Figure B-16**) were estimated using widths measured in the field on September 12 and 13, 2012 and by assuming the sides were at a 1:1 ratio. The channel bottom widths were assumed to be slightly shorter than the wetted widths (using the assumed trapezoidal cross-section) measured at the eight Solar Pathfinder™ sites on September 12 and 13, 2012 since the stream depths were shallow on those dates. The assignments of the bottom widths to each model reach were based on availability of data within each reach and linear interpolation with the closest field measurement.

The Manning's n for the headwaters boundary condition was set equal to the Manning's n calculated for segment I. Channel slope was estimated for the headwaters boundary condition using slope data at the

[7] The equations were from Cowan (1956) and Chow (1959) and published in Marcus et al. (1992).

upstream terminus of segment I. The sides of the hypothetical trapezoidal cross-section were assumed to be at a 1:1 ratio and the field-measured wetted width at FRTNC-T1 was assumed for the bottom width of the headwaters boundary condition.



Source: Chapra et al. 2008.
Note: B_0 is stream bottom width, S_{s1} and S_{s2} are side lengths relative to one, and S_0 is channel slope.
Figure B-16. Idealized trapezoidal channel assumed in QUAL2K

B3.4 Hydrologic Simulation

Although QUAL2K can reasonably simulate flow and related parameters (i.e., velocity and depth), it does have limitations. The model does not allow for the explicit simulation of any natural flow retardation processes; such processes occur in pools, riffles, deep holes, side channels, or hyporheic zone flow exchanges. These processes could have a pronounced effect on stream hydrology and temperature condition of the river.

The observed data collected in 2012 by EPA and USFS along the mainstem were used to derive the flow inputs required to run the QUAL2K model for the calibration day of August 10, 2012 (**Attachment B-2**, **Table B2-6**). EPA measured flow at the mouths of Deep Creek and Swamp Creek on August 10, 2012, and the flows (16.8 cfs and 3.6 cfs, respectively) were input into QUAL2K. The flow for Edna Creek, which was not monitored, was estimated by subtracting the flows measured on Fortine Creek above and below the confluence with Edna Creek (7.8 cfs). The headwaters boundary condition inflow was defined as the flow monitored at site FRTNC-T1 (3.7 cfs).

A water balance was used to estimate diffuse flow, with the difference between each observation assumed to be diffuse flow. Diffuse flow in reaches I through F and reaches D through A was positive (i.e., inflow or net accretion), whereas diffuse flow from reach E was negative (i.e., outflow). Irrigation diversions are along the entire creek and 15 outflows were explicitly modeled as abstractions (**Attachment B-2**, **Table B2-7**).

B3.5 Weather

Weather inputs were compiled from the closest station recording the necessary hourly data, which was Eureka RAWS since the weather stations in the Fortine Creek watershed only report daily data (**Attachment B-2**, **Tables B2-10** and **B2-11**). These data were used as model input for the August 10, 2012 date for calibration. Air temperature and dew point temperature data from the Eureka RAWS were corrected using the moist air adiabatic lapse rate (-0.00656 C/m) to account for the elevation difference between the RAWS and the individual model segments. Wind speed was corrected (Chapra et al. 2008,

p. 27, equation 48) for the height differences of the sensor at Eureka RAWS (reported as 20 feet) and the required QUAL2K height of 23 feet (7 meters).

Cloud cover was estimated on the basis of available hourly data at the Kalispell Glacier Park International Airport (elevation 2,972 feet above MSL) weather station that is operated by the National Weather Service, which is the closest weather station that measures cloud cover. Zero percent cloud cover was observed at the Glacier Park International Airport on August 10, 2012; therefore, zero percent was input for all 24 hours in the QUAL2K model. Precipitation data collected at the Eureka RAWS were evaluated to verify that no precipitation occurred on August 10, 2012 as the occurrence of precipitation would indicate the presence of cloud cover.

B3.6 Shade

Shade is a key input to the QUAL2K model. As recommended in the QUAL2K model documentation, estimates of shading are developed separately using the spreadsheet Shadev3.0.xls. For additional details on the Shade Model and how riparian shade was estimated, see **Section B3.2.3**. Hourly medians of the Shade model results were calculated for each of the nine model segments and entered into QUAL2K (**Attachment B-2**, **Table B2-12**). **Figure B-17** provides a stacked bar graph showing the existing riparian land cover within the 150 ft buffer and median percent shade for each of the model reaches. Note, the wet shrubs component indicated in purple (and present in segments I and H) are also referred to as hydrophytic shrubs within this appendix. Hydrophytic/wet shrubs represent stands of willow/alder that are at or near their potential and not anticipated to attain great height at maturity. They were identified based on a combination of aerial photographs and field work.

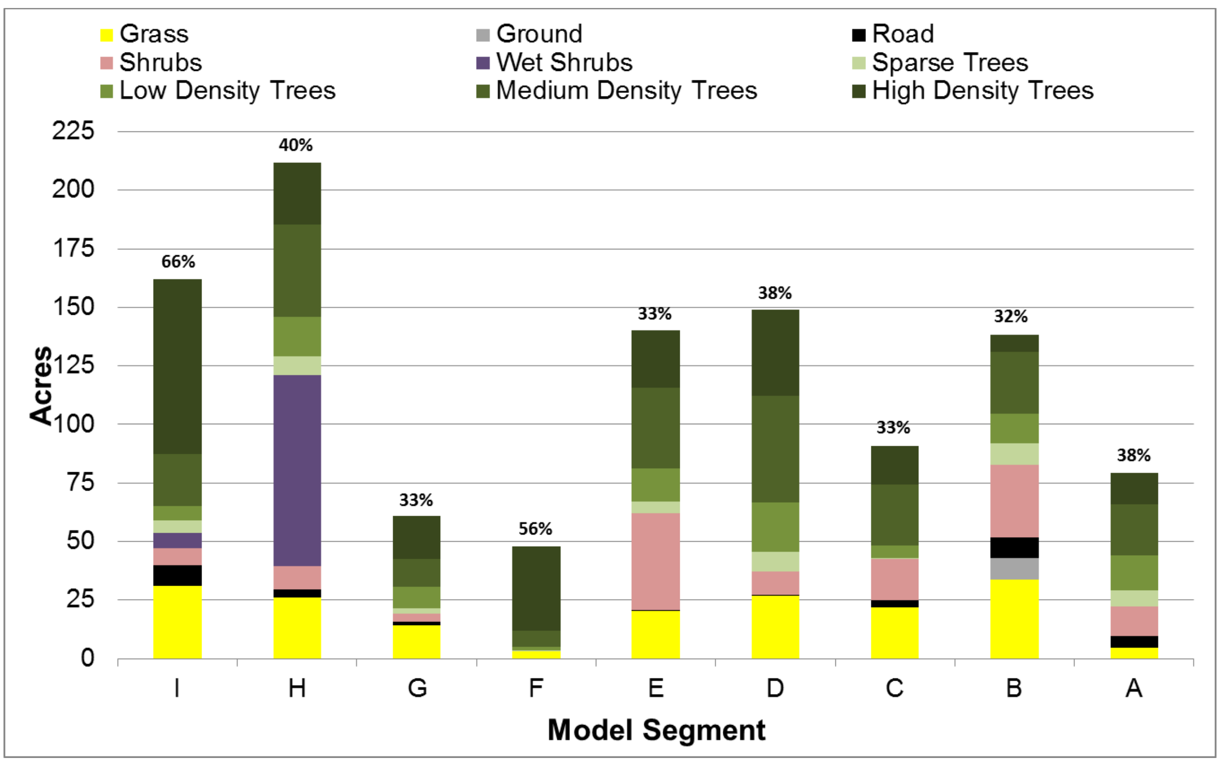


Figure B-17. Riparian vegetation within 150 feet of Fortine Creek and median percent shade (shown above each bar) under existing conditions going from the headwaters (I) to the mouth (A)

B3.7 HEAT

QUAL2K users can select various heat transfer model input parameters. For this project, default values recommended by Chapra et al. (2008) were used for some heat and light parameters; other heat and light parameters were used as calibration parameters. Calibrated heat and light parameters were within typical ranges reported in Chapra et al. (2008); the inputs are presented in **Table B2-13** in **Attachment B-2**.

B4.0 CALIBRATION AND VALIDATION

Environmental simulation models are simplified mathematical representations of complex, real-world systems. Models cannot accurately depict the multitude of processes occurring at all physical and temporal scales. Models can, however, make use of known interrelationships among variables to predict how a given quantity or variable would change in response to a change in an interdependent variable or forcing function. In this way, models can be useful frameworks for investigating how a system would likely respond to a perturbation from its current state. To provide a credible basis for predicting and evaluating mitigation options, the ability of the model to represent real-world conditions should be demonstrated through a process of model calibration and validation (CREM 2009). Discussions of calibration and validation are in the Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling (Tetra Tech 2012).

B4.1 ERROR ANALYSIS

Water quality models are often evaluated through visual comparisons, in which the simulated results are plotted against the observed data for the same location and time and are visually evaluated to determine if the model is able to mimic the trend and overall magnitude of the observed conditions. This method works well when data are limited in quantity and contain significant uncertainty. The limitation of this method is that it relies on the subjective judgment of modelers and lacks quantitative measures to differentiate among sets of calibration result. Because of this, both a visual comparison and quantitative measures were used during the Fortine Creek calibration and validation.

The two methods used to compare model predictions and observations are the deviation between model predictions and observations (i.e., absolute error) and deviation between model predictions and observations relative to the observation (i.e., relative error). The absolute error is calculated as the simulated value minus the observed value. A negative absolute error means that the model simulated cooler temperatures than were observed; a positive value means that the model simulated warmer temperatures than were observed. In this case, the relative error is simply the percentage of deviation between the model prediction and observation, with a statistic of zero being ideal.

According to the QAPP (Tetra Tech 2012), the acceptance criteria will be determined for each model on the basis of the available data. If sufficient data are available, per the QAPP, the proposed acceptable temperature differences between modeled and observed daily minima, means, and maxima are 2 degrees Celsius (°C) or a relative error of less than 10 percent for higher temperatures. These criteria were applied in this project.

B4.2 Calibration and Validation Periods

The dates for calibration and validation of the QUAL2K model were selected on the basis of the available data and the period of record during which the highest instream temperatures were observed (**Figure B-12**). The available flow and stream geometry data suggest that travel time in Fortine Creek, from headwaters to the mouth, is more than one day. Average velocities were calculated from depth-velocity interval data recorded when flow was monitored on 3 occasions across eight sites along Fortine Creek. Average velocities on August 10, 2012 ranged from 0.52 feet per second to 1.76 feet per second, with an average of 1.13 feet per second, and average velocities on September 18, 2012 ranged from 0.26 feet per second to 1.41 feet per second, with an average of 0.78 feet per second. Such velocities yield travel times of 1 day 2 hours to 3 days 15 hours on August 10, 2012 (average of 1 day 16 hours) and 1 day 8 hours to 7 days 5 hours on September 18, 2012 (average of 2 days 10 hours).

QUAL2K model input parameters were developed based upon a single day for the calibration (August 10, 2012) and validation (September 18, 2012). The dates selected to develop model input parameters consisted of warm days without precipitation on that day or preceding days during summer low-flows, which allows for calibration to conditions when temperatures are likely the highest. For both the calibration and validation, the simulation period was longer than the travel time in Fortine Creek to ensure that the model configuration achieved steady-state conditions for the Fortine creek watershed. Because QUAL2K is a steady-state model, respective input parameters were maintained throughout the entire calibration and validation periods. The calibration simulation was 4 days and the validation simulation period was 5 days, based in part upon instream velocities.

B4.3 Calibration Results

Temperature calibration for the Fortine Creek QUAL2K model relied on a comparison of model predictions to observations at the temperature loggers (**Figure B-18**). The model is able to simulate the mean and maximum temperatures fairly well but does have some difficulty consistently simulating the minimum temperatures at several locations (i.e., loggers –T2, -T4, and –T6). However, the absolute mean error (AME) for all the modeled minimum, mean and maximum temperatures for the model calibration are within 3.6°F (2° C) of the corresponding observed values (**Table B-8**), which meets the criteria set in the QAPP (Tetra Tech 2012). The calibration AME for the maximum daily temperature is 1.3°F and the relative error is 2.0%.

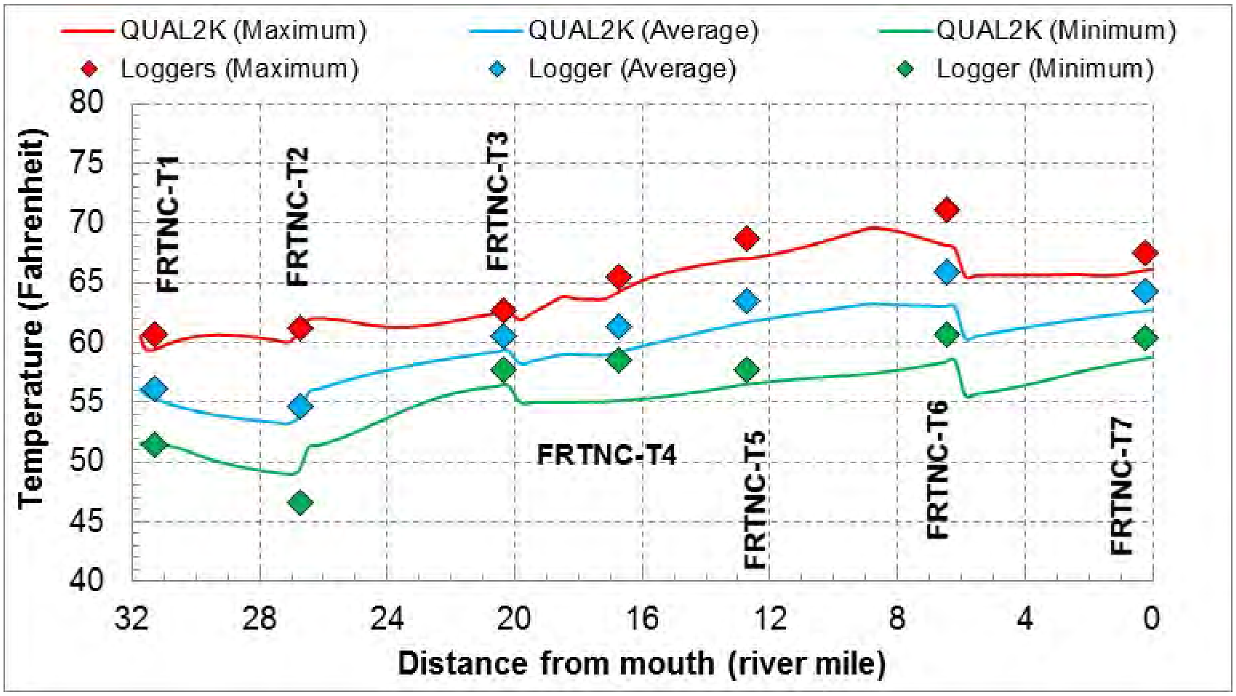


Figure B-18. Observed and modeled temperatures for the calibration (August 10, 2012)

Table B-8. Model calibration results for August 10, 2012 in Fahrenheit

Site name	RM	Average daily temperature		Maximum daily temperature		Minimum daily temperature	
		AME (°F)	REL (%)	AME (°F)	REL (%)	AME (°F)	REL (%)
FRTNC-T1	31.28	0.8	1.5%	1.2	1.9%	0.0	0.1%
FRTNC-T2	26.75	0.9	1.7%	0.4	0.7%	2.7	5.5%
FRTNC-T3	20.36	1.2	2.1%	0.2	0.4%	1.4	2.5%
FRTNC-T4	16.72	2.2	3.7%	1.4	2.2%	3.4	6.2%
FRTNC-T5	12.73	1.7	2.8%	1.7	2.5%	1.3	2.2%
FRTNC-T6	6.43	2.9	4.6%	3.0	4.4%	2.3	4.0%
FRTNC-T7	0.24	1.7	2.7%	1.4	2.1%	1.7	2.9%
Overall calibration		**1.6**	**2.7%**	**1.3**	**2.0%**	**1.8**	**3.3%**

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

B4.4 Validation Results

Model validation was determined by a second model run that was conducted under different hydrological and weather conditions (September 17, 2012). EPA temperature data (September 17, 2012) and flow data (September 18-19, 2012) were used to validate. During calibration, the model did have more difficulty consistently predicting temperatures near logger FRTNC-T6. However, similar to the calibration results, all the modeled minimum, mean, and maximum temperatures are within 3.6°F (2° C) of the corresponding observed values (**Table B-9**, **Figure B-19**), which meets the criteria set in the QAPP (Tetra Tech 2012). The validation AME for the maximum daily temperature is slightly higher than for the calibration at 2.2°F and also for the relative error, which is 3.7%.

