Madison Sediment and Temperature TMDLs and Water Quality Improvement Plan

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West Fork Madison River
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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

Symbol or Unit of Measure	Definition
cfs	Cubic Feet per Second
ft	Feet
kcal/day	Kilocalories per Day
lbs/day	Pounds per Day
mm	Millimeters
^{o}C	Degrees Celsius
^{o}F	Degrees Fahrenheit
‘	Foot
>	Greater Than
<	Less Than
≥	Greater Than or Equal To
≤	Less Than or Equal To
%	Percent
~	Approximately

Abbreviation or Acronym	Definition
AL	Aquatic Life
ARM	Administrative Rules of Montana
AUM	Animal Unit Month
BANCS	Bank Assessment for Nonpoint Source Consequences of Sediment (model)
BLM	Bureau of Land Management (Federal)
BMP	Best Management Practice
CAAP	Concentrated Aquatic Animal Production
CD	Conservation District
CFR	Code of Federal Regulations
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 & Parks (Montana)
GIS	Geographic Information System
HUC	Hydrologic Unit Code
IR	Integrated Report (Montana Water Quality)
LA	Load Allocation
MARS	Montana Aquatic Resources Services, Inc.
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MWMT	Maximum Weekly Maximum Temperature
N/A	Not Applicable
NHD	National Hydrography Dataset

Abbreviation or Acronym	Definition
NM	Not Monitored
NRCS	Natural Resources Conservation Service (U.S. Dept. of Agriculture)
PIBO	Pacfish/Infish Biological Opinion
RM	River Mile
SMZ	Streamside Management Zone
STATSGO	State Soil Geographic Database
T	Temperature
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area (Madison)
UILT	Upper Incipient Lethal Temperature
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
W/D	Width to Depth Ratio
WEPP	Water Erosion Prediction Project (model)
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan

How This Document is Organized and What it Contains

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

This document is organized into three parts, in addition to a preceding document summary. Use the tables below to determine which part(s) to read to find the information most useful to you.

Document Part	Read for:
Part 1	Introductory information that provides the context for this document and defines the total maximum daily load (TMDL) process
Part 2	The TMDL components and how they are derived
Part 3	Information on ways to improve water quality in the Madison River watershed and information on developing a local water quality restoration plan

Part 1 – Introductory Information

Part 1 Document Section	Section Contents
Section 1.0 Project Overview	Explains why DEQ writes TMDLs and provides a summary of what water quality impairments are addressed and a table of what TMDLs are included in this document
Section 2.0 Madison TMDL Planning Area Description	Describes the physical characteristics and social profile of the watershed
Section 3.0 Montana Water Quality Standards	Discusses the water quality standards that apply to the Madison River watershed and the TMDLs in this document
Section 4.0 Defining TMDLs and Their Components	Defines the components of TMDLs and how each is developed

Part 2 – TMDL Components

<table>
<tr><th>Part 2 Document Section</th><th>Section Contents</th></tr>
<tr><td>Section 5.0
Sediment TMDL Components</td><td rowspan="2">Both pollutant sections include: (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</td></tr>
<tr><td>Section 6.0
Temperature TMDL Components</td></tr>
</table>

Part 2 Document Section	Section Contents
Section 7.0 Public Participation and Public Comments	Describes other agencies and stakeholder groups who were involved with the development of this document and the public participation process used to review the draft document. Addresses comments received during the public review period.

PART 3 – WATER QUALITY RECOMMENDATIONS

Part 3 Document Section	Section Contents
Glossary	Definitions of water quality terminology used in Part 3
Section 8.0 Non-Pollutant Impairments	Describes other problems that could potentially be contributing to water quality impairment and how the TMDLs in this document might address some of these concerns. This section also provides recommendations for combating these problems.
Section 9.0 Water Quality Improvement Plan	Discusses water quality restoration objectives and a strategy to meet the identified objectives and TMDLs.
Section 10.0 Monitoring for Effectiveness	Describes a water quality monitoring plan for evaluating the long-term effectiveness of the Madison TMDLs and any implemented restoration projects.

To supplement this TMDL document, succinct summaries of all streams monitored as part of the TMDL project were also compiled. The Madison Stream Summaries 2020 document can be found on DEQ's TMDL webpages and the Madison TMDL project wiki site (mtwaterqualityprojects.pbworks.com).

INDIVIDUAL STREAM SUMMARIES

To supplement the information provided in this total maximum daily load (TMDL) document, a summary of each stream monitored by DEQ during the Madison TMDL project between 2012 and 2014 is provided in the Madison Watershed Stream Summaries 2020 document found on DEQ's TMDL webpages (search "Montana DEQ TMDL" in your web browser) and on the Madison TMDL project wiki site at mtwaterqualityprojects.pbworks.com.

The stream summary document contains a summary for each impaired stream discussed in this TMDL document. A summary, map, and photos of each stream is provided in a succinct format to aid the reader in understanding the current condition of the stream and what types of restoration projects may be undertaken to improve water quality. Information for preparing a watershed restoration plan (further discussed in **Section 9.0** of this TMDL document) is also provided. Additional detail on the general water quality improvement recommendations provided within the stream summaries can be found in **Section 9.0** of this TMDL document.

TMDL DOCUMENT SUMMARY

This document presents a total maximum daily load (TMDL) and framework water quality improvement plan for 16 impaired tributaries to the Madison River (see **Figure 1-1**).

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

The Madison TMDL Planning Area follows the Madison River from the Wyoming border, near West Yellowstone, to the river's mouth at the headwaters of the Missouri River near Three Forks, Montana. The planning area includes the watersheds of many tributary streams draining directly to the Madison River, but does not include the portion of the Madison River watershed within Yellowstone National Park. The TMDL planning area encompasses approximately 2,583 square miles (1,653,311 acres) in western Montana, and includes portions of Madison and Gallatin counties.

DEQ determined that a number of tributaries do not meet the applicable water quality standards. The scope of the TMDLs in this document address problems with sediment and temperature, and 16 TMDLs are included that address 17 pollutant impairments (**Table DS-1**). Although DEQ recognizes that there are other pollutant listings for the Madison TMDL planning area, this document addresses only those impairments identified in **Tables DS-1** and **1-1**. Future TMDL projects may require additional TMDLs for this TMDL planning area (**Table 1-2**).

Sediment

Sediment was identified as impairing aquatic life in Antelope, Bear, Blaine Spring, Cherry, Elk, Hot Springs, Moore, North Meadow, Red Canyon, Ruby, South Meadow, Watkins, and Wigwam creeks. Sediment is affecting designated uses in these streams by altering aquatic insect communities, reducing fish spawning success, and increasing turbidity. Water quality restoration objectives for sediment were established on the basis of fine sediment levels in trout spawning areas and aquatic insect habitat, stream morphology and available instream habitat as it related to the effects of sediment, and the stability of streambanks. DEQ believes that once these water quality objectives are met, all water uses currently affected by sediment will be restored. DEQ's water quality assessment methods for sediment impairment are designed to evaluate the most sensitive use, thus ensuring protection of all designated uses. For streams in Western Montana, the most sensitive use assessed for sediment is aquatic life.

Sediment loads are quantified for unpaved roads and eroding streambanks for all tributaries with sediment TMDLs, as well as for upland hillslope erosion for Elk Creek. The most significant sources include streamside livestock grazing, removal of streamside vegetation, parallel road segments and undersized culverts, as well as natural sources. The Madison TMDL Planning Area sediment TMDLs indicate that reductions in sediment loads ranging from 7% to 38% will satisfy the water quality restoration objectives.

Recommended strategies for achieving the sediment reduction objectives are also presented in this plan. They include best management practices (BMPs) for building and maintaining roads, for riparian (streamside) livestock grazing, and for developing subdivisions. In addition, they include BMPs for expanding riparian buffer areas and using other land, soil, and water conservation practices that improve stream channel conditions and associated riparian vegetation.

Temperature

Temperature was identified as impairing aquatic life in Cherry, Elk, and Moore creeks. Aquatic life and fish depend upon cool water for survival. Increased stream temperatures are affecting designated uses in these streams by decreasing dissolved oxygen levels and increasing primary production via algal and bacterial growth that can lead to further decreases in dissolved oxygen. Additionally, higher instream temperatures make fish more prone to disease and may create lethal conditions for fish populations.

Water quality restoration objectives for temperature were established based on indicator parameters that influence temperature and can be linked to human causes. The indicator or target parameters include riparian (streamside) vegetation health and shading conditions and stream channel geometry/dimensions (with/depth ratio). Improved streamflow conditions, where applicable, will also help decrease stream temperatures. DEQ believes that once these water quality objectives are met, all water uses currently affected by temperature will be restored. DEQ's water quality assessment methods for temperature impairment are designed to evaluate the most sensitive use, thus ensuring protection of all designated uses. For streams in Western Montana, the most sensitive use assessed for temperature is aquatic life.

Destruction of riparian vegetation from livestock grazing, agricultural crop production, and urban development are the primary causes of temperature impairment in Cherry, Elk, and Moore creeks. The temperature TMDLs indicate that 14% to 26% reductions in temperature loads are necessary. General strategies for achieving the instream water temperature reduction goals are also presented in this plan and include BMPs for managing riparian areas.

Water Quality Improvement Measures

Implementation of most 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. This 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. Impaired Waterbodies in the Madison TMDL Planning Area with TMDLs Contained in this Document

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	TMDL Prepared	Pollutant Group	Impaired Use
Antelope Creek, Headwaters to mouth (Cliff Lake)	MT41F004_140	Sediment	Sediment	Aquatic Life
Bear Creek, Headwaters to mouth (O'Dell Spring Creek)	MT41F004_021	Sediment	Sediment	Aquatic Life
Blaine Spring Creek, Headwaters to mouth (Madison River, T7S R1W S6)	MT41F004_010	Sediment	Sediment	Aquatic Life
Cherry Creek, Headwaters to mouth (Madison River)	MT41F002_010	Sediment	Sediment	Aquatic Life
		Temperature	Temperature	Aquatic Life
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Sediment	Sediment	Aquatic Life
		Temperature	Temperature	Aquatic Life
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Sediment	Sediment	Aquatic Life
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Sediment	Sediment	Aquatic Life
		Temperature	Temperature	Aquatic Life
North Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_060	Sediment	Sediment	Aquatic Life
Red Canyon Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_020	Sediment	Sediment	Aquatic Life
Ruby Creek, Headwaters to mouth (Madison River)	MT41F004_080	Sediment	Sediment	Aquatic Life
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Sediment	Sediment	Aquatic Life
Watkins Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_030	Sediment	Sediment	Aquatic Life

Table DS-1. Impaired Waterbodies in the Madison TMDL Planning Area with TMDLs Contained in this Document

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	TMDL Prepared	Pollutant Group	Impaired Use
Wigwam Creek, Headwaters to mouth (Madison River)	MT41F004_160	Sediment	Sediment	Aquatic Life

PART 1
INTRODUCTORY INFORMATION

1.0 PROJECT OVERVIEW

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for sediment and temperature problems in the Madison TMDL Planning Area (TPA). This document also presents a general framework for resolving these problems. **Figure 1-1** below shows a map of the Madison River watershed. The Madison TMDL Planning Area, however, only encompasses the portion of the watershed within the state of Montana and excludes the portion within Yellowstone National Park.

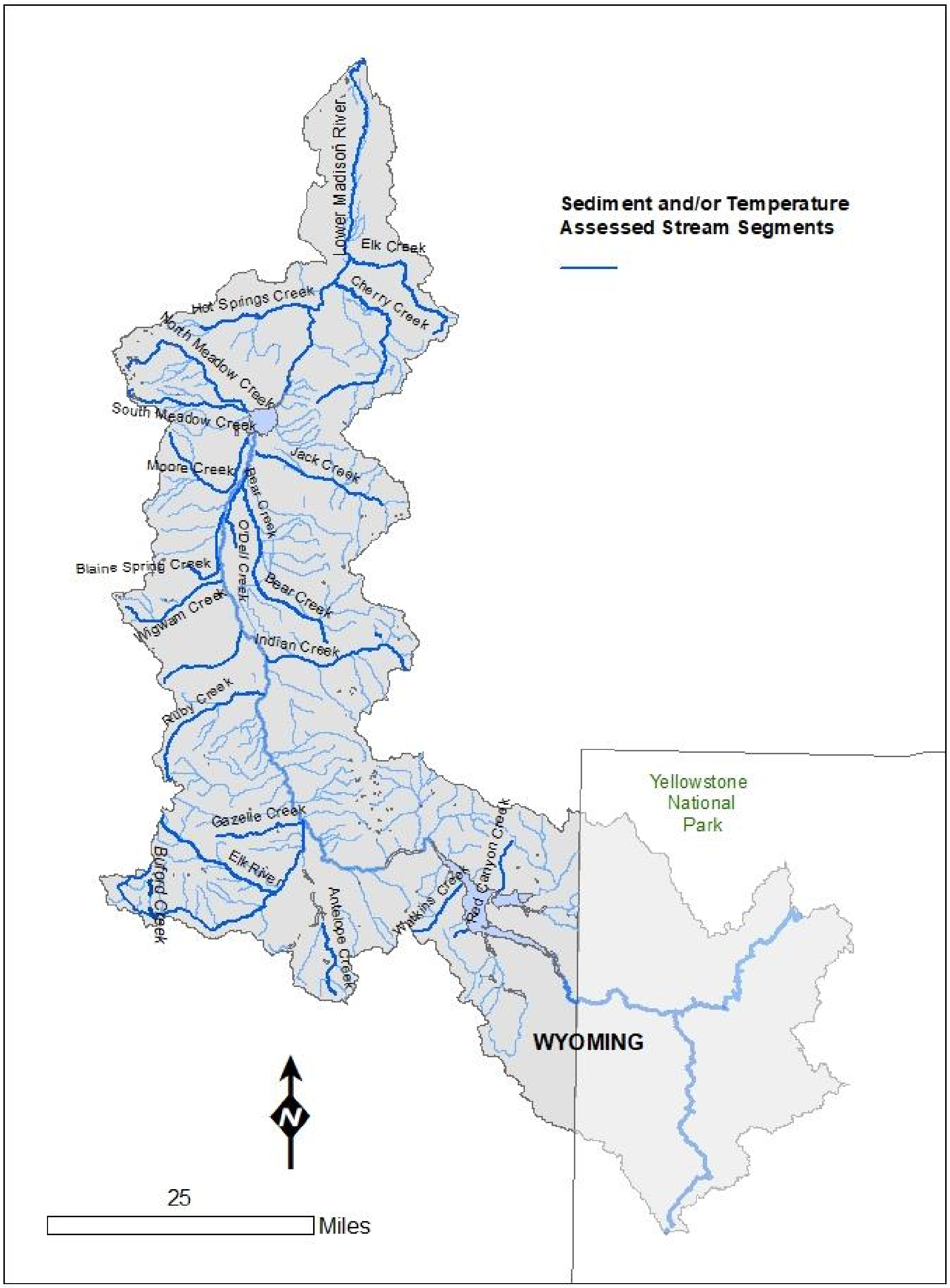

Figure 1-1. Location of the Madison River Watershed

1.1 Why We Write TMDLs

The Montana Department of Environmental Quality (DEQ) is charged with protection a clean and healthy environment. This includes actions that protect, maintain, and improve water quality, consistent with the Montana Water Quality Act and the federal Clean Water Act.

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 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. Both Montana state law (Section 75-5-701, Montana Code Annotated (MCA) of the Montana Water Quality Act) and section 303(d) of the federal Clean Water Act require the development of TMDLs for impaired waterbodies when water quality is impaired by a pollutant. TMDLs are not required for non-pollutant causes of impairment.

A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. **Section 4.0** provides more detail on TMDL development and the required TMDL components. In Montana, restoration strategies and monitoring recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation (**Sections 9.0** and **10.0**).

Tables 1-1 and **1-2** identify all impaired waters for the Madison TMDL Planning Area from Montana's 2018 303(d) List, and include non-pollutant impairment causes included in Montana's "2018 Water Quality Integrated Report" (DEQ 2018). Both tables provide the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

1.2 Water Quality Impairments and TMDLs Addressed by this Document

Table 1-1 below lists the impairment causes from the "2018 Water Quality Integrated Report" (DEQ 2018) that are addressed in this document (also see **Figure 1-1**). Each pollutant impairment falls within a TMDL pollutant category (i.e., sediment or temperature), and this document is organized by those categories.

TMDLs are completed for each waterbody – pollutant combination, and this document contains 16 TMDLs that address 17 pollutant impairments (**Table 1-1**). There are several non-pollutant types of impairment that are also addressed in this document. As noted above, TMDLs are not required for non-pollutants, although 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 overlap between the pollutant TMDLs and non-pollutant impairment causes is discussed in **Section 8.0**, Non-Pollutant Impairments. **Section 9.0**, Water Quality Improvement Plan, also provides some basic water quality solutions to address those non-pollutant causes not specifically addressed by TMDLs in this document.

Table 1-1. Water Quality Impairment Causes for the Madison TMDL Planning Area Addressed in This Document

Waterbody (Assessment Unit) [1]	Waterbody ID (Assessment Unit ID)	Impairment Cause	Pollutant Category	Impairment Cause Status
Antelope Creek, Headwaters to mouth (Cliff Lake)	MT41F004_140	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL
		Flow Regime Modification	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
Bear Creek, Headwaters to mouth (O'Dell Spring Creek)	MT41F004_021	Sedimentation-Siltation	Sediment	Sediment TMDL completed
Blaine Spring Creek, Headwaters to mouth (Madison River, T7S R1W S6)	MT41F004_010	Flow Regime Modification	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
Cherry Creek, Headwaters to mouth (Madison River)	MT41F002_010	Sedimentation-Siltation	Sediment	Sediment TMDL completed
		Temperature	Temperature	Temperature TMDL completed
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
		Temperature	Temperature	Temperature TMDL completed
		Turbidity	Sediment	Addressed by sediment TMDL
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Flow Regime Modification	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed

Table 1-1. Water Quality Impairment Causes for the Madison TMDL Planning Area Addressed in This Document

Waterbody (Assessment Unit) [1]	Waterbody ID (Assessment Unit ID)	Impairment Cause	Pollutant Category	Impairment Cause Status
Indian Creek, Lee Metcalf Wilderness boundary to mouth (Madison River)	MT41F004_040	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Flow Regime Modification	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
Jack Creek, Headwaters to mouth (Madison River, T5S R1W S23)	MT41F004_050	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Flow Regime Modification	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant	Addressed by sediment TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
		Temperature	Temperature	Temperature TMDL completed
North Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_060	Flow Regime Modification	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Other anthropogenic substrate alterations	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL

Table 1-1. Water Quality Impairment Causes for the Madison TMDL Planning Area Addressed in This Document

Waterbody (Assessment Unit) [1]	Waterbody ID (Assessment Unit ID)	Impairment Cause	Pollutant Category	Impairment Cause Status
Red Canyon Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant	Addressed by sediment TMDL
		Flow Regime Modification	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
Ruby Creek, Headwaters to mouth (Madison River)	MT41F004_080	Flow Regime Modification	Not Applicable; Non-Pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Sedimentation-Siltation	Sediment	Sediment TMDL completed
Watkins Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_030	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-pollutant	Addressed by sediment TMDL
		Flow Regime Modification	Not Applicable; Non-pollutant	Addressed in document (**Sections 8** and **9**); not linked to a TMDL
		Sedimentation-Siltation	Sediment	Sediment TMDL completed
Wigwam Creek, Headwaters to mouth (Madison River)	MT41F004_160	Sedimentation-Siltation	Sediment	Sediment TMDL completed
West Fork Madison River, Headwaters to mouth (Madison River)	MT41F004_100	Temperature	Temperature	Partially addressed in document (**Appendix H**)

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

1.3 Completed TMDLs and Future TMDL Development

Although DEQ recognizes that there are other pollutant listings for this TMDL planning area without completed TMDLs (**Table 1-2**), this document only addresses those identified in **Table 1-1** above. This is because DEQ sometimes develops TMDLs in a watershed at varying phases, with a focus on one or a couple of specific pollutant types. Nutrient, pathogen, and metal TMDLs were previously completed for the Madison TMDL planning area in 2019 for Elk, Hot Springs, Moore, O'Dell Spring, and South Meadow creeks (DEQ 2019).

Table 1-2. Water Quality Impairment Causes for the Madison TMDL Planning Area to be Addressed in a Future Project

Waterbody (Assessment Unit) [1]	Waterbody ID (Assessment Unit ID)	Impairment Cause	Pollutant Category
Blaine Spring Creek, Headwaters to mouth (Madison River, T7S R1W S6)	MT41F004_010	Arsenic	Metals
		Total Nitrogen	Nutrients
Buford Creek, Headwaters to confluence with West Fork Madison River	MT41F004_150	Arsenic	Metals
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Arsenic	Metals
Ennis Lake	MT41F005_030	Arsenic	Metals
		Flow Regime Modification	Not Applicable; Non-Pollutant
		Other anthropogenic substrate alterations	Not Applicable; Non-Pollutant
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant
Madison River, Hebgen Dam to Quake Lake	MT41F001_030	Arsenic	Metals
Madison River, Quake Lake to Ennis Lake	MT41F001_020	Arsenic	Metals
Madison River, Madison Dam to mouth (Missouri River)	MT41F001_010	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant
		Arsenic	Metals
		Sedimentation – Siltation	Sediment
		Temperature	Temperature
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Arsenic	Metals
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Arsenic	Metals
West Fork Madison River, Headwaters to mouth (Madison River)	MT41F004_100	Temperature	Temperature

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

2.0 Madison TMDL Planning Area Description

This document section provides a general overview of the physical and social characteristics of the Madison TMDL Planning Area. Although certain information is current only through the 2016 to 2018 timeframe, the addition of more recently collected watershed description data would not affect overall TMDL development given the purpose of this section of the document.

2.1 Physical Characteristics

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

2.1.1 Location

The Madison TMDL Planning Area follows the mainstem of the Madison River from the Wyoming border, near West Yellowstone, to the river's mouth at the headwaters of the Missouri River near Three Forks, Montana. The area includes the watersheds of many tributary streams draining directly to the Madison River. The planning area does not include the portion of the Madison River watershed within Yellowstone National Park. The TMDL planning area encompasses approximately 2,583 square miles (1,653,311 acres) in western Montana, and includes portions of Madison and Gallatin counties (**Figure 2-1**).

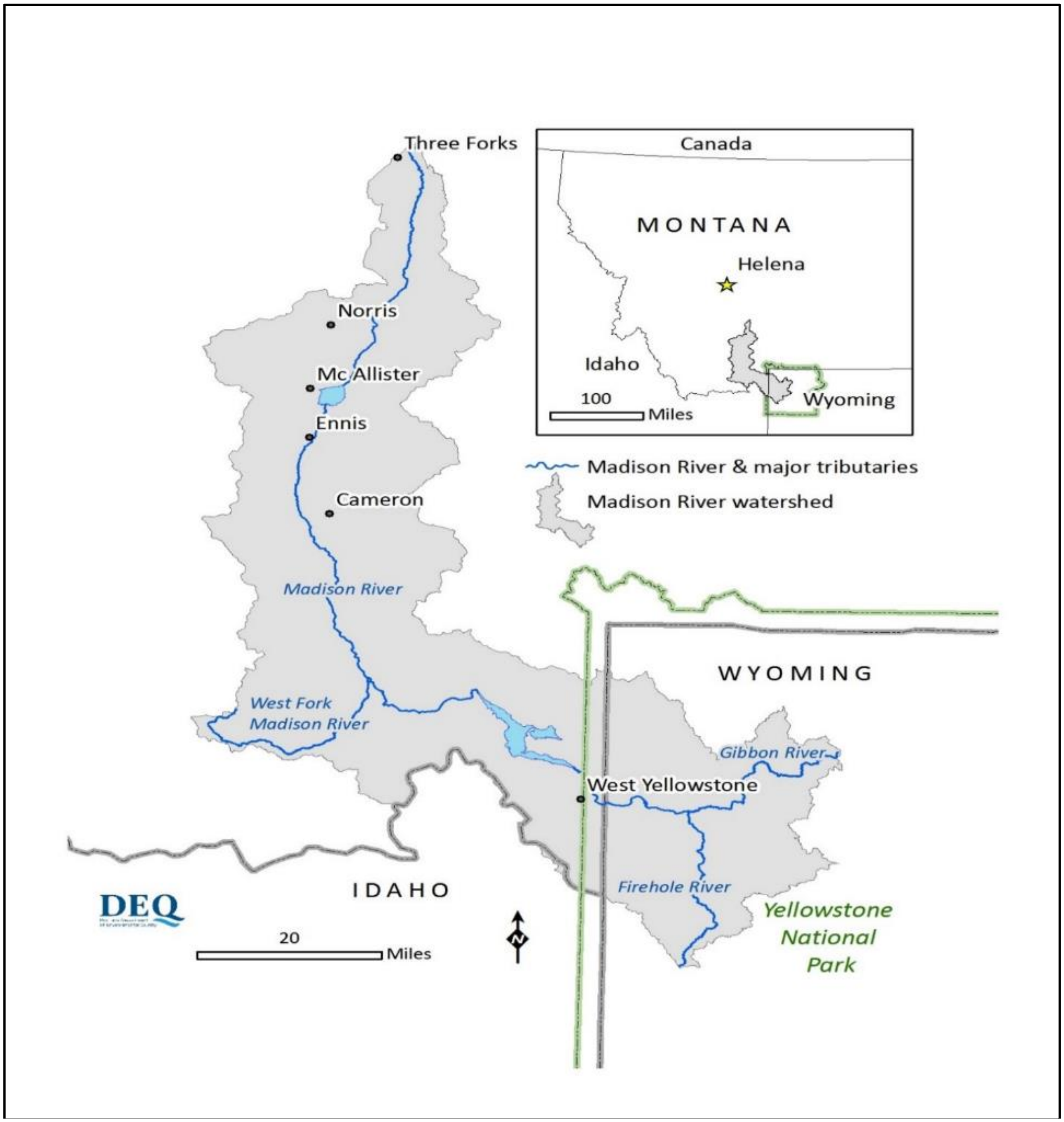

Figure 2-1. Location of the Madison TMDL Planning Area

2.1.2 Topography

The topography of the full Madison River watershed is mapped below in **Figure 2-2**. Elevation ranges from 11,316 feet (Hilgard Peak, north of Earthquake Lake) in the Madison Range on the east side of the Madison River, to 4,040 feet at the Madison River's mouth and confluence with the Jefferson River near Three Forks, Montana.

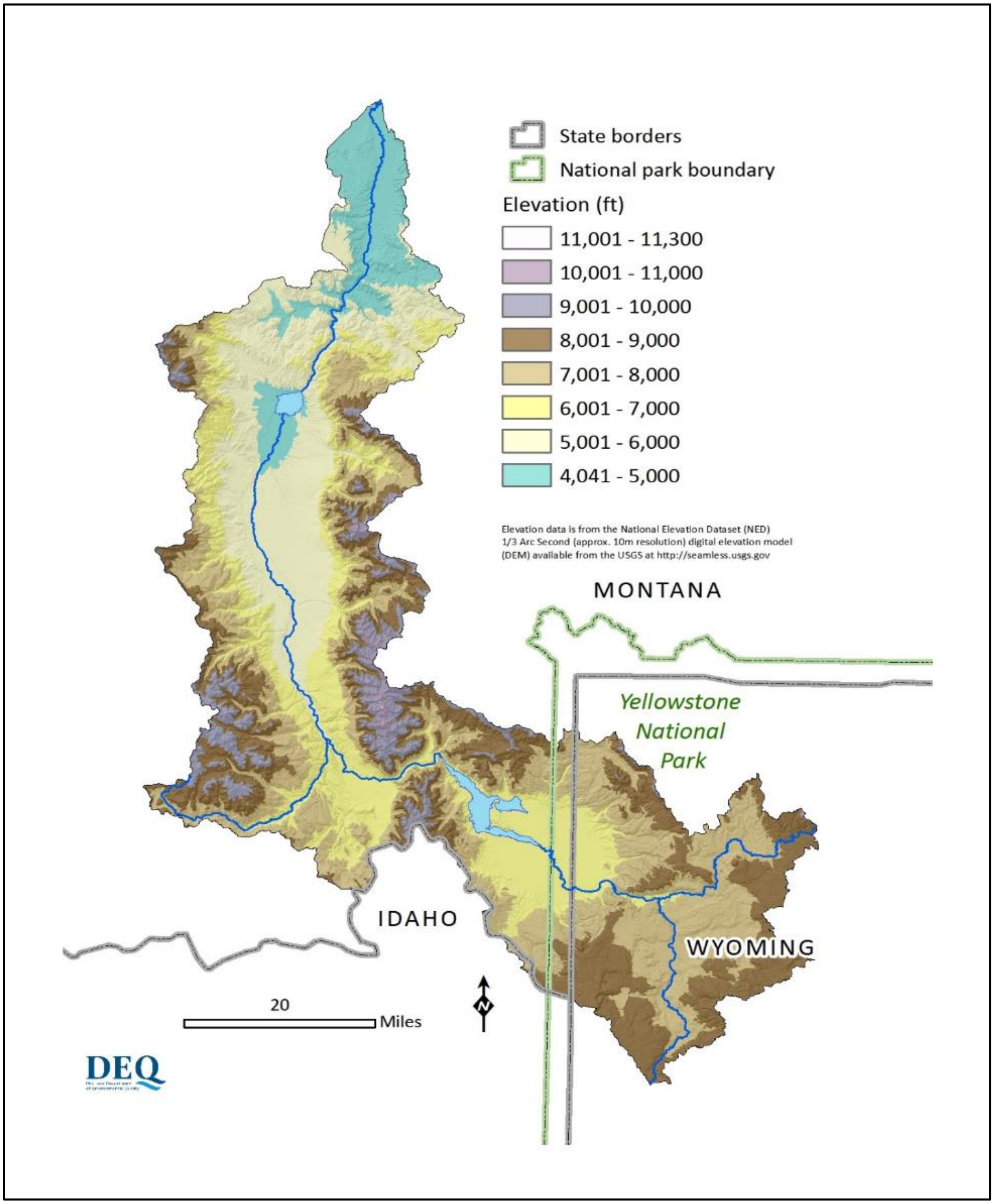

Figure 2-2. Topography of the Madison River Watershed

2.1.3 Climate

Due to the large area of the TMDL planning area, there is a measurable gradient in climate along its length. This is well illustrated by considering average precipitation and temperature. Average precipitation along the Madison River corridor ranges from just over 24 inches per year near West Yellowstone to 11 inches per year at Three Forks, according to 30-year average precipitation data (http://prism.oregonstate.edu/explorer/). May and June are consistently the wettest months of the year, and winter precipitation is dominated by snowfall according to climate summaries of West Yellowstone and Ennis provided by the Western Regional Climate Center (http://www.wrcc.dri.edu/summary/Climsmnidwmt.html). Average annual precipitation of the TMDL planning area is mapped below in **Figure 2-3**. The map shows both Snow Telemetry (SNOTEL) and Climate monitoring stations in the planning area.

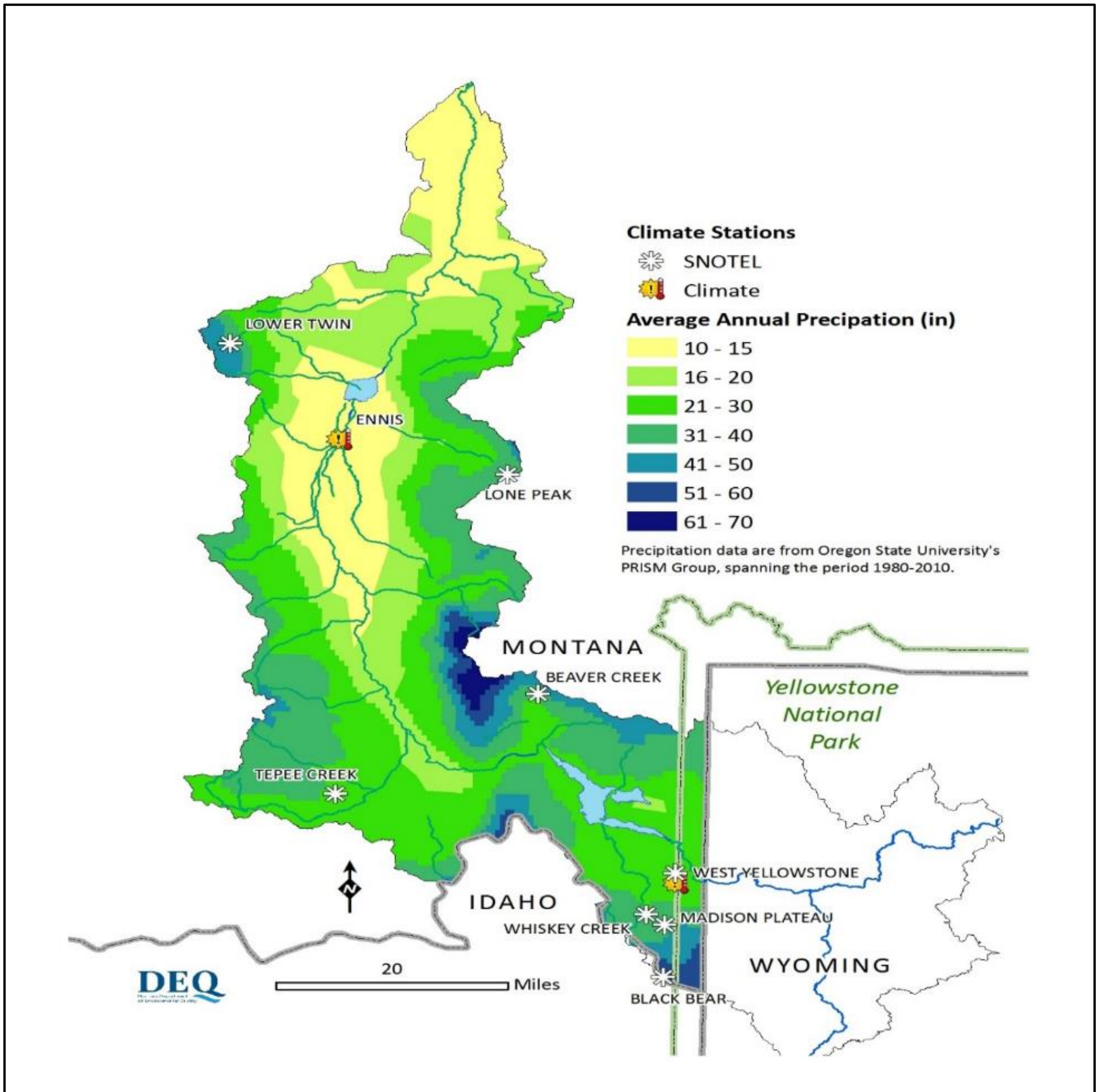

Figure 2-3. Average Annual Precipitation of the Madison TMDL Planning Area

The Madison Valley is a mid-elevation intermontane basin typified by cold winters and mild summers (Kendy and Tresch, 1996). Precipitation is greater and average temperatures are lower in the higher-elevation valley around Hebgen Lake and West Yellowstone. Average annual temperatures of the planning area are mapped below in **Figure 2-4**.

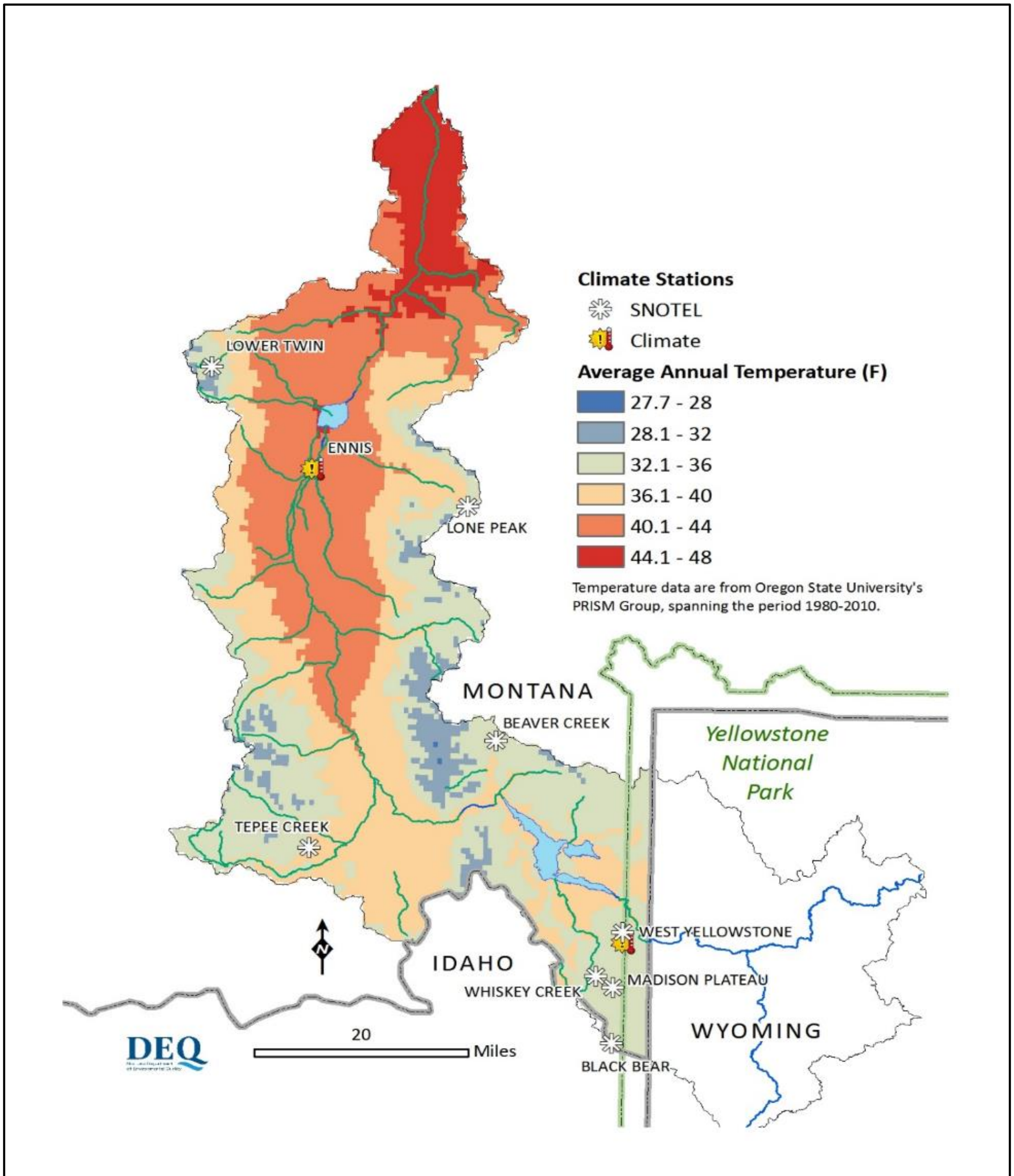

Figure 2-4. Average Annual Temperatures in the Madison TMDL Planning Area

2.1.4 Hydrology

The Madison River is one of the three forks forming the Missouri River, which begins at the confluence of the Madison and Jefferson rivers. The third fork, the Gallatin River, drains into the Missouri River a short distance below, at Three Forks, Montana. The Madison River begins at the confluence of the Firehole and Gibbon rivers in Yellowstone National Park in Wyoming. The drainage of the planning area is characterized by the mainstem of the Madison River and its tributary watersheds, mapped below in **Figure 2-5**. The Madison River is a 6th order stream at the outlet of Hebgen Dam, shown near the southern end of the planning area. The major tributaries tend to be 3rd and 4th order streams.

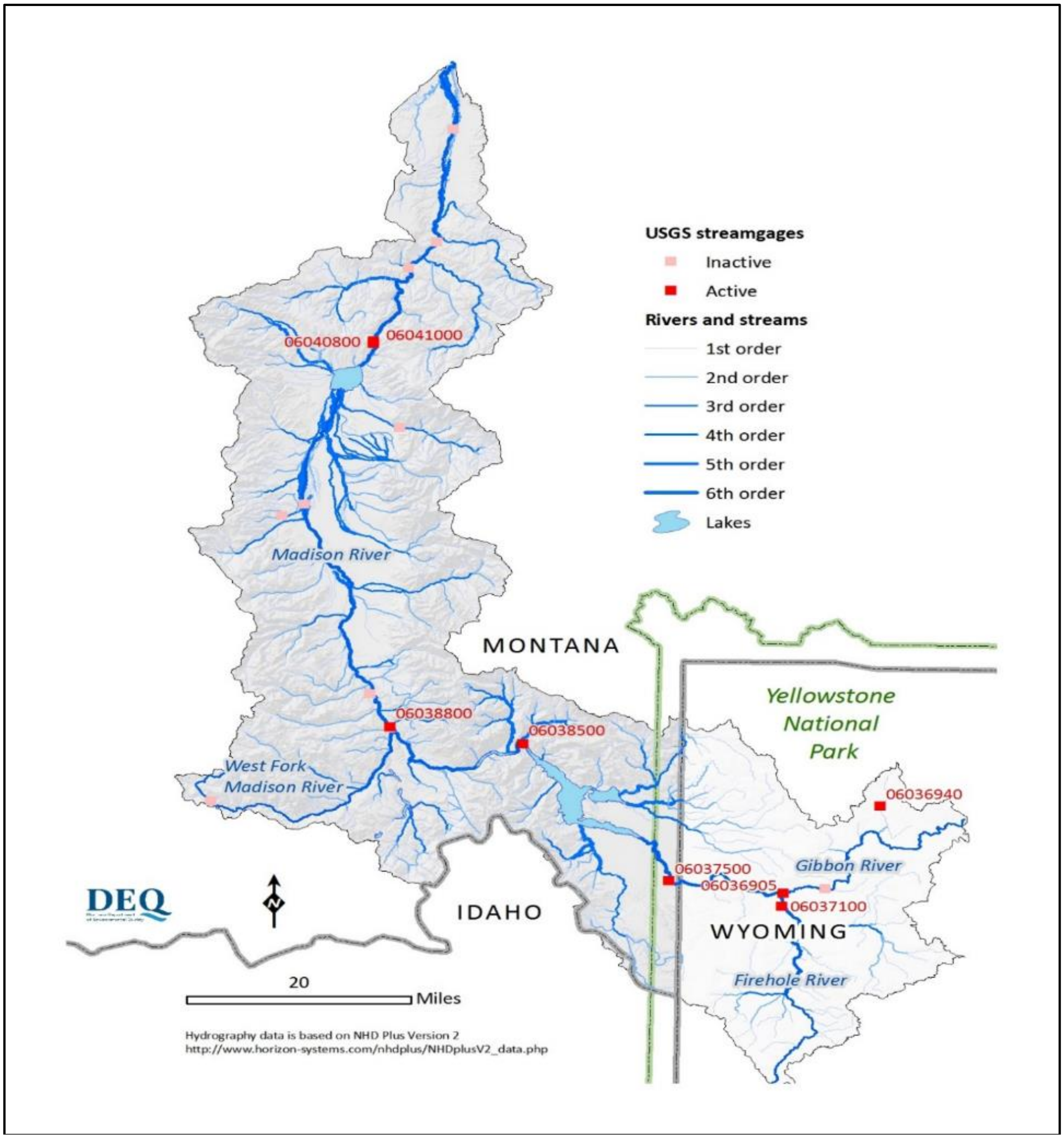

Figure 2-5. Hydrography of the Madison River Watershed

The tributary streams generally are not monitored by U.S. Geological Survey (USGS) gaging stations. Their streamflow generally follows a hydrograph typical for the region, highest in May and June. These are the months with the greatest amount of precipitation and snowmelt runoff. Streamflow begins to decline in late June or early July, reaching minimum flow levels in September when many streams go dry. Streamflow begins to rebound in October and November when fall storms supplement the base-flow levels.

2.1.5 Geology and Soils

The geology of the Madison River watershed is varied (**Figure 2-6**). Bedrock is dominated by Precambrian metamorphic rocks, with significant areas of Paleozoic and Mesozoic sedimentary rocks. Upstream of the planning area, in Wyoming, the watershed headwaters are underlain by mainly rhyolitic volcanic rocks of the Yellowstone caldera.

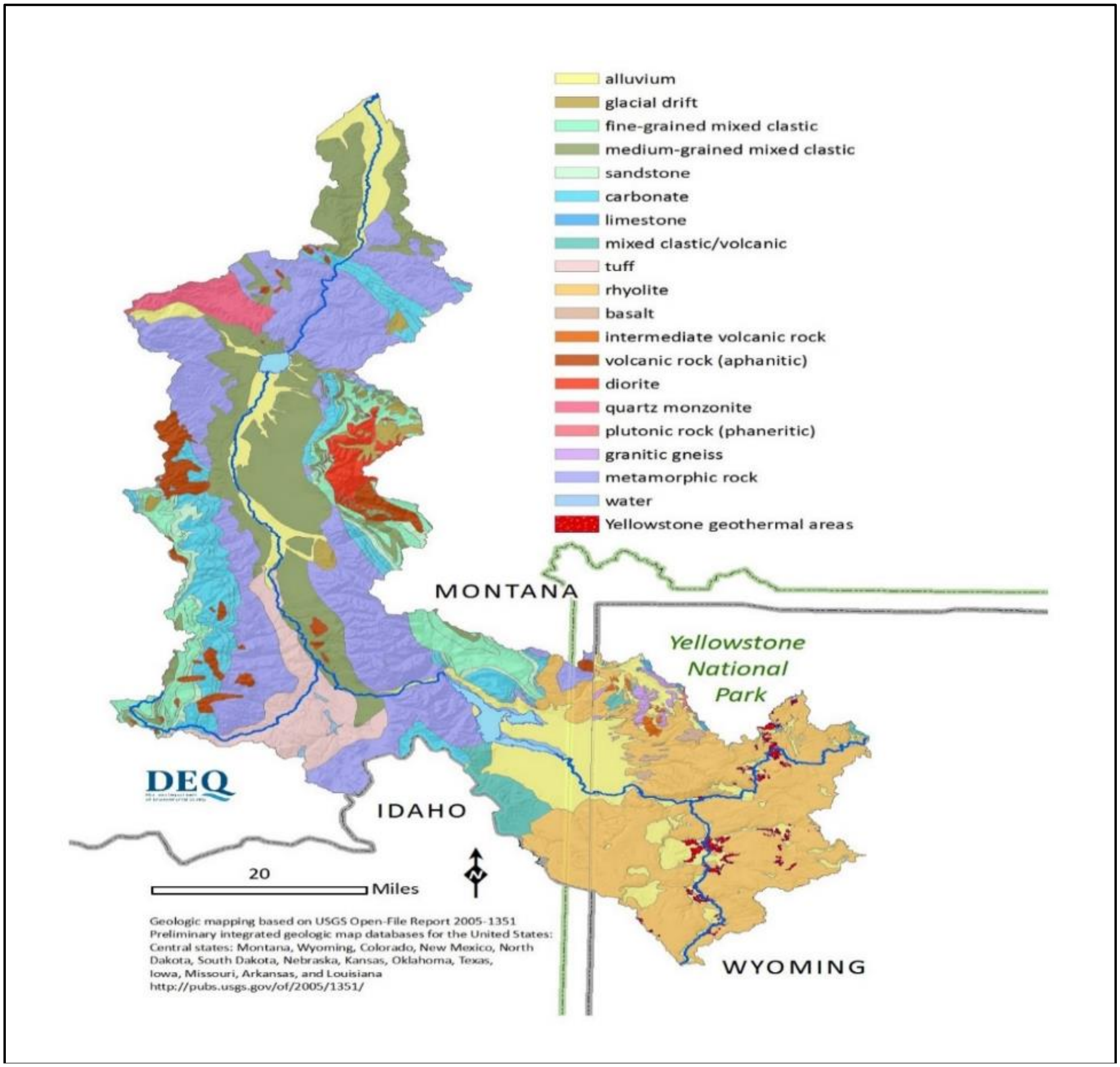

Figure 2-6. Generalized Geology of the Madison River Watershed

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

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier and Smith 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped below in **Figure 2-7**, with soil units assigned to the following ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of > 0.4 are considered highly susceptible to erosion. Despite the steep and rugged topography, most of the planning area is mapped with soils rated as having low and moderate-low erodibility. Soils mapped with moderate-high erodibility are largely found along the margin of the Gravelly Range on the west side of the Madison River. No values greater than 0.34 are mapped in the planning area.

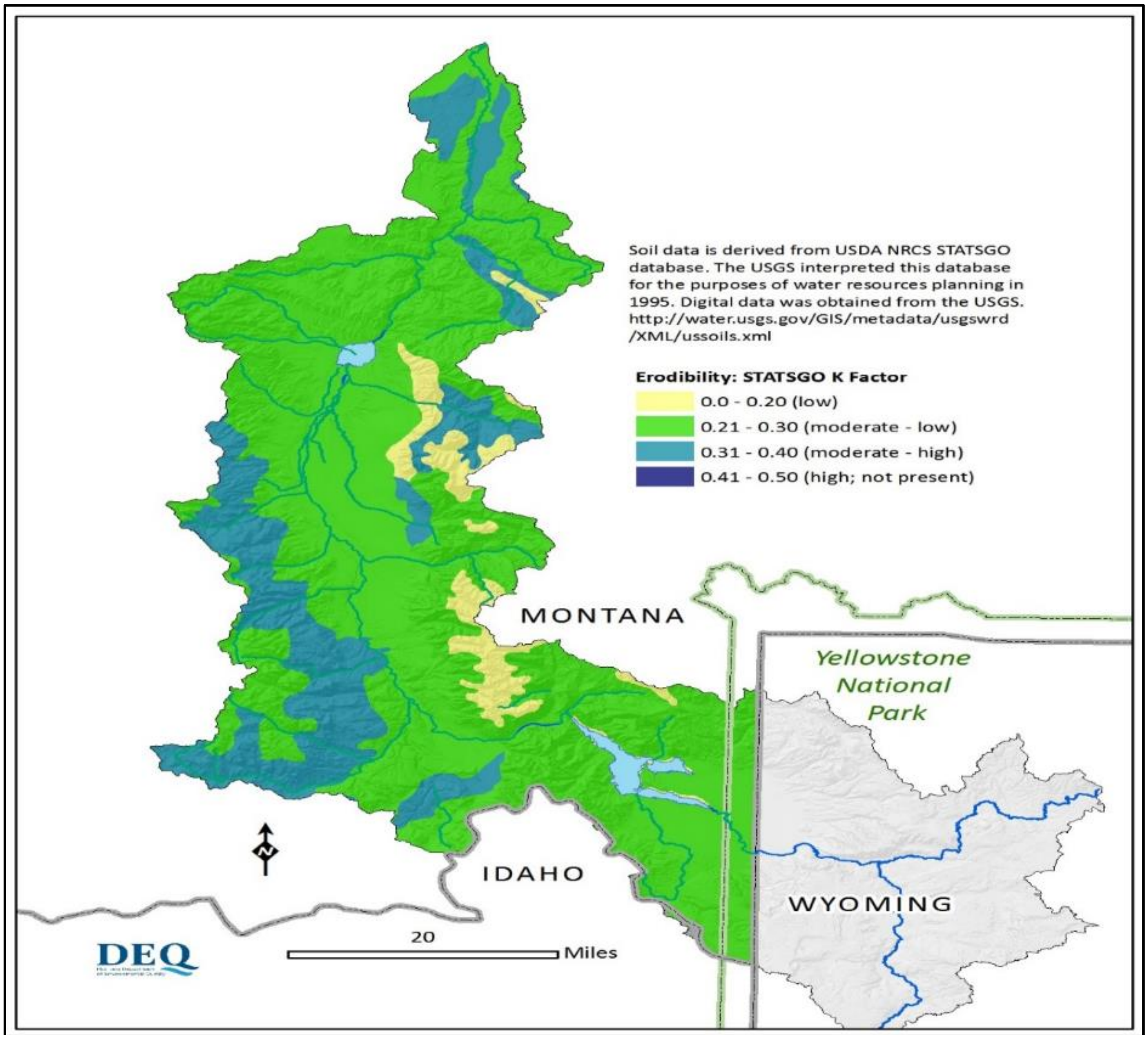

Figure 2-7. Soil Erodibility of the Madison TMDL Planning Area

2.2 Ecological Profile

This section describes the ecology of the Madison TMDL Planning Area, including the ecoregions mapped within it, land cover, fire history, and fish species of concern.

2.2.1 Ecoregions

The Madison TMDL planning area is located within the Middle Rockies Level III Ecoregion (Woods, et al., 2002). Twelve Level IV ecoregions are mapped within the full Madison River watershed, shown below in **Figure 2-8**. More detailed information about the ecoregions is available at: http://www.epa.gov/wed/pages/ecoregions/mt_eco.htm.

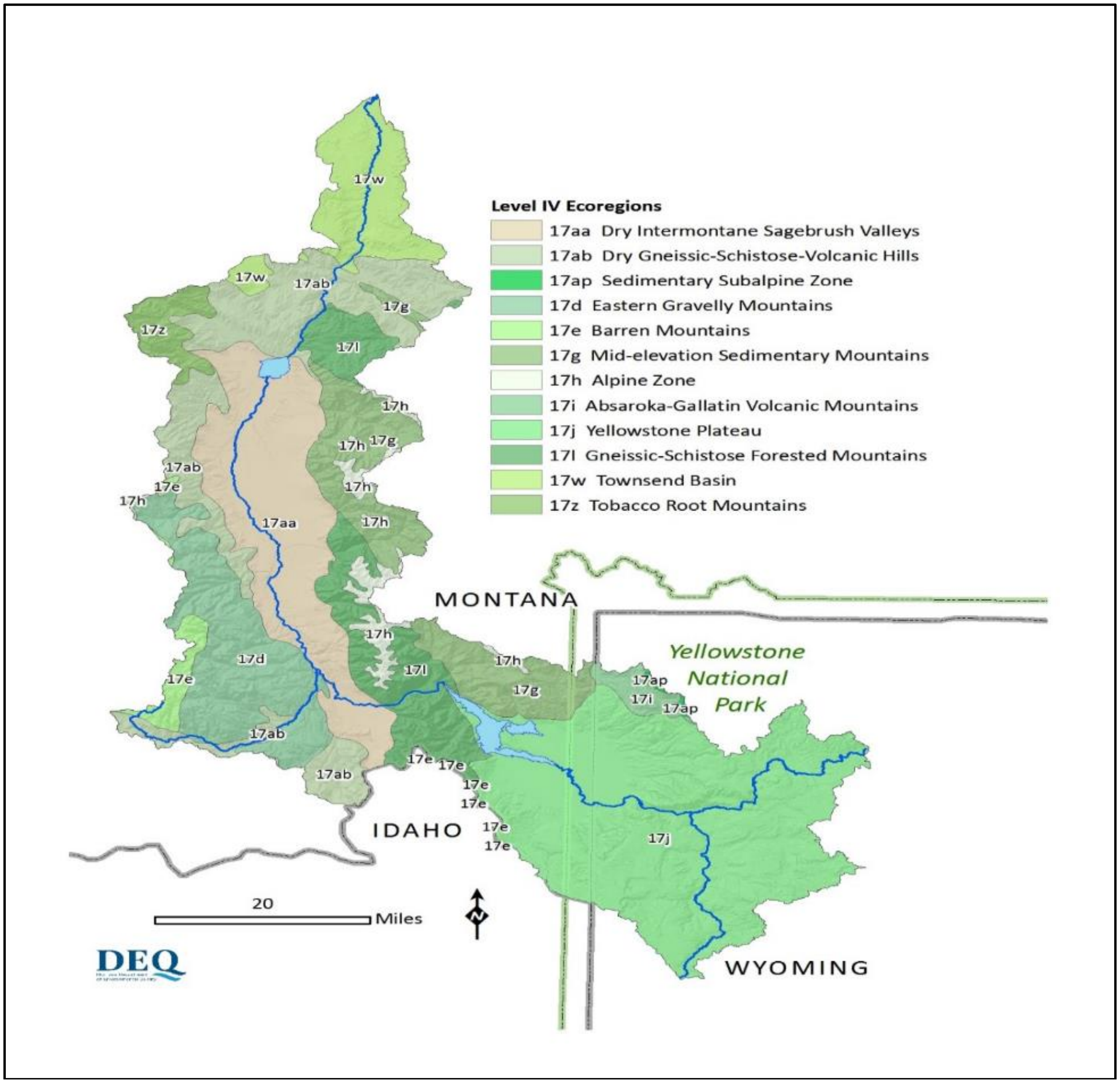

Figure 2-8. Level IV Ecoregions in the Madison River Watershed

2.2.2 Land Cover

Land cover is mapped below in **Figure 2-9**, based on the USGS 2013 National Land Cover Dataset, or NLCD (https://catalog.data.gov/dataset). As apparent in this figure, the planning area is dominated by evergreen forest in the uplands, and herbaceous and shrub/scrub cover in the lowlands. Development is largely limited to the larger communities of Ennis and West Yellowstone.

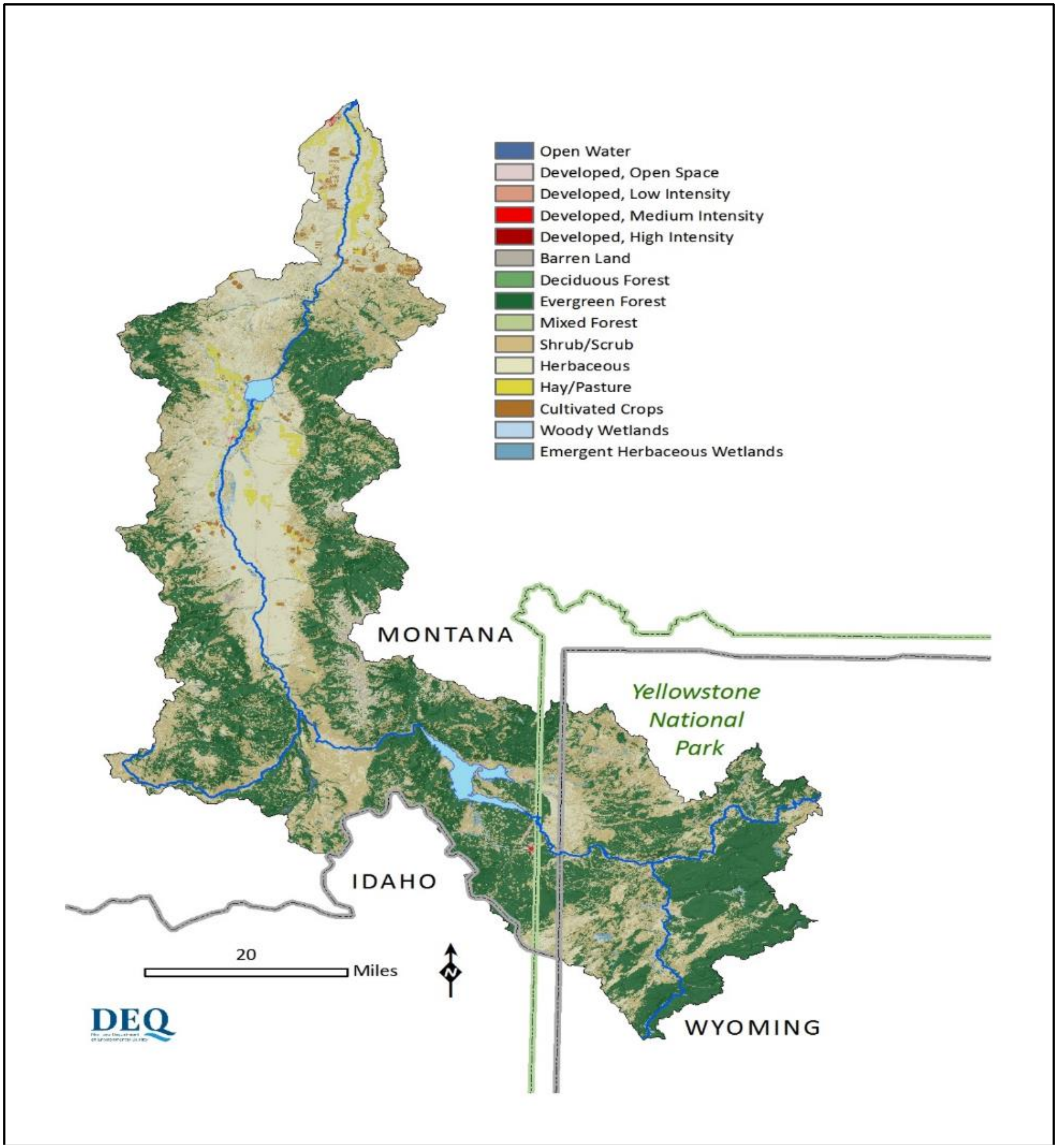

Figure 2-9. Land Cover in the Madison River Watershed

2.23 Fire History

Fire history from 1985 through 2013 is mapped below in **Figure 2-10**. Minor regions of the TMDL planning area have burned in more recent years. The largest fire of recent years was the Beartrap Fire of 2012, which burned approximately 15,000 acres.

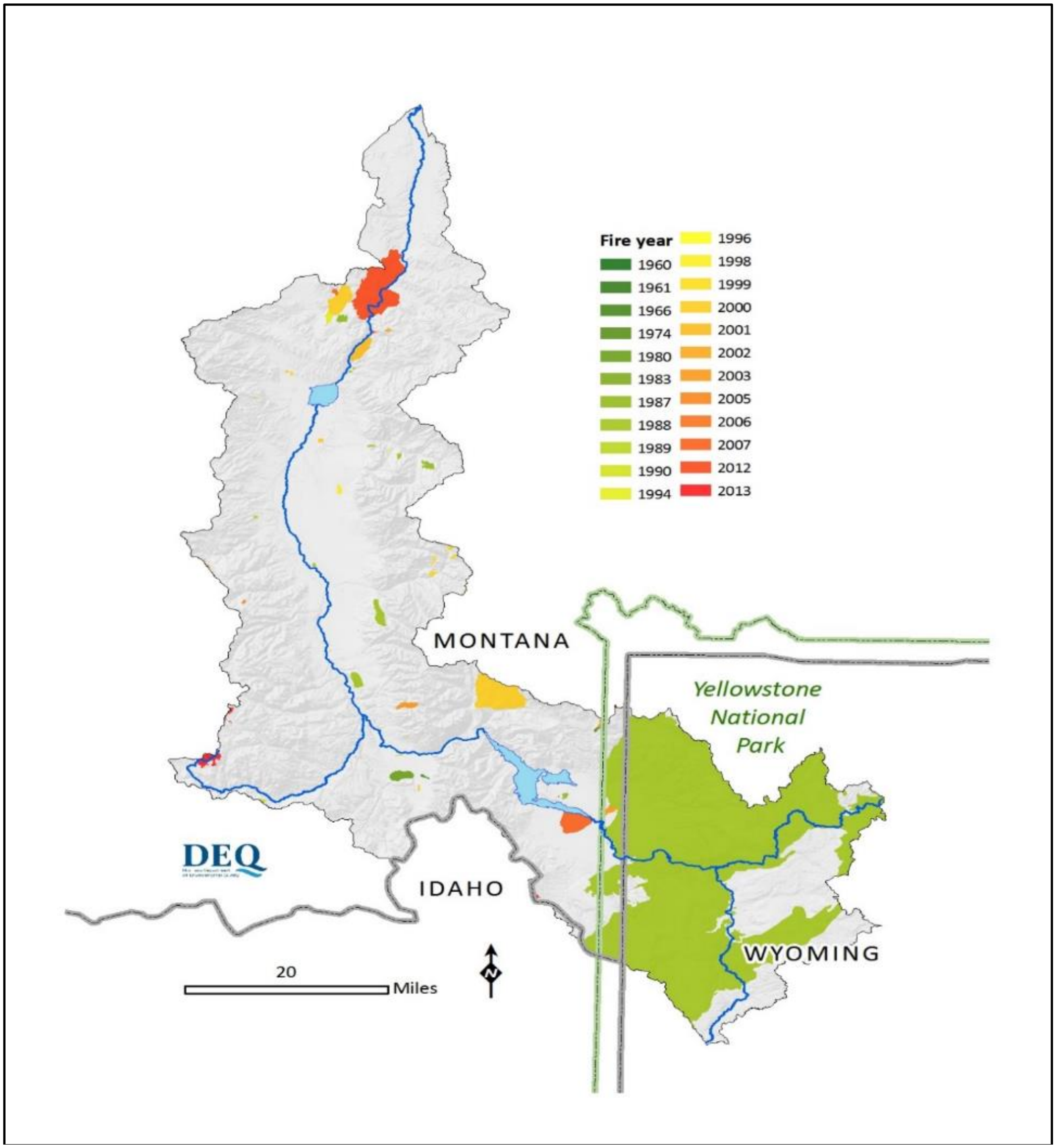

Figure 2-10. Fire History (1985-2013) of the Madison River Watershed

2.2.4 Fish Distribution

The planning area provides habitat for arctic grayling, yellowstone cutthroat trout, and westslope cutthroat trout, all Montana species of concern. Westslope cutthroat trout are found in tributary streams, particularly in the higher reaches. Yellowstone cutthroat trout are mapped in larger streams as well as in the mainstem Madison River. Arctic grayling are mapped in the Madison River and North Meadow Creek. The mapped distribution of these species is shown below in **Figure 2-11**, based on data provided by Montana Fish, Wildlife & Parks (http://fwp.mt.gov/gis/maps/mFish/?zoomFeatures=%7BlayerName:%22STREAMS%22,features:[%7BLLID:%221123386455677%22%7D],fadeOutTimer:4%7D). In addition, the Madison River is a designated Blue Ribbon fishery.

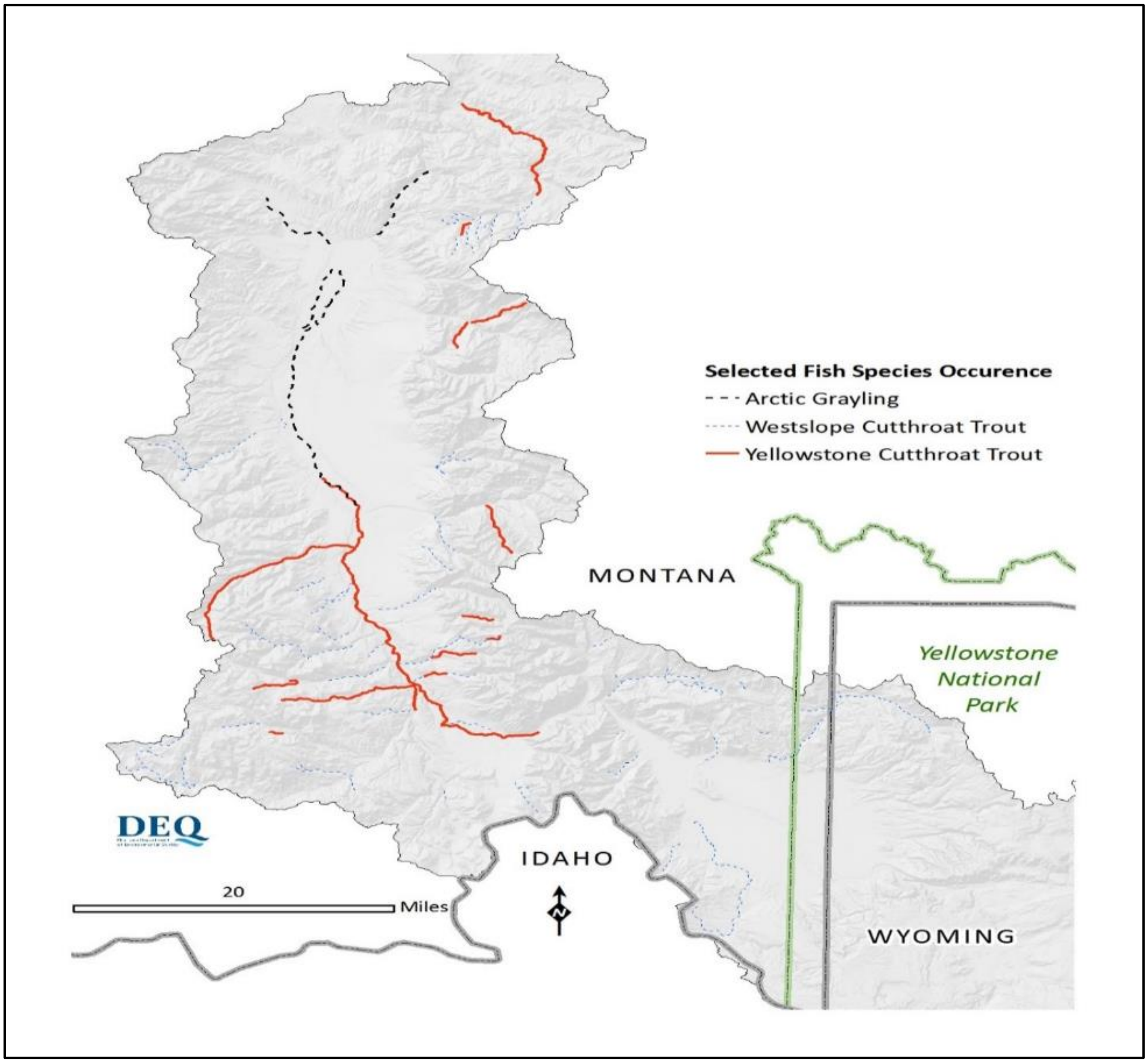

Figure 2-11. Arctic Grayling, Yellowstone Cutthroat Trout, and Westslope Cutthroat Trout Distribution in the Madison TMDL Planning Area

2.3 Social Profile

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

2.3.1 Population Density

There are no census geometries that exactly correspond to the Madison TMDL planning area, but DEQ estimates the population at 2,544 people based on 2010 census GIS files. The population centers are Ennis (838 residents) and West Yellowstone (1,271 residents). Large areas of USFS land are uninhabited, although there are isolated inholdings. Population density is mapped below in **Figure 2-12**.

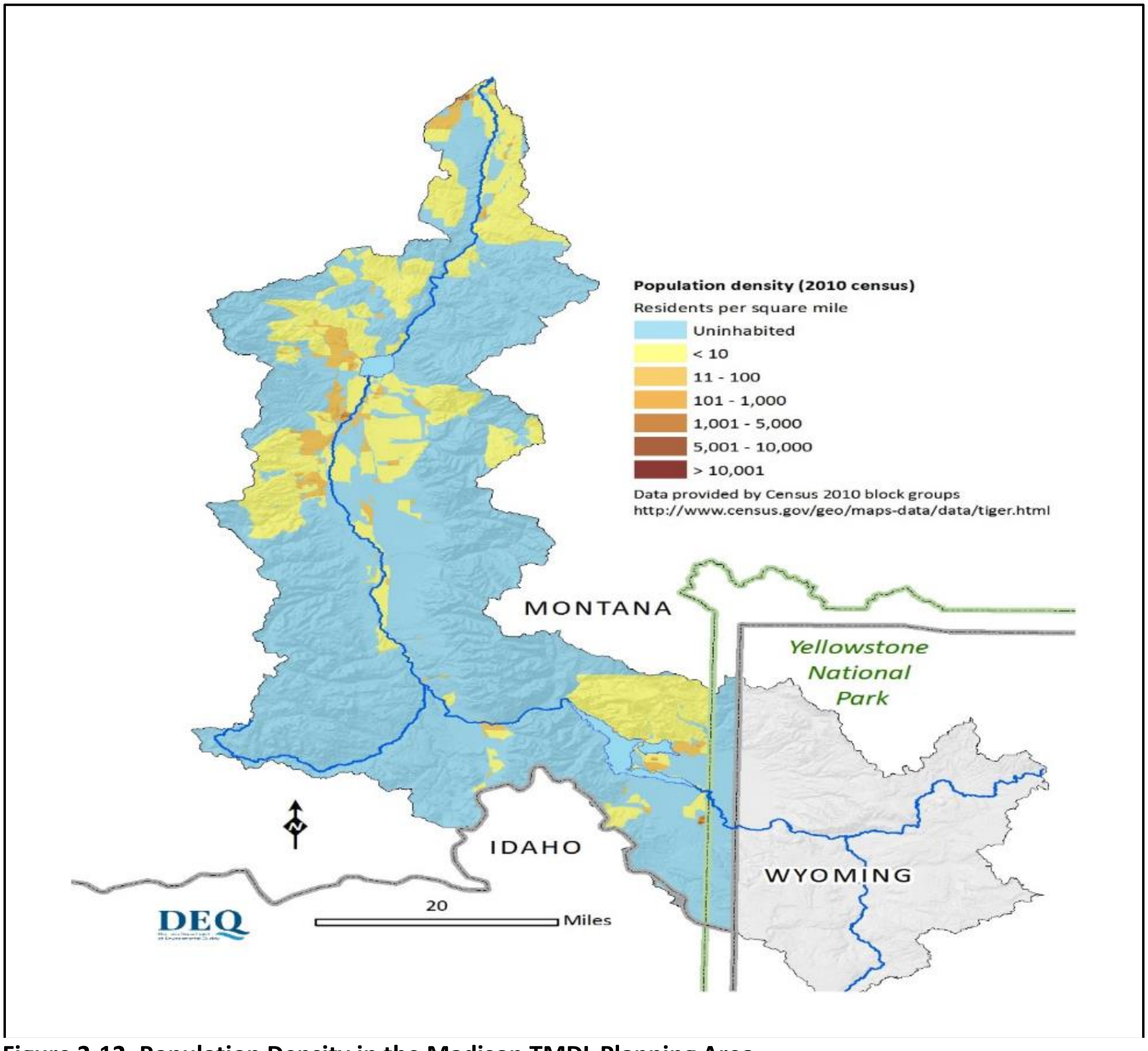

Figure 2-12. Population Density in the Madison TMDL Planning Area

2.3.2 Land Management

Federal lands managed by the U.S. Forest Service (USFS) dominate the planning area, and are found mostly in the upland areas (**Figure 2-13**). The U.S. Bureau of Land Management (BLM) oversees significant lands in the valley and foothills. Private lands dominate the river corridor and valley bottoms.

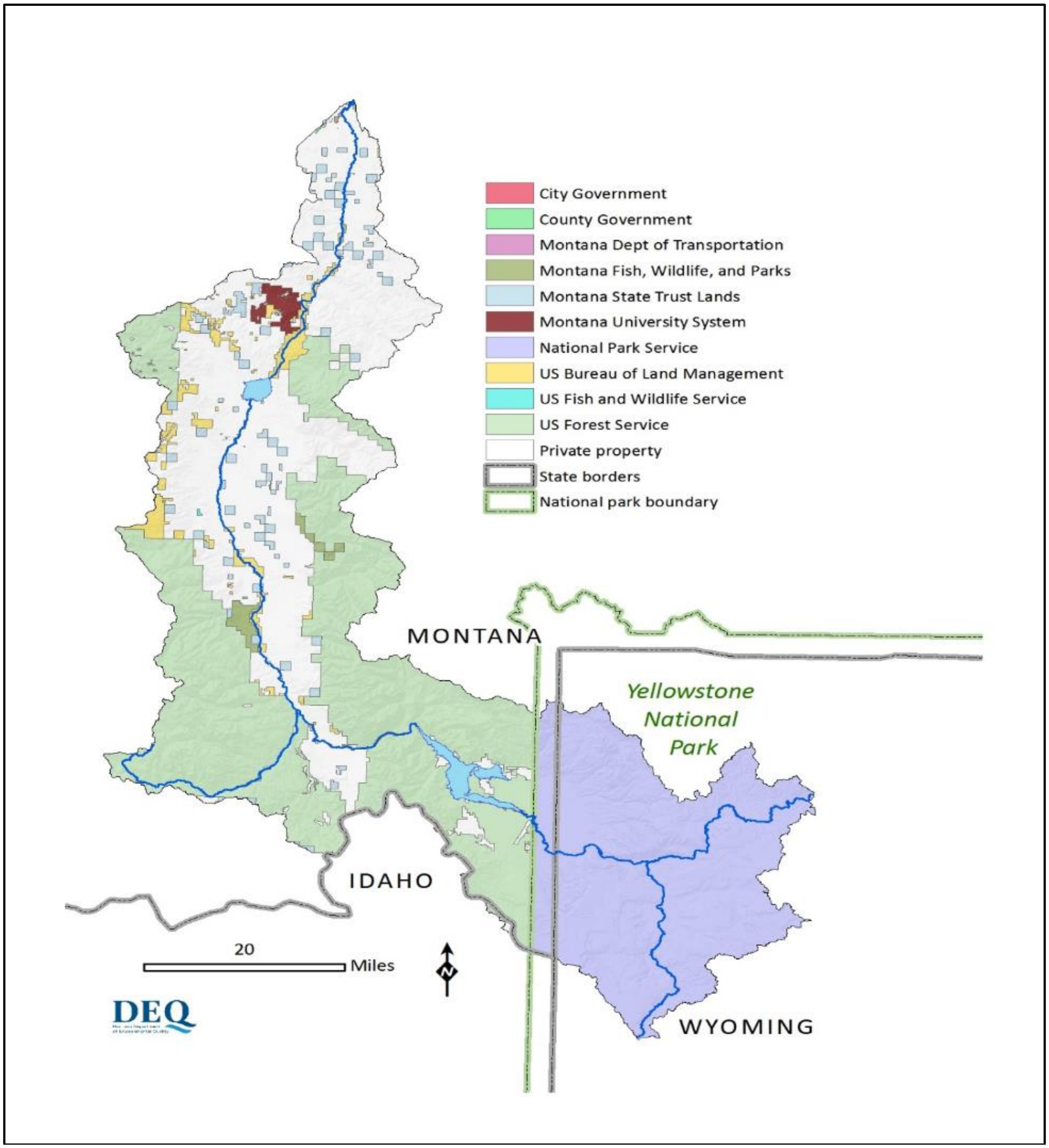

Figure 2-13. Land Management in the Madison River Watershed

2.2.3 Agricultural Land Use

Montana Department of Revenue assesses agricultural land for taxation; the resulting dataset is known as the Final Land Unit (FLU) classification. The agricultural uses were determined by Department of Revenue GIS specialists, and confirmed by maps sent to private landholders for verification. Agricultural uses as determined in the Final Land Unit classification are mapped below in **Figure 2-14**. The Final Land Use data are available at:
ftp://ftp.geoinfo.msl.mt.gov/Data/Spatial/NonMSDI/Geodatabases/revenue_flu.zip.