Table B-9. Model validation results for September 17, 2012 in Fahrenheit

Site name	RM	Average daily temperature		Maximum daily temperature		Minimum daily temperature	
		AME (°F)	REL (%)	AME (°F)	REL (%)	AME (°F)	REL (%)
FRTNC-T1	31.28	1.3	2.8%	1.0	1.9%	0.0	0.1%
FRTNC-T2	26.75	1.2	2.5%	1.0	1.9%	1.4	3.1%
FRTNC-T3	20.36	0.5	0.9%	1.8	3.2%	0.4	0.8%
FRTNC-T4	16.72	1.1	2.1%	1.1	1.8%	0.7	1.4%
FRTNC-T5	12.73	1.1	2.0%	3.4	5.7%	0.2	0.4%
FRTNC-T6	6.43	2.3	4.0%	3.3	5.5%	1.5	3.0%
FRTNC-T7	0.24	2.5	4.5%	3.6	6.0%	2.6	5.1%
Overall validation		**1.4**	**2.7%**	**2.2**	**3.7%**	**1.0**	**2.0%**

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

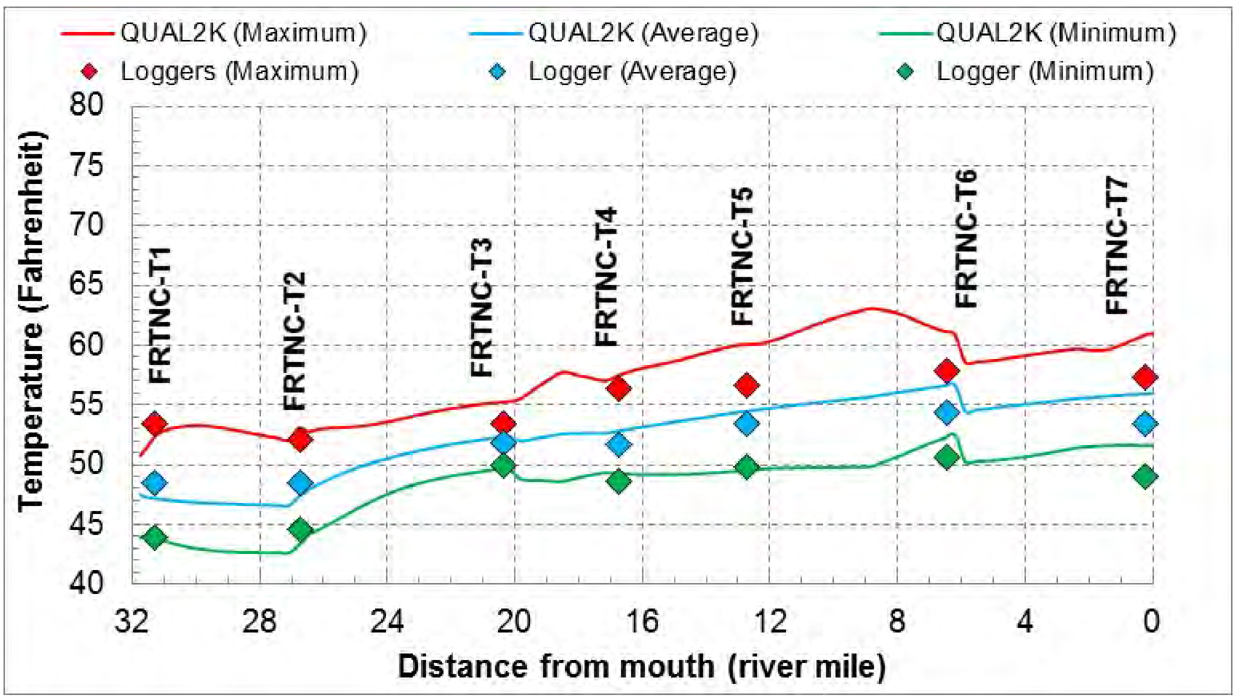


Figure B-19. Observed and modeled temperatures for the validation (September 17, 2012)

B5.0 Model Scenarios

The Fortine Creek QUAL2K model was used to evaluate instream temperature response associated with multiple scenarios. **Table B-10** summarizes the alterations to input parameters for each model scenario. The following sections discuss the modifications to the QUAL2K model and the results for each scenario. For each scenario, the simulated temperature range and degree of change relative to the existing condition scenario is summarized for all model elements, which essentially represents all of Fortine Creek. This information is then presented in a graph and for each logger location in a table.

Table B-10. Fortine Creek QUAL2K model scenarios and summary of inputs

Scenario	Summary
1 – Existing Condition (calibration)	Existing condition scenario from which to test model sensitivity and management induced changes to streamflow and riparian shade. Based on current streamflow, climate, and shade conditions.
2 – No withdrawals (sensitivity analysis)	Existing condition without water withdrawals. To test the sensitivity of the model to water withdrawals and not intended for management purposes.
3 - Maximum Shade (sensitivity analysis)	Existing condition with all vegetation communities within the 150 foot buffer along each side of the stream transformed to "high density trees" with the exception of roads, railroads, and areas dominated by hydrophytic shrubs[1]. To test the sensitivity of the model to shade and not intended for management purposes.
4 – Improved Shade	Existing condition with all vegetation communities, with the exception of hydrophytic shrubs[1], roads, and railroads transformed to medium density trees within 50 feet of the streambanks. Existing medium density and high density trees were retained and existing conditions vegetation was retained beyond the 50-foot buffer. To simulate achievement of all reasonable land and soil conservation practices.
5 – Improved Water Management	Existing condition with withdrawals reduced by 15%. To simulate achievement of all reasonable water conservation practices.
6 – Naturally Occurring	Existing condition scenario with improved riparian vegetation in a 50-foot buffer and a 15 percent reduction of water withdrawals. This is to simulate full standards attainment via the use of all reasonable land, soil, and water conservation practices.
7 – Low Flow Existing Condition	Low flow existing condition scenario. To simulate stream temperatures on a drier year than the existing baseline (Scenario 1).
8 – Low Flow Naturally Occurring	Existing condition scenario with improved riparian vegetation in a 50-foot buffer and a 15 percent reduction of water withdrawals. To simulate full standards attainment via the use of all reasonable land, soil, and water conservation practices relative to the Low Flow Baseline (Scenario 7).

[1]Hydrophytic shrubs represent stands of willow/alder that are at or near their potential and not anticipated to attain great height at maturity. They were identified based on a combination of aerial photographs and field work.

B5.1 Scenario 1: Existing Condition (Baseline)

The calibration model serves as the existing condition scenario (i.e., baseline). This scenario represents dry conditions during August when instream temperatures were at or near their maximum in 2012. The construction of the model and its inputs are discussed in **Section B3.0**. As shown in **Figure B-20**, maximum daily temperatures under this scenario range from 59.4°F to 69.6°F.

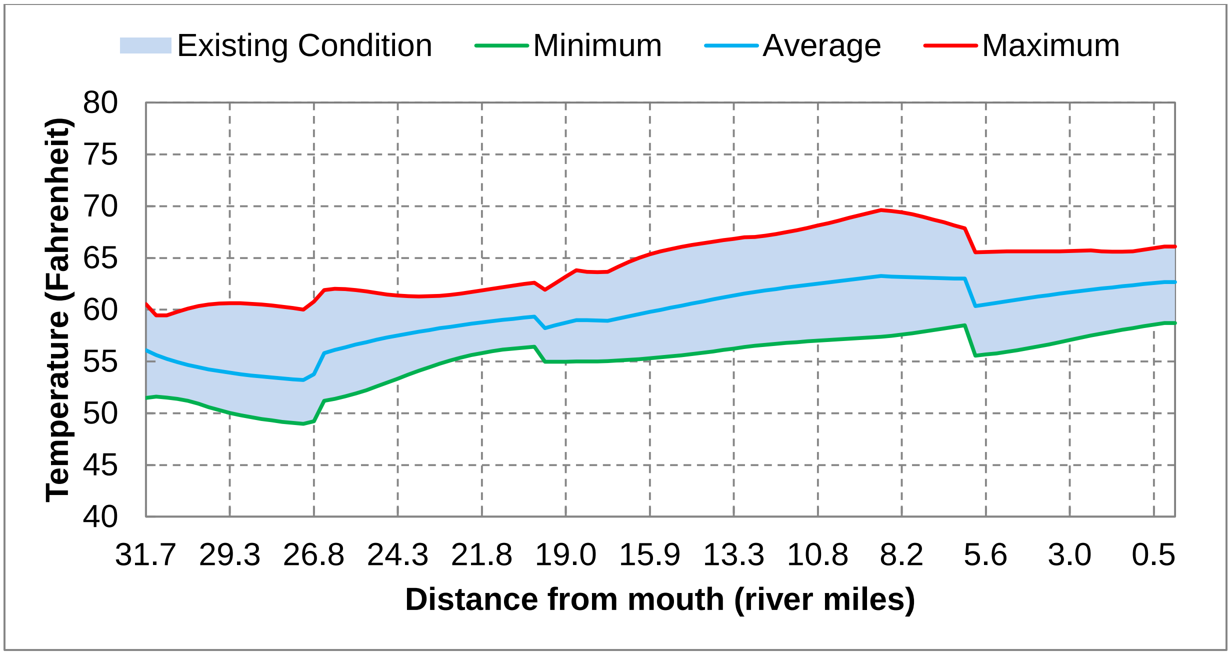


Figure B-20. Simulated water temperatures for the existing condition (August 10, 2012)

B5.2 Scenarios 2 and 3: Sensitivity Scenarios

Scenarios 2 and 3 were run entirely for the purpose of testing model sensitivity to shade and water usage. Neither is intended to reflect a reasonable management scenario.

B5.2.1 Scenario 2: No Water Withdrawals

In this scenario, the point source abstractions representing the withdrawals (see **Table B-6** for the withdrawals) in the QUAL2K model are removed. This scenario represents a lack of withdrawals for irrigation, domestic use, and other uses in the Fortine Creek watershed. The 6.24 cfs of water previously withdrawn is now allowed to flow down Fortine Creek. While not feasible due to water rights and other issues, the 100 percent decrease scenario indicates the maximum possible achievable change in water temperatures from changes in water use. To put this amount of water into context, in the existing condition scenario (i.e., Scenario 1) streamflow increases from 3.7 cfs near the headwaters to 59.3 cfs at the mouth and tributary inputs total 28.2 cfs.

No Water Withdrawal Scenario Results

The no withdrawal scenario results in little change along most of the stream, indicating the model is not very sensitive to changes in streamflow related to withdrawals. This is likely because the withdrawals are dispersed among roughly 25 miles and streamflow increases quite a bit along the stream. Under this scenario, the daily maximum temperatures range from 59.4°F to 69.2°F. Daily mean temperatures change along Fortine Creek, as compared to the existing condition scenario, from a 0.13°F decrease to a 0.20°F increase (river mile-weight average decrease of 0.01°F) [8]. The daily maximum temperatures vary between a 0.38°F decrease and a 0.09°F increase (river mile-weighted average decrease of 0.1°F) and the daily minimum temperatures vary between a 0.01°F decrease to a 0.34°F increase (river mile-weighted average increase of 0.06°F). Decreases in the maximum temperature do not start until close to river mile 23, which is midway between loggers FRTNC-T2 and FRTNC-T3. The maximum decrease occurs

[8] The river mile-weighted average is calculated with the temperature change per element and length per element.

in the lower watershed near Brimstone Creek, which is close to river mile 9 and between loggers FRTNC-T5 and FRTNC-T6, and where the largest withdrawal is located. **Table B-11** presents the results at the temperature logger sites and **Figure B-21** presents the continuous results along Fortine Creek.

Table B-11. Comparison of model results between baseline (1) and no water withdrawals (2)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	59.5	60.8	62.5	64.1	66.9	68.0	65.8
	Difference	**0**	**0**	**-0.010**	**-0.1**	**-0.1**	**-0.2**	**-0.3**
Mean	Existing	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Scenario	55.3	53.8	59.2	59.2	61.6	63.0	62.7
	Difference	**0**	**0**	**0.0**	**0.0**	**-0.1**	**-0.1**	**-0.01**
Minimum	Existing	51.5	49.2	59.2	55.1	56.5	58.3	58.7
	Scenario	51.5	49.2	59.3	55.2	56.5	58.3	58.9
	Difference	**0**	**0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.2**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition and positive results indicate the scenario yields warmer instream temperatures as compared to the existing condition.

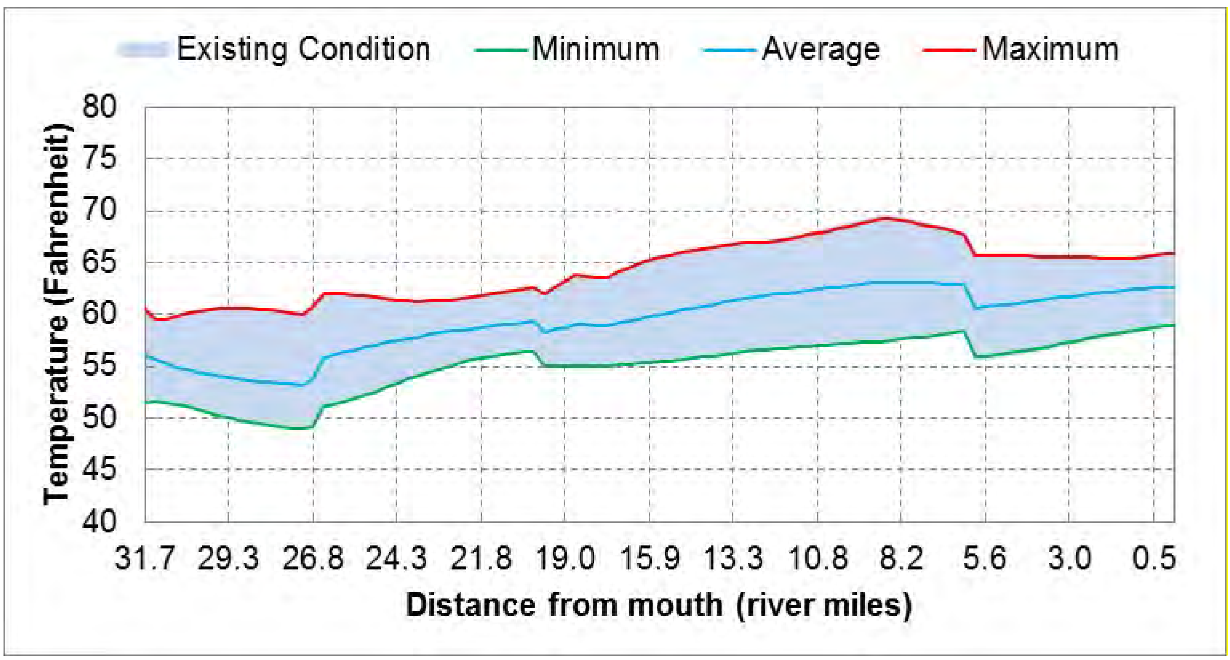


Figure B-21. Comparison of existing model results to Scenario 2: No water withdrawals

B5.2.2 Scenario 3: Maximum Shade

The maximum shade scenario uses the existing condition model and increases shading along Fortine Creek. Except for water, roads, railroads, and hydrophytic shrubs, all land covers were transformed to high density forest, and the Shade Model was re-run using this vegetation configuration (see **Figure B-22** and **Table B-12** for a comparison of the effective shade under the maximum shade scenario with the existing condition scenario). Similar to Scenario 2, this scenario was developed only to assess model sensitivity and not a management goal.