Grazing is common on both private lands and forested public lands. BLM and USFS grazing allotments are shown on the map, totaling 138 and 559 square miles, respectively. Private grazing operations are not specifically identified; however, much of the gray area on the map includes private land where grazing occurs. Grazing allotments and operations are further discussed in **Section 5.4.3**.

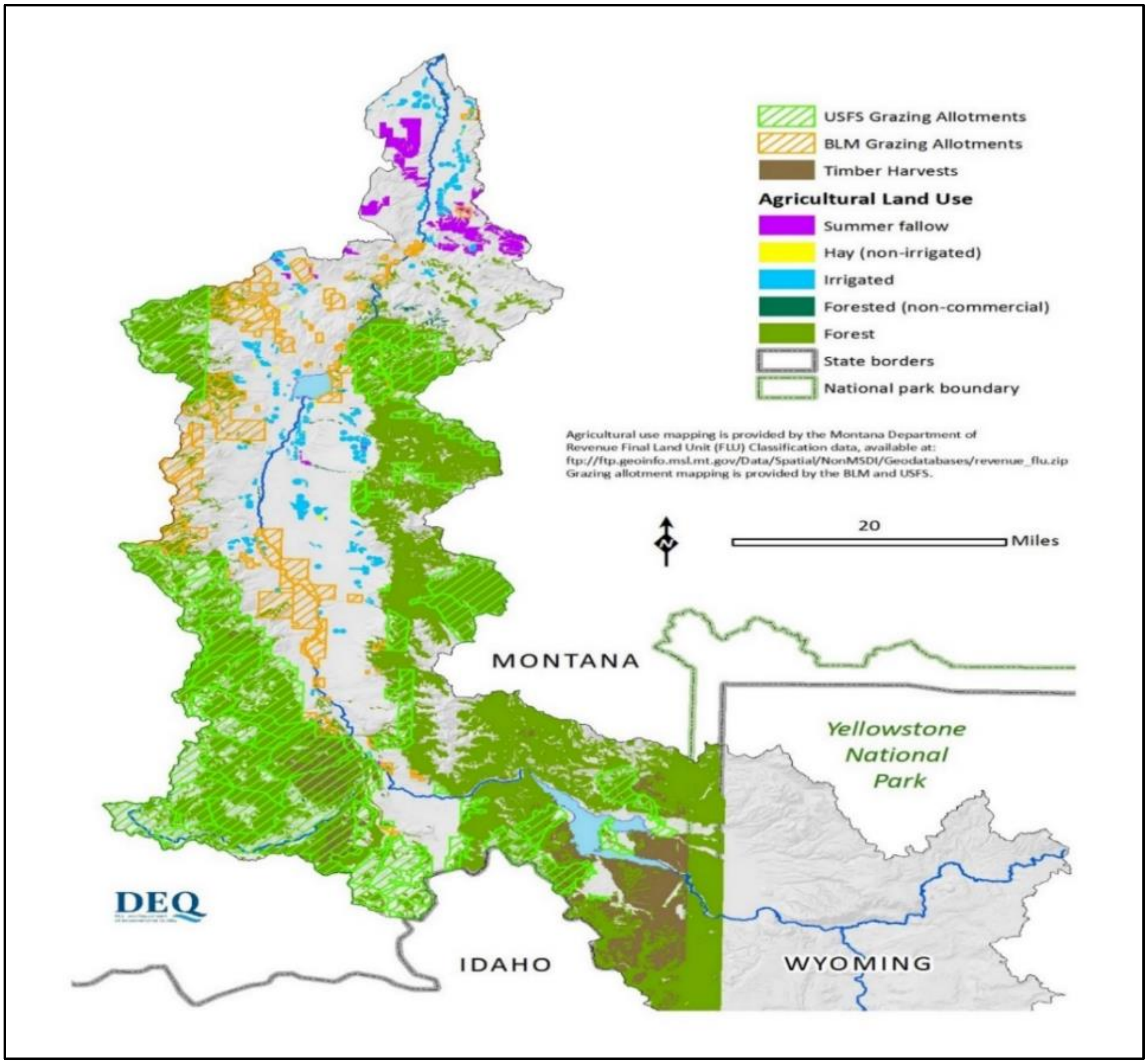

Figure 2-14. Agricultural Use and Grazing Allotments in the Madison River Watershed

2.3.4 Road Networks

The Madison TMDL Planning Area includes significant roadless areas, particularly around the Lee Metcalf Wilderness Area east of the Madison River in the Madison Range. There are extensive road networks both in the valley bottoms and in the timbered uplands. Some roads were constructed for timber harvesting, and may have been decommissioned. The planning area is too large to analyze the road network at this scale; however, **Figure 2-15** below provides a general idea of where the upland road networks are most extensive.

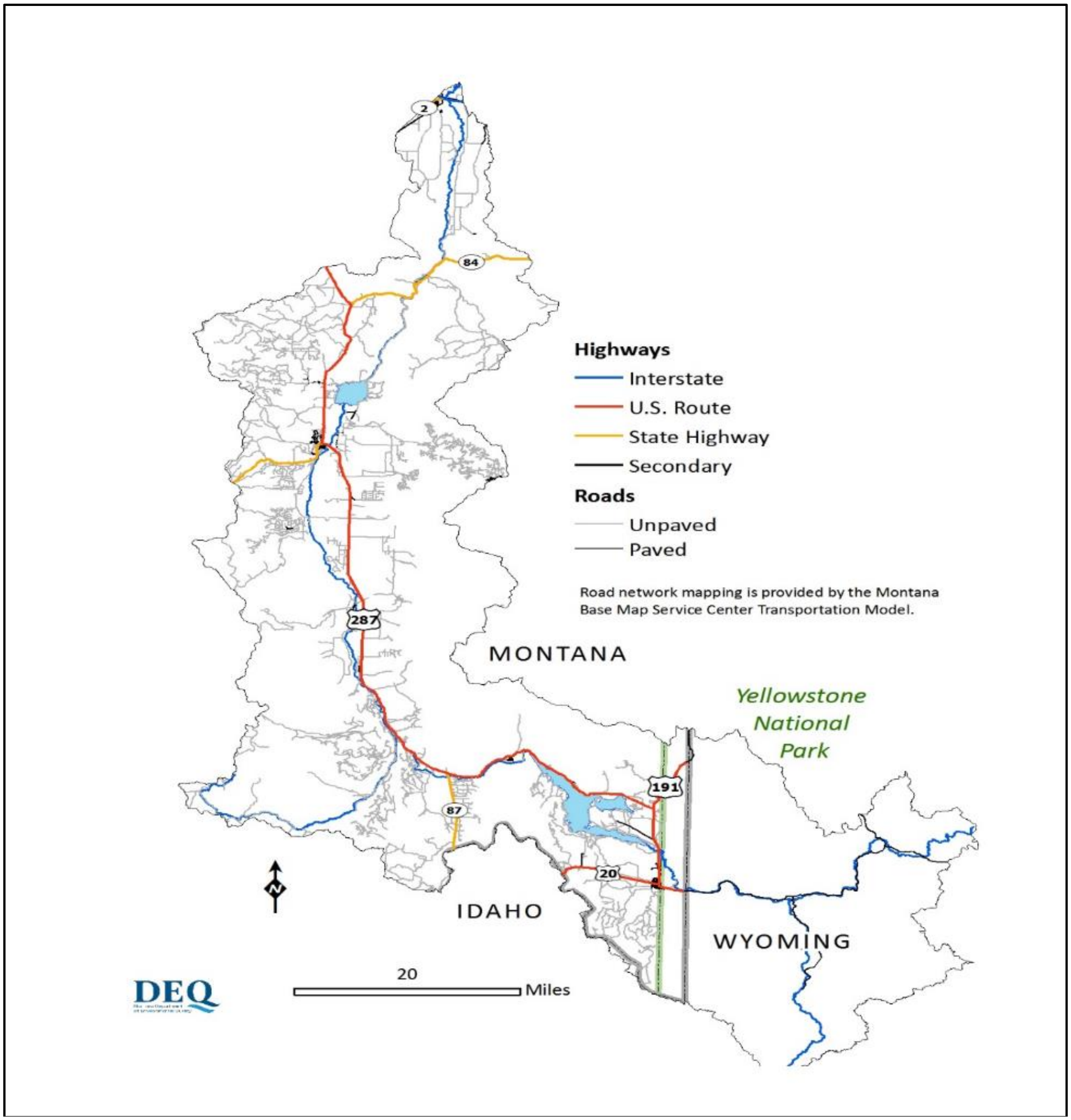

Figure 2-15. Road Network in the Madison TMDL Planning Area

2.3.5 Wastewater Discharges

Sources of pollution originating from a point source wastewater discharge are permitted and regulated through the Montana Pollutant Discharge Elimination System (MPDES) administered by Montana DEQ. The goal of the MPDES program is to control point source discharges of wastewater such that water quality in state surface water is protected. Levels of water quality that are required to maintain the various beneficial uses of state surface waters are set forth in the state's water quality standards. There are two types of discharge permits: general and individual.

A MPDES General Permit is a permit for wastewater discharges associated with common activities, such as concentrated animal feeding operations and storm water discharges from construction or industrial activity. Authorizations for General Permits are issued if a facility or activity falls within the guidelines of the existing permit. Individual MPDES Permits regulate wastewater discharges from point sources that do not fall under the guidelines for a General Permit. The individual permitting process is more rigorous, as individual permits address the specific conditions of the facility or activity needing authorization.

All point sources of wastewater discharge are required to obtain and comply with MPDES permits. The effluent limitations and other conditions for certain categories of wastewaters are required to be treated to federally-specified minimum levels based on available and achievable water treatment technologies. Additionally, effluent limits and permit conditions are established to protect beneficial uses and applicable water quality standards. Each MPDES permit issued is designed to protect the state surface water quality at the point of discharge. In addition, recognizing the dynamic nature of streams and the potential additive or cumulative effects of pollutants, MPDES permits also address stream reach or basin-wide pollution problems. If a TMDL has been developed for a waterbody, any wasteload allocations (WLAs) are incorporated into the applicable MPDES permits with discharges into that waterbody.

There are two MPDES permitted facilities that discharge to a waterbody in the Madison TMDL Planning Area: the Ennis National Fish Hatchery (permit number MTG13008) and the Ennis Wastewater Treatment Plant (permit number MT0030732). The permit for the Ennis National Fish Hatchery is a general permit for concentrated aquatic animal production. The permit for the Ennis Wastewater Treatment Plant is an individual MPDES permit for wastewater produced by the town of Ennis (**Table 2-1**). The Ennis National Fish Hatchery releases total suspended solids into Blaine Spring Creek, which is impaired for sediment. However, this load is organic and is not considered to be a contributor to the inorganic sediment load. Therefore, a wasteload allocation for the fish hatchery will not be included as part of the sediment TMDL for Blaine Spring Creek. The Ennis Wastewater Treatment Plant does not have water quality impairments addressed by a TMDL in this document.

Table 2-1. MPDES Permits in the Madison TMDL Planning Area

Facility Name	Permit Number	Permit Expiration Date	Receiving Waterbody
Ennis National Fish Hatchery	MTG13008	June 30, 2021	Blaine Spring Creek
Ennis Wastewater Treatment Plant	MT0030732	April 20, 2019 (Administratively Extended)	Madison River

3.0 MONTANA WATER QUALITY STANDARDS

The Montana Water Quality Act provides for the restoration and maintenance of the chemical, physical, and biological integrity of the state'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

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

Those water quality standards that apply to this document are reviewed briefly below. More detailed descriptions of Montana's water quality standards may be found in the Montana Water Quality Act (75-5-301,302 Montana Code Annotated (MCA)), Montana's Surface Water Quality Standards and Procedures (Administrative Rules of Montana (ARM) 17.30.601-670), and **Appendix A**, Regulatory Framework and Reference Condition Approach.

3.1 STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Stream classification is the assignment (designation) of a single group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated uses, or beneficial uses, are simple narrative descriptions of water quality expectations or water quality goals. Montana waters are classified for multiple uses. All streams and lakes within the Madison River TMDL Planning Area are classified as B-1 (ARM 17.30.623). In accordance with ARM 17.30.623, waters classified as B-1 are to be maintained suitable for:

- Culinary and food processing purposes after conventional treatment (Drinking Water)
- Bathing, swimming, and recreation (Primary Contact Recreation)
- Growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers (Aquatic Life)
- Agricultural and industrial water supply

While a waterbody might not actually be used for a designated use (e.g., drinking water supply), its water quality still must be maintained suitable for that designated use. More detailed descriptions of Montana's surface water classifications and designated uses are provided in **Appendix A**. 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 (DEQ 2011). For streams in Western Montana, the most sensitive use assessed for sediment and temperature is aquatic life. DEQ determined that 13 waterbody segments in the Madison TMDL Planning Area do not meet the sediment and temperature water quality standards (**Table 3-1**).

Table 3-1. Impaired Waterbodies and Their Impaired Designated Uses in the Madison TMDL Planning Area

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Impairment Cause[1]	Impaired Use[2]
Antelope Creek, Headwaters to mouth (Cliff Lake)	MT41F004_140	Sedimentation – Siltation	Aquatic Life
Bear Creek, Headwaters to mouth (O'Dell Spring Creek)	MT41F004_021	Sedimentation - Siltation	Aquatic Life
Blaine Spring Creek, Headwaters to mouth (Madison River, T7S R1W S6)	MT41F004_010	Sedimentation – Siltation	Aquatic Life
Cherry Creek, Headwaters to mouth (Madison River)	MT41F002_010	Sedimentation – Siltation	Aquatic Life
		Temperature	Aquatic Life
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Sedimentation – Siltation	Aquatic Life
		Temperature	Aquatic Life
		Turbidity	Aquatic Life
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Sedimentation – Siltation	Aquatic Life
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Sedimentation – Siltation	Aquatic Life
		Temperature	Aquatic Life
North Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_060	Sedimentation – Siltation	Aquatic Life
Red Canyon Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_020	Sedimentation – Siltation	Aquatic Life
Ruby Creek, Headwaters to mouth (Madison River)	MT41F004_080	Sedimentation – Siltation	Aquatic Life
South Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_070	Sedimentation – Siltation	Aquatic Life
Watkins Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_030	Sedimentation – Siltation	Aquatic Life
Wigwam Creek, Headwaters to mouth (Madison River)	MT41F004_160	Sedimentation – Siltation	Aquatic Life

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

[2] A full summary of beneficial use support Information for each waterbody is contained at cwaic.mt.gov

It is important to note that waterbodies monitored by Montana DEQ are assigned an assessment unit (**Table 3-1**). Assessment units can be the full length of a stream, the full extent of a lake or reservoir, or they may be a portion of a lake or of a stream (a stream segment). Streams may be broken into individual segments, determined by a variety of factors such as stream length for very long streams, or lakes may be broken by ownership boundaries (tribal versus state, for example). Due to its length and multiple dam impoundments, the Madison River, for example, has three assessment units / three stream segments (shown in **Table 1-2**).

3.2 Numeric and Narrative Water Quality Standards

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

Numeric standards apply to pollutants that are known to have adverse effects on human health, aquatic life, or other beneficial uses of water (e.g., metals, nutrients, *E. coli*, 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. Narrative standards describe the allowable or desired condition and are also designed to protect the designated beneficial uses. This condition is often defined as an allowable increase above "naturally occurring." DEQ often uses the naturally occurring condition, called a "reference condition," to help determine whether or not narrative standards are being met (see **Appendix A**). For sediment and temperature TMDL development in the Madison TMDL Planning Area, only narrative standards are applicable; they are summarized in **Appendix A**.

3.3 Nondegradation Provisions

Nondegradation is addressed via the Nondegradation Policy within Montana state statute (75-5-303, MCA) and via Montana's nondegradation rules (ARM 17.30.7). The Nondegradation Policy states that existing uses of state waters and the level of water quality necessary to protect those uses must be maintained and protected. Montana nondegradation rules apply to any new or increased point or nonpoint source resulting in a change of existing water quality occurring on or after April 29, 1993 (ARM 17.30.702).

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. The ultimate goal of the TMDL is to identify an approach to achieve and maintain water quality standards.

Pollutant sources are generally defined as two categories: point sources and nonpoint sources. Point sources are often linked to community wastewater treatment or industrial facilities with discernible, confined and discrete conveyances, such as pipes or ditches from which pollutants are being, or may be, discharged to a waterbody. Some sources such as return flows from irrigated agriculture are not included in this definition. Pollutant loading sources that do not meet the definition of a point source are considered nonpoint sources. Nonpoint sources are associated with diffuse pollutant loading to a waterbody and are often linked to runoff from agricultural, urban, or forestry activities, as well as streambank erosion and groundwater seepage that can occur from these activities. Natural background loading and atmospheric deposition are both considered types of nonpoint sources.

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: $TMDL = \Sigma WLA + \Sigma LA + MOS$, where:

ΣWLA is the sum of the wasteload allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)
MOS = margin of safety

TMDL development must include a margin of safety (MOS), which can be explicitly incorporated into the above equation as shown. Alternatively, the MOS can be implicit in the TMDL, meaning that the explicit MOS in the above equation is equal to zero and can therefore be removed from the above equation. 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., changes in pollutant loading during the year, or seasonal water quality standards).

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.

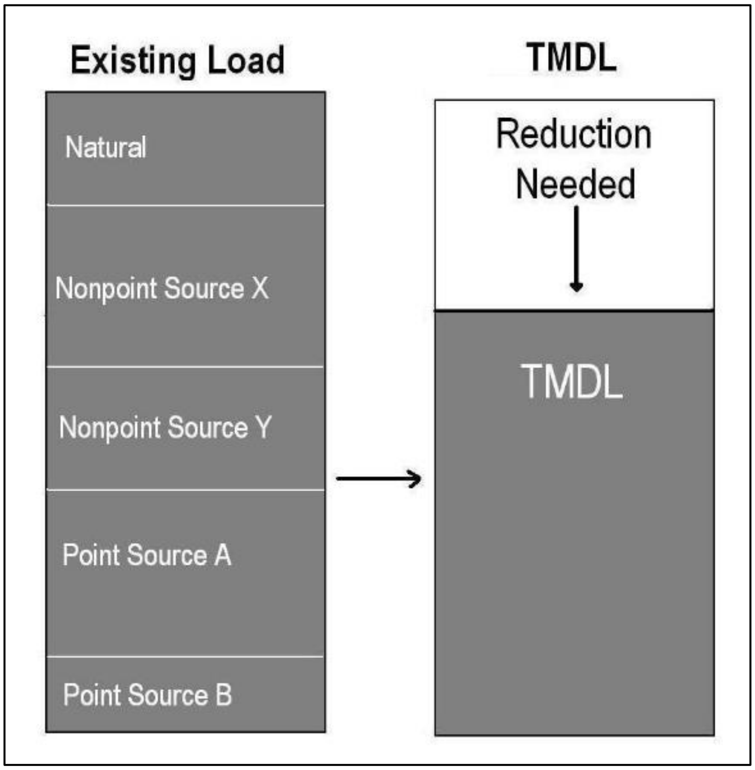

Figure 4-1: Schematic Example of TMDL Development

4.1 Developing Water Quality Targets

For each pollutant, TMDL water quality targets are applied to one or more parameters that link directly to the impaired beneficial use(s) and applicable water quality standard(s). 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 translation of how the narrative standard(s) applies to the waterbody. 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

The goal of TMDL source assessment is to identify all significant pollutant loading sources, including natural background loading, and quantify them 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 includes 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.

Source assessments are conducted on a watershed scale and can vary in level of detail resulting in reasonably accurate estimates or gross allotments, depending on the data availability and the techniques used for predicting the loading (40 CFR 130.2(i)). Montana TMDL development often includes a combination of approaches, depending on the level of desired certainty for setting allocations and guiding implementation activities.

Nonpoint sources are quantified by source categories (e.g., eroding streambanks or unpaved roads) and/or by land uses (e.g., crop production or forestry). These source categories and land uses can be divided further by ownership, such as federal, state, or private. Alternatively, most, or all, nonpoint pollutant sources in a sub-watershed or source area can be combined for quantification and TMDL load allocation purposes.

Pollutant loading is typically quantified for each individual surface water point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Through MPDES permit requirements, point source dischargers provide discharge and other information that can be used for source assessment purposes. The allowable loading within each MPDES surface water permit condition must be consistent with the assumptions and requirements of the available WLA developed within the TMDL (40 CFR 122.44).

4.3 Establishing the Total Allowable Load

TMDL development requires a determination of the total allowable load over the appropriate time period necessary to comply with the applicable water quality standard(s). Per EPA requirements (40 CFR 130.2), “TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure.” Where 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 results in a mass per unit time TMDL expression such as pounds per day. This same approach can be applied when a numeric target is developed to interpret a narrative standard.

Although a “TMDL” is specifically defined as a “daily load,” determining a daily load 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.

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 so that the sum of the allocations is equal to the TMDL, consistent with the above TMDL equation. For sediment, the allocations are often determined by quantifying feasible and achievable load reductions through application of a variety of best management practices (BMPs) and other reasonable conservation practices. Where a TMDL is variable based on streamflow, nonpoint source load allocations are often variable based on this same receiving streamflow. On the other hand, point source wasteload allocations are often based on conservative streamflow and discharge conditions and/or can be variable based on the point source discharge flow and a discharge concentration limit. Where the TMDL is a function of streamflow, the TMDL and allocations are calculated for example high and low flow stream conditions.

Figure 4-2 illustrates how the TMDL is allocated to different sources using WLAs for point sources and load allocations (LA) for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the TMDL for all segments of the waterbody. **Figure 4-2** shows multiple point and nonpoint source allocations. In Montana, nonpoint source allocations are sometimes grouped into one composite allocation. This composite load allocation approach is applied in cases where data is limited, there is significant source assessment uncertainty, and/or DEQ has determined that the best approach is to provide stakeholders with flexibility in addressing sources, allowing them to choose where to focus on improved land management practices and other remediation or restoration efforts.

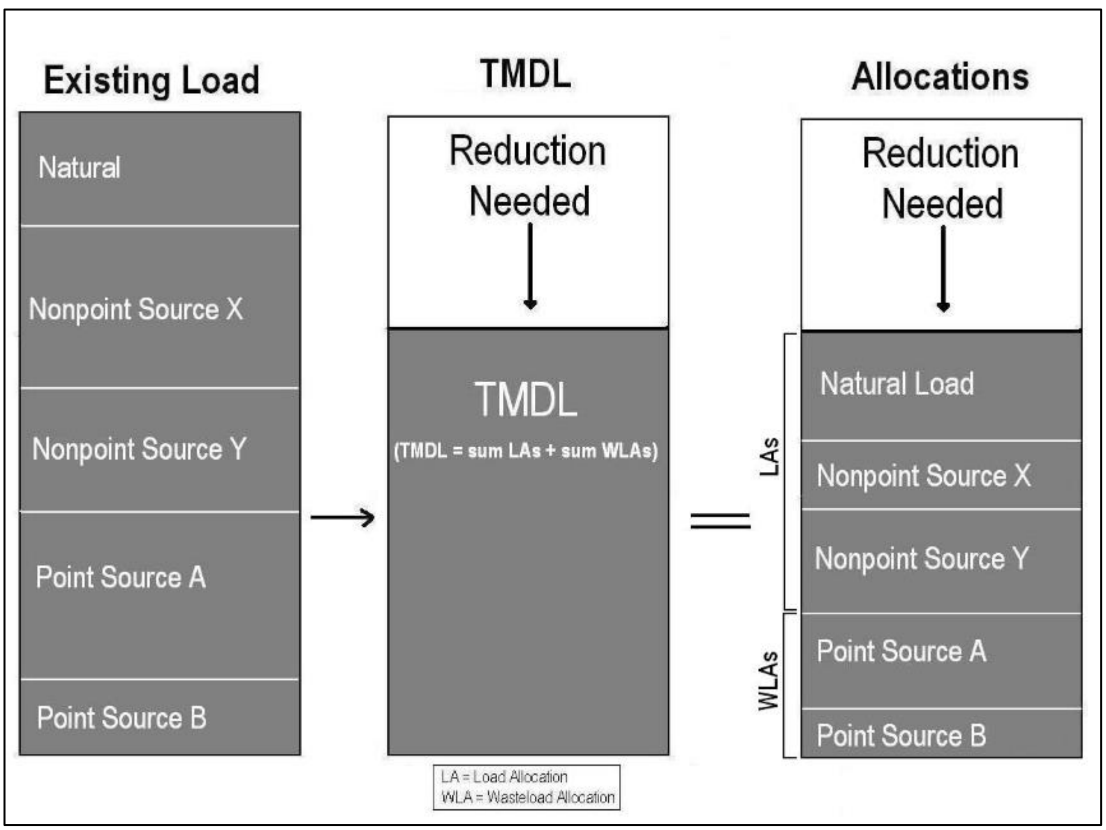

Figure 4.2: Schematic Diagram of a TMDL and its Allocations

4.5 IMPLEMENTING TMDL ALLOCATIONS

Montana law (Section 75-5-703, MCA of the Montana Water Quality Act) requires that wasteload allocations be incorporated into appropriate discharge permits, thereby providing a regulatory mechanism to achieve load reductions from point sources. Per federal regulation (40 CFR 122.44), the discharge permit effluent limits must be consistent with the assumptions and requirements of the available WLA developed within the TMDL.

Because of limited state and federal regulatory requirements, nonpoint source reductions linked to LAs are implemented primarily through voluntary measures, although there are some important nonpoint source regulatory requirements, such as Montana streamside management zone law and applicable septic system requirements.

This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 9.0** provides a water quality improvement plan that discusses restoration strategies by pollutant group and source category, and provides recommended BMPs per source category (e.g., grazing, cropland, urban, etc.). **Section 9.7** discusses potential funding sources that stakeholders can use to implement best management practices (BMPs) for nonpoint sources. Other site-specific pollutant sources are discussed throughout the document, and can be used to target implementation activities. DEQ's 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 (DEQ 2017) 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 10.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute (Section 75-5-703, MCA of the Montana Water Quality Act). TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

PART 2
TMDL COMPONENTS

5.0 SEDIMENT TMDL COMPONENTS

This portion of the document focuses on sediment as a cause of water quality impairment in the Madison Total Maximum Daily Load (TMDL) Planning Area (TPA). It describes: (1) how excess sediment impairs beneficial uses, (2) the affected stream segments, (3) the currently available data pertaining to sediment impairments in the planning area, (4) the sources of sediment, based on recent studies, and (5) the sediment TMDLs and their rationales.

5.1 EFFECTS OF EXCESS SEDIMENT ON BENEFICIAL USES

Sediment is a naturally occurring component of healthy and stable stream and lake ecosystems. Regular flooding allows sediment deposition to build floodplain soils and point bars, and it prevents excess scour of the stream channel (Knighton 1998). Riparian and wetland vegetation and natural instream barriers such as large woody debris, beaver dams, or overhanging vegetation help trap sediment and build channel and floodplain features. When these barriers are absent or excessive sediment enters the system from increased bank erosion or other sources, it may alter channel form and function and affect fish and other aquatic life by increasing turbidity and causing excess sediment to accumulate in critical aquatic habitat areas (Suttle et al. 2004, Sullivan et al. 2010)

Specifically, sediment may block light and cause a decline in plant and algal growth, and it may also interfere with fish and macroinvertebrate survival and reproduction. Fine sediment deposition reduces availability of suitable spawning habitat for salmonid fishes, such as trout, and can smother eggs or fry (Bowerman et al. 2014). Effects from excess sediment are not limited to suspended or fine sediment; an accumulation of larger sediment (e.g., cobbles) can fill pools, reduce the percentage of desirable particle sizes for fish spawning, and cause channel over-widening (which may lead to additional sediment loading and/or increased temperatures). This larger sediment can also reduce or eliminate flow in some stream reaches when it is deposited in excess within the channel, causing flow to go subsurface (May and Lee, 2004). Although fish and aquatic life are typically the most sensitive beneficial uses regarding sediment, excess sediment may also affect other uses. For example, high concentrations of suspended sediment in streams can cause water to appear murky and discolored, negatively impacting recreational use, and can increase filtration costs for water treatment facilities that provide safe drinking water.

5.2 SEDIMENT TMDL STREAM SEGMENTS

Based on the comparison of existing conditions to water quality targets, DEQ developed 13 sediment TMDLs in the Madison TPA (**Table 5-1**)**:** Antelope, Bear, Blaine Spring, Cherry, Elk, Hot Springs, Moore, North Meadow, Red Canyon, Ruby, South Meadow, Watkins, and Wigwam creeks (**Figure 5-1**). For a complete list of streams evaluated for sediment and details of the DEQ 2013-2014 sampling effort, see **Appendix B**. Habitat alterations are non-pollutant impairment causes commonly associated with sediment impairment. TMDLs are limited to pollutants, but implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some non-pollutant impairments (further discussed in **Section 8.0**).

Table 5-1. Sediment TMDL Development Summary

Waterbody (Assessment Unit)	Assessment Unit ID
Antelope Creek	MT41F004_140
Bear Creek	MT41F004_021

Table 5-1. Sediment TMDL Development Summary

Waterbody (Assessment Unit)	**Assessment Unit ID**
Blaine Spring Creek	MT41F004_010
Cherry Creek	MT41F002_010
Elk Creek	MT41F002_020
Hot Springs Creek	MT41F002_030
Moore Creek	MT41F004_130
North Meadow Creek	MT41F004_060
Red Canyon Creek	MT41F006_020
Ruby Creek	MT41F004_080
South Meadow Creek	MT41F004_070
Watkins Creek	MT41F006_030
Wigwam Creek	MT41F004_160

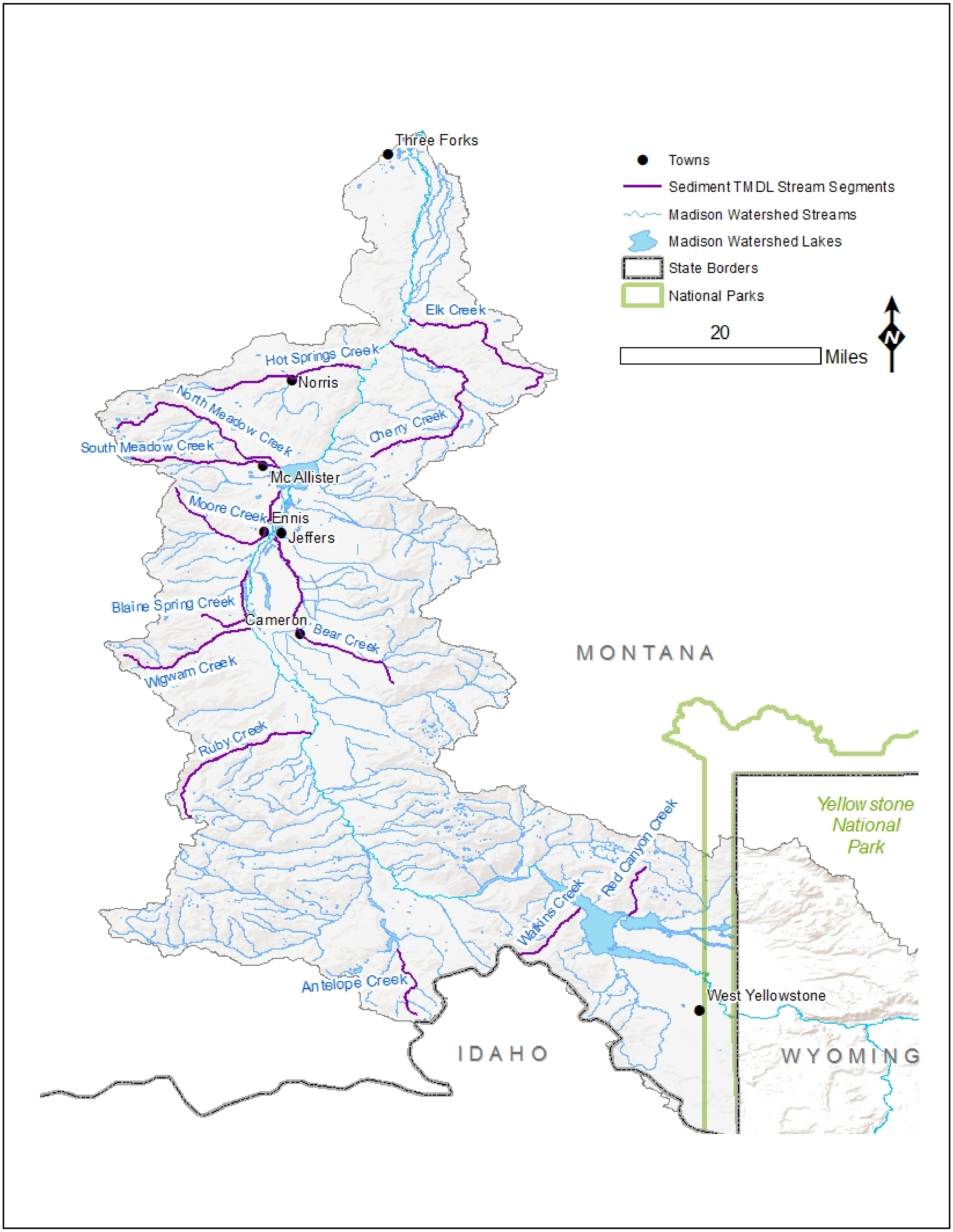

Figure 5-1. Sediment TMDL Stream Segments in the Madison TMDL Planning Area

5.3 Information Sources and Assessment Methods

Sediment TMDL development involves a review of available sediment and habitat data and field investigations to characterize overall stream health conditions and also quantify sources of sediment loading. DEQ compiled available sediment data and performed additional field investigations during 2013 and 2014. The data sources listed below were used to characterize water quality and/or develop TMDL targets. Summarized field data can be found in **Appendix B**.

- DEQ Assessment Files (cwaic.mt.gov)
- DEQ Sediment and Habitat Assessment Field Data (DEQ 2013, 2014)
- DEQ Bank Erosion Hazard Index and Greenline Field Data (DEQ 2015)
- DEQ Unpaved Road Sediment Assessment (DEQ 2014)
- U.S. Forest Service Pacfish/Infish Biological Opinion (PIBO) Program Data
- DEQ reference site data
- Other data and reports

5.4 Water Quality Targets and Target Development Rationale

The concept of water quality targets is presented in **Section 4.1**. This section provides the rationale for each sediment-related target parameter and discusses the basis of the target values. In developing targets, natural variation within and among streams must be considered. As discussed in more detail in **Appendix A**, DEQ uses the reference condition to gage natural variability and assess the effects of pollutants with narrative standards, such as sediment. The preferred approach to establishing the reference condition is using reference site data; however, modeling, professional judgment, and literature values may also be used. Although sediment water quality targets typically relate most directly to the aquatic life beneficial use, the targets are intended to protect all designated beneficial uses because they are based on the reference approach, which strives for the highest achievable quality condition.

The basis for each water quality target value varies depending on the availability of reference data. As discussed in **Appendix A**, there are several statistical approaches DEQ uses for target development. They include using percentiles of reference data or of the entire sample dataset, if reference data are limited. Although the basis for target values may differ by parameter, the goal is to define achievable sediment conditions that represent a translation of the narrative sediment standards.

5.4.1 Targets Summary

Consistent with EPA guidance for sediment TMDLs (U.S. Environmental Protection Agency, 1999), water quality targets for the Madison TMDL Planning Area include a suite of measurements of instream siltation, channel form, and habitat characteristics that contribute to loading, storage, and transport of sediment, or that demonstrate those effects. Water quality targets most closely linked to sediment accumulation or sediment-related effects to aquatic life habitat are given the most weight (i.e., fine sediment indices).

Sediment-related water quality targets for the Madison TPA are summarized in **Table 5-2** and described in detail in the sections that follow. These targets are based on reference site data discussed in **Section 5.4.2**. All statistical analyses were conducted on average values for each sample location and not on all site records, to avoid any single site or subset of sites having undue influence on the larger analysis.

For all water quality targets, future surveys should document stable (if meeting criterion) or improving trends. The exceedance of one or more target values does not necessarily equate to a determination that the information suggests impairment; the relative magnitude to which one or more targets are exceeded is taken into account, as well as the existing 303(d) listing status for sediment. The combination of target analysis, qualitative observations, and sound, scientific professional judgment is crucial when assessing stream condition. Site-specific conditions such as recent wildfires, changes in beaver activity, flow variability, or other natural long term or episodic events within a watershed may warrant the selection of unique indicator values that differ from those presented below, or alternate interpretation of the data relative to the sediment target values.

Target parameters and values are based on the current best available information but will be assessed during future TMDL reviews for their applicability and may be modified if new information provides a better understanding of reference conditions or if assessment metrics or field protocols are modified.

Table 5-2. Sediment targets for the Madison TMDL Planning Area

Parameter Type	Target Description	Criterion applicable to:	Target
Fine Sediment	Percentage of surface fine sediment < 6 mm in riffles via pebble count (site value) (1)	Channel slope ≤ 2% (excludes E channels)	≤ 19%
		Channel slope > 2%	≤ 16%
		Rosgen E channels	≤ 37%
	Percentage of surface fine sediment < 2mm in riffles via pebble count (site value) (1)	Channel slope ≤ 2% (excludes E channels)	≤ 17%
		Channel slope > 2%	≤ 12%
		Rosgen E channels	≤ 28%
	Percentage of fine surface sediment < 6mm in pool tails via grid toss (site average) (1)	Channel slope ≤ 2% (excludes E channels)	≤ 15%
		Channel slope > 2%	≤ 13%
		Rosgen E channels	≤ 31%
Channel Form and Stability	Bankfull width/depth ratio (site average) (2)	< 15 ft bankfull width	≤ 11
		15 ft - 30 ft bankfull width	≤ 24
		> 30 ft bankfull width	≤ 30
	Entrenchment ratio (site average)	Rosgen A stream type	≤ 1.6
		Rosgen B stream type	≥ 1.2
		Rosgen C and E stream types	≥ 2.0
Instream Habitat	Residual pool depth (site average) (2)	< 15' bankfull width	≥ 0.7 ft
		15'-30' bankfull width	≥ 0.9 ft
		> 30' bankfull width	≥ 1.4 ft
	Pools/1000 ft (2)	< 15' bankfull width	≥ 16
		15'-30' bankfull width	≥ 4
		> 30' bankfull width	≥ 3

[1] Primary indicator used to determine sediment impairment (Kusnierz et al., 2013)
[2] Primary indicator used to determine habitat impairment (Kusnierz et al., 2013)

5.4.2 Target Development Rationale

Targets were developed using a statistical approach consistent with **Appendix A**, and consistent with Montana's water quality standard for sediment as described in **Section 3.2** since targets must represent naturally occurring conditions. Literature values are usually taken into consideration during target development, however naturally occurring fine sediment conditions in the Madison trend higher than the low-end limits shown in the literature values below.

5.4.2.1 Percent Fine Sediment < 6mm and < 2mm in Riffles via Pebble Count

Bryce, et al. (2010) evaluated the effect of surface fine sediment (via reach transect pebble counts) on fish and macroinvertebrates and found that the minimum effect level for sediment < 2mm is 13% for fish and 10% for macroinvertebrates. Surface fine sediment measured in riffles by a modified Wolman pebble count (Wolman, 1954) describes the particle size distribution within riffles and is an indicator of aquatic habitat condition that can point to excessive sediment loading. Pebble counts by DEQ at reference sites and at stream assessment sites in the Madison TMDL Planning Area were conducted in four riffles per sampling site for a total of at least 400 particles.

The PIBO pebble count data are a composite of riffle and pool particles and are not directly relatable to DEQ methods. The PIBO method of collection typically results in a higher percentage of fines than a riffle pebble count. For this reason, the DEQ Middle Rockies reference dataset was used. Targets for fine sediment < 6mm and < 2mm are set at less than or equal to the 75th percentile of the DEQ Middle Rockies reference dataset for those parameters (**Tables 5-3** and **5-4**). Values are sorted by slope, as high gradient reaches are typically "transport" reaches, or those reaches where slope and velocity are conducive to the movement of sediment through a system, and low gradient reaches tend to deposit sediment on the stream bottom. As a result, it is expected that transport reaches will have less percent surface fines than low gradient reaches and thus targets are split into ≤ 2% and > 2% slope categories. Due to the low slope and high sinuosity of Rosgen E channels, fine sediment is readily stored, and they tend to have a higher percentage of fines than other channel types. Because of this inherent difference, Rosgen E channels were examined separately. As the DEQ reference dataset included only a single site that exhibited an E type channel (M01PRICC01), and the DEQ Madison TPA data for E channels consisted of sites with sediment sources and high fines values, the 10th percentile of the DEQ Madison TPA dataset and data from the single DEQ reference site was used to set the targets (**Tables 5-3** and **5-4**). Target values should be compared to the overall site value from the individual pebble counts.

Table 5-3. DEQ data summary for reference sites and Madison TPA assessment sites for percent fine sediment < 6 mm. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
DEQ reference data – Channel Slope ≤ 2% (excludes E channels)	3	0.3	8.7	29.1	**19**[a]
DEQ reference data – Channel Slope > 2%	12	0.5	13.0	20.5	**16**[a]
DEQ reference data and DEQ Madison TPA data (E channels only)	7	20.8	51.3	95.8	**37**[b]

[a] 75th percentile of the dataset
[b] 10th percentile of the dataset

Table 5-4. DEQ data summary for reference sites and Madison TPA assessment sites for percent fine sediment < 2 mm. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
DEQ reference data – Channel Slope ≤ 2% (excludes E channels)	3	0.3	7.4	27.1	**17**[a]
DEQ reference data – Channel Slope > 2%	12	0.5	11.1	18.5	**12**[a]
DEQ reference data and DEQ Madison TPA data (E channels only)	7	15.9	43.3	89.7	**28**[b]

[a] 75th percentile of the dataset
[b] 10th percentile of the dataset

5.4.2.2 Percent Fine Sediment < 6mm in Pool Tails via Grid Toss

Grid toss measurements in pool tails assess the level of fine sediment accumulation in macroinvertebrate habitat and potential fish spawning sites. Three tosses of a 49-point grid (Kramer, et al., 1993) were used to estimate the percent surface fine sediment < 6mm in in each pool tail in the Madison TPA. The percent fines < 6mm value in each pool tail were averaged to yield a site value. For the PIBO reference data, the value for each site was averaged across all site visits. The targets for percent fine sediment < 6mm in pool tails are set at less than or equal to the 75th percentile of the combined DEQ and PIBO Middle Rockies reference datasets for all streams except E channels (**Table 5-5**). Similar to the riffle fines targets, pool tail targets were split into ≤ 2% and > 2% slope categories. It should be noted that PIBO does not assign a Rosgen stream type to their sample sites, and the PIBO reference dataset may include some E channels. Due to an inherently high percentage of fines typical in Rosgen Type E channels, E channel values were examined separately. As with the percent fines in riffles, the 10th percentile of the DEQ Madison TPA and single reference site data was used to set the target for fine sediment in pool tails for E channels (**Table 5-5**). Target values should be compared to the site average value.

Table 5-5. Data summary for PIBO reference sites and Madison TPA assessment sites for percent fine sediment < 6mm via grid toss in pool tails. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
DEQ and PIBO reference data – Channel Slope ≤ 2% (excludes E channels)	27	1.3	8.8	90.3	**15**[a]
DEQ and PIBO reference data – Channel Slope > 2%	30	0.5	6.5	95.8	**13**[a]
DEQ reference data and DEQ Madison TPA data (E channels only)	7	10.1	57.7	98.6	**31**[b]

[a] 75th percentile of the dataset
[b] 10th percentile of the dataset

5.4.2.3 Width/Depth Ratio

There is reference riffle width/depth ratio data for both the DEQ and PIBO datasets and the two were combined to develop the targets. Statistical analyses determined that bankfull width was the best way to categorize width/depth ratio, given that PIBO does not assign a Rosgen stream type. The target values for width/depth ratio are based on the 75th percentile of the combined DEQ and PIBO Middle Rockies reference datasets and are defined by bankfull width category (**Table 5-6**). Values greater than the target represent an over widening of the channel.

Table 5-6. Data summary for DEQ and PIBO Middle Rockies reference sites for width/depth ratios. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
< 15 ft bankfull width	17	6.4	10.6	14.9	**11**
15 - 30 ft bankfull width	34	14.2	20.1	43.4	**24**
> 30 ft bankfull width	5	25.5	29.1	34.4	**30**

5.4.2.4 Entrenchment Ratio

The entrenchment ratio is an index value used to describe the degree of vertical containment of a river channel. It is measured as the width of the floodprone area at an elevation twice bankfull depth, divided by the bankfull width. Delineative criteria based on Rosgen stream type classification for entrenchment gives guidance of < 1.6 for A, F and G streams, 1.2-2.4 for B streams, and > 2.0 for C, E streams (Rosgen, 1996). These literature values will serve as the basis for the entrenchment ratio targets in the Madison TPA **(Table 5-7)**.

Table 5-7. Entrenchment targets for the Madison TMDL Planning Area

Rosgen Stream Type	Target Value
A	**≤ 1.6**
B	**≥ 1.2**
C, E	**≥ 2.0**

5.4.2.5 Instream Habitat Measures

For all instream habitat measures (i.e., residual pool depth and pool frequency), there is available reference data from DEQ and PIBO. All the instream habitat measures are important indicators of sediment input and movement as well as fish and aquatic life support, but they may be given less weight in the target evaluation if they do not seem to be directly related to sediment impacts. The use of instream habitat measures in evaluating or characterizing sediment impairment needs to be considered from the perspective of whether these measures are linked to fine, coarse, or total sediment loading.

Residual Pool Depth

The residual pool depth is the difference in the maximum depth of a pool and the pool crest depth, which is the depth at the downstream end of the pool before it becomes a riffle. The definition of pools for the PIBO protocol is similar to the definition used for DEQ site assessment data collection; both define a pool as having its maximum depth greater than or equal to 1.5 times the pool tail crest depth. However, the PIBO protocol only counts pools greater than half the wetted channel width whereas some DEQ pool data collected prior to 2013 was collected following the PIBO protocol and data collected during 2013 and 2014 counted all pools encountered. As a result, the DEQ dataset could potentially have a greater pool frequency and more pools with a smaller residual pool depth. When comparing the two datasets, however, there is little difference in residual pool depth (**Table 5-8**). As a result, the two were combined to develop the residual pool depth target.

Table 5-8. Residual pool depth and pool count comparisons between the DEQ and PIBO reference datasets

Dataset	Residual Pool Depth 25th Percentile (feet)			Pools/1000 feet 25th Percentile		
	< 15 ft bankfull width	15 - 30 ft bankfull width	> 30 ft bankfull width	< 15 ft bankfull width	15 - 30 ft bankfull width	> 30 ft bankfull width
DEQ Reference	0.7	0.9	1.3	25.8	12.0	3.9
PIBO Reference	0.7	0.9	1.6	11.2	3.9	3.9

Because the targets for residual pool depth and pool frequency are minimum values (i.e., larger values represent a preferred condition), the targets were based on the 25th percentile of the combined DEQ and PIBO reference datasets (**Table 5-9**). Target comparisons should be based on the reach average residual pool depth value. Because residual pool depths may indicate if excess sediment is limiting pool habitat, this parameter will be particularly valuable for future trend analysis using the data collected in 2013 and 2014 as a baseline. Future monitoring should document an improving trend (i.e., deeper pools) at sites which fail to meet the target criteria.

Table 5-9. Data summary for DEQ and PIBO Middle Rockies reference sites for residual pool depth. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
< 15 ft bankfull width	18	0.3	1.0	3.8	**0.7**
15 - 30 ft bankfull width	35	0	1.3	2.1	**0.9**
> 30 ft bankfull width	6	1.1	1.6	2.1	**1.4**

Pool Frequency

Pool frequency is the number of measured pools per site and scaled to frequency per 1,000 feet of stream reach. As mentioned in the previous section, methods for identification of pools between the DEQ and PIBO datasets differed because PIBO only counts pools greater than 1.5 times the wetted width. However, when all pools were counted regardless of size, the majority were greater than one half the wetted channel width. As a result, the two datasets were combined and the 25th percentile was used to develop the pool frequency targets (**Table 5-10**), A higher frequency value represents a preferred condition.

Table 5-10. Data summary for PIBO reference sites and Madison TPA assessment sites for pools/1,000 feet. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
< 15 ft bankfull width	18	2.4	26.3	66.5	**16**

Table 5-10. Data summary for PIBO reference sites and Madison TPA assessment sites for pools/1,000 feet. Targets are shown in **bold**

Data Source	Sample Size	Minimum	Median	Maximum	Target
15 - 30 ft bankfull width	36	0	9.4	54.3	**4**
> 30 ft bankfull width	6	2.5	5.6	11.2	**3**

5.4.2.6 Periphyton

Periphyton are microscopic algae that attach or cling to plants and other objects in the stream. DEQ collects periphyton from rocks, sediment, and submerged branches in the summer or fall according to the Periphyton Standard Operating Procedure (DEQ 2011). Within periphyton samples, diatoms are single celled algae, that increase or decrease in response to stress. The diatom assemblage from periphyton samples was used in conjunction with habitat measures to support a listing of impairment. The probability of impairment increased as the presence of sediment increaser taxa increased. "Sediment increaser taxa" are those diatom taxa that have been found to increase with increasing likelihood of sediment impairment (Teply and Bahls 2007).

5.4.3 Existing Condition and Comparison to Water Quality Targets

This section presents summaries and evaluations of relevant water quality data for Madison TPA waterbodies assessed for sediment and found to be impaired. Summaries for streams investigated for sediment and habitat that were not determined to be impaired for sediment can be found in **Appendix B**. The weight-of-evidence approach using a suite of water quality targets, described in **Section 4.1**, has been applied to each waterbody evaluated. Data presented in this section comes primarily from sediment, habitat, BEHI (Bank Erosion Hazard Index), and greenline data collection performed by DEQ during summer 2013 and 2014. Results of the 2013 and 2014 data collection are supported by additional data in the DEQ Assessment Files, DEQ reference data, and PIBO managed site data (versus reference which was used for target development). However, this section is not intended to provide an exhaustive review of all available data.

5.4.3.1 Antelope Creek (MT41F004_140)

Antelope Creek (MT41F004_140) is listed for sedimentation-siltation on the 2018 303(d) List. This segment is also listed for alteration in streamside or littoral vegetative covers which is a non-pollutant listing that can often be linked to sediment impairment. The segment flows 9.48 miles from the headwaters to the mouth at Cliff Lake, through metamorphic and volcanic geology and a shrub/scrub landscape with smaller areas of evergreen forest. The channel goes dry as a result of diversions in the Antelope Basin. Groundwater returns restore flow in the lower portion above Cliff Lake.

Physical Condition and Sediment Sources

In 2014 DEQ collected sediment and habitat data from two sites on Antelope Creek: ALTP 04-02 and ALTP 10-01 (**Appendix B**; Figure B-1**)**. ALTP 04-02 was the upstream site in this segment and was located in a grazed riparian setting (DEQ 2014; **Figure 5-2**). Vegetation consisted of about 44% sedges/rushes, 16% grasses/forbs, and 20% shrubs/trees (DEQ 2015). Grazing was apparent with disturbed bare ground and hummocking observed at 20% and 38% of the site, respectively. Most streambanks were unstable and consisted primarily of fine gravel (10-40%) and sand/clay (50-80%) with only about 10-20% being coarse gravel or larger sediment (DEQ 2015). About 88% of the site length had eroding banks with the majority being attributed to riparian grazing (84%) and the remainder being due to natural processes.

Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 51.4% that the assemblage represented a stream impaired by sediment.

Figure 5-2. Evidence of cattle use including pugging, hoof shear, and eroding banks at ALTP 04-02

ALTP 10-1 was located about 5 miles downstream of ALTP 04-02, downstream of a dry reach of Antelope Creek that is grazed by cattle (DEQ 2014). The site was well vegetated with willows, sedges, and native forbs and grasses with about 91% of the vegetation being grasses/forbs and 7% being shrubs/trees (DEQ 2014, 2015). Although cattle were observed upstream of the site, they appeared to have been fenced out; 1% of the site was disturbed bare ground. Most of the land use impacts at this site (i.e., trails, lack of woody vegetation) appeared historical. Streambanks were generally stable and were composed primarily of fine gravel (0-45%) and sand/clay (45-85%) with about 5-30% being coarse gravel or larger sediment (DEQ 2015). About 11% of the site length had eroding banks with 96% being attributed to natural processes and the remainder to a livestock crossing. Nine linear feet of bank erosion within the site were the result of a cattle crossing.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Antelope Creek are summarized in **Table 5-11**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, one site fails to meet the targets for riffle pebble count < 6 mm and < 2 mm. W/D ratio and residual pool depth each failed to meet the target values at one (different) site. These results indicate that while the channel appears stable, there potentially is excess fine sediment moving through the system.

Table 5-11. Existing sediment-related data for Antelope Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
ALTP 04-02	2014	11.9	1.2	C	**29**	**19**	13	**13.5**	7.5	0.8	32.4
ALTP 10-01	2014	18.1	0.7	C	19	15	4	19.7	2.2	**0.5**	19.2

Summary
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that while the lower site appears to be managed appropriately, grazing in riparian areas contributes excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from this source. The existing listings for Antelope Creek are supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, failure of both riffle targets at the upper site, the observed lack of woody vegetation at both sites, and the excessive bare ground and eroding banks at the upper site.

5.4.3.2 Bear Creek (MT41F004_021)
Bear Creek (MT41F004_021) is listed for sedimentation-siltation on the 2018 303(d) List. The segment impaired segment flows 27.3 miles from the headwaters to the mouth at O’Dell Spring Creek through sedimentary geology and a grass-dominated landscape with willows and sedges growing in riparian areas.

Physical Condition and Sediment Sources
In 2014 DEQ collected sediment and habitat data from two sites on Bear Creek: BEAR 09-03 and BEAR 10-01 (**Appendix B**; Figure B-2). BEAR 09-03 was the upstream site in this segment and was located in a grazed riparian setting (DEQ 2014). The site was vegetated with sedges and some willows with about 73% of the vegetation being sedges/rushes, 24% grasses/forbs, and 3% being shrubs/trees (DEQ 2014, 2015). Grazing was pervasive with hummocking observed at 100% of the site. Most streambanks were unstable but were lined with sedges and would stabilize given the time to recover. Banks were composed entirely of sand/clay (DEQ 2015). About 15% of the site length had eroding banks with 94% being attributed to riparian grazing and the remainder being due to natural processes. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 60.4% that the assemblage represented a stream impaired by sediment.

BEAR 10-01 was located about 2 miles downstream of BEAR 09-03 and was located in a reach that appears to have been heavily grazed in the past but was recovering (DEQ 2014). The site was vegetated with willows, sedges, cattails, and bulrush with about 72% of the vegetation being sedges/rushes, 23% grasses/forbs, and 5% being shrubs/trees (DEQ 2014, 2015). Non-native thistle and mustard species were present in upland areas. No disturbed bare ground was observed, but 38% of the site had hummocking. (**Figure 5-3**). Most of the land use impacts at this site appeared to be either historical (i.e., lack of woody vegetation, eroding banks, hummocking) or from upstream grazing (i.e., high fine sediment). Streambanks were generally stable at the site and were composed primarily of fine gravel (0-20%) and sand/clay (75-100%) with only a small amount (0-15%) being coarse gravel or larger sediment (DEQ 2015). About 18% of the site length had eroding banks with about half (52%) being attributed to natural processes and the remainder being from riparian grazing. Many fish were observed at this site. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. Based on this data, a 45.8% probability existed that the sample collected at BEAR 10-01 represented a site impaired by sediment. One diatom sample collected at the site yielded a probability of 45.8% that the assemblage represented a stream impaired by sediment.

Figure 5-3. An example of hummocking on Bear Creek

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Bear Creek are summarized in **Table 5-12**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm and pool tail fines. In addition, BEAR 09-03 fails to meet the targets for residual pool depth and pool frequency. These results indicate that while the channel form is meeting the targets, there is an excess amount of fine sediment and the sediment loading is likely having a negative impact on pool depth and frequency.

Table 5-12. Existing sediment-related data for Bear Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
BEAR 09-03	2014	14.9	0.5	E	**91**	**90**	**58**	10	2.5	**0.4**	**9.8**
BEAR 10-01	2014	20.8	0.2	C	**50**	**47**	**56**	18.2	2.2	1.1	5.8

Summary
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that cattle grazing is contributing excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for Bear Creek is supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, and the failures of instream data to the targets.

5.4.3.3 Blaine Spring Creek (MT41F004_010)
Blaine Spring Creek (MT41F004_010) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 4.95 miles from the headwaters to the mouth at the Madison River through sedimentary geology and a grass-dominated landscape with willows and sedges growing in riparian areas. Ennis National Fish Hatchery, operated by the U.S. Fish and Wildlife Service is located near the headwaters of Blaine Spring Creek.

Physical Condition and Sediment Sources
In 2014 DEQ collected sediment and habitat data from two sites on Blaine Spring Creek: BLNS 04-01 and BLNS 06-01 (**Appendix B**; Figure B-2**)**. BLNS 04-01 was the upstream site in this segment (DEQ 2014). Willows, juniper, gooseberry, sedges, and grass were observed at the site with vegetation consisting of about 3% sedges/rushes, 65% grasses/forbs, and 30% shrubs/trees (DEQ 2014, 2015). There was little evidence of grazing with disturbed bare ground observed at 2% of the site and no hummocking. Most streambanks appeared stable and consisted of 10-40% fine gravel, 20-70% sand/clay, and 15-80% coarse gravel or larger sediment (DEQ 2015). About 35% of the site length had eroding banks with 75% being attributed to natural processes, 24% to historical grazing, and the remainder being from diversion of stream energy via structures.

BLNS 06-01 was located about 2.5 miles downstream of BLNS 04-01 in an area fenced to exclude cattle from grazing (DEQ 2014). The site was well vegetated with willows, sedges, and grasses on high banks with about 17% of the vegetation being sedges/rushes, 78% grasses/forbs, and 5% being shrubs/trees (DEQ 2014, 2015; **Figure 5-4**). No disturbed bare ground was observed with 12% of the site having hummocking. Most of the land use impacts at this site appeared to be from past grazing. Streambanks were generally stable at the site and were composed primarily of sand/clay (50-90%) with a smaller amount of fine gravel (5-20%) and coarse gravel or larger sediment (0-30%) (DEQ 2015). About 63% of the site length had eroding banks with about 76% being attributed to natural processes and the remainder being from riparian grazing. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 23.5% that the assemblage represented a stream impaired by sediment.

Figure 5-4. Riparian vegetation conditions at BLNS 06-01
Note the vegetation present to the waterline and lack of exposed banks

In addition to the DEQ data collection, the Madison Conservation District collected pebble counts from three sites on Blaine Spring Creek in July 2014; percent fines < 2 mm were 0%, 4%, and 25% (Madison Conservation District 2014).

Comparison to Water Quality Targets
The existing physical data in comparison with the targets for Blaine Spring Creek are summarized in **Table 5-13**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, the upper site fails to meet the targets for riffle pebble count < 6 mm and < 2 mm. With regards to the channel form and instream habitat variables, one site fails to meet the target for entrenchments while the other site fails to meet the target for residual pool depth. These results indicate that while the channel form and instream habitat are generally meeting the targets, there is an excess amount of fine sediment in the upper portion of Blaine Spring Creek.

Table 5-13. Existing sediment-related data for Blaine Spring Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
BLNS 04-01	2014	16.8	2.2	B	**25**	**19**	4	11.5	2.4	**0.7**	11.4
BLNS 06-01	2014	26.7	0.8	C	12	11	2	17.4	**1.6**	1.4	7.6

Summary
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that while the lower site appears to be managed appropriately, historical grazing in riparian areas contributes excess fine sediment to the segment and that restoration and continued implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for Blaine Spring Creek is supported based on current and past land management practices that are contributing human sources of sediment, human-caused erosion observed, and failure of both riffle targets at the upper site.

5.4.3.4 Cherry Creek (MT41F002_010)
Cherry Creek (MT41F002_010) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 24 miles from the headwaters to the mouth at the Madison River through sedimentary geology and a shrub/scrub landscape with pockets of grasses and willows and sedges growing in the riparian areas. Cherry Creek was the location of a westslope cutthroat restoration project that re-established the species in 60 miles of the drainage (Wilkinson 2012).

Physical Condition and Sediment Sources
In 2014 DEQ collected sediment and habitat data from two sites on Cherry Creek: CHRR 18-02 and CHRR 20-01 (**Appendix B**; Figure B-2**)**. CHRR 18-02 was the upstream site in this segment and had evidence of channel restoration (rock placed on an outside meander, recently planted cottonwood and aspen; DEQ 2014). The site was well vegetated with rushes, grasses, and willows with about 9% of the vegetation being sedges/rushes, 89% grasses/forbs and 2% being shrubs/trees (DEQ 2014, 2015). No disturbed bare ground or hummocking was observed at the site. Streambanks were composed primarily of sand/clay (40-50%) and fine gravel (40%) with a lesser amount of coarse gravel or larger sediment (10-20%) (DEQ 2015). About 58% of the site length had eroding banks with 64% being attributed to natural processes and the remainder being historical (riparian grazing). A layer of sand within the banks made them easily eroded (**Figure 5-5**). Fine sediment was observed along the channel margins and within pools resulting in reduced pool volume. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 23.4% that the assemblage represented a stream impaired by sediment. Despite this low value, physical data from this site indicated impairment.

Figure 5-5. Eroding bank displaying a layer of easily eroded sand

CHRR 20-01 was located about 4 miles downstream of CHRR 18-02 within an area fenced to exclude livestock (DEQ 2014). This site had stable banks and was well vegetated with sedges, willows, and grass with about 18.5% of the vegetation being sedges/rushes, 80.5% grasses/forbs, and 1% being shrubs/trees (DEQ, 2014 2015). No disturbed bare ground or hummocking was observed at the site. Streambanks were composed of 20-40% sand/clay, 20-40% fine gravel, and 20% coarse gravel or larger sediment (DEQ 2015). About 62% of the site length had eroding banks with 80% being attributed to natural processes and the remainder being historical (riparian grazing). Some pools were storing sediment resulting in decreased depth. The channel was storing silt, likely from an upstream source. Many small fish were observed at the site suggesting that the creek is a spawning and rearing tributary for the lower Madison River. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 20.1% that the assemblage represented a stream impaired by sediment. However, despite this low value, the impairment listing is supported by the physical fine sediment data.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Cherry Creek are summarized in **Table 5-14**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm and the upper site fails the target for pool tail fines. Entrenchment ratio at the lower site is the only other target that is not met. These results indicate that while channel form and instream habitat targets are generally being met, there is an excess amount of fine sediment.

Table 5-14. Existing sediment-related data for Cherry Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
CHRR 18-02	2014	30.5	0.5	C	**48**	**41**	**43**	18.5	3.1	2.5	6.5
CHRR 20-01	2014	33.1	0.6	C	**24**	**21**	7	21.2	**1.6**	1.5	7.5

Summary
Restoration work on Cherry Creek has included replacing culverts with bridges and planting vegetation in riparian areas (Madison Conservation District 2015). Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that historical grazing practices are contributing excess fine sediment to the segment and that continued implementation of best management practices and additional restoration activities will reduce sediment input from these sources. The stream appears to be in recovery and it is likely that if the existing land management practices continue to be implemented, conditions will improve in Cherry Creek. The sedimentation-siltation listing for Cherry Creek is supported based on the historical load of fine sediment that remains within Cherry Creek, the existing loading caused by historical land use practices, and the failures of instream sediment targets.

5.4.3.5 Elk Creek (MT41F002_020)

Elk Creek (MT41F002_020) is listed for sedimentation-siltation on the 2018 303(d) List. In addition, this segment is listed for alteration in streamside or littoral vegetative covers which is a non-pollutant listing that can often be linked to sediment impairment. The segment flows 18.33 miles from the headwaters to the mouth at the Madison River through sedimentary geology and a grass-dominated landscape with willows and sedges growing in riparian areas. Beaver activity is present in the middle to lower portions of the creek. This segment is also listed for turbidity. Given that excess sediment is contributing to this turbidity, any actions to reduce sediment would also reduce turbidity. Therefore, turbidity is also addressed by the sediment TMDL.

Physical Condition and Sediment Sources
In 2010, DEQ collected sediment and habitat data from one site and in 2013 from four sites on Elk Creek: M06ELKC07, ELKC 05-01, ELKC 06-02, ELKC 11-01 (**Appendix B**; Figure B-2). Descriptive vegetation information was available for three of these sites and bank erosion data were available for two. ELKC 05-01 was the second to most upstream site in this segment and was located in a historically grazed riparian setting (DEQ 2014). The site was vegetated with sedge, willow, and alder with about 16% of the vegetation being sedges/rushes, 78% grasses/forbs, and 3% being shrubs/trees (DEQ 2014, 2015). Cheatgrass and Canada thistle were present in upland areas. Past cattle use was evident by the presence of the noxious weeds. About 3% of the site consisted of disturbed bare ground and no hummocking was

observed. Streambanks were composed entirely of sand/clay (DEQ 2015). About 74% of the site length had eroding banks with 90% being attributed to natural processes and the remainder being from riparian grazing. There was relatively little sediment loading coming from within the site. Sample diatom counts from site ELKC 05-01 were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. A diatom sampled collected at the site yielded a probability of 72.7% that the assemblage represented a stream impaired by sediment. An additional sample collected in close proximity upstream (at M06ELKC07) yielded a probability of 81.5%.

ELKC 06-02 was located about 4.3 miles downstream of ELKC 05-01 in a heavily grazed setting (DEQ 2014). The site was vegetated with native riparian shrubs and invasive weeds (DEQ 2014). Cattle use was evident with extensive pugging and streambank sloughing observed. Pugging occurs when the hooves of grazing livestock penetrate the soil surface during wet conditions causing damage to pasture plants as well as soil structure. Pasture plants can be torn and buried. A layer of silt was overlying most of the stream channel. Two diatom samples collected at the site yielded probabilities of 45.3% and 52.5% that the assemblage represented a stream impaired by sediment.

ELKC 11-01 was located about 6.5 miles downstream of ELKC 06-02 in a dry channel resulting from irrigation diversion (DEQ 2014). The site was vegetated with grasses, sedges, willow, alder, Canada thistle, and houndstongue with about 7% of the vegetation being sedges/rushes, 88% grasses/forbs and 5% being shrubs/trees (DEQ 2014, 2015). There were no clear indicators of grazing at the site with no disturbed bare ground or hummocking observed. Streambanks were composed primarily of sand/clay (80-100%) and fine gravel (5-18%) with a lesser amount of coarse gravel or larger sediment (0-2%) (DEQ 2015). About 48% of the site length had eroding banks with 50% being attributed to natural processes and the remainder being historical riparian grazing. A layer of fine sediment covered the substrate throughout the site.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Elk Creek are summarized in **Table 5-15**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, all sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm and the target for pool tail fines. W/D ratio and entrenchment ratio each fail to meet their respective targets at one (different) site. Two sites fail to meet the target for residual pool depth. These results indicate that there is excessive fine sediment in Elk Creek. In addition, the failure of multiple channel form and instream habitat targets indicates that there are issues with habitat quality.

Table 5-15. Existing sediment-related data for Elk Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
MO6ELKC07 [1]	2013	7.5	2	E	**91**	**36**	**99**	9.4	2.5	**0.5**	52.7
ELKC 05-01	2013	5.6	1.3	E	**96**	**67**	**91**	7.9	8.1	**0.5**	30.8

Table 5-15. Existing sediment-related data for Elk Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
ELKC 06-02[2]	2010, 2013	13.6	1.7	C	**47**	**42**	**59**	**19.3**	3.0	0.9	26.1
ELKC 11-01	2013	7	1.7	C	**58**	**48**	-	9.0	**1.7**	-	18.9

[1]Located on the same stratified reach as ELKC 05-01
[2]Values are averages from one sampling event in 2010 and two in 2013 by different field crews

Summary and TMDL Development Determination
Data collected by DEQ in 2013 (DEQ 2013, 2015) indicate that riparian grazing (present and historical) is contributing excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from these sources. The existing listings for Elk Creek are supported based on the current land management practices that are contributing human sources of sediment, the human-caused erosion observed, the failures of instream sediment targets, and the observed poor riparian conditions.

5.4.3.6 Hot Springs Creek (MT41F002_030)
Hot Springs Creek (MT41F002_030) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 14 miles from the headwaters to the mouth at the Madison River through metamorphic, intrusive, and sedimentary geology and a grass and shrub/scrub landscape with pockets of evergreen forest and willows and sedges growing in the riparian areas.

Physical Condition and Sediment Sources
Sediment and habitat data were collected from Hot Springs Creek by DEQ at three sites in 2013: HOTS 05-01, HOTS 10-01, and HOTS 16-01 (**Appendix B**; Figure B-2). HOTS 05-01 was the upstream site in this segment, located in a grazed riparian setting (DEQ 2013). The site was vegetated with willow and alder with about 2% of the vegetation being sedges/rushes, 85% grasses/forbs, and 7% being shrubs/trees (DEQ 2013, 2015). Despite heaving grazing pressure in upland areas weeds were not observed. Disturbed bare ground and rock each made up 3% of the site with hummocking observed at 24% of the site. Streambanks overall appeared stable and were composed primarily of sand/clay (65-95%) with lesser amounts of fine gravel (5%) and coarse gravel or larger sediment (0-30%) (DEQ 2015). About 24% of the site length had eroding banks with 69% of this erosion being attributed to riparian grazing and the remainder being from natural processes. Sample diatom counts from site HOTS 05-01 were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 85.8% that the assemblage represented a stream impaired by sediment.

HOTS 10-01 was located about 4.6 miles downstream of HOTS 05-01 in a setting that appears to have been heavily grazed in the past (DEQ 2013). The site was thickly vegetated with grasses, willow, and alder with about 19% of the vegetation being sedges/rushes, 53% grasses/forbs, and 28% being shrubs/trees (DEQ 2013, 2015). Cattle use was evident with hummocking at 6% of the site; no disturbed bare ground or rock was observed. Streambanks were well-supported by grasses and shrubs and were composed primarily of sand/clay (80%) with lesser amounts of fine gravel (10%) and coarse gravel or larger sediment (10%) (DEQ 2015). About 21% of the site length had eroding banks with 57% being attributed to natural processes and the remainder being from riparian grazing.

HOTS 16-01 was located about 5.6 miles downstream of HOTS 10-01 in a site with vegetation consisting of about 40.5% sedges/rushes and 41.5% grasses/forbs (DEQ 2013, 2015). About 16% of the site was disturbed bare ground with rock comprising 2%; hummocking was not observed. Streambanks were composed primarily of sand/clay (40-100%) with lesser amounts of fine gravel (0-5%) and coarse gravel or larger sediment (0-60%) (DEQ 2015). About 28% of the site length had eroding banks with 46% being attributed to natural processes, about 39% being attributed to road crossings, and the remainder to historical sources (i.e., 2012 fire). One diatom sample collected at the site yielded a probability of 92.6% that the assemblage represented a stream impaired by sediment.

Evaluation of tributaries to Hot Springs Creek on grazing allotments by the BLM indicated that there are many sources of human-caused sediment loading and habitat disturbance in the watershed (BLM 2009). These sources included over widening of the stream, undersized culverts, mining waste, roads, and livestock-caused bank erosion. In addition, deep rooting vegetation and a middle age class of willows was absent while non-native and invasive plant species were present. Riparian conditions were judged to range from proper functioning condition to functioning at risk.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Hot Springs Creek are summarized in **Table 5-16**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, all three sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm and pool tail grid toss. All three sites also fail to meet the residual pool depth target. W/D ratio and pool frequency each fail at one (different) site. These results indicate that there is excess fine sediment loading to Hot Springs Creek and habitat quality is poor.

Table 5-16. Existing sediment-related data for Hot Springs Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
HOTS 05-01	2013	4.8	3.3	B	**76**	**63**	**65**	8	5.9	**0.2**	37.3
HOTS 10-01	2013	4.8	1.0	C	**95**	**68**	**67**	**11.2**	3.4	**0.5**	21
HOTS 16-01	2013	11.0	1.5	E	**47**	**42**	**68**	8.3	7	**0.6**	**15.4**

Summary

Data collected by DEQ in 2013 (DEQ 2013, 2015) indicate that riparian grazing and roads are contributing excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for Hot Springs Creek is supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, and the failures of instream data to the targets.

5.4.3.7 Moore Creek (MT41F004_130)

Moore Creek (MT41F004_130) is listed for sedimentation-siltation on the 2018 303(d) List. In addition, this segment is listed for alteration in streamside or littoral vegetative covers which is a non-pollutant listing that can often be linked to sediment impairment. The segment flows 15.83 miles from springs in the headwaters to the mouth at Fletcher Channel of the Madison River through metamorphic and sedimentary geology and a landscape composed of shrub/scrub and evergreen in the headwaters, grasses and shrub/scrub in the middle portion of the watershed, and grasses, hay/pasture, and riparian vegetation near the mouth.

Physical Condition and Sediment Sources

In 2008, 18,500 feet of Moore Creek near the confluence with the Madison River were restored via rechanneling the stream and about 400 acres of wetlands were improved (Madison Conservation District 2015). Since 2010, the Madison Stream Team has performed monitoring within this section of Moore Creek. As of May 2015, there were plans to install ½ mile of fencing on Moore Creek to limit livestock access to the stream.

In 2014 DEQ collected sediment and habitat data from two sites on Moore Creek: MOOR 09-01 and MOOR 09-04 (**Appendix B**; Figure B-2). MOOR 09-01 was the upstream site in this segment and was located in an area that has not been grazed by cattle in more than 5 years (DEQ 2014). The site was vegetated with reed canary grass, willow, alder, cottonwood, and mint but also had Canada thistle, tansy, and houndstongue with about 9% of the vegetation being sedges/rushes, 64% grasses/forbs, and 27% being shrubs/trees (DEQ 2014, 2015). Disturbed bare ground and hummocking were not observed at the site. Streambanks appeared to be in good condition, have recovered from past disturbance, and were primarily composed of sand/clay (70-85%) with lesser amounts of fine gravel (10-20%) and coarse gravel or larger sediment (0-20%) (DEQ 2015). About 53% of the site length had eroding banks with 54% being attributed to natural processes and the remainder being historical riparian grazing. A periphyton sample from the site yielded a 95% probability of the site having excess fine sediment. A layer of silt is covering the predominantly gravel substrate and areas of sandy/silty deposition were present (DEQ 2014). The site appears to be in recovery. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 95% that the assemblage represented a stream impaired by sediment.