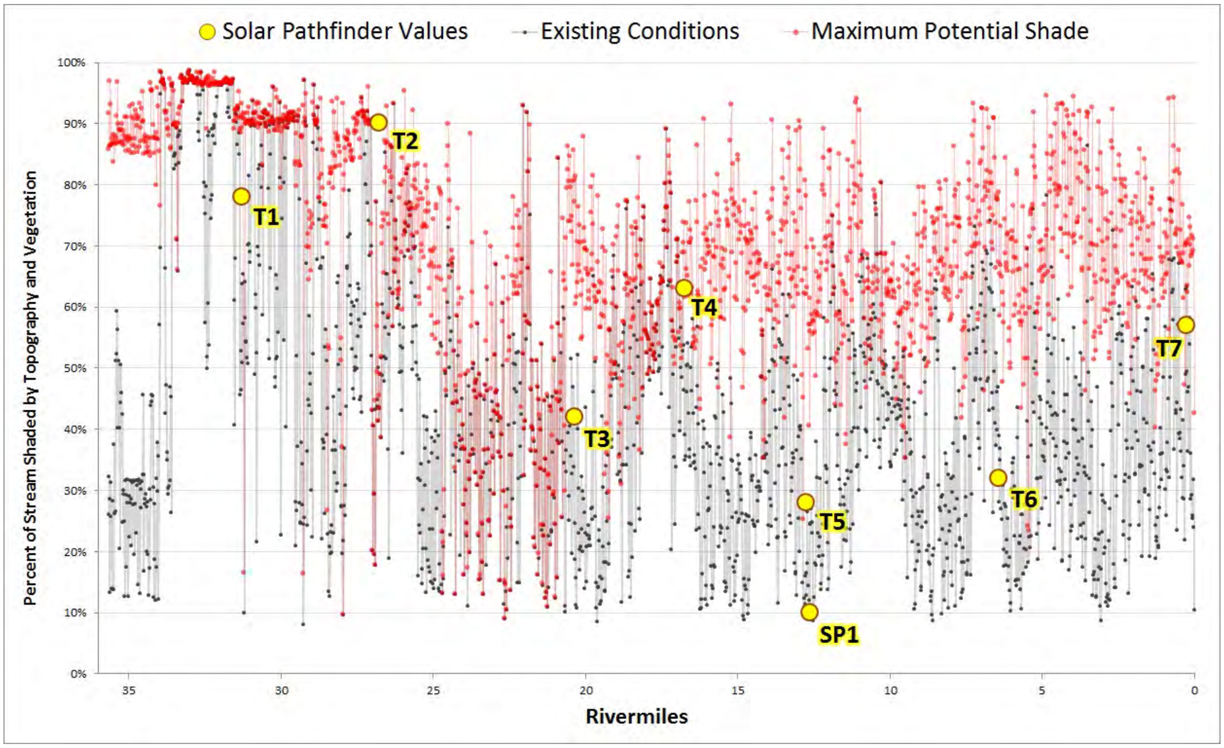


Figure B-22. Longitudinal estimates of effective shade for existing conditions and the maximum shade scenario along Fortine Creek

Table B-12. Comparison of effective shade per model segment between existing (1) and maximum shade scenario (3)

Model segment	Existing Condition (scenario 1)	Maximum Shade (scenario 3)
I (near headwaters)	82%	98%
H	55%	72%
G	47%	79%
F	73%	78%
E	48%	83%
D	52%	79%
C	49%	86%
B	42%	88%
A (mouth)	53%	83%

Maximum Shade Scenario Results

The results of this scenario indicate the Fortine Creek QUAL2K model is much more sensitive to changes in riparian shade than to increases in streamflow. This scenario results in cooler water temperatures along all of Fortine Creek. Under this scenario, the daily maximum temperatures range from 52.7°F to 62.1°F. Daily mean temperatures along Fortine Creek decrease, as compared to the existing condition scenario, between 0.4°F and 5.7°F (river mile-weighted average[9] decrease of 3.7°F). Daily maximum temperatures decrease between 0.6°F and 7.9°F (river mile-weighted average decrease of 5.8°F) and daily minimum temperatures decrease, between less than 0.1°F to 3.6°F (river mile-weighted average

[9] The river mile-weighted average is calculated with the temperature change per element and length per element.

decrease of 2.0 °F). **Table B-13** presents the results at the temperature logger sites and **Figure B-23** presents the continuous results along Fortine Creek.

Table B-13. Comparison of model results between existing (1) maximum shade scenario (3)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	57.7	54.1	58.7	60.2	59.4	60.4	58.8
	Difference	**-1.8**	**-6.7**	**-3.8**	**-4.0**	**-7.6**	**-7.8**	**-7.3**
Mean	Existing	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Scenario	54.5	51.0	56.2	56.4	56.9	57.5	57.1
	Difference	**-0.8**	**-2.8**	**-3.0**	**-2.8**	**-4.8**	**-5.5**	**-5.6**
Minimum	Existing	51.5	49.2	59.2	55.1	56.5	58.3	58.7
	Scenario	51.4	48.6	54.1	53.5	54.0	55.0	55.1
	Difference	**-0.1**	**-0.6**	**-5.2**	**-1.6**	**-2.5**	**-3.3**	**-3.6**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition.

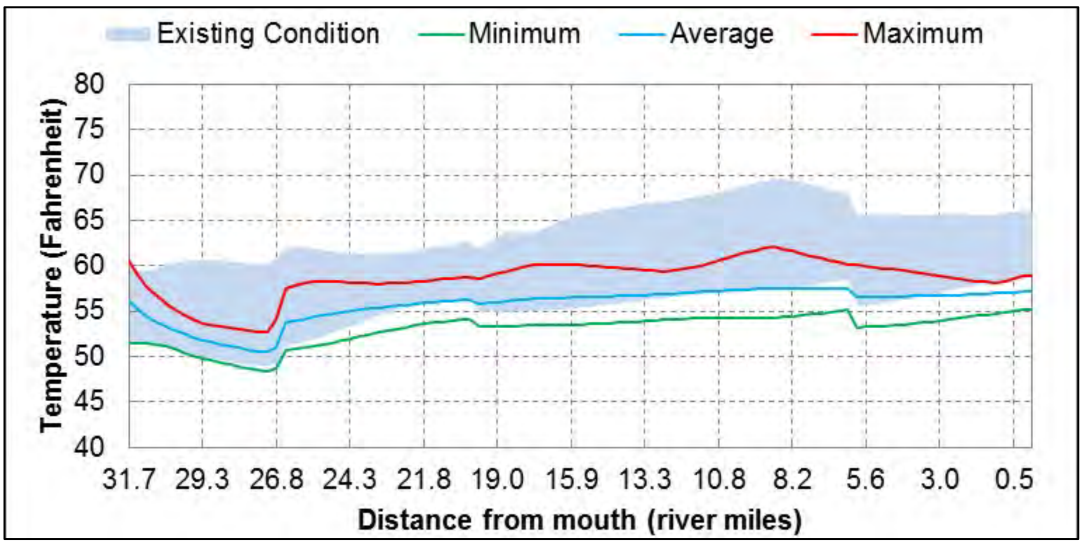


Figure B-23. Comparison of existing model results to Scenario 3: Maximum Shade

B5.3 Scenario 4: Improved Shade

The improved shade scenario consists of the existing condition scenario with a 50-foot buffer along the stream channel where vegetation is allowed to grow to its potential. All vegetation communities, with the exception of hydrophytic shrubs, roads, and railroads, are transformed to medium density trees within 50 feet of the streambanks. Beyond 50 feet, existing condition vegetation remains. This scenario was selected based on areas of reference riparian health in various portions of the watershed and documented removal of much of the overstory trees in the valley (DEQ 2014), as well as the NRCS recommendation for buffers with medium to high shade value (NRCS 2011a; 2011b). Considering the variability in potential vegetation and shade, medium density trees was used as a surrogate to represent the average achievable shade condition; effective shade is the result of topography and vegetative height and density, so the results of this scenario could be achieved by a large combination of vegetation types and densities.

To estimate the change in effective shade under this scenario, the Shade Model was re-run using this vegetation configuration (see **Figure B-24** and **Table B-14** for a comparison of the effective shade under the improved shade scenario with the existing condition scenario). The 50-foot buffer was selected to be generally consistent with Montana's Streamside Management Zone Law, which limits clearcutting within 50 feet of the ordinary high water mark in order to provide large woody debris, stream shading, water filtering effects, and to protect stream channels and banks. This scenario is intended to represent application of *all reasonable land, soil and water conservation practices* relative to shade.

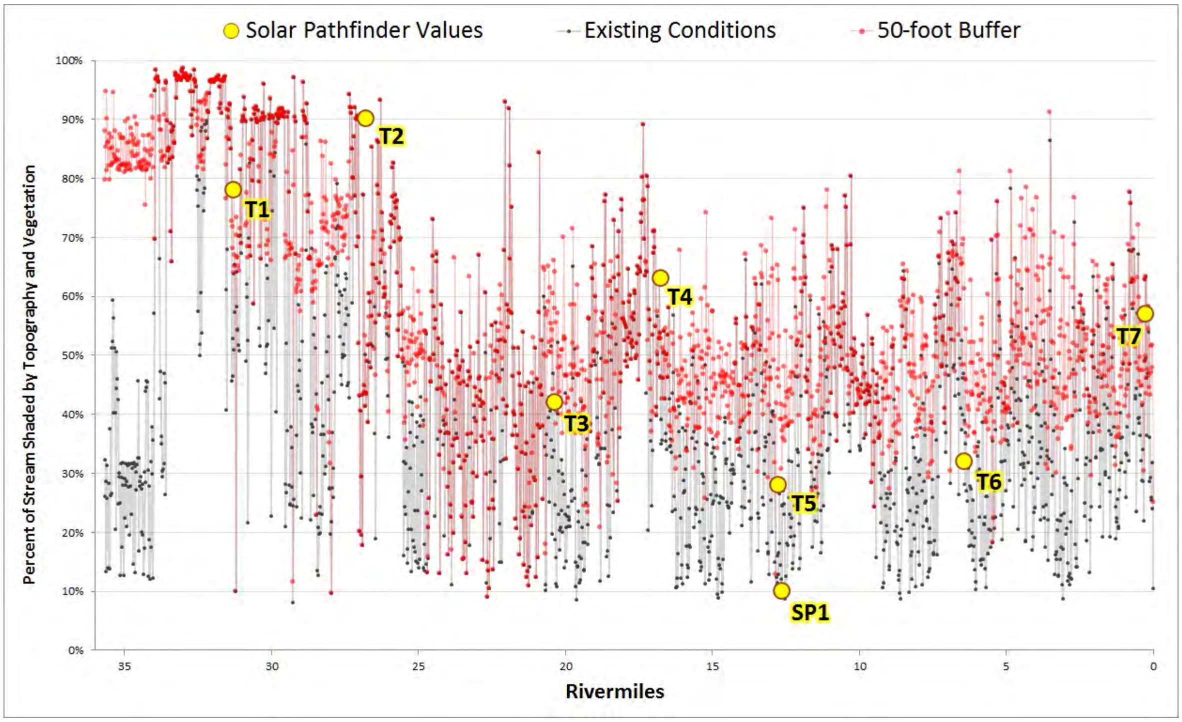


Figure B-24. Longitudinal estimates of effective shade for existing conditions and the improved shade scenario along Fortine Creek

Table B-14. Comparison of effective shade per model segment between existing (1) and improved shade scenario (4)

Model segment	Existing Condition (scenario 1)	Improved Shade (scenario 4)
I (near headwaters)	82%	86%
H	55%	62%
G	47%	61%
F	73%	74%
E	48%	60%
D	52%	61%
C	49%	63%
B	42%	60%
A (mouth)	53%	63%

Improved Shade Scenario Results

Similar to the maximum shade scenario, the improved shade scenario results in cooler water temperatures along all of Fortine Creek. Under this scenario, the daily maximum temperatures range from 57.1°F to 66.3°F. Daily mean temperatures throughout Fortine Creek decrease, as compared to the existing condition scenario, between 0.2°F and 2.3°F (river mile-weighted average[10] decrease of 1.6°F). Daily maximum temperatures decrease between 0.3°F and 3.5°F (river mile-weighted average decrease of 2.6°F). The 0.3°F decrease is the only change less than 1.0°F and occurs at the most upstream element, which represents approximately 0.2 miles of stream. The daily minimum temperatures decrease at all but the uppermost mile of the stream, between less than 0.1°F and 1.3°F (river mile-weighted average decrease of 0.8°F). **Table B-15** presents the results at the temperature logger sites and **Figure B-25** presents the continuous results along Fortine Creek.

Table B-15. Comparison of model results between existing (1) and improved shade scenario (4)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	58.1	58.0	60.5	62.4	63.6	64.8	62.7
	Difference	**-1.4**	**-2.7**	**-2.0**	**-1.7**	**-3.4**	**-3.4**	**-3.4**
Mean	Existing	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Scenario	55.0	52.7	57.8	57.9	59.6	60.8	60.4
	Difference	**-0.3**	**-1.0**	**-1.4**	**-1.3**	**-2.1**	**-2.2**	**-2.3**
Minimum	Existing	51.5	49.2	59.2	55.1	56.5	58.3	58.7
	Scenario	51.6	49.0	55.4	54.3	55.4	57.1	57.4
	Difference	**0.1**	**-0.2**	**-3.9**	**-0.8**	**-1.1**	**-1.2**	**-1.3**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition and positive results indicate the scenario yields warmer instream temperatures as compared to the existing condition.