MOOR 09-04 was located about 3.8 miles downstream of MOOR 09-01 in an area that appears to have been heavily grazed in the past (DEQ 2014). The site was vegetated with reed canary grass, sedges, native grasses, and Canada thistle with about 53% of the vegetation being sedges/rushes and 47% being grasses/forbs (DEQ 2014, 2015). The riparian area upstream of the site appeared to be heavily grazed pasture. Disturbed bare ground and hummocking were not observed at the site. Streambanks were supported by thick growth of sedges and reed canary and were composed of 100% sand/clay (DEQ 2015). About 62% of the site length had eroding banks with 60% being attributed to natural processes and the remainder being riparian grazing. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 42.3% that the assemblage represented a stream impaired by sediment.

In addition to the DEQ data collection, the Madison Conservation District collected pebble counts from three sites on Moore Creek in July 2014; percent fines < 2 mm were 18%, 45%, and 63% (Madison Conservation District 2014).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Moore Creek are summarized in **Table 5-17**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm and pool tail fines. In addition, both sites fail the residual pool depth targets and the targets for entrenchment ratio and pool frequency are each failed at one (different) site. These results indicate that while the channel form is generally meeting the targets, there is an excess amount of fine sediment and the sediment loading is likely having a negative impact on pool depth and frequency.

Table 5-17. Existing sediment-related data for Moore Creek relative to targets

Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
MOOR 09-01	2014	18.3	1.0	C	**58**	**50**	**51**	21.1	**1.8**	**0.5**	13.4
MOOR 09-04	2014	4.6	0.5	E	**51**	**45**	**45**	4.8	59.1	**0.6**	**6.5**

Summary

Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that historical and existing riparian grazing are contributing excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from these sources. The existing listings for Moore Creek are supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, the failures of instream data to the targets, and the lack of willows and many noxious weeds present.

5.4.3.8 North Meadow Creek (MT41F004_060)

North Meadow Creek (MT41F004_060) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 18.53 miles from the headwaters to the mouth at Ennis Lake through primarily sedimentary geology and a landscape composed of evergreen in the headwaters, evergreen, grasses, and shrub/scrub in the middle portion of the watershed, and grasses, hay/pasture, and riparian vegetation near the mouth.

Physical Condition and Sediment Sources

Sediment and habitat data were collected from North Meadow Creek at one site by PIBO in 2009 and 2014 and two sites by DEQ in 2014: 2699 (PIBO), NMDW 14-02, and NMDW 17-01 (**Appendix B**; Figure B-2). NMDW 14-02 was the upstream site visited by DEQ in this segment and located in a grazed riparian setting (DEQ 2014). The site was located within a pasture enclosure; grazing had occurred during the year of the visit and pugging was observed. Pugging occurs when the hooves of grazing livestock penetrate the soil surface during wet conditions causing damage to pasture plants as well as soil structure. Pasture plants can be torn and buried. Streambanks were eroding in areas throughout the site, typically in locations where willows were absent, and grazing had occurred up to the stream channel. The site was vegetated with sedges, grasses, and willow with about 31% of the vegetation being sedges/rushes, 39% grasses/forbs, and 25% being shrubs/tree cover (DEQ 2014, 2015). Disturbed bare ground and riprap each made up 4.5% and 0.5% of the site respectively; 4.4% of the site had hummocking. Banks were primarily composed of sand/clay (70-100%) with lesser amounts of fine gravel (0-10%), and coarse gravel or larger sediment (0-20%) (DEQ 2015). About 69% of the site length had eroding banks with 80% being attributed to riparian grazing and the remainder to natural processes. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 18.9% that the assemblage represented a stream impaired by sediment.

NMDW 17-01 was located about 5.2 miles downstream of NMDW 14-02. The site was well vegetated with willow, sedges, rushes, alder, cottonwood, and non-native grasses with about 3% of the vegetation being sedges/rushes, 93% grasses/forbs, and 4% being shrubs/trees (DEQ 2014, 2015). Disturbed bare ground and hummocking were not observed at the site. Streambanks appeared to be stable and were primarily composed of 20-90% sand/clay, 10-70% fine gravel, and 0-10% coarse gravel or larger sediment (DEQ 2015). About 48% of the site length had eroding banks with 69% being attributed to natural processes, 14% to historical channel manipulation, 12% to residential/urban development, and the remainder to a bridge where humans and animals access the stream. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 63% that the assemblage represented a stream impaired by sediment.

In addition to the DEQ data collection, the Madison Conservation District collected a pebble count from one site on North Meadow Creek in July 2014 near the mouth percent fines < 2 mm were 27% (Madison Conservation District 2014).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for North Meadow Creek are summarized in **Table 5-18**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, one DEQ site fails to meet the targets for riffle pebble count %< 6 mm and %< 2 mm. The other DEQ site failed to meet the target for riffle pebble count % < 6 mm. The PIBO site failed to meet the grid toss target of %< 6 mm. No other target failures were observed. These results indicate that while the channel form and instream habitat are meeting the targets, there is an excess amount of fine sediment in North Meadow Creek.

Table 5-18. Existing sediment-related data for North Meadow Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
2699 (PIBO)[1]	2009, 2014	27.9	0.45	*NC*	*NC*	*NC*	**25**	16.0	*NC*	1.8	10.6
NMDW 14-02	2014	18.9	1.6	C	**30**	**20**	7	16.3	2.4	1.1	13.2
NMDW 17-01	2014	18.5	0.8	C	**20**	17	14	11.3	2.3	1.2	8.9

[1] Values are averages from sampling events in 2009 and 2014
NC = not collected

Summary
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that riparian grazing, historical channel manipulation, and development are contributing excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for North Meadow Creek is supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, and the failures of instream data to the targets.

5.4.3.9 Red Canyon Creek (MT41F006_020)
Red Canyon Creek (MT41F006_020) is listed for sedimentation-siltation on the 2018 303(d) List. In addition, this segment is listed for alteration in streamside or littoral vegetative covers which is a non-pollutant listing that can often be linked to sediment impairment. The segment flows 6.27 miles from the headwaters to the mouth at Hebgen Lake through primarily sedimentary geology and an evergreen-dominated landscape interspersed with shrub/scrub vegetation.

Physical Condition and Sediment Sources
Sediment and habitat data were collected from Red Canyon Creek at one site by PIBO in 2006 and 2011 and three sites by DEQ in 2013: 1929 (PIBO), RCYN 07-01, RCYN 08-01, RCYN 09-02 (**Appendix B**; Figure B-1**)**. RCYN 07-01 was the most upstream site visited by DEQ in this segment and was located upstream of the end of the forest service road (DEQ 2013). The site was vegetated with conifer, willow, grasses, and forbs with about 69% of the vegetation being grasses/forbs and 15% being shrubs/trees (DEQ 2013, 2015). Disturbed bare ground and rock each made up 9.5% and 6.5% of the site respectively; no hummocking was observed. Undercut streambanks were common with banks being primarily composed of sand/clay (40-90%) with lesser amounts of fine gravel (5-20%) and coarse gravel or larger sediment (5-40%) (DEQ 2015). About 21% of the site length had eroding banks with 92% being attributed to natural processes, with 5% to transportation, and the remainder to grazing (pack horses). Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 41.1% that the assemblage represented a stream impaired by sediment.

RCYN 08-01 was located about 1.1 miles downstream of RCYN 07-01 in a similar setting. The site was vegetated primarily with conifer with about 33.5% of the vegetation being grasses/forbs and 64.5% being shrubs/trees (DEQ 2013, 2015). Disturbed bare ground and rock each made up 1% of the site; no hummocking was observed. Eroding streambanks were common and were primarily composed of sand/clay (55-98%) with lesser amounts of fine gravel (0-25%) and coarse gravel or larger sediment (2-30%) (DEQ 2015). About 55% of the site length had eroding banks with 80% being attributed to natural processes, 15% to transportation/roads, and the remainder to dispersed camping. One diatom sample collected at the site yielded a probability of 26.5% that the assemblage represented a stream impaired by sediment.

RCYN 09-02 was located about 1.6 miles downstream of RCYN 08-01 in an area that appears to have been historically been grazed by cattle as evident by slumping and the presence of invasive plant species (DEQ 2013). The riparian vegetation community was in recovery with Canada thistle and brome species present with about 72% of the vegetation being grasses/forbs and 28% being shrubs/trees (DEQ 2013, 2015). Disturbed bare ground and hummocking were not observed at the site. Bank sloughing was identified, and streambanks were composed of 100% sand/clay (DEQ 2015). About 60% of the site length had eroding banks with about 50% being attributed to historical grazing with 43% being natural processes, 6.5% existing riparian grazing, and the remainder to transportation. A layer of silt is covering the predominantly cobble substrate (DEQ 2013).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Red Canyon Creek are summarized in **Table 5-19**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, three sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm. In addition, the pool tail fines and residual pool depth targets each fail to be achieved at one site. W/D ratio fails to meet the target at all four sites and pool frequency fails at two sites. These results indicate that there is an excess amount of fine sediment in Red Canyon Creek and that both channel form and instream habitat are degraded.

Table 5-19. Existing sediment-related data for Red Canyon Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
1929 (PIBO)[1]	2006, 2011	12.0	2.75	*NC*	*NC*	*NC*	13.5	**16.2**	*NC*	0.9	**13.5**
RCYN 07-01	2013	12.0	4.7	B	**17**	**14**	7	**15.2**	1.9	0.7	30.8
RCYN 08-01	2013	11.1	2.6	B	**25**	**25**	8	**12.6**	1.4	0.7	**9.6**
RCYN 09-02	2013	9.0	1.8	C	**91**	**90**	**96**	**13.1**	3.5	**0.6**	23.4

[1] Values are averages from sampling events in 2006 and 2011; NC = not collected

Summary

Data collected by DEQ in 2013 (DEQ 2013, 2015) indicate that existing and historical grazing, the road along the creek, and dispersed camping are contributing excess fine sediment to the segment and that restoration and implementation of best management practices will reduce sediment input from these sources. The existing listings for Red Canyon Creek are supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, the failures of instream data to the targets, and the poor riparian vegetation condition at the lower site.

5.4.3.10 Ruby Creek (MT41F004_080)

Ruby Creek (MT41F004_080) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 15.91 miles from the headwaters to the mouth at the Madison River primarily through sedimentary (with some metamorphic and volcanic) geology and an evergreen landscape with shrub/scrub and grasses in the headwaters and near the mouth. A westslope cutthroat trout restoration project involving removal of non-native trout and the introduction of westslope cutthroat eggs, has been ongoing on Ruby Creek since 2012 (FWP 2015).

Physical Condition and Sediment Sources

A portion of Ruby Creek is located within the BLM Bar Seven Grazing Allotment (BLM 2009). A report by the BLM (BLM 2009) indicates that the uplands adjacent to Ruby Creek are functioning at risk due in part to the existing livestock management and a revision of the terms and conditions for livestock grazing is recommended. With regards to riparian areas, livestock use has led to a change in riparian vegetation and streambank erosion (BLM 2009).

In October 2015, about 75 feet of channel was relocated and restored on Ruby Creek (see FWP 2014 for plan details) to address a seven-foot-tall eroding bank and prevent an historical building from falling into the creek. Before and after photos of the project site are shown in **Figures 5-6** and **5-7**, respectively.

Figure 5-6. Ruby Creek at the McAtee Homestead cabin prior to restoration in October 2015 (FWP photo by Pat Clancey)

Figure 5-7. Ruby Creek at the McAtee Homestead cabin after restoration in October 2015 (FWP photo by Pat Clancey)

Sediment and habitat data were collected from Ruby Creek at one site by PIBO in 2008 and 2013 and two sites by DEQ in 2013: 2663 (PIBO), RUBY 17-01, RUBY 18-02 (**Appendix B**; Figure B-1**)**. RUBY 17-01 was the most upstream site visited by DEQ in this segment and was in a lightly grazed riparian setting (DEQ 2013). The understory was vegetated with willow and water birch. About 42.5% of the groundcover vegetation was grasses/forbs (DEQ 2013, 2015). Undisturbed bare ground made up 16% of the groundcover, and disturbed bare ground made up 41.5% of the ground cover. No hummocking was observed. Streambanks were primarily composed of sand/clay (40-100%) with lesser amounts of fine gravel (0-10%), and coarse gravel or larger sediment (0-50%) (DEQ 2015). About 43% of the site length had eroding banks with 76% being attributed to riparian grazing, with 22% to natural processes, and the remainder to an old road/trail. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 40% that the assemblage represented a stream impaired by sediment.

RUBY 18-02 was located about 2 miles downstream of RUBY 17-01 near the confluence the Madison River. Vegetation at the site consisted of about 1% sedges/rushes, 78.5% grass/forbs, and 16% shrubs/trees (DEQ 2013, 2015). Disturbed bare ground made up 4.5% of the site; no hummocking was observed. Streambanks were primarily composed of sand/clay (50-100%) with lesser amounts of fine gravel (0-15%), and coarse gravel or larger sediment (0-35%) (DEQ 2015). About 31% of the site length had eroding banks with 78% being attributed to natural processes and the remainder to historical riparian grazing. The probability that the diatom assemblage represented a stream impaired by sediment was 38.6%, which is a moderate value. This information, combined with the physical data, supports an impairment listing.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Ruby Creek are summarized in **Table 5-20**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both DEQ sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm. These results indicate that although the channel form and habitat quality in Ruby Creek appear healthy, there is an excess amount of fine sediment.

Table 5-20. Existing sediment-related data for Ruby Creek relative to targets
Values that do not meet the target are in **bold**

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
2663 (PIBO)[1]	2008, 2013	25.5	2.3	*NM*	*NM*	*NM*	3.5	23.2	*NM*	1.2	11.4
RUBY 17-01	2013	16.2	2.8	C	**17**	**15**	8	14.5	3.1	1.3	12.8
RUBY 18-02	2013	9.9	1.6	B	**24**	**23**	7	9.7	1.9	1.3	17.3

[1] Values are averages from sampling events in 2008 and 2013

Summary

Data collected by DEQ in 2013 (DEQ 2013, 2015) indicate that existing and historical grazing and an old road are contributing excess fine sediment to the segment and that continued restoration and implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for Ruby Creek is supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, and the failures of instream data to the fine sediment targets.

5.4.3.11 South Meadow Creek (MT41F004_070)

South Meadow Creek (MT41F004_070) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 12.98 miles from the headwaters to the mouth at the Ennis Lake through metamorphic and sedimentary geology and a landscape composed of evergreen in the headwaters, grasses and shrub/scrub in the middle portion of the watershed, and grasses, hay/pasture, and riparian vegetation near the mouth.

A 0.5 mile segment impacted by grazing was fenced in 2010 (Madison Conservation District 2015). Since this project was implemented, riparian vegetation has improved in the fenced section. In addition, in

2015, a second restoration project was successfully undertaken to relocate a straightened section of the stream channel and restore sinuosity.

Physical Condition and Sediment Sources

Sediment and habitat data were collected from South Meadow Creek at two sites by DEQ in 2014: SMDW 18-01 and SMDW 19-01 (**Appendix B**; Figure B-2**)**. SMDW 18-01 was the upstream site in this segment and was located in a grazed riparian setting (DEQ 2014). The site was vegetated with grasses, sedges, water birch, and willow with about 16.5% of the vegetation being sedges/rushes, 53% grasses/forbs, and 22.5% being shrubs/trees (DEQ 2013, 2015). Disturbed bare ground made up 8% of the site; hummocking was present on 31% of the site. Streambanks generally appeared to be stable and were primarily composed of sand/clay (60-95%) with lesser amounts of fine gravel (5-40%), and coarse gravel or larger sediment (0-15%) (DEQ 2015). About 16% of the site length had eroding banks with 68% being attributed to riparian grazing and the remainder to natural processes.

SMDW 19-01 was located about 1.9 miles downstream of SMDW 18-01 in a dewatered reach that is fenced to exclude livestock (DEQ 2014). Vegetation at the site consisted of about 6% sedges/rushes, 89% grasses/forbs, and 1% shrub/tree (DEQ 2013, 2015). Disturbed bare ground made up 4% of the site; no hummocking was observed. Bank sloughing was observed, and streambanks were primarily composed of sand/clay (50-100%) with lesser amounts of fine gravel (0-20%), and coarse gravel or larger sediment (0-30%) (DEQ 2015). About 98% of the site length had eroding banks with 80% being attributed to riparian grazing and the remainder to natural processes. A periphyton sample from the site yielded a 29.1% probability of the site having excess fine sediment.

In addition to the DEQ data collection, the Madison Conservation District collected pebble counts from three sites on South Meadow Creek in July 2014; percent fines < 2 mm were 6%, 10%, and 14% (Madison Conservation District 2014).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for South Meadow Creek are summarized in **Table 5-21**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both DEQ sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm and the upper site fails to meet the target for pool tail fines. There were no target failures for any of the channel form and instream habitat variables. These results indicate that although the channel form and habitat quality in South Meadow Creek appears healthy, there is an excess amount of fine sediment.

Table 5-21. Existing sediment-related data for South Meadow Creek relative to targets
Values that do not meet the target are in **bold**

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
SMDW 18-01	2014	19.0	1.5	C	**38**	**32**	**21**	17.4	5.8	1.1	10.7
SMDW 19-01	2014	7.4	1.0	C	**25**	**23**	13	7.7	2.4	0.7	30.8

Summary
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that riparian grazing is contributing excess fine sediment to the segment and that continued restoration and implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for South Meadow Creek is supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, and the failures of instream data to the fine sediment targets.

5.4.3.12 Watkins Creek (MT41F006_030)
Watkins Creek (MT41F006_030) is listed for sedimentation-siltation on the 2018 303(d) List. In addition, this segment is listed for alteration in streamside or littoral vegetative covers which is a non-pollutant listing that can often be linked to sediment impairment. The segment flows 7.08 miles from the headwaters to the mouth at Hebgen Lake through metamorphic and sedimentary geology and an evergreen-dominated landscape with shrub/scrub and grasses at the mouth.

Physical Condition and Sediment Sources
Sediment and habitat data were collected from Watkins Creek at two sites by DEQ in 2013: WATK 12-01 and WATK 14-01 (**Appendix B**; Figure B-1**)**. WATK 12-01 was the upstream site in this segment and was located in a grazed riparian setting (DEQ 2013). Cattle use was evident by extensive pugging along the banks. Pugging occurs when the hooves of grazing livestock penetrate the soil surface during wet conditions causing damage to pasture plants as well as soil structure. Pasture plants can be torn and buried. The site was vegetated with willow, sedges, and conifer with 0.5% of the vegetation being sedges/rushes, 30% grasses/forbs, and 25.5% being shrubs/trees (DEQ 2013, 2015). Disturbed bare ground and rock made up 42% and 2% of the site respectively; hummocking was not observed. Streambanks generally appeared to be stable and were primarily composed of sand/clay (50-100%) with lesser amounts of fine gravel (0-10%) and coarse gravel or larger sediment (0-40%) (DEQ 2015). About 47% of the site length had eroding banks with 64% being attributed to riparian grazing, 24% to natural processes, and the remainder to logs that had been place in the creek for habitat. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 13.5% that the assemblage represented a stream impaired by sediment.

WATK 14-01 was located about 1.8 miles downstream of WATK 12-01, near the mouth. The site was vegetated with willow and grass with about 30.5% of the vegetation being grasses/forbs and 19.5% being shrubs/trees (DEQ 2013, 2015). Large wood appeared to have been added to the stream. Disturbed bare ground and hummocking were not observed at the site. Streambanks were primarily composed of sand/clay (70-100%) with lesser amounts of fine gravel (0-10%) and coarse gravel or larger sediment (0-30%) (DEQ 2015). About 30% of the site length had eroding banks with 100% being attributed to natural processes. One diatom sample collected at the site yielded a probability of 11.8% that the assemblage represented a stream impaired by sediment.

A portion of Watkins Creek is located within the Watkins Creek Grazing Allotment (USFS, 2011). The USFS allotment report (USFS, 2011) states that there is some bank cutting from cattle in the lower part of Watkins Creek but that the creek is in proper functioning condition; there is concern that cattle grazing could affect the channel form of Watkins Creek because of the sensitive soils adjacent to the channel. High fine sediment was observed within Watkins Creek including in areas upstream of the allotment and it was hypothesized that this sediment is predominantly natural (USFS, 2011). Restoration activities in the watershed include culvert removal and replacement to improve fish passage, installation of a fish barrier to preserve a westslope cutthroat population, and the addition of large woody debris (USFS, 2011). In 2012, the private landowner at the mouth of Watkins Creek signed a 10-year water rights lease with the Montana Department of Natural Resources for 5.5 cfs to maintain flow in the creek (Trout Unlimited, 2012).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Watkins Creek are summarized in **Table 5-22**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both DEQ sites fail to meet the targets for riffle pebble count < 2 mm and pool tail fines. The lower site fails to meet the target for riffle pebble count < 6 mm. The only other target failure was for W/D ratio at the upper site. These results indicate that although the channel form and habitat quality in Watkins Creek generally appear healthy, there is an excess amount of fine sediment.

Table 5-22. Existing sediment-related data for Watkins Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
WATK 12-01	2013	27.7	3.1	B	16	**13**	**17**	**26.3**	6.8	1.6	6.7
WATK 14-01	2013	6.3	2.0	B	**51**	**41**	**16**	7.4	3.2	0.8	20.6

Summary

Data collected by DEQ in 2013 (DEQ 2013, 2015) indicate that cattle grazing is contributing excess fine sediment to the segment and that continued restoration activities and implementation of best management practices will reduce sediment input from these sources. The existing listings for Watkins

Creek are supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, the failures of instream data to the fine sediment targets, and the extensive amount of disturbed bare ground at the upper site.

5.4.2.13 Wigwam Creek (MT41F004_160)

Wigwam Creek (MT41F004_160) is listed for sedimentation-siltation on the 2018 303(d) List. The segment flows 11.9 miles from the headwaters to the mouth at the Madison River through sedimentary geology and a shrub/scrub and evergreen forest-dominated landscape in the upper watershed and a grass-dominated landscape with willows and sedges growing in riparian areas in the lower watershed.

Physical Condition and Sediment Sources

A portion of Wigwam Creek is located within the BLM North Morgan Grazing Allotment (BLM 2009). A report by the BLM (BLM 2009) indicates that the uplands adjacent to Wigwam Creek are functioning at risk due in part to the existing livestock management and a revision of the terms and conditions for livestock grazing is recommended.

Restoration work in the Wigwam Creek watershed includes the construction of an exclosure and a hardened crossing on Wigwam Creek in 2010 and erecting two miles of exclusion fencing on a tributary of Wigwam Creek in 2012 (Madison River Foundation 2015). This work was performed by the Madison River Foundation and USFS.

Sediment and habitat data were collected from Wigwam Creek at two sites by DEQ in 2013 (WGWM 08-01, and WGWM 18-01 (**Appendix B**; Figure B-2**)**. WGWM 08-01 was the upstream site in this segment and was located in a restored reach (DEQ 2013). The site was vegetated with sedges, willow, grasses, and forbs with about 74% of the vegetation being sedges/rushes and 25% being shrubs/trees (DEQ 2013, 2015). Rock made up 1% of the site and no hummocking was observed. Livestock are excluded (with fence) from the site. Streambanks were primarily composed of sand/clay (85-100%) with lesser amounts of fine gravel (0-5%) and coarse gravel or larger sediment (0-10%) (DEQ 2015). About 13% of the site length had eroding banks with 60% being attributed to natural processes and the remainder to historical grazing. Trout were observed at the site. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 40% that the assemblage represented a stream impaired by sediment.

WGWM 18-01 was located about 8.4 miles downstream of WGWM 08-01 in a grazed riparian setting. The site was vegetated with cottonwoods and weeds with about 5% of the vegetation being sedges/rushes, 77% grasses/forbs, and 14% being shrubs/trees (DEQ 2013, 2015). Disturbed bare ground made up 4% of the site with hummocking covering 27%. Streambanks were primarily composed of sand/clay (85-100%) with lesser amounts of fine gravel (0-10%), and coarse gravel or larger sediment (0-10%) (DEQ 2015). About 20% of the site length had eroding banks with 90% being attributed to riparian grazing and the remainder to natural processes. Sample diatom counts were evaluated to determine the probability of impairment for sediment using the sediment increaser taxa list for the Middle Rockies. One diatom sample collected at the site yielded a probability of 56% that the assemblage represented a stream impaired by sediment.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Wigwam Creek are summarized in **Table 5-23**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both DEQ sites fail to meet the targets for riffle pebble count < 6mm and < 2 mm and pool tail fines. The only other target failure was for W/D ratio at the lower site. These results indicate that there is an excess amount of fine sediment in Wigwam Creek.

Table 5-23. Existing sediment-related data for Wigwam Creek relative to targets
Values that do not meet the target are in **bold** and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
WGWM 08-01	2013	8.1	1.8	C	**33**	**25**	**32**	7.5	5.5	0.8	28.8
WGWM 18-01	2013	17.2	3.6	B	**30**	**25**	**23**	23.1	1.5	**0.6**	11.1

Summary
Data collected by DEQ in 2013 (DEQ 2013, 2015) indicate that riparian grazing is contributing excess fine sediment to the segment and that continued restoration activities and implementation of best management practices will reduce sediment input from these sources. The sedimentation-siltation listing for Wigwam Creek is supported based on current land management practices that are contributing human sources of sediment, the human-caused erosion observed, and the failures of instream data to the targets.

5.5 Source Assessment and Quantification

This section summarizes the assessment approach, current sediment load estimates, and the determination of the allowable load for each source category. DEQ determines the allowable load by estimating the obtainable load reduction once all reasonable land, soil, and water conservation practices have been implemented. The reduction forms the basis of the allocations and TMDLs provided in **Section 5.7** This section focuses on three potentially significant sediment source categories and associated controllable human loading for each of these sediment source categories:

- Streambank erosion
- Upland erosion and riparian health
- Unpaved roads

EPA's guidance for developing sediment TMDLs provides the basic procedure for assessing sources, which includes inventorying all sediment sources to the waterbody. In addition, the guidance suggests using one or more methods to determine the relative magnitude of loading, focusing on the primary and controllable sources (U.S. Environmental Protection Agency, 1999b). Federal regulations allow that loading determinations "may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" (Water quality planning and management, 40 CFR 130.2(G), 2012).

For each impaired waterbody segment, sediment loads from each source category are estimated according to field surveys, load extrapolation, and limited hillslope modeling techniques (described below). The results include a mix of sediment sizes. Bank erosion involves both fine and coarse sediment loading to the receiving water. Conversely, loading from roads and upland erosion is predominately of fine sediment. The complete methods and results for source assessments for streambank erosion, roads, and upland erosion are found in **Appendices C**, **D**, and **E**, respectively.

5.5.1 Eroding Streambank Sediment Assessment

In the absence of human activities, streambank erosion is typically dominated by small and/or slowly eroding streambanks. Human disturbances to riparian vegetation and health and stream hydrology may result in greater lengths of eroding banks and accelerate the erosion rate. This commonly occurs when streambanks change from being well vegetated to being largely, or entirely, unvegetated with vertical banks. Causes of streambank erosion include the following:

- transportation
- riparian grazing
- cropping
- mining
- silviculture
- irrigation-related shifts in stream energy
- other (e.g. historical or legacy sources)
- natural processes

DEQ assessed streambank erosion for all 13 waterbodies impaired for sediment in the Madison TPA. The streambank erosion assessment involved several procedures. First, impaired segments of streams were stratified into reaches with similar gradient, confinement, and stream size using an aerial assessment performed in GIS (DEQ 2015b). As part of the aerial assessment, the percent of the reach within the 100-foot buffer that was in "natural" riparian quality, with little evidence of grazing or other anthropogenic disturbance was also estimated via aerial photography (DEQ 2015b). Streambank erosion data was then collected in the field at 42 monitoring sites in 2013 and 2014.

For each eroding streambank at each sampled site, channel cross section measurements were collected to estimate the erosive force (i.e., near bank stress) (Rosgen, 1996), and measurements of the bank height, bankfull height, root depth, root density, bank angle, and surface protection were collected as indicators of each streambank's susceptibility to erosion (i.e., bank erosion hazard index or BEHI). A combination of the BEHI score and near bank stress were used to estimate the depth of sediment eroded per year (i.e., retreat rate) using the Bank Erosion for Nonpoint Sources of Sediment (BANCS) model method as described in Appendix C. This depth was multiplied by the height and length of the bank to obtain an estimate of the total volume eroded for each sampled bank. This was summed across the sampled site to obtain an estimate of total loading for the site, then adjusted to standardize to a 1,000 foot length (**Appendix C**). For each bank the cause of erosion (due to natural factors, roads, riparian grazing, residential/urban land use, historic land use, and other) was also estimated, and the loading estimates were weighted by these values to determine how each land use contributed to loading amounts (**Appendix C**)

Sediment loads from field assessed monitoring sites were then extrapolated to the unassessed stream reaches and segments in each impaired subwatershed to estimate a loading for the entire subwatershed. All reaches in the Madison TPA are in the Middle Rockies Ecoregion. Gradient, stream order, and estimated percent of riparian zone in natural vegetation (based on aerial photos) were used to extrapolate the amount of bank erosion to unassessed streams (**Table 5-24**). The role of riparian vegetation was based on the finding that low and mid gradient sites with > 70% of the riparian zone intact had significantly lower rates of streambank erosion than sites with < 70% riparian vegetation intact.

Table 5-24. Average loading from sampled reaches used to estimate loading in unsampled reaches

Sampled Reaches			**Assigned to**	**Unsampled Reaches**		
Gradient	**Order**	**Condition (based on aerial photos)**		**Gradient**	**Order**	**Condition (based on aerial photos)**
0-2%	Non 1st	High (> 70%) of riparian zone in natural condition	--->	0-2%	Non 1st	High (> 70%) of riparian zone in natural condition
0-2%	Non 1st	Low (≤ 70%)of riparian zone in natural condition	--->	0-2%	Non 1st	Low (≤ 70%)of riparian zone in natural condition
>2-4%	Non 1st	High (> 70%) of riparian zone in natural condition	--->	>2-4%	Non 1st	High (> 70%) of riparian zone in natural condition
>2-4%	Non 1st	Low (≤ 70%)of riparian zone in natural condition	--->	>2-4%	Non 1st	Low (≤ 70%)of riparian zone in natural condition
>4-10%	Non 1st	All land uses	--->	>4-10%	Non 1st	All land uses
> 10%	Non 1st	All land uses	--->	> 10%	Non 1st	All land uses
Any	1st	All land uses	--->	Any	1st	All land uses

The assumptions used during the assessment of eroding streambanks are provided below:

- The condition of streambanks at monitored sites sampled during 2013 and 2014 is representative of current conditions within the larger Madison TPA.
- The average annual load at sampled reaches are applicable to reaches in the Madison TPA within the same gradient, order and condition category (**Table 5-24**).
- The annual streambank retreat rates used to develop the sediment loading numbers were based on Rosgen BEHI studies in the Lamar Valley of Yellowstone National Park (Rosgen, 2001). The Madison TPA primarily has similar geology including weakly lithified sedimentary geology, with broad areas of volcaniclastic tuff in the upper Madison River and West Fork valleys (Kellogg et al. 2007). Therefore, we assume the retreat rates from Rosgen 2001 can be applied to the Madison TPA.

Substantial human-caused sources of streambank erosion contribute to the sediment loads in the Madison TPA. Based on the visual assessment of contributing factors immediately adjacent to eroding streambanks, riparian grazing and the past history of land use activities (usually grazing) contributed large amounts (approximately 19% each) of the sediment load from bank erosion (**Table 5-25**). However, natural sources were the biggest cause of erosion.

Table 5-25. Estimated sources of bank erosion at sampled sites

Source	Sediment Load (Tons/Year)	Sediment Load (Percent)
Natural	655.1	51.1
Roads	52.9	4.1
Riparian Grazing	252.7	19.7
Other	72.5	5.7
Residential/Urban	2.3	0.2
Historic	246.5	19.2
Total	**1282.1**	**100**

The extrapolation procedure outlined in **Appendix C** allowed for estimation of total loading from bank erosion within each impaired subwatershed. Streambank erosion loads range from 652 tons per year in the Watkins Creek subwatershed to 7481 tons per year in the Cherry Creek subwatershed (**Table 5-26**).

Table 5-26. Estimated bank erosion load by subwatershed from highest to lowest

Subwatershed	Estimated Load (Tons/Yr)	Estimated Load (Tons/Stream Mile/Yr)
Cherry Creek	7481	319.4
Bear Creek	6990	272.5
Elk Creek	4840	277.0
Hot Springs Creek	3884	227.8
Moore Creek	3523	226.1
North Meadow Creek	3277	179.5
Blaine Spring Creek	2508	278.1
Antelope Creek	2115	227.7
Ruby Creek	2073	138.0
South Meadow Creek	2032	171.7
Wigwam Creek	1269	111.8
Red Canyon Creek	1015	170.0
Watkins Creek	652	96.6

5.5.2 Unpaved Road Sediment Assessment

DEQ conducted a sediment source assessment on the unpaved road network in the Madison TMDL Planning Area (**Appendix D**). DEQ staff used ArcGIS software to locate each unpaved crossing (e.g., bridges, culverts, fords) and stream-adjacent stretch of road (called "parallel road segment") that could contribute sediment to streams in the Madison TPA. A total of 554 unpaved road crossings and 130 miles of unpaved parallel road segments were identified within the sediment-impaired watersheds of the Madison TPA.

A total of 25 randomly selected crossings and 16 parallel road segments were sampled in summer 2014. Road parameters evaluated at the field sites included those needed to estimate sediment loading. The estimate of loading was conducted using the WEPP: Road forest road erosion prediction model (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP: Road is an interface to the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston, 1995), developed by the USDA Forest Service and other agencies, and is used to predict runoff, erosion, and sediment delivery from forest roads. The model predicts sediment yields based on the specific soil, climate, ground cover, and topographic conditions collected in the field. In the WEPP analysis, detailed weather information for Norris, MT Ranger Station was used for cross-sections and parallel road segments < 6300 feet in elevation. For cross-sections and parallel road segments > 6,300 feet, a custom climate was implemented to represent higher locations in the watershed based on PRISM climate data.

Data collected at sampled sites was used to estimate sediment loads at unsampled crossings and parallel road segments based on average estimated loading values within different ownership and elevation categories, including: 1) public, high (> 6,300 feet) elevation; 2) public, low (≤ 6,300 feet) elevation; and 3) private, low (≤ 6,300 feet) elevation. The contribution from private, high elevation crossings and parallel road segments was not estimated due to their extremely low prevalence within the impaired watersheds of Madison TPA.

A simple breakdown of the modeled loads shows which subwatersheds have significant sediment contributions attributable to unpaved roads (**Figure 5-8** and **Table 5-27**). It also shows in which subwatersheds unpaved roads have a negligible contribution to the overall sediment load. In general, the subwatersheds with the highest number of unpaved road crossings and parallel road segments are predicted to have the greatest sediment contributions from roads. Some of the highest estimated contributions are from Bear Creek, Hot Springs Creek, and North Meadow Creek. The subwatersheds with the smallest contributions include Watkins and Antelope, due to the small size of these subwatersheds and the low number of crossings and parallel road segments.

Loading per stream mile may be used to more accurately assess the potential impact of roads on aquatic biota because it indicates a higher intensity of roads and more potential deposition to the stream bed. The two subwatersheds with notably higher loading per stream mile are South Meadow and Red Canyon. Antelope and Watkins have the lowest estimated sediment contributions per stream mile (**Table 5-27**).

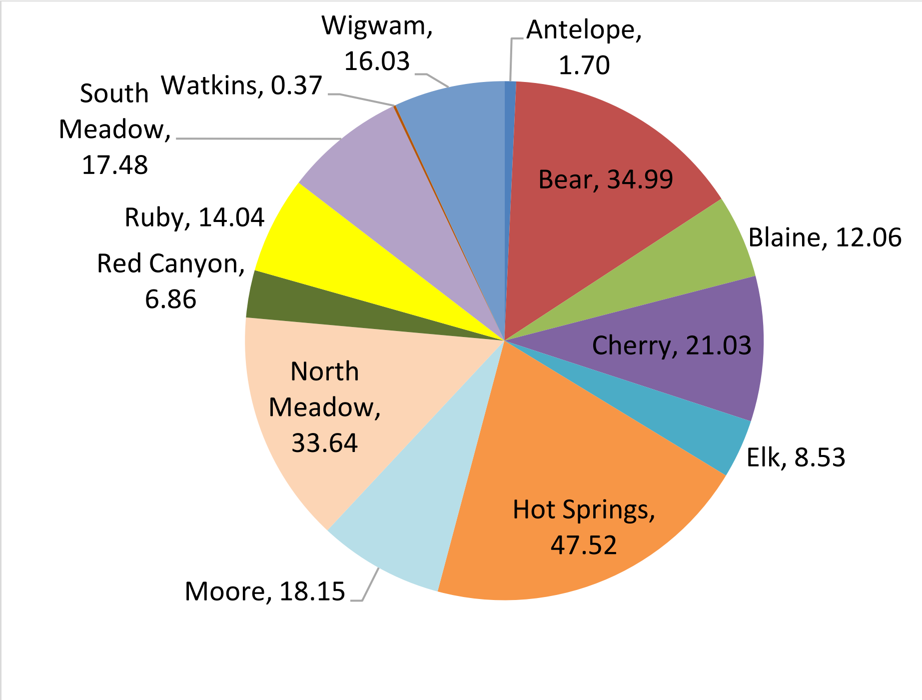

Figure 5-8. Estimated percent sediment contribution by subwatershed from unpaved road crossings and parallel road segments

Table 5-27. Loading estimates per subwatershed, ranked by decreasing load per stream mile

Subwatershed	No. Crossings	No. Parallel Road Miles	Stream Crossings (Tons/Yr)	Parallel Segments (Tons/Yr)	Total Loading (Tons/Yr)	(Tons/Mile/Yr)
South Meadow	39	8.92	7.46	10.02	17.48	0.46
Red Canyon	15	4.82	4.30	2.56	6.86	0.41
Blaine	33	8.02	4.25	7.81	12.06	0.34
Hot Springs	96	22.41	9.25	38.27	47.52	0.30
Ruby	9	5.98	0.34	13.70	14.04	0.29
Moore	30	11.74	4.13	14.02	18.15	0.28
North Meadow	87	18.17	14.25	19.39	33.64	0.25
Wigwam	66	8.22	7.43	8.60	16.03	0.15
Bear	84	24.20	10.06	24.93	34.99	0.12
Cherry	66	13.24	9.10	11.93	21.03	0.11
Elk	19	4.84	2.39	6.14	8.53	0.09
Antelope	7	0.08	1.63	0.07	1.70	0.05
Watkins	3	0.27	0.15	0.22	0.37	0.02

5.5.3 Upland Sediment Assessment

In general, DEQ does not consider transport of upland sediment to be a significant source of stream sediment in the Madison TPA. This conclusion is based upon a planning area-wide survey of land uses and riparian buffer conditions during the three-year field work process. Upland areas were found to have reasonable land, soil and water conservation practices. This is supported by the general appearance of upslope grazing lands and overall application of Montana forest management practices in silvicultural areas. Localized areas of bare ground near streams were observed, but this is generally incorporated into the bank erosion assessment. A review of aerial photos for all watersheds with sediment TMDLs only identified tilled fields in the near stream areas of Elk Creek as potentially having a significant contribution of fine sediment to the streams. Therefore, the upland sediment assessment scope was limited to agricultural lands in the Elk Creek drainage.

DEQ conducted an analysis of upland sediment for Elk Creek, identifying numerous near stream agricultural fields may have a significant sediment contribution to the stream (**Figure 5-9**). Many of the agricultural fields have areas within 50-100 feet of the stream that have poor cover and little to no riparian buffer or buffer strips to filter sediment contribution to the stream. Collectively, these areas of ground disturbance have the potential to be significant sediment sources if proper BMPs are not implemented and maintained.

Figure 5-9. Fields along Elk Creek identified as having an elevated sediment contribution to the stream

To analyze the contribution of sediment from these fields to Elk Creek, hillslope erosion was estimated for fields in the Elk Creek watershed within 100 feet of Elk C reek using upland erosion rates estimated for cultivated fields in the Boulder-Elkhorn watershed, which is in the same ecoregion. Fields 10 and 17 were removed from the analysis because additional GIS measurements showed that they were already > 100 feet from the stream (and therefore had high sediment filtering ability). Riparian health was assessed for each field to estimate the percent reduction the existing buffer provides in sediment delivery to the stream (**Table 5-28**). The estimated reduction in sediment due to the width of the buffer was extrapolated based on the sediment filtering ability of buffer strips of a given width according to the literature (Wegner 1999, Knutson and Naef 1997). By multiplying the field acres by the estimated loading rate for fields without BMPs (0.037 tons/acre/year), and then subtracting the amount retained by the buffer, the existing load was estimated (**Table 5-28**; **Appendix E**):

Existing Field Load= (Acres * Field Erosion Rate: 0.037) - (Acres*Field Erosion Rate: 0.037*Existing Buffer Efficiency)

Table 5-28. Estimated load delivered by agricultural fields to the stream based on existing field conditions and buffer quality

Field No	Acres	Existing Field Load (Tons/Year)	Existing Buffer Efficiency (Proportion Entering Stream)	Existing load Delivered to Stream (Tons/Year) = Existing Field Load * Proportion Entering Stream
1	76	2.81	Poor (0.70)	1.97
2	132	4.88	Poor (0.70)	3.42
3	52	1.92	Poor (0.70)	1.35
4	32	1.18	Moderate-Fair (0.60)	0.71
5	20	0.74	Moderate-Fair (0.60)	0.44
6	10	0.37	Moderate-Fair (0.60)	0.22
7	104	3.85	Moderate-Fair (0.60)	2.31
8	20	0.74	Moderate-Fair (0.60)	0.44
9	1	0.04	Moderate-Fair (0.60)	0.02
10	> 100 Foot Buffer Already Present			
11	11	0.41	Moderate-Fair (0.60)	0.24
12	3	0.11	Fair (0.50)	0.06
13	80	2.96	Moderate-Good (0.40)	1.18
14	5	0.19	Moderate-Fair (0.60)	0.11
15	5	0.19	Fair (0.50)	0.09
16	28	1.04	Poor (0.70)	0.73
17	> 100 Foot Buffer Already Present			
18	11	0.41	Fair (0.50)	0.20
Total	590	21.83		13.50

5.5.4 Source Assessment Summary

Based on field observations, all assessed source categories represent controllable loads within the Madison TMDL Planning Area. Because each source category has different seasonal loading rates, the relative percentage of the total load from each source category may vary by season. The intention of the source assessments is to broadly evaluate source effects (e.g., bank erosion, upland erosion, roads). Results for each source assessment category provide an adequate tool to focus water quality restoration activities in the Madison TPA. They indicate the relative contribution of sediment to different subwatersheds for each source category and the potential for percent loading reductions with the implementation of improved management practices.

5.6 Determining the Total Allowable Sediment Load

The percent-reduction allocations are based on the BMP scenarios for each major source type (e.g., streambank erosion, upland erosion, and roads). These BMP scenarios are discussed within this section and within associated appendices, and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and/or field assessments. Sediment loading reductions can be achieved through a combination of BMPs, and the most appropriate BMPs will vary. Sediment loading was evaluated at the watershed scale and associated sediment reductions are also applied at the watershed scale.

5.6.1 Streambank Erosion

Streambank erosion is closely linked to the health of the riparian zone because vegetation provides the roots and soil structure to hold the streambank soil in place. Therefore, BMPs that involve restoring vegetation to the riparian zone will typically result in reduced streambank loading. These include improvements in grazing management, road maintenance or relocation, and general reductions in intensity of human activities within the riparian zone.

Based on aerial photo analysis, sampled sites in subwatersheds of the Madison TPA that were unimpaired for sediment had a greater percentage of the riparian zone in natural conditions (meaning not heavily influenced by grazing, transportation, or other human activities) than sites in unimpaired subwatersheds. It was assumed that these sampled sites had more BMPs already occurring in the riparian zone. Across both unimpaired and unimpaired subwatersheds, amounts of estimated streambank erosion were also substantially lower at sites with >70% of the riparian zone in natural conditions. This information was used to estimate reductions in streambank erosion loading rates with BMPs.

The average sediment loading rates from reaches in good (> 70% natural) riparian condition were used as the BMP loading rate in unsampled reaches of stream with similar geomorphic characteristics that were in poor ≤70% riparian condition (**Table 5-29**). The exception was mid-high gradient and first order streams, which had too few sampled sites for such an estimate. Loading at mid-gradient streams was estimated by determining the new loading rate if bank erosion was reduced at the reaches with the highest erosion. High gradient and first order streams were found to have good riparian conditions and comparatively little contribution of sediment. Therefore, the loading rate for these reaches went unchanged in the BMP scenario (**Table 5-29**). The loading in reaches already estimated to have good riparian condition also went unchanged in the BMP scenario. Loading was summed across all reaches in a subwatershed to obtain the total loading from bank erosion if BMPs were implemented (**Appendix C**).

Table 5-29. Conditions used to estimate BMP loads at unsampled reaches

Gradient	Order	Riparian Condition	BMP Action	Pre-BMP Load (Tons/Yr/1000 Ft)	Post-BMP Load (Tons/Yr/1000 Ft)
0-2%	Non 1st	High, > 70% Riparian Zone in Natural Condition	NONE	43.5	43.5
0-2%	Non 1st	Low, ≤ 70% Riparian Zone in	Change to average at reaches with	59.8	43.5

Table 5-29. Conditions used to estimate BMP loads at unsampled reaches

Gradient	Order	Riparian Condition	BMP Action	Pre-BMP Load (Tons/Yr/1000 Ft)	Post-BMP Load (Tons/Yr/1000 Ft)
		Natural Condition	riparian zone in high condition		
>2-4%	Non 1st	High, > 70% Riparian Zone in Natural Condition	NONE	27.0	27.0
>2-4%	Non 1st	Low, ≤ 70% Riparian Zone in Natural Condition	Change to average at reaches with riparian zone in high condition	38.1	27.0
>4-10%	Non 1st	Any	Average at sampled reaches after changing bank erosion from extreme to very high, very high to high, and from high to moderate	14.0	11.3
> 10%	Non 1st	Any	NONE	12.5	12.5
Any	1st	Any	NONE	20.7	20.7

However, while this method is considered adequate to provide a good approximation of changes in sediment loading due to potential BMPs, it should not be seen as a substitute for on-the-ground reconnaissance. Further, BMPs may still be needed in portions of reaches estimated to have high riparian condition because not all issues can be observed from aerial photography.

The annual sediment loads, and the methods used to estimate loads, are based on aerial photography, best professional judgment, and limited on-the-ground access to stream reaches. DEQ recognizes that local land owners and managers are often in a better position to identify the causes of bank erosion and adopt practices to reduce bank erosion wherever practical.

Depending on the subwatershed, DEQ estimates that implementing riparian best management practices (BMPs) could decrease the level of human-caused streambank erosion by up to 38% (**Table 5-30**).

Appendix C contains additional information about the streambank erosion source assessment and associated load estimates for the 303(d) listed streams in the Madison TMDL Planning Area.

Table 5-30. Estimated reduction in sediment loads with BMPs implemented

Subbasin	Existing Load (Tons/Yr)	BMP Load Estimated Load (Tons/Yr)	% Reduction
Antelope Creek	2115.4	1612.9	23.8%
Bear Creek	6990.27	5059.4	27.6%
Blaine Spring Creek	2507.6	1545.2	38.4%
Cherry Creek	7481.4	5835.0	22.0%
Elk Creek	4839.5	3346.0	30.9%
Hot Springs Creek	3884.3	2801.1	27.9%
Moore Creek	3522.5	2199.4	37.6%
North Meadow Creek	3277.4	2508.3	23.5%
Red Canyon Creek	1014.7	701.2	30.9%
Ruby Creek	2072.7	1914.2	7.6%
South Meadow Creek	2032.2	1378.1	32.2%
Watkins Creek	652.2	459.2	29.6%
Wigwam Creek	1269.3	1044.2	17.7%
Total	**41659.5**	**30404.3**	**27.0%**

5.6.2 Unpaved Roads

A total of 25 randomly selected crossings and 16 parallel road segments were sampled in summer 2014. Road parameters evaluated at the field sites included those needed to estimate sediment loading. The estimate of loading was conducted using the WEPP: Road forest road erosion prediction model as described in **Section 5.5.2**. As an estimate of the amount of loading once BMPs were implemented, the contributing length in the model was shortened to 200 feet for crossings and 500 feet for parallel road segmentse. This represented the type of reduction that could be achieved through actions suggested in Montana's Nonpoint Source Management Plan (DEQ 2017) such as constructing waterbars, rolling dips, and insloping roads along steep banks.

Adjusted WEPP loads were used to estimate sediment loads at unsampled crossings and parallel road segments based on average BMP-adjusted estimated loading values within different ownership and elevation categories, including: 1) public, high (> 6,300 feet) elevation; 2) public, low (≤ 6,300 feet) elevation; and 3) private, low (≤ 6,300 feet) elevation (**Appendix D**). Based on these estimates, an average 46% reduction in sediment from crossings and similar 46% reduction in sediment from unpaved roads is potentially achievable across the Madison TMDL Planning Area by implementing standard road BMPs (**Table 5-31**).

Table 5-31. WEPP: Road Model Results by Subwatershed given the BMP Scenario

Subwatershed	Crossings (Tons/Yr)	Crossings-BMPs (Tons/Yr)	% Reduction-Crossings	Parallel Road Segments (Tons/Yr)	Parallel Road Segments BMPs (Tons/Yr)	% Reduction-Parallel Road Segments
Antelope	1.63	0.38	77%	0.07	0.04	46%
Bear	10.06	6.76	33%	24.93	12.72	49%
Blaine	4.25	2.89	32%	7.81	3.87	50%
Cherry	9.10	5.71	37%	11.93	5.85	51%
Elk	2.39	1.61	33%	6.14	3.26	47%

Table 5-31. WEPP: Road Model Results by Subwatershed given the BMP Scenario

Subwatershed	Crossings (Tons/Yr)	Crossings-BMPs (Tons/Yr)	% Reduction-Crossings	Parallel Road Segments (Tons/Yr)	Parallel Road Segments BMPs (Tons/Yr)	% Reduction-Parallel Road Segments
Hot Springs	9.25	5.80	37%	38.27	21.62	44%
Moore	4.13	2.04	51%	14.02	7.60	46%
North Meadow	14.25	7.23	49%	19.39	10.06	48%
Red Canyon	4.30	0.90	79%	2.56	1.39	46%
Ruby	0.34	0.15	55%	13.70	8.08	41%
South Meadow	7.46	2.85	62%	10.02	5.36	47%
Watkins	0.15	0.02	88%	0.22	0.12	46%
Wigwam	7.43	4.09	34%	8.60	4.59	47%
Total	**74.7**	**40.43**	**46%**	**157.7**	**84.6**	**46%**

5.6.3 Upland Sediment

DEQ conducted an analysis of upland sediment for the Elk Creek watershed, as numerous near stream agricultural fields were identified through on the ground and aerial photo observation to have a potentially significant sediment contribution to the stream. Many of the fields have areas within 50-100 feet of the stream that have poor cover and little to no riparian buffer to filter sediment contribution to the stream. Collectively, these areas of ground disturbance have the potential to be significant sediment sources if proper BMPs are not implemented and maintained.

DEQ estimated potential reductions in upland sediment loading to Elk Creek given three scenarios: 1) implementing upland BMPs by increasing groundcover crops, 2) implementing riparian BMPs by increasing vegetation in the 100-foot buffer of the creek, and 3) both implementing upland and riparian BMPs. A hypothetical 20% increase in groundcover was used as an estimate of the outcome of implementing Upland BMPs. A potential load after implementing riparian BMP's was estimated by decreasing the sediment passing through the buffer by 20% with a total reduction no greater than 75%, which is the value considered attainable once reasonable BMPs have been put in place (**Table 5-32**; **Appendix E**).

Table 5-32. Elk Creek existing sediment loading, management scenarios, and reduction estimates

Field No	Acres	Existing Load Delivered to Stream (Tons/Yr)	Upland BMP Only (Tons/Yr)	% Change from Existing Load	Buffer BMP Only (Tons/Yr)	% Change from Existing Load	Upland and Buffer BMPs (Tons/Yr)	% Change from Existing Load
1	76	1.97	1.01	49%	1.41	29%	0.72	63%
2	132	3.42	1.76	49%	2.44	29%	1.25	63%
3	52	1.35	0.69	49%	0.96	29%	0.49	63%
4	32	0.71	0.36	49%	0.47	33%	0.24	66%
5	20	0.44	0.23	49%	0.3	33%	0.15	66%
6	10	0.22	0.11	49%	0.15	33%	0.08	66%

Table 5-32. Elk Creek existing sediment loading, management scenarios, and reduction estimates

Field No	Acres	Existing Load Delivered to Stream (Tons/Yr)	Upland BMP Only (Tons/Yr)	% Change from Existing Load	Buffer BMP Only (Tons/Yr)	% Change from Existing Load	Upland and Buffer BMPs (Tons/Yr)	% Change from Existing Load
7	104	2.31	1.19	49%	1.54	33%	0.79	66%
8	20	0.44	0.23	49%	0.3	33%	0.15	66%
9	1	0.02	0.01	49%	0.01	33%	0.01	66%
10	>100 Foot Buffer Already Present							
11	11	0.24	0.13	49%	0.16	33%	0.08	66%
12	3	0.06	0.03	49%	0.03	40%	0.02	69%
13	80	1.18	0.61	49%	0.89	25%	0.46	61%
14	5	0.11	0.06	49%	0.07	33%	0.04	66%
15	5	0.09	0.05	49%	0.06	40%	0.03	69%
16	28	0.73	0.37	49%	0.52	29%	0.27	63%
17	>100 Foot Buffer Already Present							
18	11	0.2	0.1	49%	0.12	40%	0.06	69%
Total	**590**	**13.5**	**6.93**	**49%**	**9.43**	**30%**	**4.84**	**64%**

5.7 Sediment TMDLs and Allocations

The allowable loads described above are determined by modeling reasonable load reduction conditions for each source category. These allowable loads provide the load allocations to each sediment source. Conceptually, the sediment TMDL is the sum of the load allocations. This differs from DEQ's approach for other pollutants (e.g., metals or nutrients) where the TMDL is calculated first and then apportioned amongst contributing sources. The difference between the existing and allowable loads equals the excess amount of sediment causing impaired conditions for each stream. Eliminating this excess load for each source category within an impaired stream's watershed would equate to meeting all load allocations and represents a best path forward toward meeting sediment target conditions at all locations within the stream.

The total allowable sediment load is the sum of the load allocations to: bank erosion (natural and human caused), road sediment, and upland sediment runoff (significant areas where BMPs are obviously lacking).

Although all the sediment loads are presented in units of tons per year, direct comparison of sediment loads between sources is problematic and unpractical. This is because the loading estimates are produced by separate and unrelated models: BEHI, WEPP: Road and USLE. Therefore, the most important consideration is the relative percent reductions between subwatersheds. Percent reduction provides a useful and relatable description of the magnitude of the problem, the degree to which it can be mitigated, and a way to prioritize mitigation efforts and resources.

Sediment load allocations and TMDLs for each stream are provided below in **Tables 5-33** through **5-45** and estimated daily loads can be found in **Appendix F**.

5.7.1 Antelope Creek (MT41F004_140)

Sediment issues in the Antelope Creek subwatershed are predominantly due to eroding banks. There are few road crossings in the watershed. Moderate reductions in bank erosion are needed to achieve target conditions (**Table 5-33**).

Table 5-33. Antelope Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	1.7	0.4	76.5%
Eroding Banks	2115	1613	23.7%
Total	**2117**	**1613**	**23.8%**

5.7.2 Bear Creek (MT41F004_021)

Sediment issues in the Bear Creek subwatershed arise from both the unpaved road network and eroding banks, with the highest loads being from eroding banks. Moderate reductions are needed to achieve target conditions (**Table 5-34**).

Table 5-34. Bear Creek Sediment Source Assessment, Allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	35	19	45.7%
Eroding Banks	6990	5059	27.6%
Total	**7025**	**5079**	**27.7%**

5.7.3 Blaine Spring Creek (MT41F004_010)

Sediment issues in the Blaine Spring Creek subwatershed arise from both the unpaved road network and eroding banks, with the highest loads being from eroding banks. Moderate-high reductions are needed to achieve target conditions (**Table 5-35**).

Table 5-35. Blaine Spring Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	12	7	41.7%
Eroding Banks	2508	1545	38.4%
Total	**2520**	**1552**	**38.4%**

5.7.4 Cherry Creek (MT41F002_010)

Sediment issues in the Cherry Creek subwatershed arise from both the unpaved road network and eroding banks, with the highest loads being from eroding banks. Moderate reductions are needed in order to achieve target conditions (**Table 5-36**).

Table 5-36. Cherry Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	21	11.5	45.2%
Eroding Banks	7481	5835	22.0%

Table 5-36. Cherry Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Total	**7502**	**5847**	**22.1%**

5.7.5 Elk Creek (MT41F002_020)

Sediment issues in the Elk Creek subwatershed arise from the unpaved road network, upland erosion from near stream crop production, and eroding banks. Eroding banks need the most significant reductions in order to achieve target conditions (**Table 5-37**). Moderate-high reductions are needed to achieve target conditions.

Table 5-37. Elk Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	9	5	44.4%
Eroding Banks	4840	3346	30.9%
Upland Erosion	14	9	35.7%
Total	**4863**	**3360**	**30.9%**

totals are rounded

5.7.6 Hot Springs Creek (MT41F002_030)

Sediment issues in the Hot Springs Creek subwatershed arise from both the unpaved road network and eroding banks, with the highest loads being from eroding banks. Moderate reductions are needed to achieve target conditions (**Table 5-38**).

Table 5-38. Hot Springs Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/year)	Reduced Load (tons/year)	Load Allocation (Percent Reduction)
Unpaved Roads	47.5	27	43.2%
Eroding Banks	3884	2801	27.9%
Total	**3932**	**2828**	**28.1%**

5.7.7 Moore Creek (MT41F004_130)

Sediment issues in the Moore Creek subwatershed arise from both the unpaved road network and eroding banks, with the highest loads being from eroding banks. Moderate-high reductions are needed in order to achieve target conditions (**Table 5-39**).

Table 5-39. Moore Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	18	10	44.4%
Eroding Banks	3523	2199	37.6%
Total	**3541**	**2209**	**37.6%**

5.7.8 North Meadow Creek (MT41F004_060)

Sediment issues in the North Meadow Creek subwatershed arise from both the unpaved road network and eroding banks, with the highest loads being from eroding banks. Moderate reductions are needed in order to achieve target conditions (**Table 5-40**).

Table 5-40. North Meadow Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	34	17	50.0%
Eroding Banks	3277	2508	23.5%
Total	**3311**	**2525**	**23.7%**

5.7.9 Red Canyon Creek (MT41F006_020)

The Red Canyon Creek subwatershed has few unpaved road crossings or parallel road segments; sediment issues are mostly due to eroding banks. Moderate-high reductions are needed to achieve target conditions (**Table 5-41**).

Table 5-41. Red Canyon sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	7	2	71.4%
Eroding Banks	1015	701	30.9%
Total	**1022**	**703**	**31.2%**

5.7.10 Ruby Creek (MT41F004_080)

The Ruby Creek subwatershed has few unpaved road crossings or parallel road segments; sediment issues are mostly due to eroding banks. Relatively low reductions in sediment loading are needed to achieve target conditions (**Table 5-42**).

Table 5-42. Ruby Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	14	8	42.9%
Eroding Banks	2073	1914	7.7%
Total	**2087**	**1922**	**7.9%**

5.7.11 South Meadow Creek (MT41F004_070)

Sediment issues in the South Meadow Creek subwatershed arise from both the unpaved road network and eroding banks, but most erosion is from eroding banks. Moderate-high reductions are needed in order to achieve target conditions (**Table 5-43**).

Table 5-43. South Meadow Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	17	8	52.9%
Eroding Banks	2032	1378	32.2%

Table 5-43. South Meadow Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Total	**2049**	**1386**	**32.4%**

5.7.12 Watkins Creek (MT41F006_030)

The Watkins Creek subwatershed has few unpaved road crossings; sediment issues are mostly due to eroding banks. Moderate reductions in sediment loading are needed to achieve target conditions (**Table 5-44**).

Table 5-44. Watkins Creek sediment source assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	0.40	0.15	62.5%
Eroding Banks	652	459	29.6%
Total	**652.5**	**459**	**29.6%**

5.7.13 Wigwam Creek (MT41F004_160)

The Wigwam Creek subwatershed has few unpaved road crossings; sediment issues are mostly due to eroding banks. Relatively low reductions in sediment loading are needed to achieve target conditions (**Table 5-45**).

Table 5-45. Wigwam Creek sediment source Assessment, allocations, and TMDL

Sediment Sources	Existing Load (Tons/Year)	Reduced Load (Tons/Year)	Load Allocation (Percent Reduction)
Unpaved Roads	16	9	43.8%
Eroding Banks	1270	1044	17.8%
Total	**1286**	**1053**	**18.1%**

It is important to recognize that the first critical step toward meeting the sediment allocations involves applying and/or maintaining the land management practices or BMPs that will reduce sediment 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 sediment 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 after implementing grazing BMPs or allowing re-growth in areas of historical riparian harvest. 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 sediment loading. For a description of potential BMP practices, refer to **Section 9.0** and Montana DEQ's Nonpoint Source Management Plan (DEQ 2017).

5.8 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 were applied during development of the Madison TPA sediment TMDLs.

5.8.1 Seasonality

All TMDL documents must consider the seasonal applicability of water quality standards as well as the seasonal variability of pollutant loads to a stream. Seasonality was addressed in several ways:

- The applicable narrative water quality standards (**Appendix A**) are not seasonally dependent, although low flow conditions provide the best ability to measure harm to use based on the selected target parameters. The low flow or base flow condition represents the most practical time period for assessing substrate and habitat conditions, and also represents a time period when high fine sediment in riffles or pool tails will likely influence fish and aquatic life. Therefore, meeting targets during this time frame represents an adequate approach for determining standards attainment.
- The substrate and habitat target parameters within each stream are measured during summer or autumn low flow conditions consistent with the time of year when reference stream measurements are conducted. This time period also represents an opportunity to assess effects of the annual snow runoff and early spring rains, which is the typical time frame for sediment loading to occur.
- The DEQ sampling protocol for macroinvertebrates identifies a specific time period for collecting samples based on macroinvertebrate life cycles. This time period coincides with the low flow or base flow condition.
- All assessment modeling approaches are standard approaches that specifically incorporate the yearly hydrologic cycle specific to the Madison TPA. The resulting loads are expressed as average yearly loading rates to fully assess loading throughout the year.
- Allocations are based on average yearly loading and the preferred TMDL expression is as an average yearly load reduction, consistent with the assessment methods.

5.8.2 Margin of Safety

Natural systems are inherently complex. Any approach used to quantify or define the relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty or error. To compensate for this uncertainty and ensure water quality standards are attained, a margin of safety is required as a component of each TMDL. 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, 1999). This plan incorporates an implicit MOS in a variety of ways:

- By using multiple targets to assess a broad range of physical and biological parameters known to illustrate the effects of sediment in streams and rivers. These targets serve as indicators of potential impairment from sediment and also help signal recovery, and eventual standards attainment, after TMDL implementation. Conservative assumptions were used during development of these targets.
- By developing TMDLs for streams that were close to meeting all target values. This approach addresses some of the uncertainty associated with sampling variability and site representativeness and recognizes that capabilities to reduce sediments exist throughout the watershed.
- Sediment impairment is typically identified based on excess fine sediment but the targets and TMDLs address both coarse and fine sediment delivery.
- By properly incorporating seasonality into target development, source assessments, and TMDL allocations.

- By using an adaptive management approach to evaluate target attainment and allow for refinement of load allocation, targets, modeling assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development (discussed below in **Section 5.9**).
- By using naturally occurring sediment loads as described in ARM 17.30.602(17) to establish the TMDLs and allocations based on reasonably achievable load reductions for each source category.

5.9 TMDL Development Uncertainties and Adaptive Management

A degree of uncertainty is inherent in any study of watershed processes. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainty through adaptive management is a key component of TMDL implementation. The process of adaptive management is predicated on the premise that sediment assessment methods, TMDLs, allocations and their supporting analyses are not static, but are processes that can be subject to periodic modification or adjustment as new information and relationships are better understood. Within the Madison TPA, adaptive management for sediment TMDLs relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts from human activities and natural conditions, and continued assessment of how aquatic life and coldwater fish respond to changes in water quality and stream habitat conditions.

As further monitoring and assessment is conducted, uncertainties with present assumptions and consideration may be mitigated via periodic revision or review of the assessment that occurred for this document. As noted in **Section 5.8.2**, adaptive management represents an important component of the implicit margin of safety. This document provides a framework to satisfy the MOS by including sections focused on TMDL implementation, monitoring and adaptive management (**Sections 9.0** and **10.0**). Furthermore, state law (ARM 75-5-703), requires monitoring to gage progress toward meeting water quality standards and satisfying TMDL requirements. These TMDL implementation evaluations represent an important component of adaptive management in Montana.

Perhaps the most significant uncertainties within this document involve the accuracy and representativeness of 1) field data and target development and 2) the accuracy and representativeness of the source assessments and associated load reductions. These uncertainties and approaches used to reduce uncertainty are discussed in following subsections.

5.9.1 Sediment and Habitat Data Collection and Target Development

Some of the uncertainties regarding accuracy and representativeness of the data and information used to characterize existing water quality conditions and develop water quality targets are discussed below.

Data Collection

The stream sampling approach used to characterize water quality is described within **Appendix B**. To control sampling variability and improve accuracy, the sampling was done by trained environmental professionals using a standard DEQ procedure developed for the purpose of sediment TMDL development (Montana Department of Environmental Quality, 2012). This procedure defines specific methods for each parameter, including sampling location and frequency to ensure proper representation and applicability of results. Prior to any sampling, a sampling and analysis plan was developed to ensure that all activity was consistent with applicable quality control and quality assurance requirements. Site selection was a major component of the sampling and analysis plan, and was based on a stratification process described in **Appendix B**. The stratification work ensured that each stream included one or more sample sites representing a location where excess sediment loading or altered stream habitat could affect fish or aquatic life.

Even with the applied quality controls, a level of uncertainty regarding overall accuracy of collected data will exist. There is uncertainty regarding whether or not the appropriate sites were assessed and whether or not an adequate number of sites were evaluated for each stream. Also, there is the uncertainty of the representativeness of collecting data from one sampling season. These uncertainties are difficult to quantify and even more difficult to eliminate given resource limitations and occasional stream access problems.

Target Development

DEQ evaluated several data sets to ensure that the most representative information and statistic were used to develop each target parameter, consistent with the reference approach framework outlined in **Section 5.4.2**. Using reference data is the preferred approach for target setting; however, some uncertainty is introduced because of differing protocols between the available reference data and recent sample data for the project area. These differences were acknowledged within the target development discussion and taken into consideration during target setting. For each target parameter, DEQ stratified the Madison sample results and target data into similar categories, such as stream width or Rosgen stream type, to ensure that the target exceedance evaluations were based on appropriate comparisons.

The established targets are meant to apply under median conditions of natural background and natural disturbance. DEQ recognizes that under some natural conditions, such as a large fire or flood event, it may be impossible to satisfy one or more of the targets until the stream and/or watershed recovers from the natural event. Under these conditions the goal is to ensure that management activities do not significantly delay achievement of targets as compared to the time for natural recovery to occur.

Also, human activity should not significantly increase the magnitude of water quality effects from natural events. For example, extreme flood events can cause a naturally high level of sediment loading that could be further increased by a large number of road crossing or culvert failures.

Because sediment target values are based on data percentiles, DEQ recognizes that it may be impossible to meet all targets for some streams even under normal levels of disturbance. On the other hand, some target values may underestimate the potential of a given stream, and it may be appropriate to apply more protective targets upon further evaluation during adaptive management. It is important to recognize that the adaptive management approach provides flexibility to refine targets as necessary to ensure resource protection and to adapt to new information concerning target achievability. This approach is consistent with the continuous improvement activities DEQ has pursued toward interpreting and applying the narrative sediment standards.

5.9.2 Source Assessments and Load Reduction Analyses

Each assessment method introduces uncertainties regarding the accuracy and representativeness of the sediment load estimates and percent load reduction analyses. For each source assessment, assumptions must be made to evaluate sediment loading and potential reductions at the watershed scale, and because of these uncertainties, conclusions may not be representative of existing conditions and achievable reductions at all locations within the watershed. Uncertainties are discussed independently for the three major source categories of bank erosion, upland erosion, and unpaved road crossings.

Bank Erosion

The load quantification approach for bank erosion is based on a standard methodology (BANCS model) as defined within **Appendix C**. Field data collection was by trained environmental professionals per a standard DEQ procedure (Montana Department of Environmental Quality, 2012). Prior to any sampling, a sampling and analysis plan was developed to ensure that all activity was consistent with applicable quality control and quality assurance requirements. Site selection was a major component of the sampling and analysis plan, and was based on a stratification process described in **Appendix C**. The results were then extrapolated across the Madison sub-watersheds as defined in **Appendix C** to provide an estimate of the relative bank erosion loading from various streams and associated stream reaches.

Notwithstanding the above quality controls, there is uncertainty regarding the bank retreat rates, which directly influence loading rates. Even with the increased bank erosion sites, stratifying and assessing each unique reach type was not practical, therefore adding to uncertainty associated with the load extrapolation results. Also, the complexity of the BANCS methodology can introduce error and uncertainty, although this is somewhat limited by the averaging component of the measured variables.

There is additional uncertainty regarding the amount of bank erosion linked to human activities and the specific human sources, as well as the ability to reduce the human related bank erosion levels. This is further complicated by historical human disturbances in the watershed, which could still be influencing proper channel shape, pattern and profile and thus contributing to increased bank erosion loading that may appear natural. Even if difficult to quantify, the linkages between human activity such as riparian clearing and bank erosion, are well established and these linkages clearly exist at different locations throughout the Madison watershed. Evaluating bank erosion levels, particularly where best management practices have been applied along streams, is an important part of adaptive management that can help define the level of human-caused bank erosion as well as the relative impact that bank erosion has on water quality throughout the Madison watershed.

Roads

As described in **Appendix D**, the road crossings sediment load was estimated via a standardized simple yearly model developed by the U.S. Forest Service. This model relies on a few basic input parameters that are easily measured in the field, as well as inclusion of precipitation data from local weather stations. Roughly 10% of the total population of unpaved road crossings in the watershed were evaluated in the field. The results from these sites were extrapolated to the whole population of roads. The potential to reduce sediment loads from unpaved roads through the application of BMPs was assessed by reducing the existing length to the potential BMP length based on the field measured values. This approach introduces uncertainty based on how well the sites and associated BMPs represent the whole population. Although the exact percent reduction will vary by road, the analysis clearly shows the potential for sediment loading reduction by applying standard road BMPs in places where they are lacking or can be improved. The percent reductions resulting from this analysis are comparable to most road sediment reduction evaluations from other DEQ completed TMDLs.

Upland Erosion

A USLE model from the Boulder-Elkhorn TMDL assessment (which has similar ecoregions and land practices) was used to determine upland erosion loads from cultivated fields in the Elk Creek watershed, as discussed in **Appendix E**. As with any model, there will be uncertainty in the model input parameters including uncertainties regarding land use, land cover and assumptions regarding existing levels of BMP application.

The upland erosion assessment for Elk Creek integrates sediment delivery based on riparian health. The potential to reduce sediment loading was based on land cover improvements to reduce the generation of eroded sediment particles in combination with riparian improvements. The uncertainty regarding existing erosion prevention BMPs and ability to reduce erosion with additional BMPs represents a level of uncertainty. Even with these uncertainties, the ability to reduce upland sediment erosion and delivery to nearby waterbodies is well documented in literature and the reduction values used for estimating load reductions and setting allocations are based on literature values coupled with specific assessment results for Elk Creek.

Application of Source Assessment Results

Model results should not be applied as absolute accurate sediment loading values within each watershed or for each source category because of the uncertainties discussed above. Because of the un-calibrated nature of the source assessment work, the relative percentage of the total load from each source category does not necessarily indicate its importance as a loading source. Instead, the intention is to separately evaluate source impacts within each assessment category (e.g., bank erosion, upland erosion, roads) and use the modeling and assessment results from each source category to evaluate reduction potentials based on different BMP scenarios. The process of adaptive management can help sort out the relative importance of the different source categories through time.

6.0 Temperature TMDL Components

This portion of the document focuses on temperature as a cause of water quality impairment in the Madison TMDL Planning Area (TPA). It describes: (1) effects of elevated water temperature on beneficial uses, (2) the affected stream segments, (3) the currently available data pertaining to temperature impairments in the planning area, (4) the sources of elevated temperature based on recent studies, and (5) the temperature TMDLs and their rationales.

6.1 Effects of Excess Temperature 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 and fish that depend upon cool water for survival. Increased water temperature reduces dissolved oxygen and causes increased primary production via algal (Robarts and Zohary 1987) and bacterial (Kaplan and Bott 1989) growth that can exacerbate nutrient-related problems and lead to further reductions in dissolved oxygen. In addition, higher instream temperatures make fish more prone to disease (Tops et al. 2006; Roth 1972). Coldwater fish species are more stressed in warmer water temperatures as these conditions increase metabolism and reduce the amount of available oxygen in the water. Coldwater fish and other aquatic species may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, sometimes creating lethal conditions for a percentage of the fish population. Elevated temperatures can also 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).

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 each stream segment of concern. To help put sampling data into perspective and understand how elevated stream temperatures may affect aquatic life, information on fish species of concern presence in the Madison TPA is described below.

The fish species of concern that historically occupied the Madison TPA are Westslope cutthroat trout and Arctic grayling. Montana Fish Wildlife and Parks data in the MFISH database (http://fwp.mt.gov/fishing/mFish/) indicate that Westslope cutthroat trout still occupy drainages within the TPA. Special temperature considerations are warranted for this species because of its status as species of concern and its requirement for coldwater habitat. 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 were found to have a similar optimum growth temperature; however, rainbow trout were predicted to grow better over a wider range of temperatures than Westslope cutthroat trout, with growth being significantly better at temperatures below 44.2° F and above 69.4°F, possibly allowing for increased competition with Westslope cutthroat trout in lower-elevation (warmer) streams. The upper incipient lethal temperature (UILT) is the temperature considered to be survivable by 50% of a population over a specified time period. The sensitivity of Westslope cutthroat trout to temperature has also been illustrated by the higher UILT values compared to rainbow trout. Bear et al. (2007) found the 60-day UILT for Westslope cutthroat trout to be 67.3°F and the 7-day UILT to be 75.4°F. In contrast they observed that rainbow trout had a 60-day UILT of 75.7°F and a 7-day UILT of 78.8°F. The lethal temperature dose in a 24 hour period for 10% of the population was found to be 73.0°F for Westslope cutthroat trout (Liknes et al. 1988).

Although Arctic grayling were nearly entirely extirpated from the drainage, re-introduction efforts have resulted in successful reproduction in Moore Creek. The 7-day UUILT for Arctic grayling is 77.0°F (Lohr et al. 1996), which is higher than that of Westslope cutthroat trout. Given the lower tolerance of Westslope cutthroat trout the temperature requirements noted above for Westslope cutthroat trout. were used in determining severity of temperature impairment and were used during source assessment, in addition to shade data, to highlight areas where Montana's temperature standard is likely being exceeded and the severity of those exceedances.

A lack of shade and an over-widened channel can also result in lower winter temperatures due to increased heat exchange (Hewlett and Fortson 1982; Poole and Berman 2001). These 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 and subsequently developing temperature TMDLs.