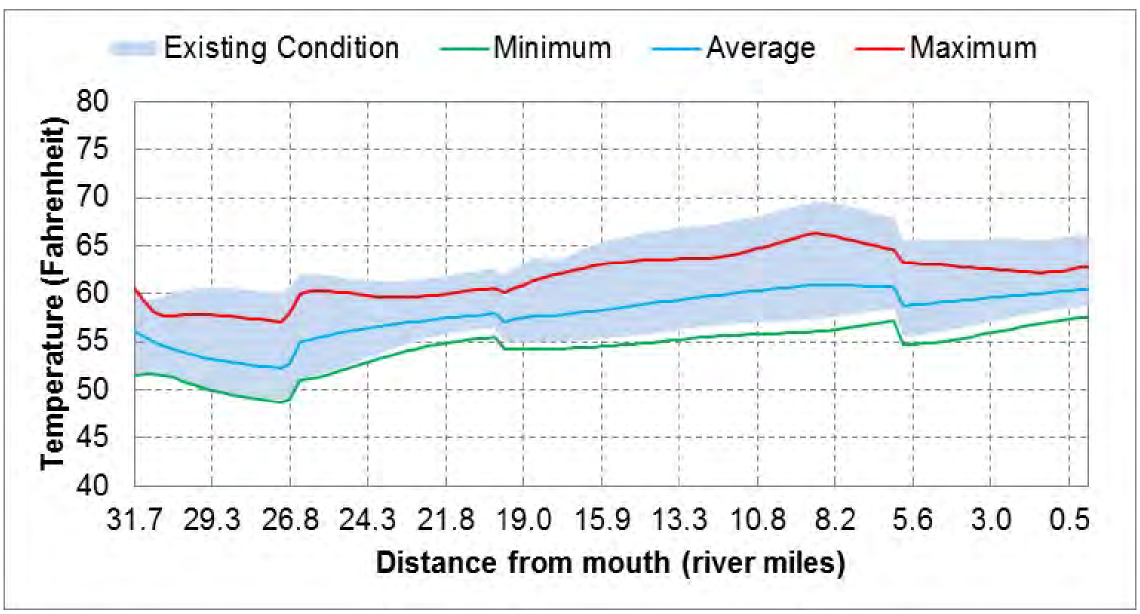


Figure B-25. Comparison of existing model results to Scenario 4: Improved Shade

[10] The river mile-weighted average is calculated with the temperature change per element and length per element.

B5.4 Scenario 5: Improved Water Management

In this scenario, the point source abstractions representing the withdrawals (see **Table B-6** for the withdrawals) in the QUAL2K model are reduced by 15 percent. The 0.94 cfs previously withdrawn daily (i.e., 15% of 6.24cfs) is now allowed to flow down Fortine Creek. This improvement is based on the low end of what research has shown to be achievable for typical improvements to irrigation efficiency (Economic Research Station, 1997; Negri et al., 1989). This scenario is intended to represent application of *all reasonable land, soil, and water conservation practices* relative to water use.

Improved Water Management Scenario Results

As indicated by the limited temperature changes in the no irrigation scenario (i.e., Scenario 2), the model is much less sensitive to increases in streamflow associated with water use than in riparian shade. This scenario results in very minor changes in temperature. The daily maximum temperatures are almost identical to the existing condition scenario with modeled differences typically only at the hundredths place; they range from 59.4°F to 69.6°F. Daily mean temperatures in Fortine Creek change as compared to the existing condition scenario from a decrease of 0.02°F to an increase of 0.03°F (river mile-weighted average[11] change is 0.0°F). Daily maximum temperatures change from a decrease of 0.06°F to an increase of 0.02°F (river mile-weighted average decrease of 0.02°F). The largest decrease in daily maximum temperatures occurs between loggers FRTNC-T5 and FRTNC-T6 near Brimstone Creek and river mile 9.0, which is where the largest withdrawal is located. The change in daily minimum temperatures ranges from 0.0°F to an increase of 0.06°F (river mile-weighted average increase of 0.01°F). **Table B-16** presents the results at the temperature logger sites and **Figure B-26** presents the continuous results along Fortine Creek.

Table B-16. Comparison of model results between existing (1) and improved water management scenario (5)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	59.5	60.8	62.5	64.1	67.0	68.1	66.1
	Difference	**0**	**0**	**-0.001**	**-0.01**	**-0.02**	**-0.02**	**-0.04**
Mean	Existing	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Scenario	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Difference	**0**	**0**	**-0.0004**	**0.001**	**-0.01**	**-0.01**	**-0.002**
Minimum	Existing	51.5	49.2	59.2	55.1	56.5	58.3	58.7
	Scenario	51.5	49.2	56.3	55.1	56.5	58.3	58.7
	Difference	**0**	**0**	**-2.9**	**0.01**	**0.003**	**-0.0004**	**0.03**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition and positive results indicate the scenario yields warmer instream temperatures as compared to the existing condition.

[11] The river mile-weighted average is calculated with the temperature change per element and length per element.

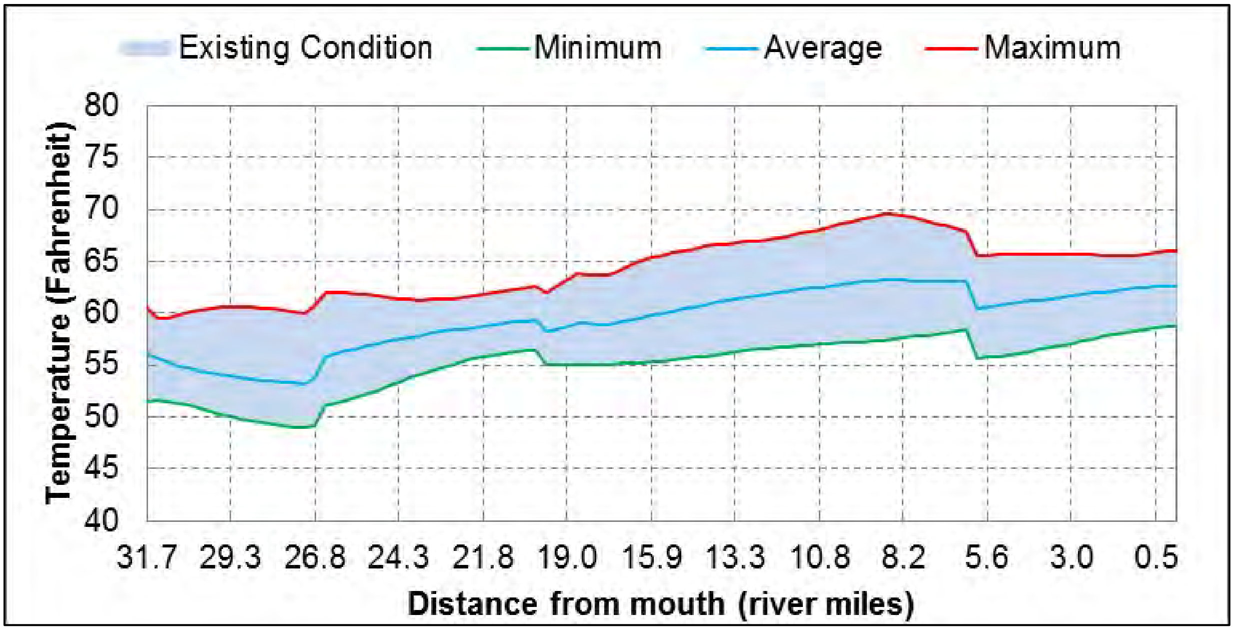


Figure B-26. Comparison of existing model results to Scenario 5: Improved Water Management

B5.5 Scenario 6: Naturally Occurring Condition

The naturally occurring scenario combines scenarios 4 and 5 (i.e., improved shade and improved water management, respectively) and is intended to represent application of *all reasonable land, soil, and water conservation practices* relative to the temperature impairment.

This scenario results in cooler mean and maximum water temperatures along all of Fortine Creek and indicates the maximum naturally occurring temperature ranges from 57.1°F in the upper watershed to 66.3°F near the mouth. Daily mean temperatures in Fortine Creek decrease, as compared to the existing condition scenario, between 0.2°F and 2.3°F (river mile-weighted average[12] decrease of 1.6°F). Daily maximum temperatures decrease between 0.3°F and 3.5°F (river mile-weighted average decrease of 2.6°F). The 0.3°F decrease is the only change less than 1.0°F and occurs at the most upstream element, which represents approximately 0.2 miles of stream (see white dot on **Figure B-28**). Daily minimum temperatures decrease at all but the upper mile between less than 0.1°F and 1.3°F (river mile-weighted average decrease of 0.8°F). **Table B-17** presents the results at the temperature logger sites and **Figure B-27** presents the continuous results along Fortine Creek. Largely driven by shade improvements, the largest decreases in temperature that can be achieved under the naturally occurring condition relative to existing conditions is in the upper watershed (upstream of Swamp Creek) and from downstream of site FRTNC-T5 near Trego to the mouth (**Figure B-28**). The maximum decrease is near Brimstone Creek and river mile 8, which is between loggers FRTNC-T5 and FRTNC-T6.

Table B-17. Comparison of model results between existing (1) and naturally occurring scenario (6)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	58.1	58.0	60.5	62.4	63.6	64.8	62.7
	Difference	**-1.4**	**-2.8**	**-2.0**	**-1.7**	**-3.4**	**-3.4**	**-3.4**

[12] The river mile-weighted average is calculated with the temperature change per element and length per element.

Table B-17. Comparison of model results between existing (1) and naturally occurring scenario (6)

Daily temperature	Source	FRTNC-*						
		***T1**	***T2**	***T3**	***T4**	***T5**	***T6**	***T7**
Mean	Existing	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Scenario	55.0	52.7	57.8	57.9	59.6	60.8	60.4
	Difference	**-0.3**	**-1.0**	**-1.4**	**-1.3**	**-2.1**	**-2.3**	**-2.3**
Minimum	Existing	51.5	49.2	59.2	55.1	56.5	58.3	58.7
	Scenario	51.6	49.0	55.4	54.3	55.4	57.1	57.5
	Difference	**0.1**	**-0.2**	**-3.9**	**-0.8**	**-1.1**	**-1.2**	**-1.2**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition and positive results indicate the scenario yields warmer instream temperatures as compared to the existing condition.

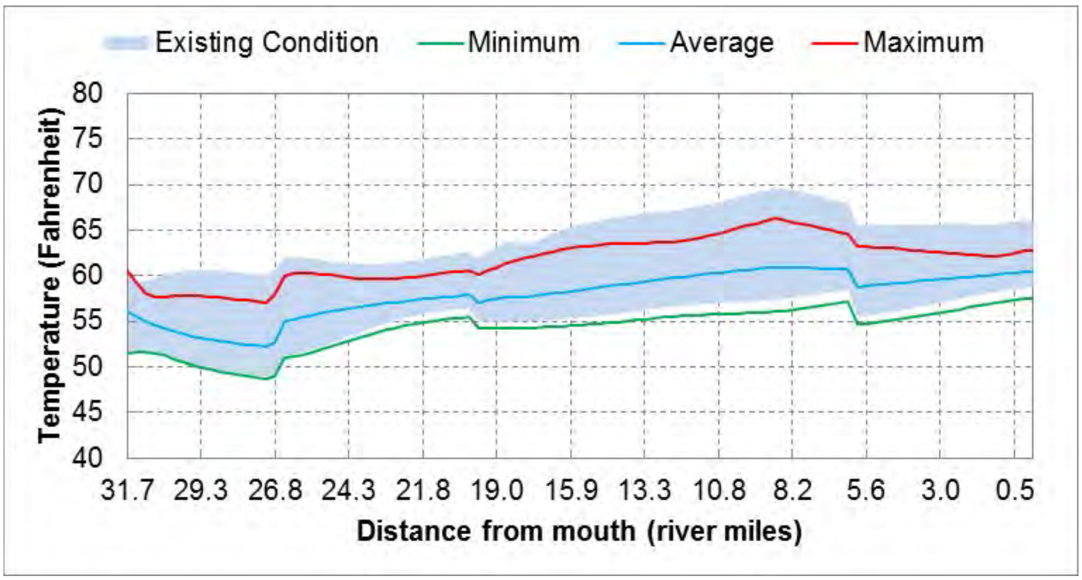


Figure B-27. Comparison of existing model results to Scenario 6: Naturally Occurring Condition

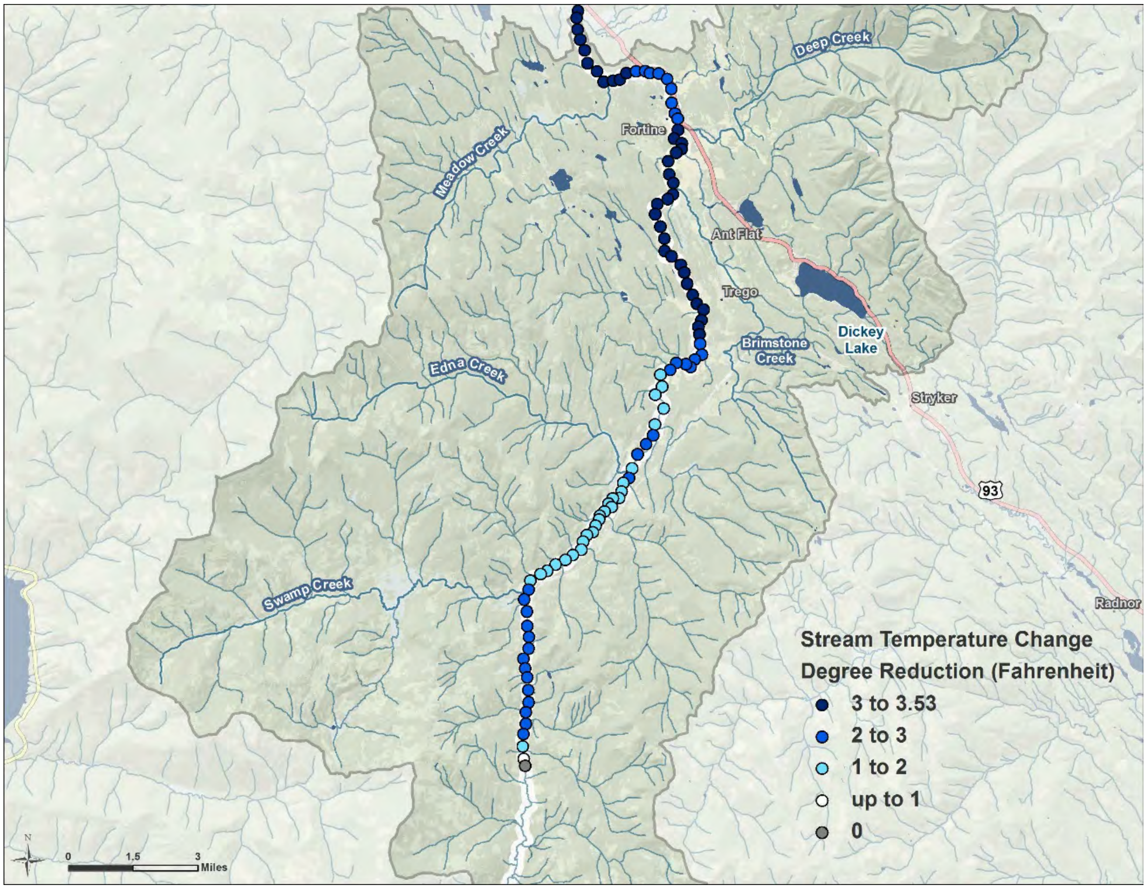


Figure B-28. Temperature reductions that can be obtained under naturally occurring conditions (relative to the baseline scenario)

B5.6 Scenario 7: Low Flow Existing Condition (Alternative Baseline)

Because streamflow conditions in 2012 were well above average (87th percentile flow, see **Figure B-8**) and a goal of the model is to evaluate stream temperatures when aquatic life are most likely to be stressed, Scenario 7 was developed to represent low flow baseline conditions. This scenario uses existing shade and climate conditions (which were applied in the existing conditions scenario (#1)) but inflow to Fortine Creek was reduced by 56 percent, which is estimated to be the 25th percentile flow. This reduction is based upon the low flow analysis for August 10 at the nearby Tobacco River USGS gage 12301300 (as discussed in **Section B2.3.4**). The August 10, 2012 flow of 199 cfs was reduced by 56 percent to 88 cfs, which is the 25th percentile flow for August 10 at gage 12301300 across its period of record (WY 1959-2012). Therefore, no measurements were used directly from the stream gage but instead its long term flow record was used to estimate the reduction to apply to measured flows in Fortine Creek.

Since the amount of water in the stream channel affects its ability to buffer incoming solar radiation, and less water will heat up faster, the alternative baseline scenario results in warmer water temperatures along all of Fortine Creek relative to the existing conditions (Scenario 1). The daily maximum temperatures range from 60.5°F to 77.5°F. Daily mean temperatures throughout Fortine Creek increase, as compared to the existing condition scenario, between 0.1°F and 4.4°F (river mile-weighted average[13] increase of 2.8°F). Daily maximum temperatures increase between 1.2°F and 8.0°F (river mile-weighted average increase of 5.1°F). Daily minimum temperatures decrease in the upper five miles by up to 1.3°F but increase throughout the rest of Fortine Creek from 0.2°F and 2.2°F (river mile-weighted average increase of 1.1°F). **Table B-18** presents the results at the temperature logger sites and **Figure B-29** presents the continuous results along Fortine Creek.

Table B-18. Comparison of model results between existing (1) and low flow existing baseline scenario (7)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Existing	59.5	60.8	62.5	64.1	67.0	68.2	66.1
	Scenario	62.2	64.4	67.1	69.3	73.5	73.5	72.9
	Difference	**2.7**	**3.6**	**4.6**	**5.2**	**6.5**	**5.3**	**6.8**
Mean	Existing	55.3	53.8	59.2	59.2	61.7	63.0	62.7
	Scenario	55.5	55.2	62.4	61.9	65.9	66.6	66.3
	Difference	**0.3**	**1.4**	**3.1**	**2.8**	**4.2**	**3.5**	**3.6**
Minimum	Existing	51.5	49.2	59.2	55.1	56.5	58.3	58.7
	Scenario	51.4	48.8	58.0	56.2	58.7	60.2	60.0
	Difference	**-0.1**	**-0.4**	**-1.2**	**1.1**	**2.2**	**1.9**	**1.3**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition and positive results indicate the scenario yields warmer instream temperatures as compared to the existing condition.

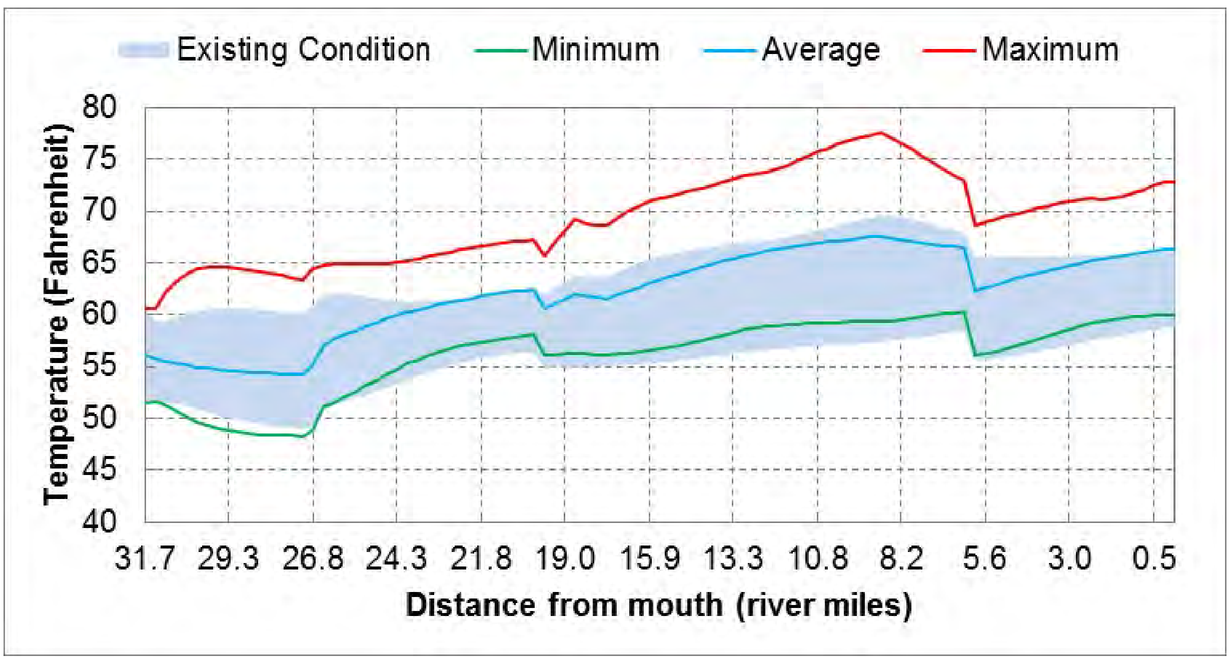


Figure B-29. Comparison of existing model results to Scenario 7: Low flow Existing Condition

[13] The river mile-weighted average is calculated with the temperature change per element and length per element.

B5.7 Scenario 8: Naturally Occurring Low Flow Condition

The naturally occurring low flow scenario combines scenarios 6 and 7 (i.e., naturally occurring and low flow existing conditions, respectively) and is intended to represent application of all reasonable land, soil, and water conservation practices during low flow conditions.

Similar to Scenario 6, the naturally occurring condition, this scenario results in cooler water temperatures along Fortine Creek. The decreases in the mean, maximum, and minimum temperatures under this scenario are all greater in magnitude than the naturally occurring condition relative to the existing baseline (i.e., Scenario 6 to 1). This means that under lower streamflows than measured in 2012, improvements in shade and streamflow have a more pronounced effect. Under this scenario, the daily maximum temperatures range from 59.0°F to 73.1°F. Daily mean temperatures throughout Fortine Creek decrease, as compared to the low flow existing condition scenario (scenario 7), between 0.3°F and 3.4°F (river mile-weighted average[14] decrease of 2.4°F). Daily maximum temperatures decrease between 1.7°F and 5.4°F (river mile-weighted average decrease of 3.9°F) and daily minimum temperatures decrease, at all but the upper 0.5 miles, between 0.1°F and 2.0°F (river mile-weighted average decrease of 1.3°F). **Table B-19** presents the results at the temperature logger sites and **Figure B-30** presents the continuous results along Fortine Creek.

Table B-19. Comparison of model results between low flow existing (7) and naturally occurring low flow scenario (8)

Daily temperature	Source	FRTNC-*						
		*T1	*T2	*T3	*T4	*T5	*T6	*T7
Maximum	Low flow existing	62.2	64.4	67.1	69.3	73.5	73.5	72.9
	Scenario	59.7	60.6	64.2	66.9	68.4	68.5	68.3
	Difference	**-2.5**	**-3.8**	**-2.9**	**-2.6**	**-5.1**	**-5.0**	**-4.6**
Mean	Low flow existing	55.5	55.2	62.4	61.9	65.9	66.6	66.3
	Scenario	54.9	53.4	60.2	60.1	62.8	63.5	62.9
	Difference	**-0.6**	**-1.8**	**-2.1**	**-1.8**	**-3.1**	**-3.1**	**-3.4**
Minimum	Low flow existing	51.4	48.8	58.0	56.2	58.7	60.2	60.0
	Scenario	51.4	48.1	56.5	55.1	57.0	58.4	58.0
	Difference	**0.01**	**-0.74**	**-1.5**	**-1.2**	**-1.7**	**-1.8**	**-2.0**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference (bolded) is calculated as the existing subtracted from the scenario. Negative results indicate that the scenario yields cooler instream temperatures as compared to the existing condition and positive results indicate the scenario yields warmer instream temperatures as compared to the existing condition.

[14] The river mile-weighted average is calculated with the temperature change per element and length per element.

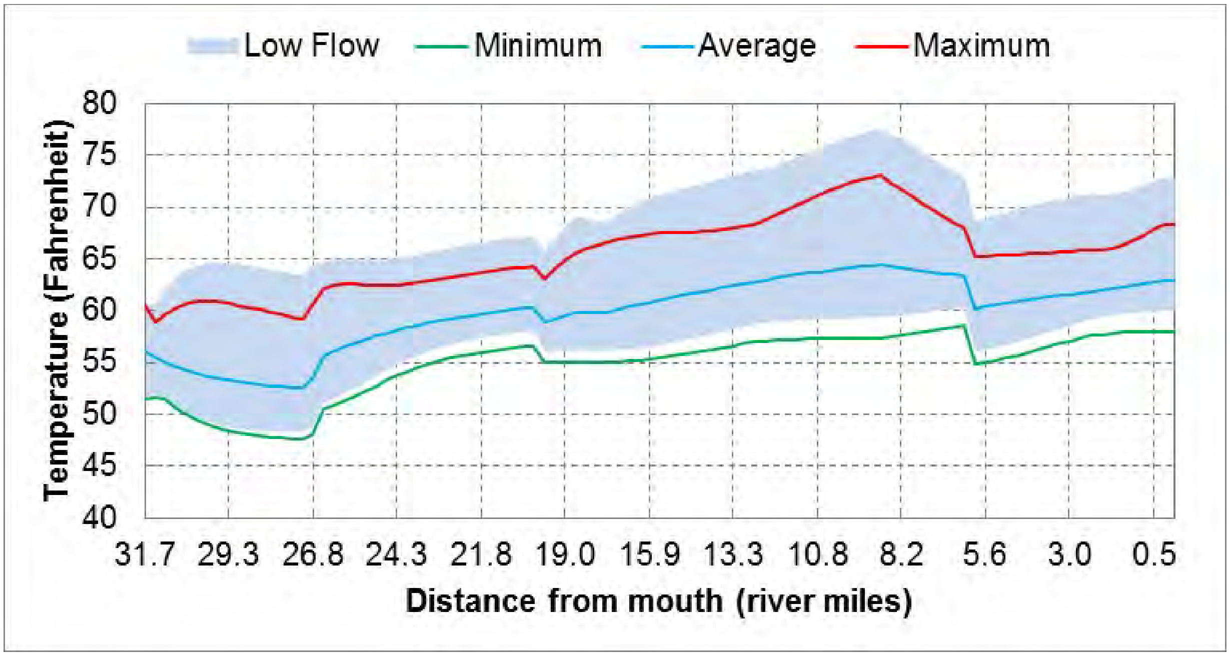


Figure B-30. Comparison of low flow existing model results to Scenario 8: Naturally occurring low flow

B6.0 Scenario Results and Discussion

Model scenarios were developed and evaluated for two primary purposes: to assess model sensitivity and to simulate potential temperature changes associated with reasonable application of best management practices. The model sensitivity scenarios (Scenarios 2 and 3) are discussed in the following section (**B7.0**) but are not summarized here since they were not management scenarios developed to assist with TMDL development.

Generally, scenarios representing increased shading (i.e., scenarios 4, 6, and 8) showed decreased water temperatures throughout Fortine Creek, including at all of the logger sites, as compared to the existing conditions. Scenarios representing alterations of water use (scenarios 5, 6, and 8) showed much smaller changes in water temperatures, resulting in water temperatures under the improved shade scenario (#4) essentially matching temperatures under the naturally occurring scenario (#6). The low flow baseline scenario (# 7) caused a fairly large increase in maximum temperatures throughout Fortine Creek relative to the existing condition, and also resulted in shade improvements under the low flow naturally occurring scenario (#8) having a much greater effect than those under the naturally occurring scenario. **Figures B-31** and **B-32** summarize all of the management scenario results in maximum daily temperature and the temperature difference relative to the baseline, while **Figures B-33** and **B-34** summarize the maximum daily temperature for just the existing conditions and naturally occurring scenario results and the temperature difference between those scenarios.

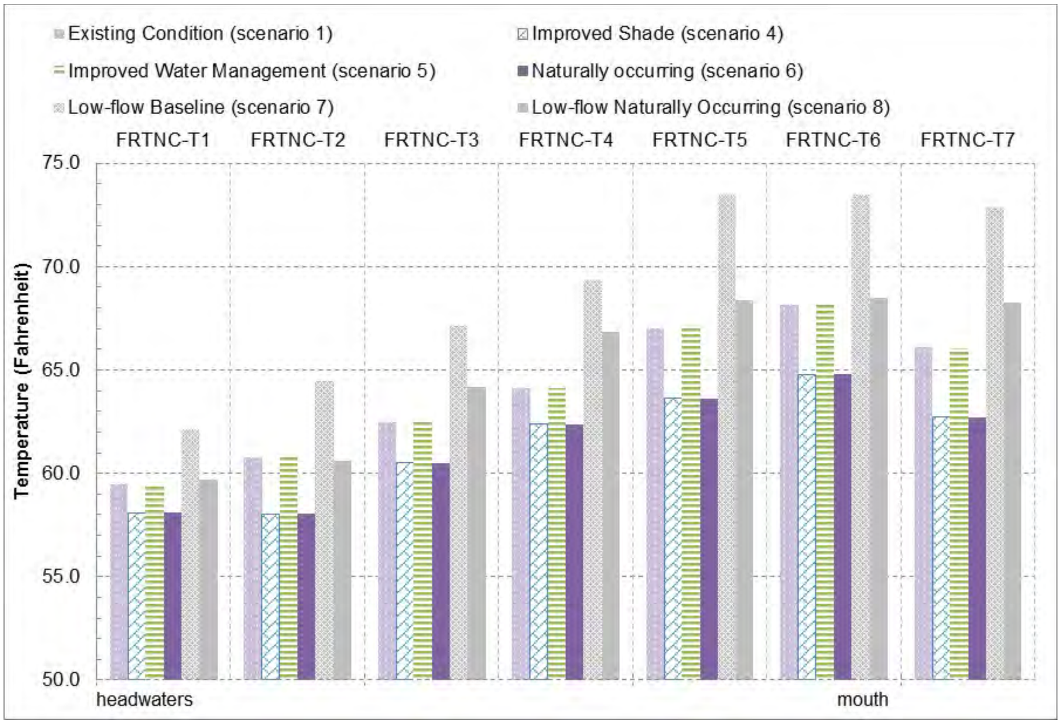


Figure B-31. Maximum daily water temperature along Fortine for each scenario

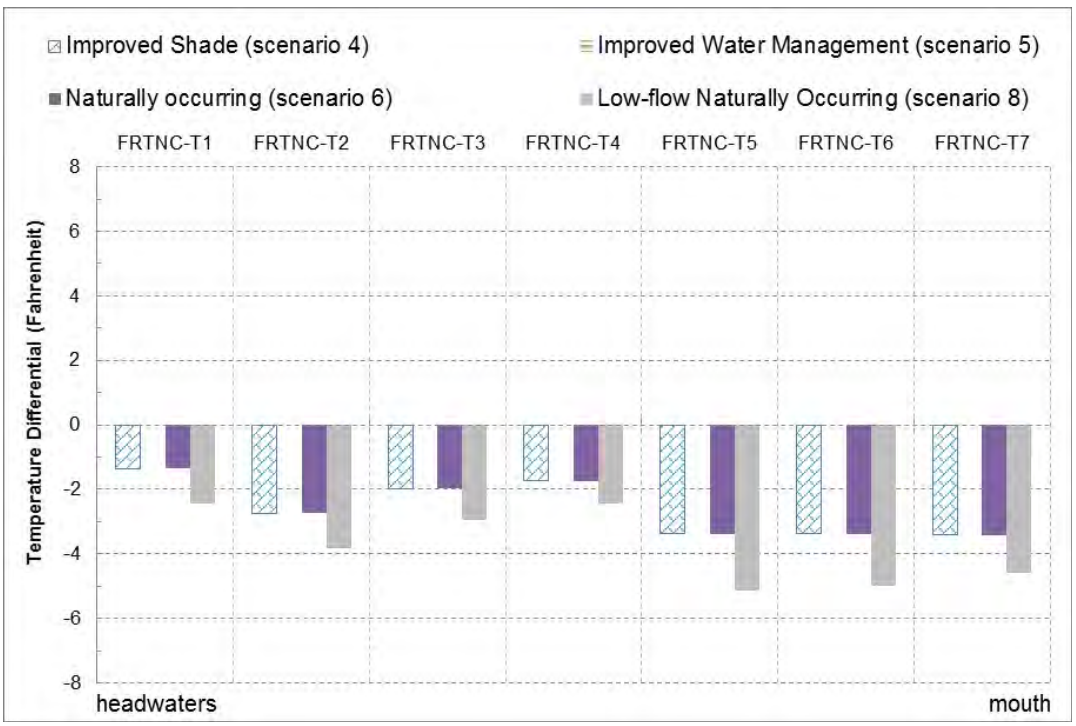


Figure B-32. Difference in simulated maximum daily temperatures relative to the existing condition scenario, except for Scenario 8 which is relative to the low flow existing condition