6.2 Stream Segments of Concern

The temperature impaired stream segments of concern for which TMDLs were developed in the Madison TPA are listed in **Table 6-1**. **Figure 6-1** shows the location of these three temperature impaired stream segments in the Madison TPA. Summaries of stream segments that were assessed with no TMDL written at this time are found in **Appendix H**.

Table 6-1. Temperature Impaired Streams in the Madison TMDL Planning Area

Waterbody (Assessment Unit)	Assessment Unit ID
Cherry Creek – headwaters to mouth (Madison River)	MT41F002_010
Elk Creek – headwaters to mouth (Madison River)	MT41F002_020
Moore Creek – springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130

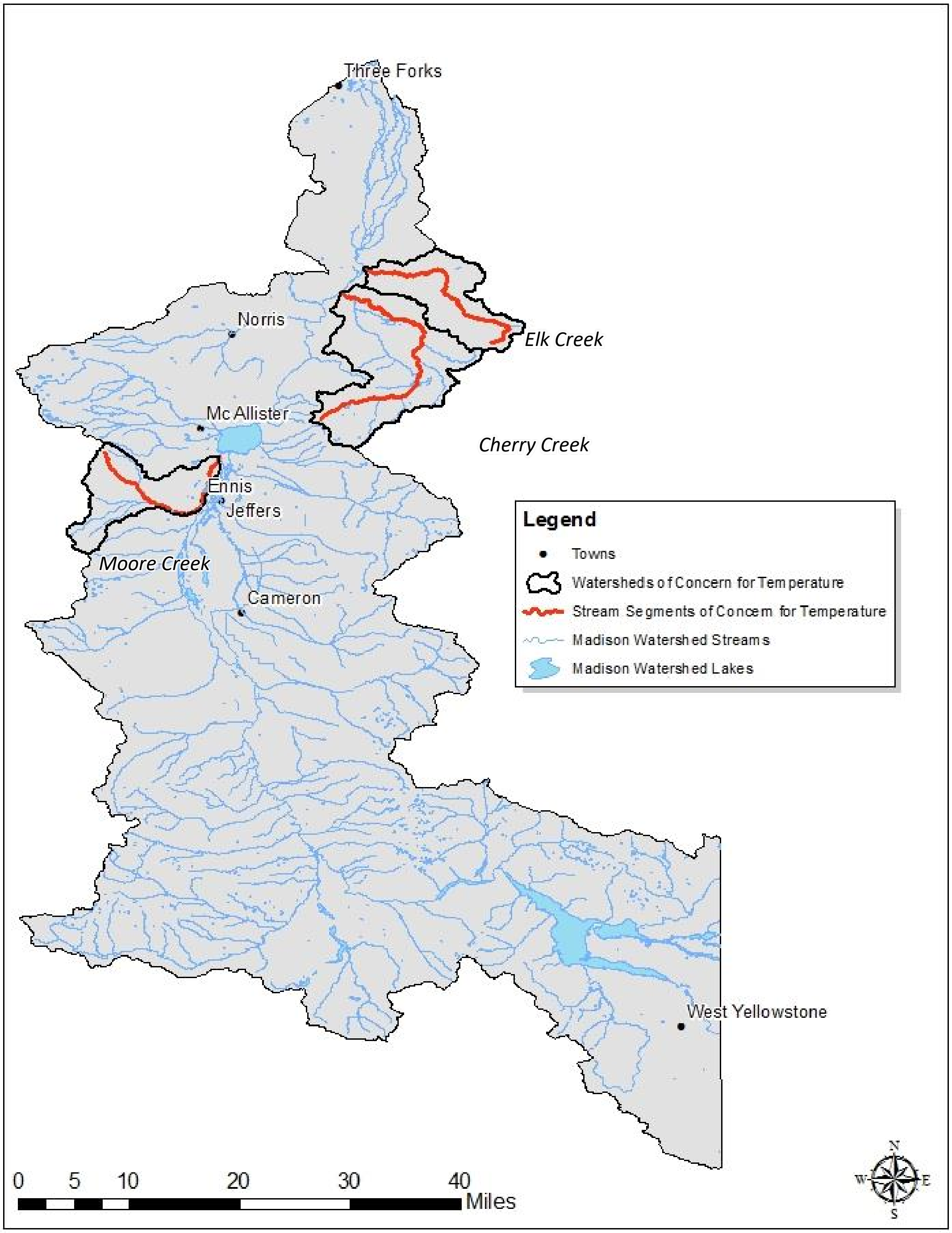

Figure 6-1. Map of the Temperature Impaired Streams in the Madison TMDL Planning Area

6.3 Information Sources

The information sources used to develop the TMDL components include data used to determine impairments (see **Section 3.0**) and data obtained during the TMDL development process. The data collected by DEQ, its contractors, other agencies or organizations, and volunteer monitoring groups, was catalogued within DEQ's centralized water quality database and DEQ collected data can also be found in

Appendix G of this document. Data and information used for impairment determination, source assessment, and TMDL development consisted of:

- Water temperature and streamflow data collected by DEQ, Montana Fish, Wildlife, and Parks (FWP), Northwestern Energy (formerly PPL Montana), and the Madison Stream Team
- Stream channel morphology, vegetation, and shade data collected by DEQ
- Fisheries inventories conducted by FWP
- Streamflow data collected by the USGS
- Grazing management plans developed by the Bureau of Land Management (BLM) and the US Forest Service (USFS)
- Cropland data collected by the US Department of Agriculture (USDA)
- Aerial photography and Geographic Information System (GIS) data and analysis
- Literature reviews

DEQ's methods for temperature TMDL development included a combination of characterizing water temperatures throughout the summer, and collecting vegetation, channel width, shade, and streamflow data, which were used to model shade using the Shade Tool (Washington State Department of Ecology 2008). Sample locations were generally such that they provided a comprehensive upstream to downstream view of stream temperature. The location of sample collection also allowed for analysis of potential source impacts (e.g., shade, irrigation influence, point sources). All data used in TMDL development were collected during June – September, the time of year when fish are likely to be the most stressed by thermal conditions.

The data used for the analyses in this document can be obtained from the Montana Department of Environmental Quality's Water Quality Division. Other water quality data from the watershed are publicly available through the Environmental Protection Agency's (EPA) Water Quality Portal and DEQ's EQuIS water quality database.

6.3.1 Temperature Monitoring

Temperature monitoring was conducted in 2013 on Cherry Creek, Elk Creek, and Moore Creek, between June and September. The study examined stream temperatures during the period when streamflow tends to be the lowest and water temperatures the warmest, and thus when negative effects to the aquatic life beneficial use are likely most pronounced. Temperature monitoring consisted of placing temperature data loggers at multiple sites within the watershed. Temperature monitoring sites were selected to bracket stream reaches with similar hydrology, riparian vegetation type, valley type, stream aspect, and channel width. Temperature data are summarized within **Section 6.4.2** of this document and **Appendix G**.

6.3.2 Streamflow

Streamflow measurements were collected at multiple locations on each of the stream segments of concern for temperature. Streamflow data used in the model included data collected by DEQ on Cherry Creek, Elk Creek, and Moore Creek in 2013, and by the Madison Stream Team on Moore Creek in 2013 (Madison Stream Team 2013, **Appendix G**).

6.3.3 Riparian Shading

Characterization of riparian shade was based on a combination of field data and aerial imagery analysis. Riparian shading was quantified using GIS tools and aerial imagery analysis to input variables into the Shade Tool (**Appendix I**), which is a model developed by the Washington Department of Ecology that calculates the percent effective shade and solar flux along a stream (Washington State Department of Ecology 2008). Field data were collected by DEQ to input into the Shade Tool, and Solar Pathfinder measured shade data were collected at multiple sites along each stream to verify and calibrate the Shade Tool outputs (**Appendix G**).

6.3.4 Channel Geometry

Although not a direct measure of thermal effect on the stream, channel geometry can influence the rate of thermal loading. Wide, shallow streams transfer heat energy faster than narrow, deep streams. Therefore, channel geometry can be used to identify areas that may be destabilized, and may be more prone to rapid thermal loading, particularly in locations where shading is minimal. Channel geometry measurements were obtained during field outings be Montana DEQ, including those selected during sediment surveys, shade surveys, and when measuring discharge as described in **Appendix G**.

6.4 Water Quality Targets

Water quality targets are measurable indicators used to evaluate attainment of water quality standards, and are discussed in further detail in **Section 4.0**. The following section describes 1) the framework for interpreting Montana's temperature standard; 2) the selection of indicator parameters used as targets for TMDL development and how target values were developed; and 3) a summary of the temperature target values for Madison TPA temperature streams of concern.

6.4.1 Temperature Targets and Target Values

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. For waters classified as B-1, which includes all stream segments of concern for temperature in the Madison TPA, 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 [Administrative Rules of Montana (ARM) 17.30.623(e)]. To further understand this standard, **Figure 6-2** is a graphic displaying the Montana temperature standard for B-1 classified waterbodies.

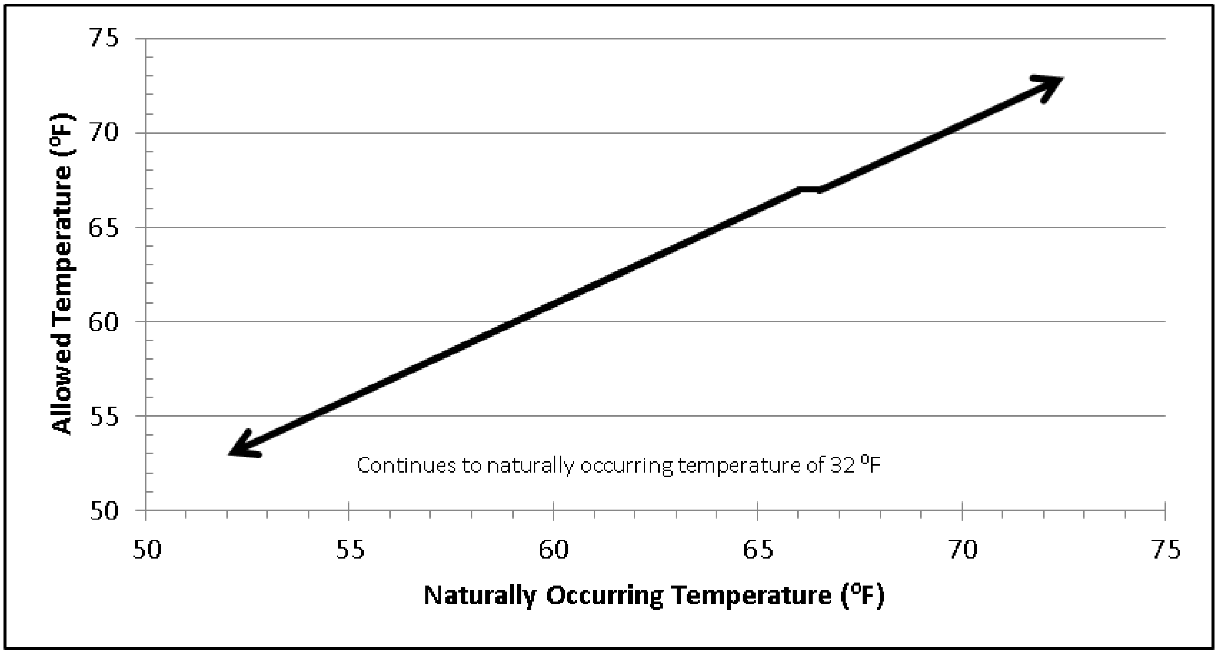

Figure 6-2. Montana's Temperature Standard for B-1 Classified Waterbodies

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 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 whether it is likely that the allowable temperature change is being exceeded, a suite of temperature TMDL targets were developed to translate the narrative temperature standard into measurable parameters that collectively represent attainment of applicable water quality standards at all times. The goal is to set the target values at levels that occur under naturally occurring conditions but are conservatively selected to incorporate an implicit margin of safety that helps account for uncertainty and natural variability.

Because naturally occurring temperatures can significantly vary throughout the summer, as well as from year to year, the quantified temperature targets include those indicator parameters that influence temperature and can be linked to human causes. These indicator or target parameters include riparian health/shade and channel geometry. Improved streamflow conditions, where applicable, will also help decrease stream temperatures. Values are developed for each target parameter and are set at levels that result in attainment of Montana's temperature standard under all seasonal and yearly variability. The goal is to set the target values at levels that would contribute to naturally occurring temperature conditions, while ensuring that any variability from naturally occurring conditions is less than that allowed by the standard. The target values presented are protective of the use most sensitive to elevated temperatures, aquatic life; as such, the targets are protective of all designated uses for the applicable waterbody segments.

For the stream segments of concern in the Madison TPA, the Shade Tool (Washington State Department of Ecology 2008) was the primary means of examining the difference between existing shade and potential shade conditions for a given stream and determining the likelihood that water temperatures are excessively warm as a result of insufficient shade. The Shade Tool estimates effective shade at a particular point based on topography, vegetation height and density, stream channel width, and time of year. Existing shade was modeled based on aerial photography and vegetation currently existing, while potential shade was determined based on shade curves for the expected vegetation community (**Appendix I**). These shade curves were developed by the EPA and Idaho DEQ, and serve as a reference condition for an expected vegetative community (Shumar and de Varona 2009).

Although the primary temperature target is the allowable human-caused temperature change (i.e., 0.5 – 1.0°F, depending on the naturally occurring temperature), it is expected that this target can be achieved by meeting the riparian shade targets and channel geometry (bankfull width/depth) targets for each stream of concern. Improvements in instream flow conditions are beneficial in helping to meet the temperature target, and a 15% increase in streamflow is recommended as a starting point. Any voluntary water savings and subsequent in-stream flow augmentation must be done in a way that protects water rights. The temperature and temperature-influencing targets are described in more detail below.

6.4.1.1 Allowable Human-Caused Temperature Change

The target for allowable human-caused temperature change for streams in the Madison TPA links directly to Montana's temperature standard for B-1 streams [ARM 17.30.623(e)] (**Section 6.4.1**). Naturally occurring temperatures incorporate natural sources, yet also include human sources that are applying all reasonable land, soil, and water conservation practices.

6.4.1.2 Riparian Health/Shade

Increased shading from riparian vegetation reduces sunlight hitting the stream, thus reducing 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. In addition, lack of established riparian areas can lead to bank instability, which could result in over-widened streams. Human influences affecting riparian canopy cover in the Madison TPA watersheds include present and historical agricultural activities, timber harvest, and residential development.

DEQ uses a reference approach to define naturally occurring conditions for riparian health. DEQ defines "reference" as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, the reference condition reflects a waterbody's greatest potential for water quality given past and current land-use activities. The riparian shade targets for the Madison TPA stream segments of concern are based on vegetation effective shade curves developed by the EPA and Idaho DEQ, which represent potential reference conditions for the respective streams based on stream orientation (aspect), bankfull width, and plant species (Shumar and de Varona 2009). The detailed shade targets for each stream can be found in **Section 6.4.2.**

Improvement in riparian health needs significant time before changes are visible. DEQ does not expect these targets to be met in the short-term; however, changes in land management practices and a commitment to those practices would need to be implemented to start meeting goals for temperature in the Madison TPA. DEQ recognizes that for any given stream segment, target values may be lower or higher than the actual potential depending on the presence of roads and road crossings and the vegetation that can be established. An adaptive management approach should be used in concert with the effective shade target values to ensure that the true potential effective shade is realized for each stream segment.

6.4.1.3 Channel Width/Depth Ratio

The width/depth ratio is a dimensionless value representing a fundamental aspect of channel morphology, and provides a measure of channel stability. As the width/depth ratio increases, streams become wider and shallower, and susceptible to an increase in thermal loading to the stream. 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). A narrower channel also increases the effectiveness of shading produced by the riparian canopy. Width/depth ratios were calculated for each DEQ assessment reach based on four riffle cross section measurements. This parallels the method used by the US Forest Service for the PacFish/InFish Biological Opinion Monitoring Program (PIBO) for width/depth from 2001-2008. From 2009-2014 the PIBO width/depth average was calculated from 10 channel cross-sections in riffle and pool features.

There is reference riffle width/depth ratio data for both the DEQ and PIBO datasets and the two were combined to develop the targets. Statistical analyses determined that bankfull width was the best correlation for width/depth ratio given that PIBO does not assign a Rosgen stream type. The target values for width/depth ratio are based on the 75th percentile of the combined DEQ and PIBO Middle Rockies level IV ecoregion reference datasets and are defined by bankfull width category (**Table 6-2**). This upper limit provides a target that prevents over widening of the channel with an accompanying decrease in mean depth.

Table 6-2. Data Summary for DEQ and PIBO Middle Rockies Reference sites for Width/Depth Ratios

Data Source	Sample Size	Minimum	Median	Maximum	Target (75th percentile)
< 15 ft bankfull width	17	6.4	10.6	14.9	11
15 - 30 ft bankfull width	34	14.2	20.1	43.4	24
> 30 ft bankfull width	5	25.5	29.1	34.4	30

The target is not intended to be specific to every given point on the stream; the intent rather, is to maintain width/depth ratios in their current condition throughout each segment. If specific locations have the potential to become narrower, improved vegetation in riparian areas will generally lead to gradual improvements in these width/depth ratios over time. If deemed appropriate, active restoration techniques could be used to give the stream channel an appropriate width and depth at these locations.

6.4.1.4 Instream Discharge (Streamflow Conditions)

Larger volumes of water take longer to heat up during the day; therefore, the volumetric heat capacity of a stream is reduced if water volumes are reduced. Reductions in water withdrawals resulting from voluntary reductions in water withdrawals, in-stream water leases and reservations, or improvements in water diversion, delivery, or application infrastructure, can lead to an increase in streamflow, and ultimately lower water temperatures for the stream. 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 Section 75-5-705). As a result, any voluntary water savings and subsequent in-stream flow augmentation must be done in a way that protects water rights, and water users are encouraged to work with the United States Department of Agriculture Natural Resource Conservation Service (NRCS), the Montana Department of Natural Resources and Conservation (DNRC), their local conservation district, and other state, federal, or local land management agencies to review their irrigation systems, practices, and the variables that may affect overall water use efficiencies (Negri and Brooks 1990; NRCS NEH 652). A target increase in stream flow of 15% is a good starting point, which may result in a decrease in daily maximum temperatures.

In-stream water leases or reservations are a way that a water right holder can reduce their water withdrawals from a stream, while still maintaining the ownership of their water right. The State of Montana has a statutory water leasing program to provide water for fish in streams. A water user that wishes to reduce irrigation water withdrawals to improve in-stream flows has three options (1) convert all or part of a consumptive-use water right to an in-stream use by seeking a change in purpose and place of use without the use of a lease; (2) lease a water right to Montana Department of Fish Wildlife and Parks; or (3) lease a water right to a private entity such as Trout Unlimited (Bradshaw ND).

Improving irrigation water application efficiencies is a potential tool to divert less water and leave more water in the stream; however, improvements in application efficiencies do not themselves equate to less water use and must be accompanied by reduced water withdrawals to achieve the goal of increased streamflow. Irrigation water application efficiencies for flood irrigation on average are 35% efficient, while high pressure sprinkler applications (hand lines and wheel lines) on average are 65% efficient, and low pressure center pivot or linear sprinklers on average are 80% efficient (NRCS NEH 652). Higher application efficiencies result in greater application uniformity, higher crop yield, and less water losses due to runoff or deep percolation. To achieve an in-stream water savings through irrigation system upgrades, the producer will likely have to sacrifice some of the increase in crop yield gained by upgrading the irrigation system, which may not be economically feasible to the producer.

Improving the efficiencies of existing irrigation diversions and delivery ditches is another potential tool that could possibly lead to additional increases in instream flow due to reduced water withdrawals. Each diversion and delivery ditch is unique, and this study did not attempt to characterize each piece of irrigation infrastructure in the watershed. Unlined delivery ditches typically have low efficiencies for getting water from the point of diversion to the point of use, and therefore more water must be diverted to obtain the desired amount of water at the point of use. Lining delivery ditches with a more impermeable material to reduce loss due to percolation or using pipe will improve water delivery efficiencies and could potentially allow the water user to leave more water in the stream during the irrigation season.

6.4.1.5 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 all temperature-influencing targets for shade (**Table 6-3**). In this approach, if all reasonable land, soil, and water conservation practices are installed or practiced, state standards are met.

Table 6-3. Temperature Targets for the Madison TPA

Temperature Target Parameter	**Target Value**
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.

Table 6-3. Temperature Targets for the Madison TPA

Temperature Target Parameter	Target Value
Riparian health/shade	A riparian buffer producing effective shade representative of the potential vegetative community for each respective Level IV Ecoregion. Waterbody and location specific shade targets can be found in **Section 6.4.2**.
Bankfull width/depth ratio[1]	< 15 ft bankfull width - Target: a width/depth ratio of ≤ 11
	15 ft - 30 ft bankfull width - Target: a width/depth ratio of ≤ 24
	> 30 ft bankfull width - Target: a width/depth ratio of ≤ 30
Instream discharge	15% water savings from improved irrigation delivery and application efficiencies (any voluntary water savings and subsequent in stream flow augmentation must be done in a way that protects water rights)

[1] Bankfull width/depth ratio targets are equal to the target values set for sediment impaired streams in **Section 5.0**

6.4.2 Existing Conditions and Comparison to Targets

DEQ evaluated temperature target attainment by comparing existing effective shade with riparian health/shade targets in **Table 6-3**. For each waterbody segment, a comparison of existing data with targets is presented.

6.4.2.1 Cherry Creek

Cherry Creek flows from its headwaters in the Madison Range to its mouth at the Madison River, below Ennis Lake. A summary of the existing temperature-related water quality conditions and a comparison of those conditions to water quality targets are presented in this section.

Water Temperature

In 2013 DEQ collected water temperature at 30-minute intervals and shade-related data from three sites on Cherry Creek (Sites 2A, 2B, and 2C, **Appendix G**) (**Table 6-4** and **Figure 6-3**). Sites CHRR 18-02 and CHRR 20-01 in **Figure 6-3** were sites where only channel geometry measurements were collected, but are shown for reference because the width of the stream affects heating at the water surface and was used in Qual-2k model development described below. A maximum temperature (T_{max}) of 77.9°F was recorded at Site 2A near the mouth, with 34 days exceeding 73°F, which is the 24-hour lethal temperature dose for 10% of the population of Westslope cutthroat trout. The warmest 7-day period in 2013, or the Maximum Weekly Maximum Temperature (MWMT) was 76.3°F, which also exceeded the 7-day Upper Incipient Lethal Temperature (UILT) of 75.4°F for Westslope cutthroat trout. The UILT is the temperature at which 50% of Westslope cutthroat die after 7 days of exposure.

Table 6-4. Temperature Data Summary for Cherry Creek in 2013

Stream	Site[1]	Maximum Temperature (T_{max})	7-day Average Daily Maximum (MWMT)	Number of Days With Water Temperatures Exceeding 73°F
Cherry Creek	2A	77.9°F	76.3°F	34
Cherry Creek	2B	66.4°F	65.2°F	0
Cherry Creek	2C	66.3°F	65.3°F	0

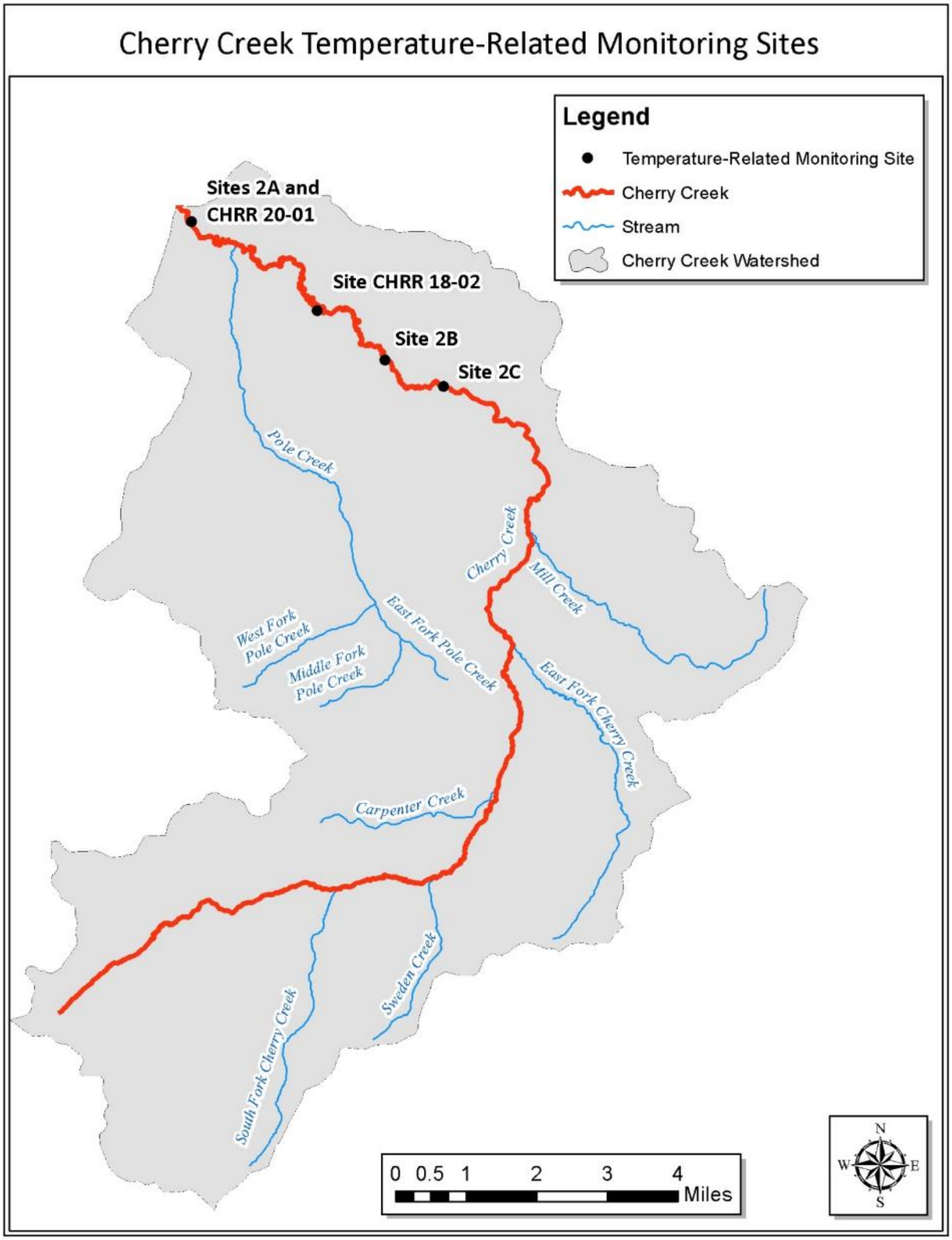

Figure 6-3. Map of Temperature-Related Monitoring Sites on Cherry Creek

Figure 6-4 shows the water temperature data for Cherry Creek near the mouth (Site 2A). This data shows that there were several exceedances of the 24-hour lethal dose threshold for 10% of the population of Westslope cutthroat trout in July, August, and September. The MWMT threshold was also exceeded in July and September, indicating that water temperature is potentially harming the Westslope cutthroat trout population in Cherry Creek.

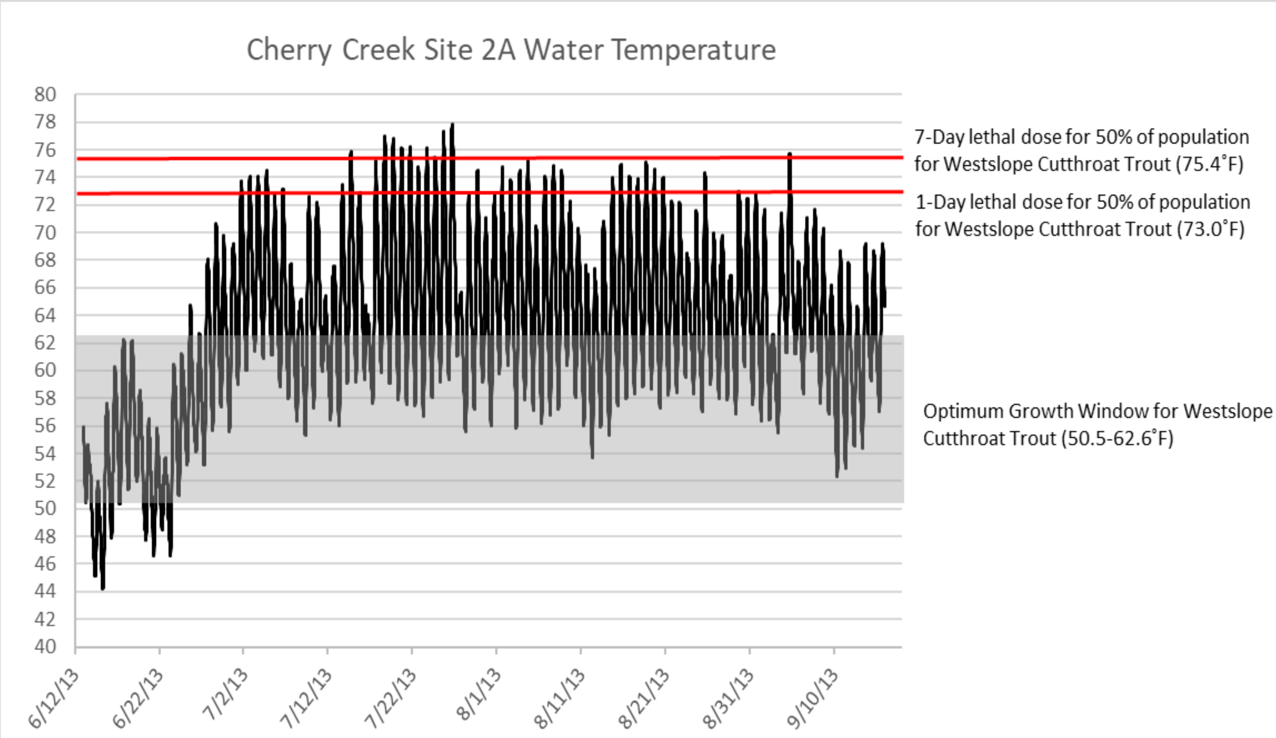

Figure 6-4. Water Temperature Data for Cherry Creek near the Mouth (Site 2A)

Riparian Health/Shade

Shade-related data, including Solar Pathfinder data (**Appendix G**) were collected at sites 2A, 2B, and 2C, and used in conjunction with aerial photography to model the existing effective shade using the Shade Tool (Washington State Department of Ecology 2007). Shade targets were developed based on level IV ecoregion and the expected riparian vegetation community for that ecoregion (**Appendix I**). That vegetation community was then compared to shade curves developed for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009). **Figure 6-5** compares the existing effective shade to its respective shade targets, while **Figure 6-6** plots the difference between the existing effective shade and the shade targets. The plots are displayed in an upstream (left) to downstream (right) orientation to easily correlate targets and existing shade to location on the stream. Positive numbers in **Figure 6-6** indicate that the existing effective shade exceeds the shade targets, while negative numbers indicate areas where existing effective shade is deficient. A section near the headwaters of Cherry Creek was excluded from this analysis because it had been burned by a forest fire and was showing a significant shade deficit when compared to shade targets. Since this was a naturally occurring event, it was excluded from the dataset as to not skew the data. As shown in **Figure 6-6**, the lower portion of Cherry Creek (downstream of Site 2B) has deficient shade in comparison to shade targets, which is ultimately contributing to the high-water temperatures collected near the mouth at Site 2A.

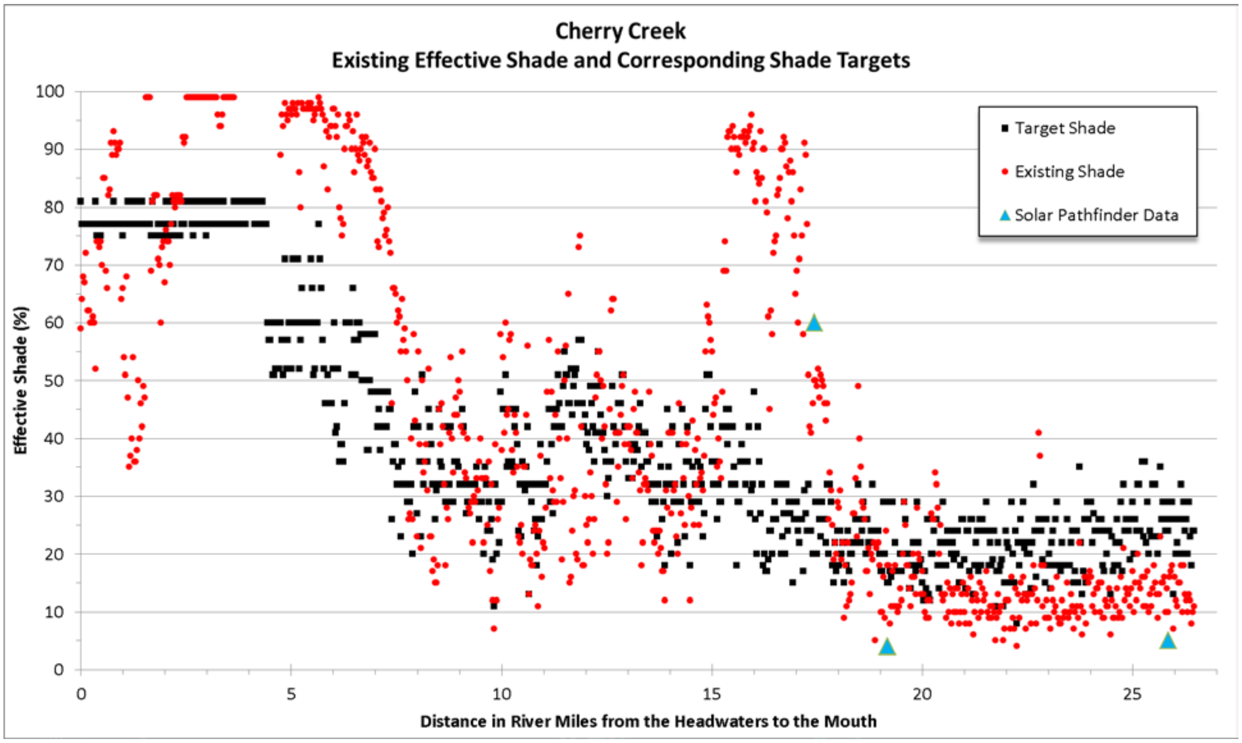

Figure 6-5. Existing Effective Shade and Corresponding Shade Targets for Cherry Creek

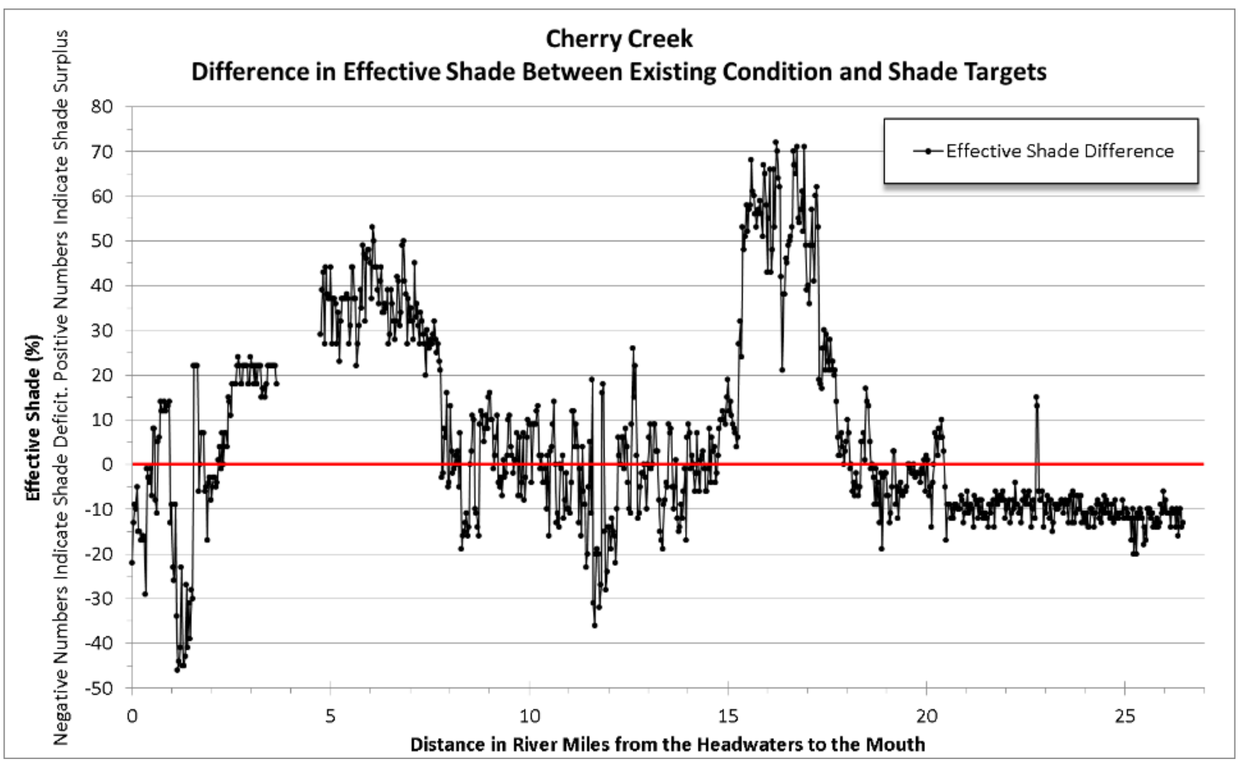

Figure 6-6. Difference in Effective Shade between Existing Condition and Shade Targets for Cherry Creek

Channel Width/Depth Ratio

Channel width/depth ratio was measured at two sites along Cherry Creek as a part of the data collection effort to assess sediment impairment (**Section 5.0**). Data collected by DEQ in 2014 indicate that Cherry Creek is meeting the width/depth ratio targets at the two monitoring sites (**Table 6-5**). Although this data was collected in two discrete locations, the locations of the monitoring sites were chosen because they are assumed to be representative of Cherry Creek as a whole. It is possible that the width/depth ratio may be exceeding targets in areas along Cherry Creek, especially in areas where land management practices are poor, but areas that have good land management practices in place should not be negatively affecting the width/depth ratio of Cherry Creek. The stream appears to be in recovery from past poor land use practices and it is likely that if the existing land management practices continue to be implemented, conditions will improve in Cherry Creek.