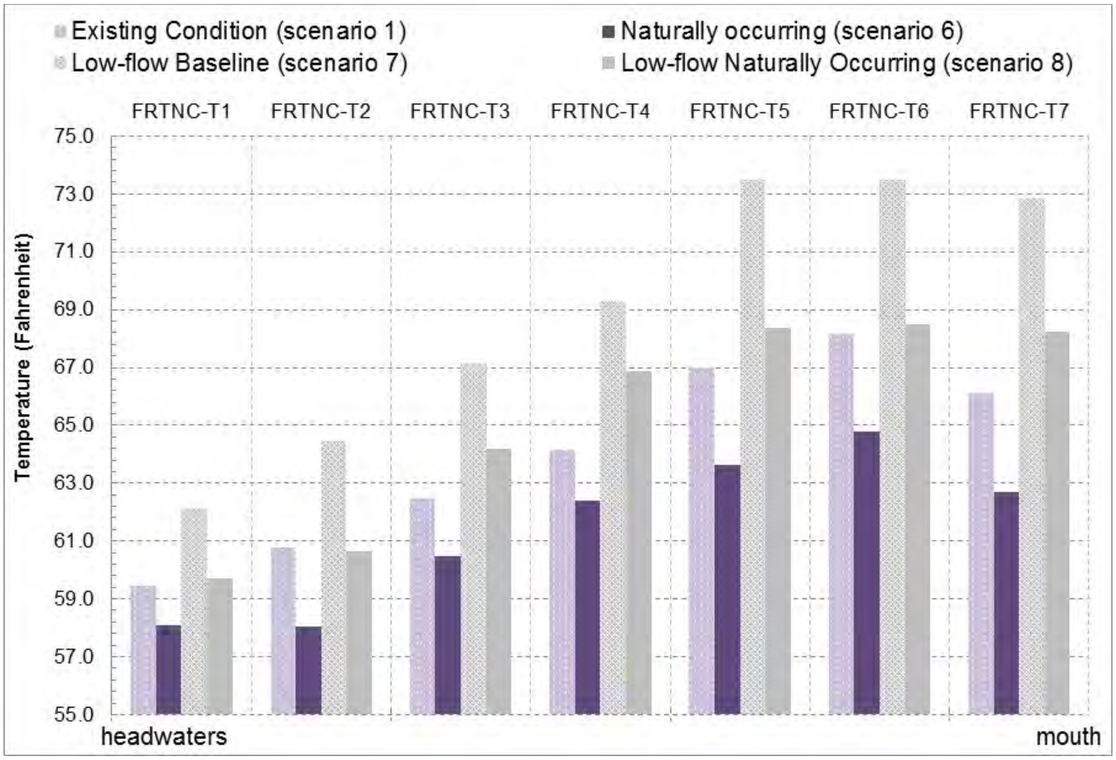


Figure B-33. Maximum daily temperature along Fortine Creek for both baseline scenarios (1 and 7) and their respective naturally occurring scenarios (6 and 8)

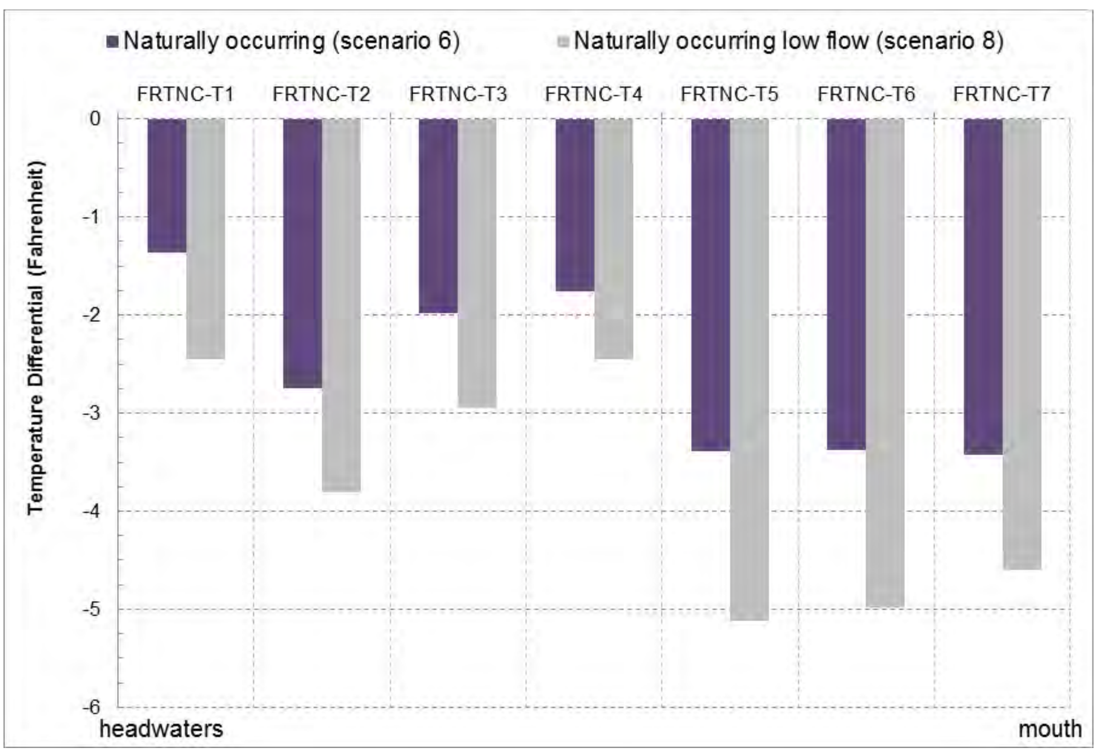


Figure B-34. Temperature difference between both naturally occurring scenarios (6 and 8) and their respective baseline scenarios (as simulated maximum daily water temperatures)

B7.0 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 2012). As discussed in the QAPP (Tetra Tech 2012), the QUAL2K model code has a long history of testing and application, so outright errors in the coding of the temperature model is 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.

The secondary data used during model setup included instantaneous flow, continuous temperature, channel geometry, hourly weather, and spatial data. Weather and spatial data were obtained from other government agencies, the values seemed reasonable, and the data are therefore assumed to be accurate. Uncertainty was minimized for the use of other secondary data following procedures described in the QAPP (Tetra Tech 2012).

In addition to uncertainty associated with secondary datasets, assumptions regarding how the secondary data are used during model development contain uncertainty. The following key assumptions were used during model development:

- Field measurements collected at discrete locations were representative of segments of Fortine Creek. Thus, segments were homogenous (as there were not sufficient channel geometry data to develop a more detailed model).
- Flow was assumed uniform within each reach using Manning's equation and a unique Manning's roughness coefficient was selected for each reach. Thus, segments were homogenous (as there were not sufficient depth, flow, and channel geometry data to develop a more detailed model).
- Stream meander and hyporheic flow paths (both of which may affect depth-velocity and temperature) were sufficiently represented during the estimation of various parameters (e.g., stream slope, channel geometry, and Manning's roughness coefficient) for each segment.
- Weather conditions at the Eureka RAWS, which were elevation-corrected, were representative of local weather conditions along Fortine Creek.
- Shade Model results were representative of riparian shading along segments of Fortine Creek. Riparian vegetation communities were identified from visual interpretation of aerial imagery and density was estimated using the NLCD and best professional judgment.
- All of the cropland associated with water rights is fully irrigated. No field measurements of irrigation withdrawals or returns were available.
- Groundwater temperatures were based upon GWIC records for nearby wells.

These sources of uncertainty are largely unavoidable, but do not invalidate the use of the model for decision purposes. Instead, as specified in the QAPP (Tetra Tech 2012, p. 18), the performance of the QUAL2K temperature models is evaluated (in lieu of using numeric acceptance criteria) and model performance guides the role of the model results in answering the principal study questions.

The most widely applied parameter uncertainty analysis approach for complex simulation models is sensitivity analysis; however, sensitivity analysis is limited in its ability to evaluate nonlinear interactions among multiple parameters. Model sensitivity of shade and water withdrawals (i.e., the key thermal mechanisms and stressors of the principal study questions [Tetra Tech 2012, p.10]) is presented below.

B7.1 Sensitivity

Stream temperatures appear to be sensitive to larger changes in flow. Existing instream temperatures increased substantially (i.e., an average of 5°F and maximum of 8°F) when stream inflows were reduced by 56 percent to represent low flow conditions (scenario 7). However, instream temperatures did not vary much (i.e., maximum decrease of 0.4°F and an average decrease of 0.1°F) when water withdrawals were eliminated (scenario 2). The total summation of water withdrawals was 6.2 cfs, which is approximately 11 percent of the 59.3 cfs monitored near the mouth of Fortine Creek on August 10, 2012.

Stream temperatures also appear to be sensitive to changes in shade provided by riparian vegetation. Although it is unlikely that the riparian corridor was ever dominated by dense tree cover, simulating such a scenario suggests that instream temperatures are heavily influenced by shade. Increasing all vegetation communities (except hydrophytic shrubs and ignoring water, roads, and railroads) to high density forest resulted in significantly cooler water temperatures; the river-mile weighted average of daily maximum temperatures was a decrease of 5.8°F.

B7.2 Application of Best Management Practices

Increases in streamflow with changes in irrigation practices (which was simulated within the model by a 15% increase in streamflow) may be feasible, however, the model indicates negligible improvements in water temperature would result. However, providing a 50-feet buffer dominated by medium density vegetation along the stream corridor is considered generally feasible along most of Fortine Creek and would greatly improve stream temperatures. Exceptions are areas where roads, railroads and structures already exist. The naturally occurring scenario combines these two concepts and represents the implementation of *all reasonable land and soil water conservation practices* (scenario 6). Both the naturally occurring scenario and improved shade scenario suggest that Fortine Creek could be up to 3.5°F cooler than the existing condition. As shown in **Figure B-28**, the magnitude of difference between these scenarios and the existing condition scenario varies spatially. Based on the model results, this is largely due to variations in existing shade. The shade deficit between the naturally occurring and existing condition scenarios is shown in **Figure B-35**. Note, the low flow model scenarios indicate that during years with a lower amount of streamflow, shade improvements would have an even greater effect and could decrease temperatures by up to 5.4°F.

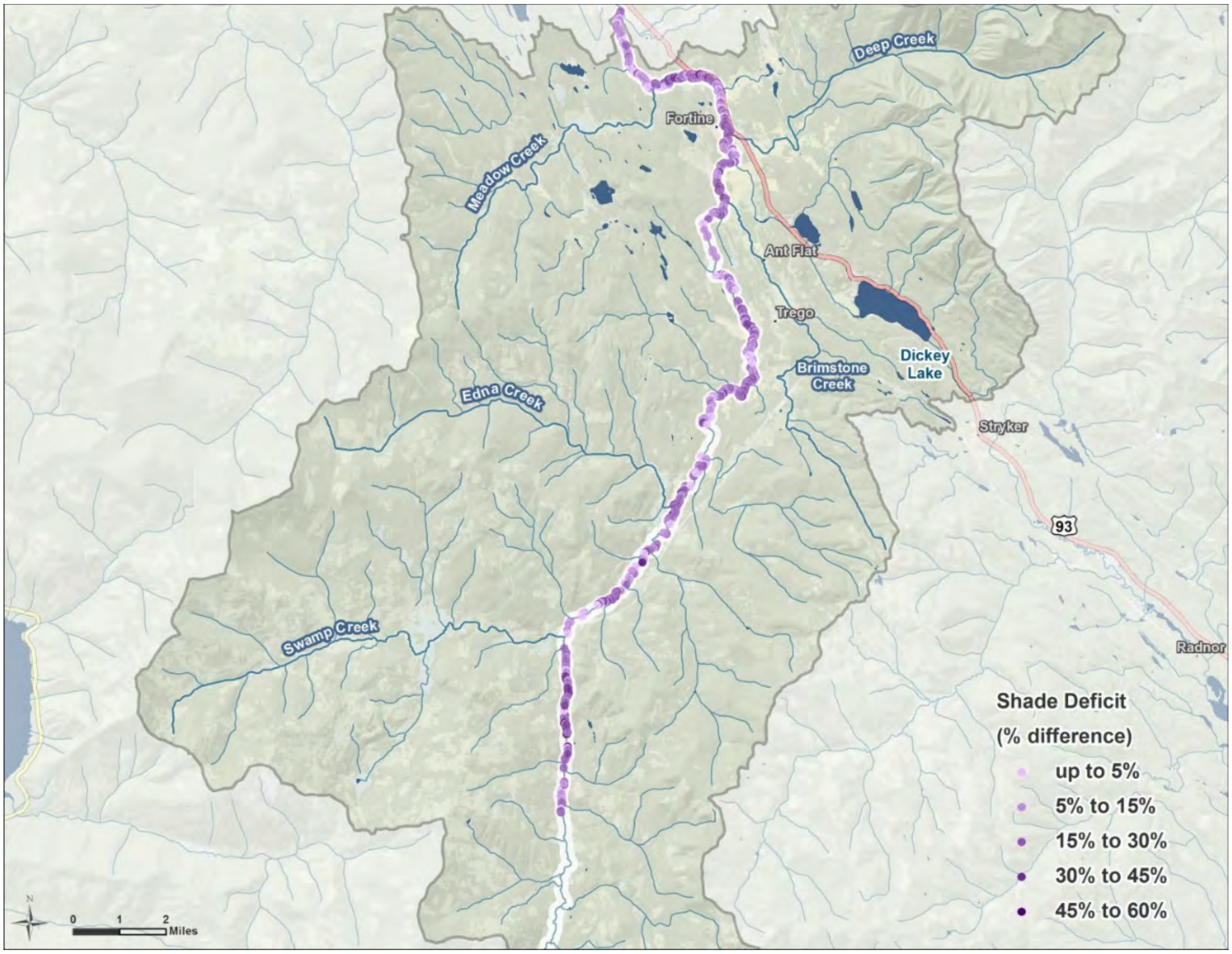


Figure B-35. Shade deficit of the existing condition from the naturally occurring scenario

B8.0 Model Use and Limitations

The model is only valid for summertime, low flow 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 principal study question can be answered using the calibrated and validated QUAL2K model for Fortine Creek. As previously discussed, Fortine Creek is sensitive to shade. The second principal study questions can be answered using the calibrated QUAL2K model and the scenarios developed to assess shade. Increasing riparian shading will decrease instream temperatures; however, there is uncertainty in the magnitude of temperature reduction necessary to achieve the temperature standard caused by uncertainty in the Shade Model results and QUAL2K model results. While a “good” model calibration was achieved, the overall AME for the maximum daily temperature was 1.3°F.

Montana's temperature standard as applied to Fortine Creek is limited to an increase of 1.0°F. The model results, therefore, should be used with caution relative to the second primary question. However, in spite of the uncertainty, the magnitude of difference between the maximum daily temperatures under existing condition scenarios and naturally occurring scenarios (as well as the shade improvement scenario) is greater than the AME for all but a 0.2 mile section near the headwaters of Fortine Creek (**Figure B-36**). The model results indicate that on average[15], a reduction of 2.6°F (range: 1.4° F to 3.5° F) in maximum daily temperatures is necessary to achieve the temperature standard in Fortine Creek.

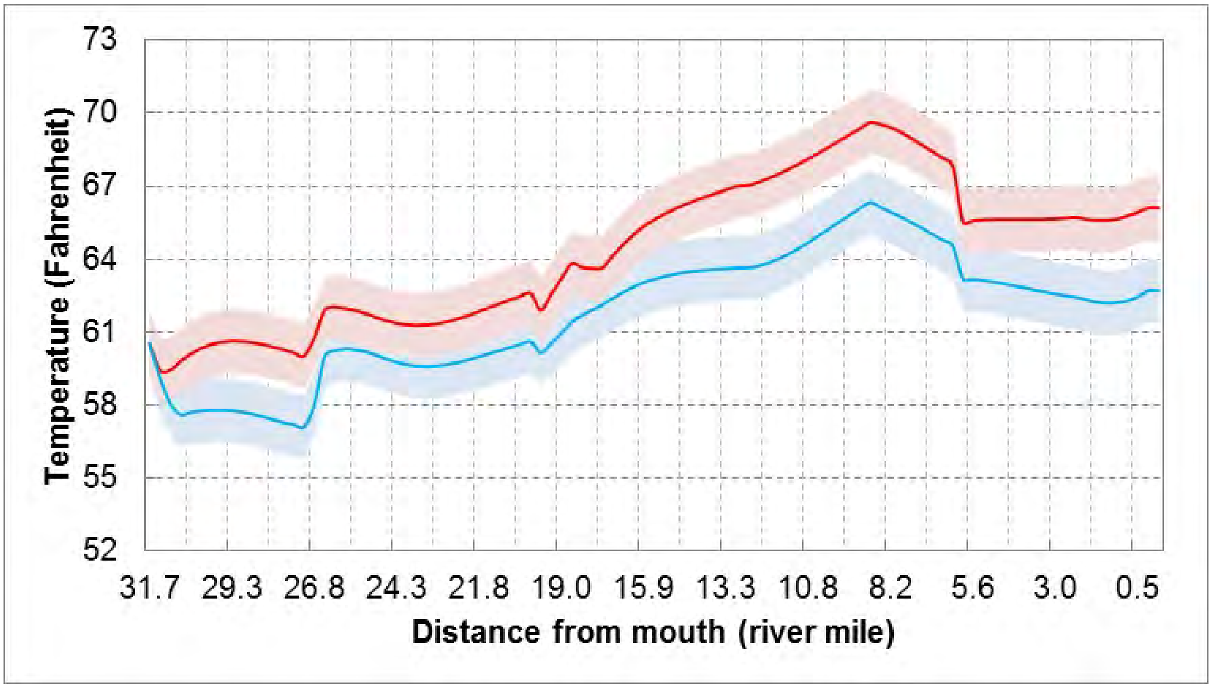


Figure B-36. Simulated daily maximum water temperatures from the existing condition (red; scenario 1) and naturally occurring condition scenario (blue; scenario 6).

[15] Spatial average of the QUAL2K output at each element along the entire length of Fortine Creek.

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ATTACHMENT B-1

This attachment contains instantaneous flow measurements that were not collected as part of this project but were used to evaluate the water balance in Fortine Creek and to develop a pre-modeling understanding of the hydrology. Recent flow measurements that were used include those collected by DEQ in 2003, 2007, 2008 and 2012 (**Tables B1-1** and **B1-2**) and by the USFS for Deep Creek in 2011 (**Table B1-3**) and Edna and Fortine creeks in 2012 (**Table B1-4**).

Table B1-1. DEQ instantaneous flow measurements (cfs) from 2003 and 2012

Date	K01SWMPC02 [a]	K01LIMEC03 [b]	K01LIMEC04 [b]	K01LIMEC01 [b]	K01DEEPC01 [c]
August 12, 2003	1.5*	--	2.64	--	--
August 13, 2003	--	--	1.57	--	--
July 12, 2012	--	0.16	1.01	--	--
August 23, 2012	--	0.11	--	4.8	--
September 19, 2012	--	--	--	2.05	6*

Notes: An asterisk (*) indicates an estimated value.
[a]. Site is located on Swamp Creek, a tributary to Fortine Creek.
[b]. Site is located on Lime Creek, a tributary to Fortine Creek.
[c]. Site is located on Deep Creek, a tributary to Fortine Creek.

Table B1-2. DEQ instantaneous flow measurements (cfs) from 2007 and 2008

Date	TOBACCO-NUT2 [a]	TOBACCO-NUT1	TOBACCO-NUT3 [b]	TOBACCO-LIME2 [c]	TOBACCO-NUT4 [c]	TOBACCO-NUT5	TOBACCO-NUT6	TOBACCO-NUT7 [d]	TOBACCO-NUT15 [e]	TOBACCO-NUT8
September 11-13, 2007	1.17	0.33	2.76	--	--	7.19	3.87	4.73	--	10.59
October 15-17, 2007	1.67	0.5	2.9	--	--	6.43	8.58	5.46	--	17.57
June 3-5, 2008	27.09	32.08	20.19	0.52	1.98	93.46	107	83.87	1.39	--
August 5-7, 2008	2.17	0.85	2.98	0.63	0.59	9.04	8.7	9.39	0*	19.55
October 1-7, 2008	1.48	0.44	2.06	0.45*	0.62	5.66	6.5	5.03	0*	13.86

Notes: An asterisk (*) indicates an estimated value.
[a.] Site is located on Swamp Creek, a tributary to Fortine Creek.
[b.] Site is located on Edna Creek, a tributary to Fortine Creek.
[c.] Site is located on Lime Creek, a tributary to Fortine Creek.
[d.] Site is located on Deep Creek, a tributary to Fortine Creek.
[e.] Site is located on Meadow Creek, a tributary to Fortine Creek.

Table B1-3. USFS instantaneous flow measurements from Deep Creek

Date	Stage (feet)	Discharge (cfs)
May 23, 2011	1.01	70.03
June 1, 2011	0.95	53.35
June 22, 2011	1.36	77.19
June 24, 2011	1.39	79.86
July 8, 2011	1.36	77.20

Table B1-4. USFS instantaneous flow measurements from Edna and Fortine creeks

Date	Edna Creek		Fortine Creek	
	Stage (feet)	Discharge (cfs)	Stage (feet)	Discharge (cfs)
4/20/2012	1.65	39.9	3.02	170.1
4/26/2012	2.12	98.8	3.13	178.1
5/10/2012	1.87	62.7	2.58	138.2
5/18/2012	1.76	50.4	2.41	125.9
5/23/2012	1.69	43.5	2.29	117.2
6/7/2012	1.59	34.9	2.39	124.5
6/13/2012	1.52	29.6	2.13	105.6
6/28/2012	1.55	31.8	2.85	157.8
7/10/2012	1.33	18.3	1.19	37.6
7/23/2012	1.34	18.8	0.98	22.4
9/11/2012	1.12	9.8	0.71	2.8

ATTACHMENT B-2

This attachment summarizes inputs and results in tabular form for the Fortine Creek QUAL2K Model developed for this project.

Table B2-1. Model input parameters

Model parameter	Source of input
Month	August 10, 2012. Warm day without rain during EPA and USFS temperature logger deployment when synoptic flows were monitored.
Day	
Year	
Local time hours to UTC	Calculated using time zone of sample locations
Daylight savings time	Enabled
Calculation step	Estimated according to monitored instream velocities
Final time	

Table B2-2. Headwaters input parameters

Model parameter	Source of input
Flow rate	Observed at FRTNC-T1 on August 10, 2012
Elevation	Calculated with GIS
Channel slope	
Manning roughness coefficient (n)	Assumed to be equivalent to Manning's n calculated for segment I
Bottom width	Assumed wetted with at site FRTNC-T1 (measured on September 12-13) was equivalent to bottom width
Side slope 1	Assumed sides were equivalent to 1.
Side slope 2	
Hourly water temperatures	Observed at FRTNC-T1 on August 10, 2012

Table B2-3. Model segment input parameters

Model parameter	Source of input
Location	
Upstream location	Calculated with GIS
Downstream location	
Upstream elevation	
Downstream elevation	
Downstream latitude	
Downstream longitude	
Weather	
Hourly air temperatures	Estimated from observations at Eureka RAWS, corrected for elevation
Hourly dew point temperatures	
Hourly wind speed	Estimated from observations at Eureka RAWS, corrected for sensor height
Hourly cloud cover	Estimated from observations at Kalispell Glacier Park International Airport
Hourly effective shade	Calculated with Shade3.0.xls as segment medians
Manning	
Location	Calculated with GIS
Manning roughness coefficient (n)	Calculated using Cowan (1956) and Chow (1959) methods as published in Marcus et al (1992)
Bottom width	Assumed wetted width at eight Solar Pathfinder™ sites (measured on September 12-13, 2012) were equivalent to bottom width
Side slope 1	Assumed sides were equivalent to 1.

Table B2-3. Model segment input parameters

Model parameter	Source of input
Side slope 2	

Table B2-4. Groundwater, point sources, and tributaries segment input parameters

Model parameter	Source of input
Groundwater inflow and outflow	
Upstream location	Calculated with GIS
Downstream location	
Diffuse abstraction (outflow)	Estimated from water balance
Diffuse inflow	
Temperature (for inflows)	Calibration parameter, based in part upon available GWIC data
Point sources and tributaries	
Location	Calculated with GIS
Abstraction (withdrawal)	Diversions: Estimated using acreages of potentially irrigated land per diversion and crop water uptake information, see **Section 0** Edna Creek: Observed , USFS logger and flow data Deep Creek: Observed , USFS logger and flow data Swamp Creek: Observed , EPA logger and flow data
Inflow	
Mean daily temperature	
One-half range	
Time of daily maximum	

Table B2-5. Light parameters and surface heat transfer models

Model parameter	Source of input
Solar Shortwave Radiation Model	
Atmospheric attenuation model for solar	Best professional judgment
Bras solar parameter (used if Bras solar model is selected)	
Atmospheric turbidity coefficient	Not applicable (Bras was not selected)
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient	Calibration parameter
Downwelling atmospheric longwave infrared radiation	
Atmospheric longwave emissivity model	QUAL2K recommendation
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	Calibration parameter
Sediment heat parameters	
Sediment thermal thickness	Calibration parameter
Sediment thermal diffusivity	Calibration parameter
Sediment density	Default
Water density	Default
Sediment heat capacity	Calibration parameter
Water heat capacity	Default

Table B2-6. Channel geometry

Segment	Channel slope	Manning's n	Stream bottom width (meter/feet)	Side 1[a]	Side 2[a]
HW[b]	0.00581	0.0700	3.65 / 12.0	1	1
I	0.00582	0.0700	2.41 / 7.9	1	1
H	0.00019	0.0700	2.41 / 7.9	1	1
G	0.00133	0.0700	3.46 / 11.4	1	1
F	0.00142	0.0700	5.49 / 18.0	1	1
E	0.00099	0.0700	4.49 / 14.7	1	1
D	0.00472	0.0700	4.49 / 14.7	1	1

Table B2-6. Channel geometry

Segment	Channel slope	Manning's n	Stream bottom width (meter/feet)	Side 1[a]	Side 2[a]
C	0.00738	0.0700	3.91 / 12.8	1	1
B	0.00135	0.0910	6.15 / 20.2	1	1
A	0.00300	0.0910	8.00 / 26.2	1	1

Notes: Segments are listed from top to bottom of the column as headwaters to mouth
[a.] Adjacent side ratio (relative to one) based on the trapezoidal cross section (**Figure B-16**). Both sides for each model segment were set to 1.
[b.] Headwaters boundary condition; the headwaters boundary condition channel slope was set equal to the channel slope for model segment I.

Table B2-7. Streamflow data

Location	Flow	
	(cubic meters per second)	(cubic feet per second)
Fortine Creek		
FRTNC-T1	0.1048	3.7
FRTNC-T2	0.2322	8.2
FRTNC-T3	0.5550	19.6
below Edna Creek	0.7759	27.4
FRTNC-T4	0.8778	31.0
FRTNC-T5	0.8099	28.6
FRTNC-T6	0.9883	34.9
FRTNC-T7	1.6792	59.3
Deep Creek		
DEEP	0.4757	16.8
Edna Creek		
calculation [a]	0.2209	7.8
Swamp Creek		
SWAMP	0.1019	3.6

Notes:
All flows used for modeling were collected by EPA.
[a.] EPA did not monitor flow on Edna Creek. Flows monitored on Fortine Creek above and below Edna Creek were subtracted to estimate flow in Edna Creek.

Table B2-8. Estimated abstractions

Diversion	Location (km)	Abstraction	
		(cubic meters per second)	(cubic feet per second)
76D 24066 00	39.72	0.0014	0.049
76D 23038 00	33.81	0.0014	0.049
76D 12420 00	32.67	0.0164	0.579
76D 48084 00	31.89	0.0003	0.011
76D 7265 00	31.59	0.0023	0.081
76D 7266 00	31.59	0.0011	0.039
76D 143758 00	30.00	0.0011	0.039
76D 141663 00	23.37	0.0006	0.021
76D 39692 00	22.35	0.0127	0.448
76D 43048 00	22.35	0.0059	0.208
76D 108116 00	20.73	0.0147	0.519
76D 140151 00	12.87	0.0875	3.09
76D 142683 00	9.24	0.0170	0.600

Table B2-8. Estimated abstractions

Diversion	Location (km)	Abstraction	
		(cubic meters per second)	(cubic feet per second)
76D 30025754	5.22	0.0008	0.028
76D 6780 00	0.63	0.0130	0.459

Table B2-9. Estimated diffuse flow and temperature

Segment	Direction	Diffuse flow		Temperature
		(cubic meter per second)	(cubic feet per second)	(Celsius)
Reach I	Inflow	0.1274	4.50	9.0
Reach H	Inflow	0.2401	8.48	12.0
Reach G	Inflow	0.0108	0.38	12.0
Reach F	Inflow	0.0959	3.39	13.0
Reach E	Outflow	0.0340	1.20	--
Reach D	Inflow	0.0355	1.25	14.0
Reach C	Inflow	0.2304	8.14	14.0
Reach B	Inflow	0.1679	5.93	15.0
Reach A	Inflow	0.0781	2.76	15.0

Table B2-10. Hourly weather data for Fortine Creek on August 10, 2012

Time	Air temperature (°C)									Wind speed (meters/sec)
Reach	**I**	**H**	**G**	**F**	**E**	**D**	**C**	**B**	**A**	**All**
12:00 AM	8.81	9.21	9.35	9.42	9.56	9.84	10.06	10.16	10.31	0.00
1:00 AM	7.71	8.11	8.25	8.32	8.46	8.74	8.96	9.06	9.21	0.45
2:00 AM	6.61	7.01	7.15	7.22	7.36	7.64	7.86	7.96	8.11	0.00
3:00 AM	5.51	5.91	6.05	6.12	6.26	6.54	6.76	6.86	7.01	0.45
4:00 AM	3.81	4.21	4.35	4.42	4.56	4.84	5.06	5.16	5.31	0.89
5:00 AM	3.81	4.21	4.35	4.42	4.56	4.84	5.06	5.16	5.31	0.45
6:00 AM	7.21	7.61	7.75	7.82	7.96	8.24	8.46	8.56	8.71	0.89
7:00 AM	13.31	13.71	13.85	13.92	14.06	14.34	14.56	14.66	14.81	0.00
8:00 AM	16.61	17.01	17.15	17.22	17.36	17.64	17.86	17.96	18.11	0.00
9:00 AM	18.81	19.21	19.35	19.42	19.56	19.84	20.06	20.16	20.31	0.45
10:00 AM	21.61	22.01	22.15	22.22	22.36	22.64	22.86	22.96	23.11	0.89
11:00 AM	22.71	23.11	23.25	23.32	23.46	23.74	23.96	24.06	24.21	0.45
12:00 PM	26.11	26.51	26.65	26.72	26.86	27.14	27.36	27.46	27.61	1.34
1:00 PM	27.71	28.11	28.25	28.32	28.46	28.74	28.96	29.06	29.21	0.89
2:00 PM	28.81	29.21	29.35	29.42	29.56	29.84	30.06	30.16	30.31	1.34
3:00 PM	29.91	30.31	30.45	30.52	30.66	30.94	31.16	31.26	31.41	1.34
4:00 PM	29.41	29.81	29.95	30.02	30.16	30.44	30.66	30.76	30.91	1.34
5:00 PM	28.81	29.21	29.35	29.42	29.56	29.84	30.06	30.16	30.31	1.34
6:00 PM	23.81	24.21	24.35	24.42	24.56	24.84	25.06	25.16	25.31	0.89
7:00 PM	19.41	19.81	19.95	20.02	20.16	20.44	20.66	20.76	20.91	0.00
8:00 PM	15.51	15.91	16.05	16.12	16.26	16.54	16.76	16.86	17.01	0.00
9:00 PM	12.71	13.11	13.25	13.32	13.46	13.74	13.96	14.06	14.21	0.89
10:00 PM	12.71	13.11	13.25	13.32	13.46	13.74	13.96	14.06	14.21	0.00
11:00 PM	11.11	11.51	11.65	11.72	11.86	12.14	12.36	12.46	12.61	0.89

Note: Data presented in this table were obtained from the Eureka RAWS and were converted to Celsius for QUAL2K input.

Table B2-11. Hourly dew point data for Fortine Creek on August 10, 2012

Time	Dew point temperature (°C)								
Segment	I	H	G	F	E	D	C	B	A
12:00 AM	6.43	6.84	6.98	7.04	7.19	7.48	7.69	7.79	7.93
1:00 AM	6.33	6.74	6.88	6.94	7.09	7.38	7.59	7.69	7.83
2:00 AM	5.43	5.84	5.98	6.04	6.19	6.48	6.69	6.79	6.93
3:00 AM	5.13	5.54	5.68	5.74	5.89	6.18	6.39	6.49	6.63
4:00 AM	4.53	4.94	5.08	5.14	5.29	5.58	5.79	5.89	6.03
5:00 AM	4.43	4.84	4.98	5.04	5.19	5.48	5.69	5.79	5.93
6:00 AM	5.43	5.84	5.98	6.04	6.19	6.48	6.69	6.79	6.93
7:00 AM	6.23	6.64	6.78	6.84	6.99	7.28	7.49	7.59	7.73
8:00 AM	7.43	7.84	7.98	8.04	8.19	8.48	8.69	8.79	8.93
9:00 AM	6.63	7.04	7.18	7.24	7.39	7.68	7.89	7.99	8.13
10:00 AM	7.93	8.34	8.48	8.54	8.69	8.98	9.19	9.29	9.43
11:00 AM	7.03	7.44	7.58	7.64	7.79	8.08	8.29	8.39	8.53
12:00 PM	6.73	7.14	7.28	7.34	7.49	7.78	7.99	8.09	8.23
1:00 PM	1.63	2.04	2.18	2.24	2.39	2.68	2.89	2.99	3.13
2:00 PM	-1.47	-1.06	-0.92	-0.86	-0.71	-0.42	-0.21	-0.11	0.03
3:00 PM	-0.67	-0.26	-0.12	-0.06	0.09	0.38	0.59	0.69	0.83
4:00 PM	1.13	1.54	1.68	1.74	1.89	2.18	2.39	2.49	2.63
5:00 PM	0.63	1.04	1.18	1.24	1.39	1.68	1.89	1.99	2.13
6:00 PM	6.03	6.44	6.58	6.64	6.79	7.08	7.29	7.39	7.53
7:00 PM	5.93	6.34	6.48	6.54	6.69	6.98	7.19	7.29	7.43
8:00 PM	7.13	7.54	7.68	7.74	7.89	8.18	8.39	8.49	8.63
9:00 PM	6.53	6.94	7.08	7.14	7.29	7.58	7.79	7.89	8.03
10:00 PM	4.53	4.94	5.08	5.14	5.29	5.58	5.79	5.89	6.03
11:00 PM	5.53	5.94	6.08	6.14	6.29	6.58	6.79	6.89	7.03

Notes: Data presented in this table were obtained from the Eureka RAWS and were converted to Celsius for QUAL2K input.
A negative dew point temperature means that the ambient air is dry enough that it would have to cool to below freezing to become saturated such that water condenses to ice crystals (instead of water droplets).

Table B2-12. Hourly shade results (hourly medians along model segments)

Time	Shade (percent)								
Model reach	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Up RM	**2.2**	**6.0**	**8.7**	**12.8**	**17.0**	**18.3**	**20.1**	**26.9**	**31.7**
Down RM	**0.0**	**2.2**	**6.0**	**8.7**	**12.8**	**17.0**	**18.3**	**20.1**	**26.9**
12:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
1:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
2:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
3:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
4:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
5:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
6:00 AM	100%	95%	95%	97%	94%	94%	94%	93%	94%
7:00 AM	100%	93%	71%	97%	92%	92%	88%	70%	91%
8:00 AM	100%	75%	58%	97%	65%	68%	68%	42%	59%
9:00 AM	90%	56%	46%	94%	39%	44%	44%	26%	29%
10:00 AM	70%	36%	33%	67%	22%	25%	24%	20%	18%
11:00 AM	60%	20%	23%	50%	16%	16%	12%	14%	11%

Table B2-12. Hourly shade results (hourly medians along model segments)

Time	Shade (percent)								
Model reach	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Up RM	**2.2**	**6.0**	**8.7**	**12.8**	**17.0**	**18.3**	**20.1**	**26.9**	**31.7**
Down RM	**0.0**	**2.2**	**6.0**	**8.7**	**12.8**	**17.0**	**18.3**	**20.1**	**26.9**
12:00 PM	50%	11%	10%	37%	11%	10%	14%	13%	13%
1:00 PM	40%	10%	8%	23%	8%	12%	11%	14%	15%
2:00 PM	50%	12%	8%	26%	10%	17%	13%	16%	24%
3:00 PM	70%	21%	11%	45%	18%	27%	19%	22%	33%
4:00 PM	90%	36%	21%	65%	28%	38%	26%	26%	45%
5:00 PM	90%	54%	39%	87%	39%	55%	42%	30%	59%
6:00 PM	100%	80%	61%	97%	58%	68%	59%	40%	75%
7:00 PM	100%	93%	84%	97%	76%	84%	79%	60%	93%
8:00 PM	100%	95%	93%	97%	92%	94%	93%	88%	95%
9:00 PM	100%	95%	95%	97%	94%	95%	95%	94%	97%
10:00 PM	100%	100%	100%	100%	100%	100%	100%	100%	100%
11:00 PM	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table B2-13. Heat parameters and transfer models

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]	0.9
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
Sediment heat parameters	
Sediment thermal thickness (centimeter)[b]	16
Sediment thermal diffusivity (square centimeter per second)[c]	0.008
Sediment density (gram per cubic centimeter)[d]	1.6
Water density (gram per cubic centimeter)[d]	1
Sediment heat capacity (calorie per [gram by degree Celsius])[d]	0.55
Water heat capacity[d]	1

Notes

[a] Atmospheric transmission coefficient default is 0.8; typical range is 0.70 to 0.91.

[b] Sediment thermal thickness default is 10 centimeters.

[c] Sediment thermal diffusivity default is 0.005 square centimeter per second

[d] These values are the model defaults.

ATTACHMENT B-3

Table B3-1. Fortine Creek Solar Pathfinder site supplemental data (Field data collected September 12 and 13, 2012. Shaded sites are at potential).

Site ID	Map ID	Reach ID	GIS Classification		Field Verification		Potential		Field Notes	Average % Shade
			Veg Type	Veg Density	Veg Type	Veg Density	Veg Type	Veg Density		
FRTNC-T1	FSP-T1	FID 2	Coniferous	Dense	Mixed Coniferous/ Deciduous	Dense (100%)	Mixed Conif/ Deciduous	Dense	This site is at potential. The floodplain is dominated by alder (50 – 100% cover) with spruce/fir immediately up gradient (75-100% cover).	78
FRTNC-T2	FSP-T2	FID 6	Coniferous	Dense	Coniferous	Dense (100%)	Coniferous	Dense	This site is at potential. This is a spruce/fir dominated forest (100% cover) with an occasional larch. There are some alders in the immediate floodplain, but spotty coverage due to dense tree canopy. A natural mass wasted bank was observed just upstream from this site on the right bank.	90
FRTNC-T3	FSP-T3	FID 10	Marsh/ Meadow	Moderate	Shrub	Dense (100%)	Shrub	Dense	The immediate floodplain shrub community (dogwood dominated with some alder and willow – 100% cover) is at potential. However, there is some grazing upgradient which resulted in converting shrub habitat to meadow. Some older beaver activity was noted. GIS interpretation erroneously identified marsh.	42

Table B3-1. Fortine Creek Solar Pathfinder site supplemental data (Field data collected September 12 and 13, 2012. Shaded sites are at potential).

Site ID	Map ID	Reach ID	GIS Classification		Field Verification		Potential		Field Notes	Average % Shade
			Veg Type	Veg Density	Veg Type	Veg Density	Veg Type	Veg Density		
FRTNC-T4	FSP-T4	FID 11	Coniferous	Dense	Coniferous	Dense (100%)	Coniferous	Dense	This site is at potential. Relatively mature spruce/fir forest (100% cover) with sparse (25% cover) alder in the floodplain. A steep (approx. 100’) bench along left bank.	63
FRTNC-SP11	FSP-SP1	FID 21			NA	NA	NA	NA	SP site was downstream of the temp logger, below the bridge. The site was heavily grazed. Alders were browsed and broomed, grass was heavily grazed. Single cottonwood trying to sprout at the site. The potential for this site is mixed coniferous/deciduous (i.e., upstream from the bridge.	10
FRTNC-T6	FSP-T6	FID 17	Mixed Conf/ Rangeland	Poor/Mod	Left bank mixed disturbed veg community	Poor/Mod	Mixed Conif/ Deciduous	Dense	A road, powerline, and railroad are adjacent to the left bank. Railroad grade (elevated fill material) currently limits vegetation potential of the left bank. The right bank includes alder, dogwood and reed canary grass in the floodplain with a deciduous/conifer mix upgradient (75% cover). A timber harvest unit exists approximately 150 from stream on right bank.	32

Table B3-1. Fortine Creek Solar Pathfinder site supplemental data (Field data collected September 12 and 13, 2012. Shaded sites are at potential).

Site ID	Map ID	Reach ID	GIS Classification		Field Verification		Potential		Field Notes	Average % Shade
			Veg Type	Veg Density	Veg Type	Veg Density	Veg Type	Veg Density		
FRTNC-T7	FSP-T7	FID 0	Coniferous	Dense	Mixed deciduous/ Coniferous	Moderately Dense	Mixed deciduous/ Coniferous	Moderately Dense	This site is at potential. Broad floodplain dominated by cottonwood/conifer mix (75% cover) with an alder understory on right bank (50% cover). Very similar on left bank but missing the conifer component and there is a cleared powerline corridor >150' from left bank. 50% cottonwood/50% cover alder on left. Diversion noted near this site.	57
FRTNC-T5	FSP-T5	FID 21	Mixed Conif/ Deciduous	Dense	Mixed Conif/ Deciduous	Moderately dense	Mixed Conif/ Deciduous	Moderately dense	This site is at potential and is a good reference site for SP1. The floodplain is predominantly alder/dogwood (50-100% cover). A few conifers are interspersed in the floodplain (25-50% cover). There are some open grassy areas on old point bars. Transitions to conifer dominated in uplands and upstream from this site.	28

APPENDIX C – LIME CREEK NUTRIENT WATER QUALITY DATA

This appendix contains recent nutrient water quality data used for impairment verification and discussed within this document for Lime Creek (**Table C-1**).

Table C-1. Recent DEQ nutrient data for Lime Creek

Station (Site) Name	Site ID	Activity Date	Latitude	Longitude	Flow (cfs)	TSS (mg/L)	Total N per Sulfate Method (mg/L)	$NO_2 + NO_3$ as N (mg/L)	Total P (mg/L)	Chlorophyll *a* (mg/m^2)	Ash-Free Dry Mass (AFDM) (g/m^2)	Periphyton (metric score)	Macros (HBI score)
Lime Creek 1/4 mile upstream from mouth (Fortine Creek)	K01LIMEC01	8/12/2003	48.66083	-114.88972	0.7	3.5		0.01	0.024			25	**4.3**
Lime Creek above mouth	TOBACCO-NUT4	9/12/2007	48.66140	-114.89090	immeasurable	10.2	0.16	<0.005	0.007				
Lime Creek above mouth	TOBACCO-NUT4	8/5/2008	48.66140	-114.89090	0.59	1	0.1	<0.01	0.011				
Lime Creek above mouth	TOBACCO-NUT4	10/1/2008	48.66140	-114.89090	0.45	1	0.1	<0.01	0.009				
Lime Creek at FR 3780 crossing	K01LIMEC03	7/12/2012	48.64375	-114.84899	0.16	<2	<0.05	<0.01	<0.005				
Lime Creek at FR 3770 crossing	K01LIMEC04	7/12/2012	48.64839	-114.86940	2.64	5	0.28	<0.01	<0.005				
Lime Creek 1/4 mile upstream from mouth (Fortine Creek)	K01LIMEC01	7/12/2012	48.66083	-114.88972	4.8	5	**0.91**	<0.01	0.008				
Lime Creek at FR 3780 crossing	K01LIMEC03	8/23/2012	48.64375	-114.84899	0.11	<2	<0.04	<0.01	<0.003	<50		**68**	
Lime Creek at FR 3770 crossing	K01LIMEC04	8/23/2012	48.64839	-114.86940	1.57	<2	0.05	0.02	<0.003	<50		29	1.9
Lime Creek 1/4 mile upstream from mouth (Fortine Creek)	K01LIMEC01	8/23/2012	48.66083	-114.88972	2.02	6	0.12	<0.01	0.007	1.1	**118**	**57**	**4.6**
Lime Creek 1/4 mile upstream from mouth (Fortine Creek)	K01LIMEC01	8/6/2013	48.66083	-114.88972	0.74	16	0.21 J	<0.01	0.021				
Lime Creek at FR 3780 crossing	K01LIMEC03	8/6/2013	48.64375	-114.84899	0.04	<2	0.04 J	<0.01	<0.003				
Lime Creek at FR 3770 crossing	K01LIMEC04	8/6/2013	48.64839	-114.86940	0.62	<2	<0.04	0.02	<0.003				
Lime Creek 1/4 mile upstream from mouth (Fortine Creek)	K01LIMEC01	9/9/2006	48.66083	-114.88972								**65**	
Lime Creek	K01LIMEC02	7/24/2008	48.64780	-114.87441									2.9

Bolded values exceed the water quality target. “J” is a data flag that indicates the analyte was detected and the value is the approximate concentration of the analyte in the sample