Table 6-5. Cherry Creek Calculated Width/Depth Ratios in Comparison to Width/Depth Ratio Targets

Reach/Site ID	Year Data Collected	Mean BFW (ft)	W/D Ratio Target	W/D Ratio
CHRR 18-02	2014	30.5	≤ 30	18.5
CHRR 20-01	2014	33.1	≤ 30	21.2

Instream Discharge (Streamflow Conditions)

As of February 4, 2020, a total of six entities held water rights on Cherry Creek and its tributaries. Historically, the lower 4.5 miles of Cherry Creek was severely dewatered during the summer irrigation season; in response to this dewatering, Montana FWP obtained a water right for an instream flow reservation of 15 cfs for the purpose of providing spawning and rearing habitats to trout and whitefish residing in the Madison River, to maintain the existing resident trout populations, and to help protect the habitat of those wildlife species which depend on the stream and its associated riparian zone for food, water, and shelter.

Qual2k Temperature Simulation and Implications for Fish Populations

Water temperature, flow, channel characteristics, and riparian shade data were incorporated into a QUAL2K water quality model to characterize existing temperature conditions and evaluate the effects of increases in shade and streamflow for Cherry Creek (Chapra et al 2012). The model was developed for the warmest water temperature day occurring during temperature logger deployment during summer 2013, which occurred on 7/26/2013.

The portion of stream modeled during this analysis extended from the mouth of Cherry Creek to approximately 9 miles upstream, which occurs near site 3C (**Figure 6-3**). Within the model, water temperatures were predicted largely based on climate data from the Western Climate Center (https://wrcc.dri.edu/) Ennis Montana weather station. Estimates of riparian shade along the length of the study section were estimated using the Shade Tool (**Section 6.4.2.1**). Headwater temperature conditions were estimated using hourly temperature loggers deployed at monitoring sites in **Figure 6-3**. Channel characteristics were based on field measurements taken by Montana DEQ during discharge measurements and sediment surveys. Detailed boundary conditions and parameter used in the model can be found in **Appendix J**. The model is considered adequate for evaluating the potential impacts of increasing shade and stream flow on water temperature. However, it may not be suitable for all purposes.

The performance of the model was evaluated by comparing modeled temperatures at temperature loggers to actual temperatures collected on 7/26/2013 using the absolute relative error method, as described in **Appendix J**. Despite limited field data, the modeled maximum temperatures approximated measured maximum temperatures with an error rate of 1.9% (representing the average percent difference between modeled and actual conditions) (**Appendix J**; Table J-1).

Based on measured and modeled conditions, actual maximum temperatures became suitable for Westslope cutthroat trout at approximately 3.5 miles upstream from the mouth. Although temperature was not collected above Site 2C, temperatures continued to decrease with distance upstream indicating that the entire section upstream of the modeled section was likely suitable for Westslope cutthroat trout during the day of 7/26/2013 (**Appendix J**; Figure J-1)

The potential management scenarios modeled as part of this exercise include an 15% increased flow scenario, an increased shade scenario to represent achievable shade increases as a result of riparian restoration, and a scenario that included both actions (15% increased flow and increased shade). The increased shade scenario was developed using predictions of natural vegetation for ecoregion IV and shade curves for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009; **Section 6.5.2.1** and **Appendix J)**. Results indicated that the increased flow scenario decreased modeled maximum temperatures by an average of 1.1˚C at the most downstream site, while the increased shade scenario decreased modeled maximum temperatures by 1.5˚C. The combined scenario decreased modeled maximum temperatures by 1.9˚C (**Appendix J**; Figure J-4)

None of the scenarios resulted in a substantial increase in potential stream miles inhabited by Westslope cutthroat trout (The combined scenario resulted in only a ~ 0.5 mile potential increase in usable habitat) although an increase in shade had the most impact. However, given that the modeling represented the warmest day of the year, increased shade could increase the habitable portion of Cherry Creek by a greater amount other parts of the summer with less warm temperatures. Westslope cutthroat trout on Cherry Creek reside primarily above a waterfall located approximately 8 miles upstream from the mouth that provides a barrier from non-native fish (Shepard et al. 2020), but some of the Westslope cutthroat residing in upper Cherry Creek have migrated to lower Cherry Creek and the Madison River (Yablonski 2014). Decreasing temperatures in this lower section could prove beneficial to Westslope cutthroat trout, although further research would be done to fully understand the impact of increased shade on temperature as well as potential impacts to the Westslope cutthroat trout population.

6.4.2.2 Elk Creek

Elk Creek flows from its headwaters in the Madison Range to its mouth at the Madison River, below Ennis Lake. Elk Creek was listed as impaired by temperature in the 2016 Integrated Report based on recent data collected and the comparison of that data to the water quality targets outlined in **Table 6-3**. A summary of the existing temperature-related water quality conditions and a comparison of those conditions to water quality targets are presented in this section.

Water Temperature

In 2013 DEQ collected water temperature at 30-minute intervals and shade-related data from four sites on Elk Creek (Sites 1A, 1B, 1C, and 1D, **Appendix G**) (**Table 6-6** and **Figure 6-7**). Sites ELKC11-01, ELKC05-01, ELKC06-02 and M06ELKC07 in **Figure 6-7** were sites where only channel geometry measurements were collected. They are shown for reference because the width of the stream affects heating at the water surface and was used in Qual-2k model development described below. A maximum temperature (T_{max}) of 84.7°F was recorded at Site 1A near the mouth, with 9 days exceeding 73°F, which is the 24-hour lethal temperature dose for 10% of the population of Westslope cutthroat trout. Site 1A went dry on June 18th due to irrigation diversions, but all sites had multiple days exceeding 73°F. The warmest 7-day period in 2013, or the Maximum Weekly Maximum Temperature (MWMT) was 78.3°F at Site 1B, and the MWMT at all sites exceeded the 7-day UILT of 75.4°F for Westslope cutthroat trout.

Table 6-6. Temperature Data Summary for Elk Creek in 2013

Stream	Site[1]	Maximum Temperature (T_{max})	7-day Average Daily Maximum (MWMT)	Number of Days With Water Temperatures Exceeding 73°F
Elk Creek	1A	84.7°F	75.8°F	9
Elk Creek	1B	80.6°F	78.3°F	16
Elk Creek	1C	77.7°F	75.7°F	15
Elk Creek	1D	77.8°F	76.0°F	12

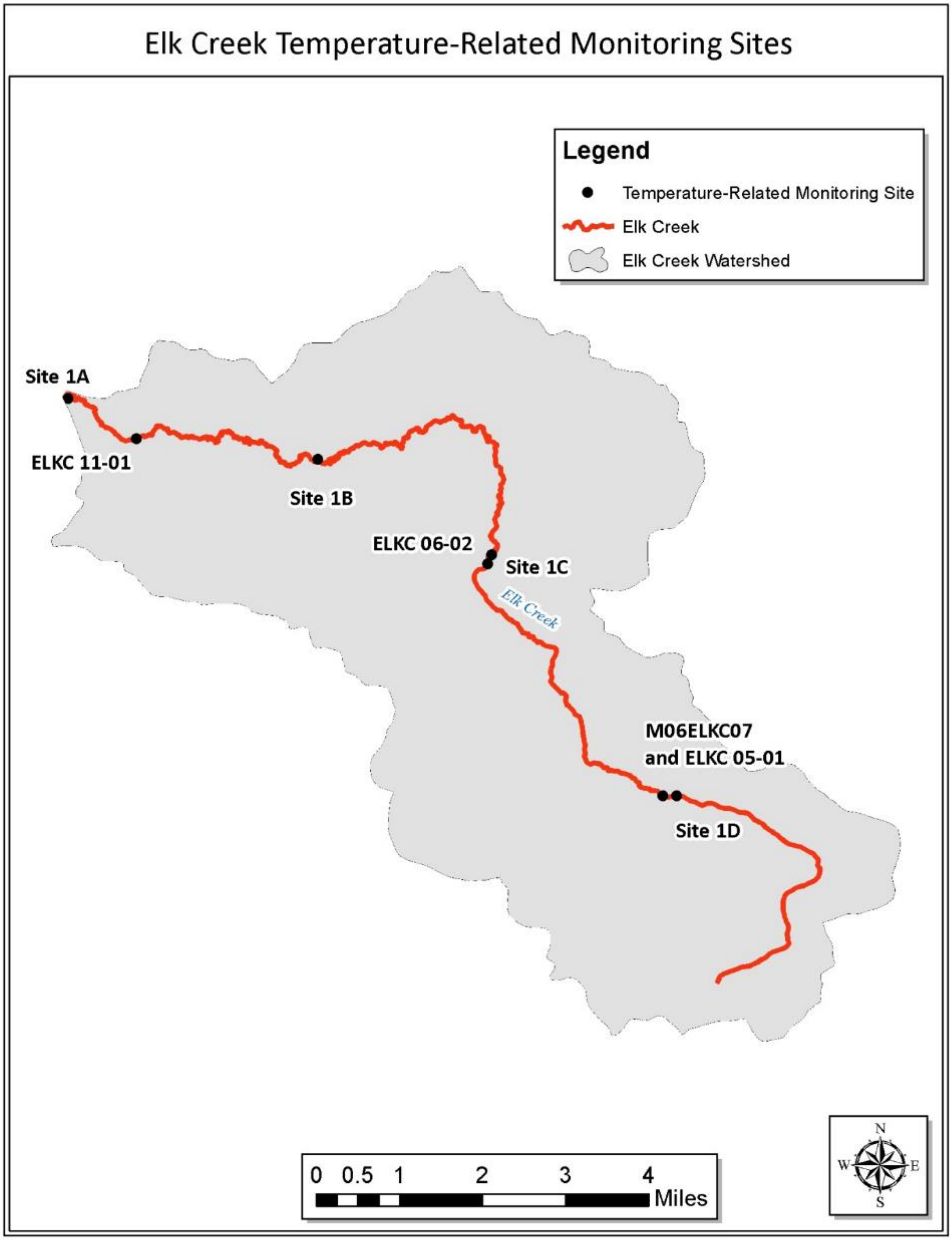

Figure 6-7. Map of Temperature-Related Monitoring Sites on Elk Creek

Figure 6-8 shows the water temperature data for Elk Creek Site 1B. This data shows that there were several exceedances of the 24-hour lethal dose threshold for 10% of the population of Westslope cutthroat trout in June and July. The MWMT threshold was also exceeded in June and July.

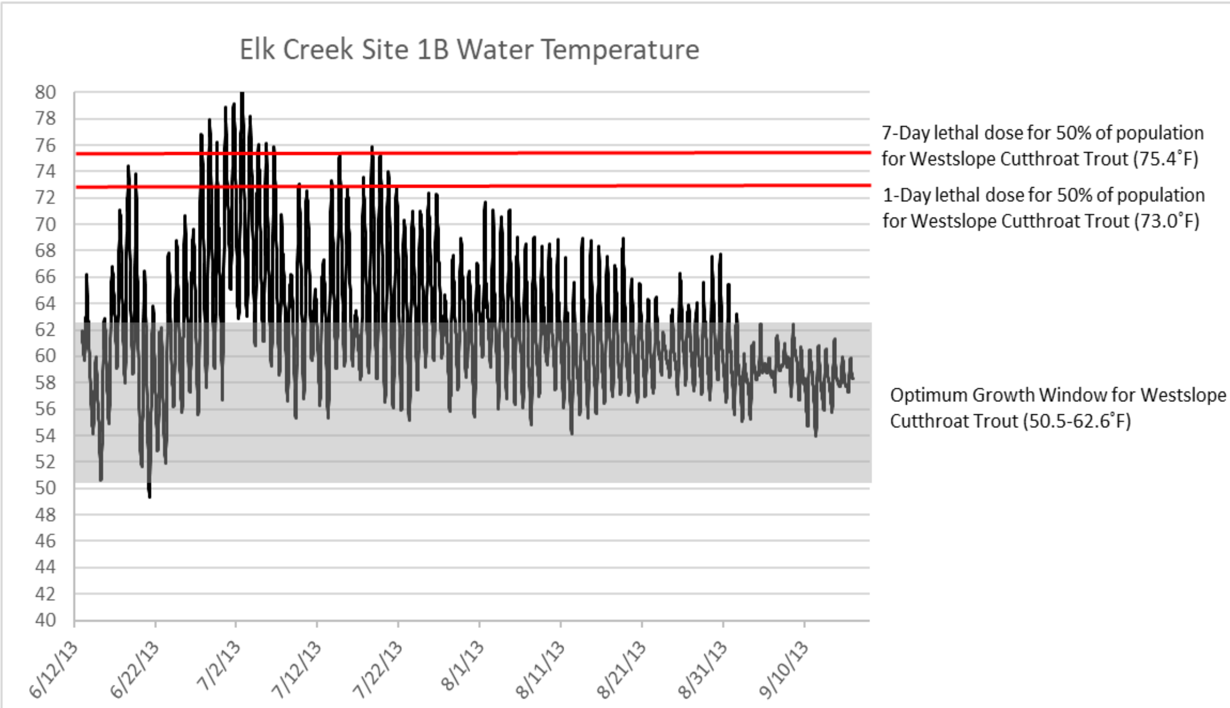

Figure 6-8. Water temperature data for Elk Creek Site 1B

Riparian Health/Shade

Shade-related data, including Solar Pathfinder data (**Appendix G**) were collected at sites 1A, 1B, 1C, and 1D, and used in conjunction with aerial photography to model the existing effective shade using the Shade Tool (Washington State Department of Ecology 2008). Shade targets were developed based on level IV ecoregion and the expected riparian vegetation community for that ecoregion (**Appendix I**). That vegetation community was then compared to shade curves developed for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009). **Figure 6-9** compares the existing effective shade to its respective shade targets, while **Figure 6-10** plots the difference between the existing effective shade and the shade targets. The plots are displayed in an upstream (left) to downstream (right) orientation to easily correlate targets and existing shade to location on the stream. Positive numbers in **Figure 6-10** indicate that the existing effective shade exceeds the shade targets, while negative numbers indicate areas where existing effective shade is deficient. As shown in **Figure 6-10**, Elk Creek has deficient shade in comparison to shade targets throughout much of the stream, which is ultimately contributing to the high water temperatures collected at all monitoring sites.

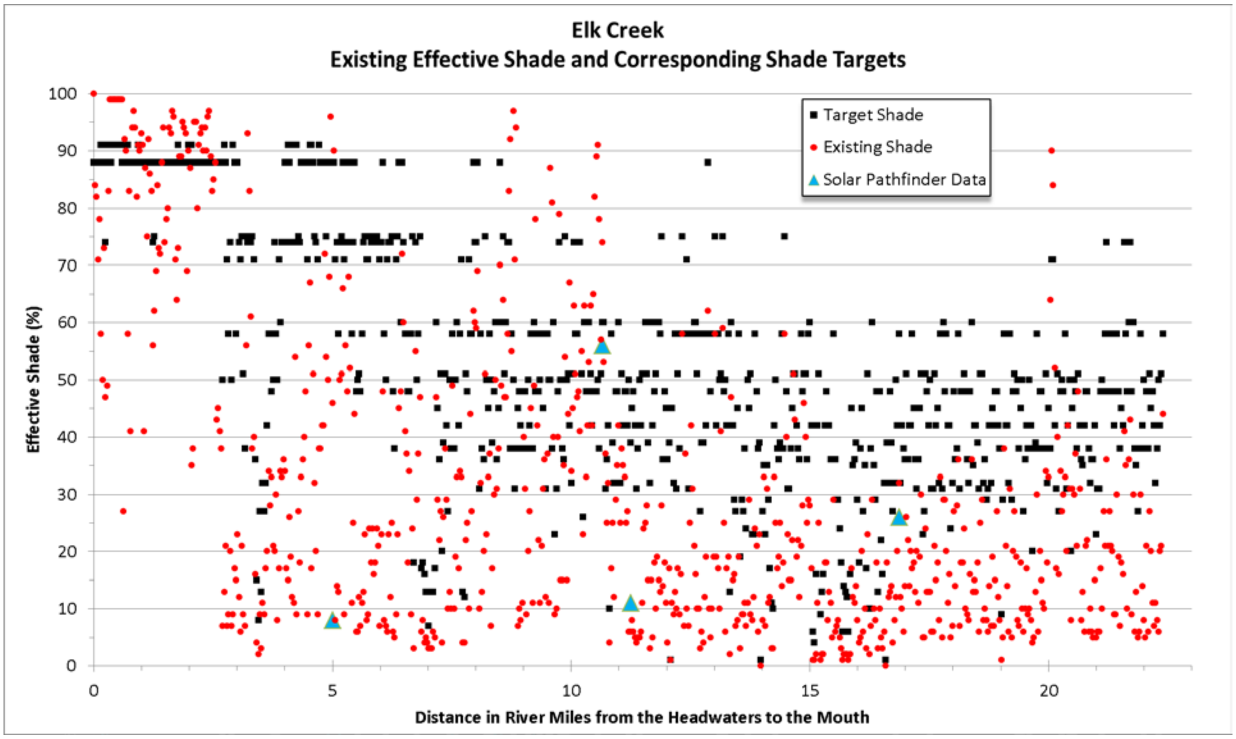

Figure 6-9. Existing Effective Shade and Corresponding Shade Targets for Elk Creek

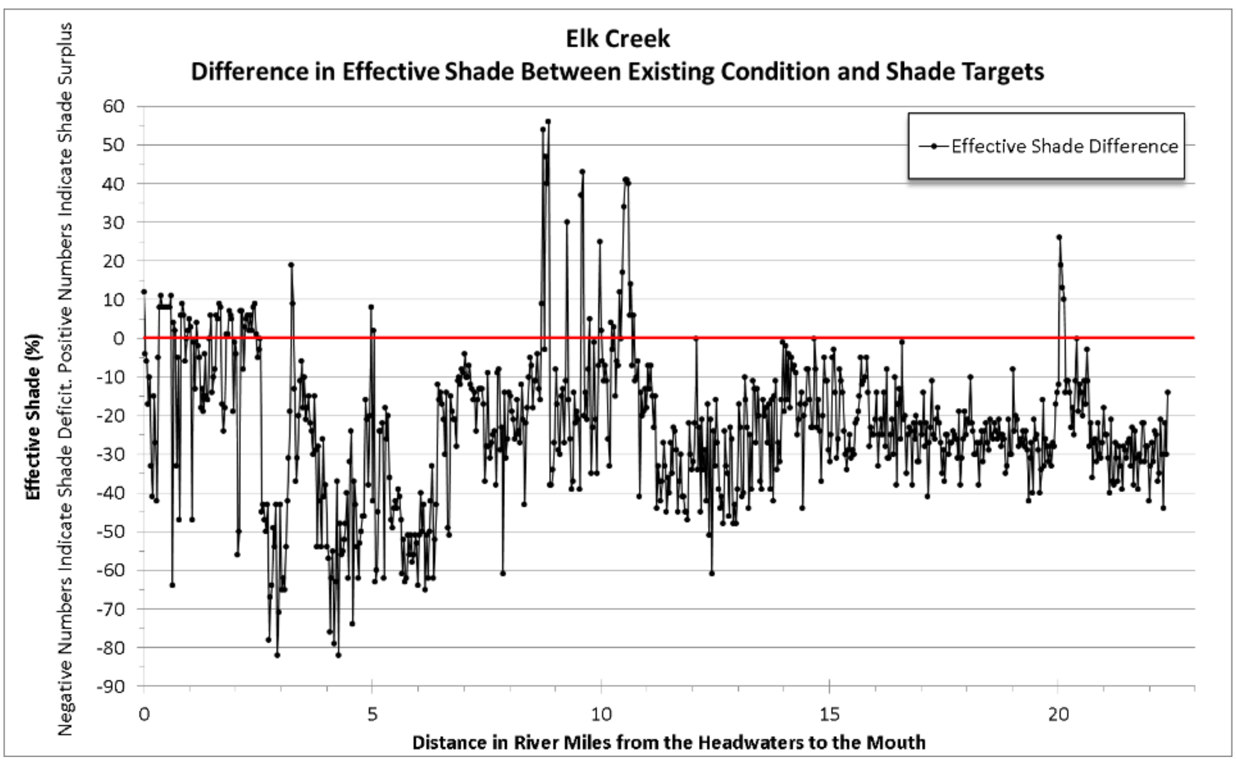

Figure 6-10. Difference in Effective Shade between Existing Condition and Shade Targets for Elk Creek

Channel Width/Depth Ratio

Channel width/depth ratio was measured at four sites along Elk Creek as a part of the data collection effort to assess sediment impairment (**Section 5.0**). Data collected by DEQ in 2010 and 2013 indicate that Elk Creek is meeting the width/depth ratio targets at three of the four monitoring sites (**Table 6-7**). It was noted in **Section 5.4.3.5** that historical and current beaver activity in addition to livestock grazing in the middle portion of Elk Creek may be affecting the width/depth ratio at site ELKC 06-02. Although this data was collected in four discrete locations, the locations of the monitoring sites were chosen because they are assumed to be representative of Elk Creek as a whole. It is possible that the width/depth ratio may be exceeding targets in more areas along Elk Creek, especially in areas where land management practices are poor, but areas that have good land management practices in place should not be negatively affecting the width/depth ratio of Elk Creek.

Table 6-7. Elk Creek Calculated Width/Depth Ratios in Comparison to Width/Depth Ratio Targets

Reach/Site ID	Year Data Collected	Mean BFW (ft)	W/D Ratio Target	W/D Ratio
M06ELKC07	2013	7.5	≤ 11	9.4
ELKC 05-01	2013	5.6	≤ 11	7.9
ELKC 06-02[1]	2010, 2013	13.6	≤ 11	19.3
ELKC 11-01	2013	7.0	≤ 11	9.0

[1]Values are averages from one sampling event in 2010 and two in 2013

Instream Discharge (Streamflow Conditions)

As of February 2, 2020, there were at least 10 entities that held water rights on Elk Creek and its tributaries. During the irrigation season in 2013, the monitoring site at the mouth (Site 1A) went dry by June 18th. Based on the in-stream temperature data collected at that site, it appears that instream discharge is having a significant effect on water temperatures in Elk Creek. The high water temperature and lack of instream flow in Elk Creek may be preventing fish from the Madison River from migrating up Elk Creek to spawn.

Qual2k Temperature Simulation and Implications for Fish Populations

Water temperature, flow, channel characteristics, and riparian shade data were incorporated into a QUAL2K water quality model to characterize existing temperature conditions and evaluate the effects of increases in shade and streamflow for Elk Creek (Chapra et al 2012). The model was developed for the warmest temperature day occurring during temperature logger deployment during summer 2013, which occurred on 7/3/2013.

The stream section modeled for this analysis included the section from the mouth of Elk Creek to 18.6 miles upstream (which is near site 1-D on **Figure 6-7**). Within the model, water temperatures were predicted largely based on climate data from the Western Climate Center (https://wrcc.dri.edu/) Ennis Montana weather station. Estimates of riparian shade along the length of the study section were estimated using the Shade Tool (**Section 6.4.2.2**) in ArcGIS. Headwater temperature conditions were estimated using hourly temperature loggers deployed at monitoring sites in **Figure 6-7**. Channel characteristics were based on field measurements taken by Montana DEQ during discharge measurements and sediment surveys. Detailed boundary conditions and parameter used in the model can be found in **Appendix J**. The model is considered adequate for evaluating the potential impacts of increasing shade and stream flow on water temperature. However, it may not be suitable for all purposes.

The performance of the model was evaluated by comparing modeled temperatures at temperature loggers to actual temperatures collected on 7/3/2013 using the absolute relative error method, as described in **Appendix J**. Despite limited field data, the modeled maximum temperatures approximated measured maximum temperatures with an error rate of 2.4% (representing the average percent difference between modeled and actual conditions) (**Appendix J**; Table J-2).

Existing data indicates that the entire modeled section of Elk Creek is currently not suitable for Westslope cutthroat trout or Arctic grayling due to high temperatures (**Appendix J**; Figure J-5) Elk Creek does not currently contain either species (Mike Duncan FWP, personal communication January 24, 2020), but a basin-wide initiative has focused on introducing these species throughout the Madison drainage (Clancy and Lohrenz 2015).

The potential management scenarios modeled as part of this exercise included an 15% increased flow scenario, an increased shade scenario to represent likely shade as a result of riparian restoration, and a scenario that included a combination of actions (15% increased flow, increased shade, and decreased wetted with on sections predicted to not meet the width: depth criteria). The increased shade scenario was developed using predictions of natural vegetation for ecoregion IV and shade curves for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009; **Section 6.4.2.2** and **Appendix I**). Results indicate that the increased flow scenario decreased maximum temperatures at the most downstream site by 0.48˚C, the increased shade scenario decreased temperatures by 4.7˚C, and the combination scenario of increased shade and flow and decreased wetted width decreased temperatures by 5.0˚C (**Appendix J**; Figure J-5 to J-8).

The increased shade scenario showed a decrease in the maximum temperature below the 7-Day Lethal Temperature for 50% of the population at the most upstream section of the modeled portion above mile 13). The combination scenario did not greatly reduce temperatures below values estimated for increased shade alone. Because the decrease of temperature below lethal limits would primarily occur only in the very upstream portion of the creek, this would not leave much stream length suitable for Westslope cutthroat or Arctic grayling if they were present. Nonetheless, Elk Creek would be suitable for these sensitive fish species during other time periods of the summer, and efforts to increase shade could increase the amount of thermal refuge available for other species. Although a 15% increase in instream flow had a minimal impact on temperature according to our models, any increase in stream flow would also be beneficial given that water withdrawals may contribute to complete dewatering of Elk Creek.

6.4.2.3 Moore Creek

Moore Creek flows from its headwaters in the Tobacco Root Mountains to its mouth at the Fletcher Channel, a side channel of the Madison River, which flows into Ennis Lake. Moore Creek was listed as impaired by temperature in the 2016 Integrated Report based on recent data collected and the comparison of that data to the water quality targets outlined in **Table 6-3**. A summary of the existing temperature-related water quality conditions and a comparison of those conditions to water quality targets are presented in this section.

Water Temperature

In 2013 DEQ collected water temperature at 30-minute intervals and shade-related data from four sites on Moore Creek (Sites 4A, 4D, 4E, and 4F, **Appendix G**) (**Table 6-7** and **Figure 6-11**). Sites 09-01 and 09-04 in **Figure 6-11** were sites where only channel geometry measurements were collected. They are shown for reference because the width of the stream affects heating at the water surface and was used in Qual-2k model development described below. A maximum temperature (T_{max}) of 78.0°F was recorded at Site 4A near the mouth, with 15 days exceeding 73°F which is the 24 hour lethal temperature dose for 10% of the population of Westslope cutthroat trout. The warmest 7-day period in 2013 or the Maximum Weekly Maximum Temperature (MWMT) was 77.0°F at Site 4A, and the MWMT at Site 4A exceeded the 7-day UILT of 75.4°F for Westslope cutthroat trout, and just met the 7-day UILT for Arctic grayling (77.0°F), which is a species of concern that has been re-introduced to Moore Creek.

Table 6-7. Temperature Data Summary for Moore Creek in 2013

Stream	Site[1]	Maximum Temperature (T_{max})	7-day Average Daily Maximum (MWMT)	Number of Days With Water Temperatures Exceeding 73°F
Moore Creek	4A	78.0°F	77.0°F	15
Moore Creek	4D	72.1°F	70.9°F	0
Moore Creek	4E	65.7°F	64.9°F	0
Moore Creek	4F	70.0°F	68.9°F	0

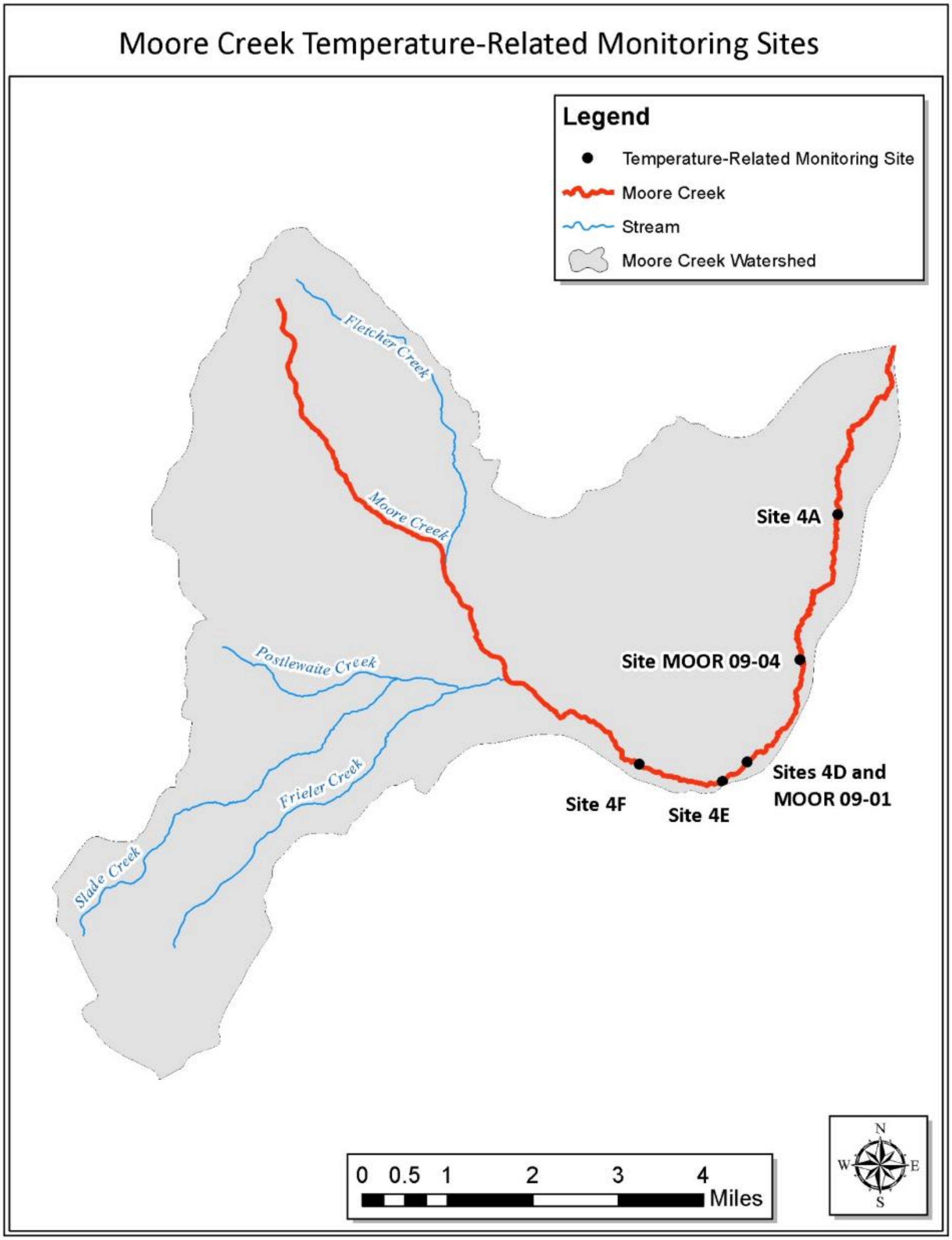

Figure 6-11. Map of Temperature-Related Monitoring Sites on Moore Creek

Figure 6-12 shows the water temperature data for Moore Creek Site 4A. This data shows that there were several exceedances of the 24-hour lethal dose threshold for 10% of the population of Westslope cutthroat trout in June and July. The MWMT threshold was also exceeded in June and July.

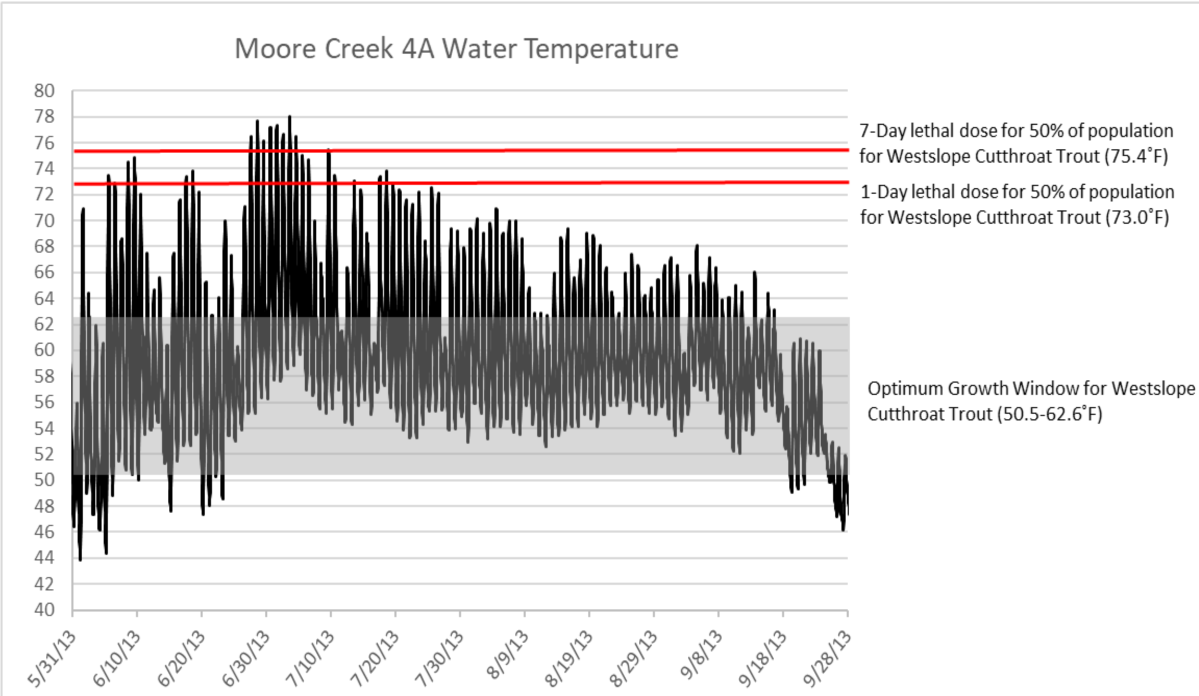

Figure 6-12. Water temperature data for Moore Creek Site 4A

Riparian Health/Shade

Shade-related data, including Solar Pathfinder data (**Appendix G)** were collected at sites 4A, 4D, 4E, and 4F, and used in conjunction with aerial photography to model the existing effective shade using the Shade Tool (Washington State Department of Ecology 2007). Shade targets were developed based on level IV ecoregion and the expected riparian vegetation community for that ecoregion (**Appendix I**). That vegetation community was then compared to shade curves developed for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009). **Figure 6-13** compares the existing effective shade to their respective shade targets, while **Figure 6-14** plots the difference between the existing effective shade and the shade targets. The plots are displayed in an upstream (left) to downstream (right) orientation to easily correlate targets and existing shade to location on the stream. Positive numbers in **Figure 6-14** indicate that the existing effective shade exceeds the shade targets, while negative numbers indicate areas where existing effective shade is deficient. As shown in **Figure 6-14**, the lower portion of Moore Creek (downstream of the Town of Ennis) has deficient shade in comparison to shade targets, which is ultimately contributing to the high water temperatures collected near the mouth at Site 4A.

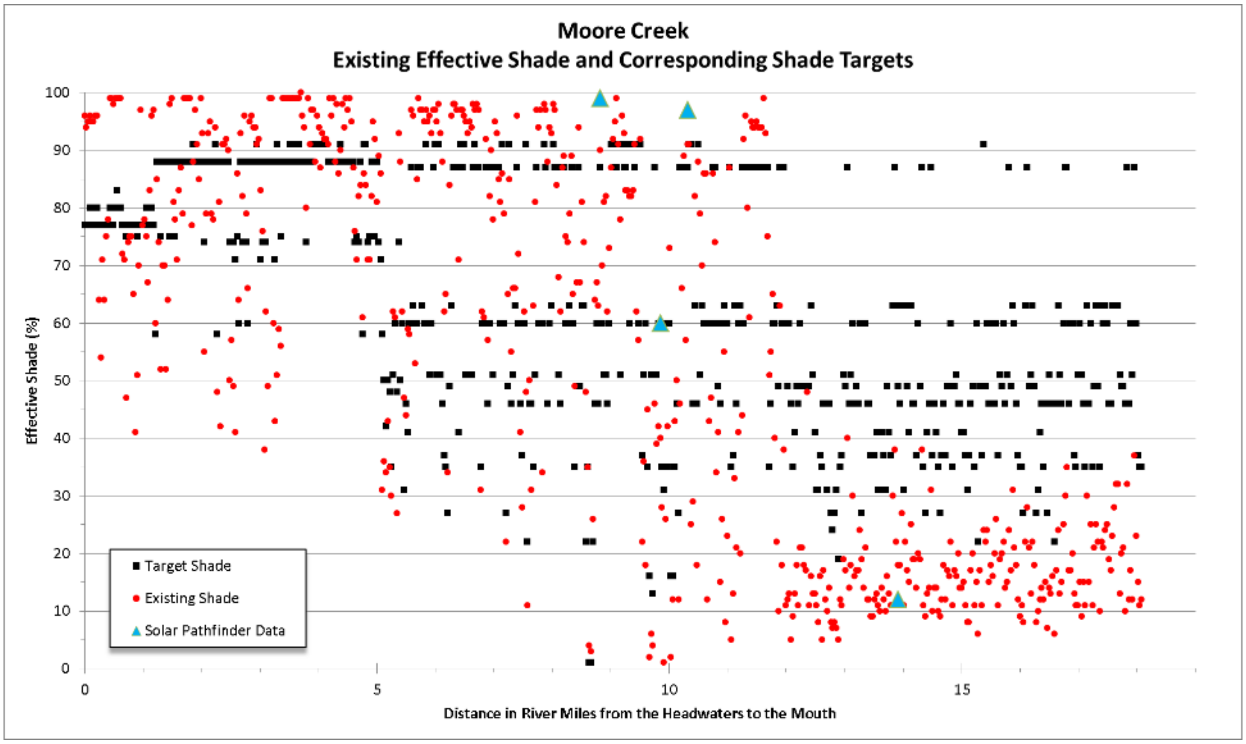

Figure 6-13. Existing Effective Shade and Corresponding Shade Targets for Moore Creek

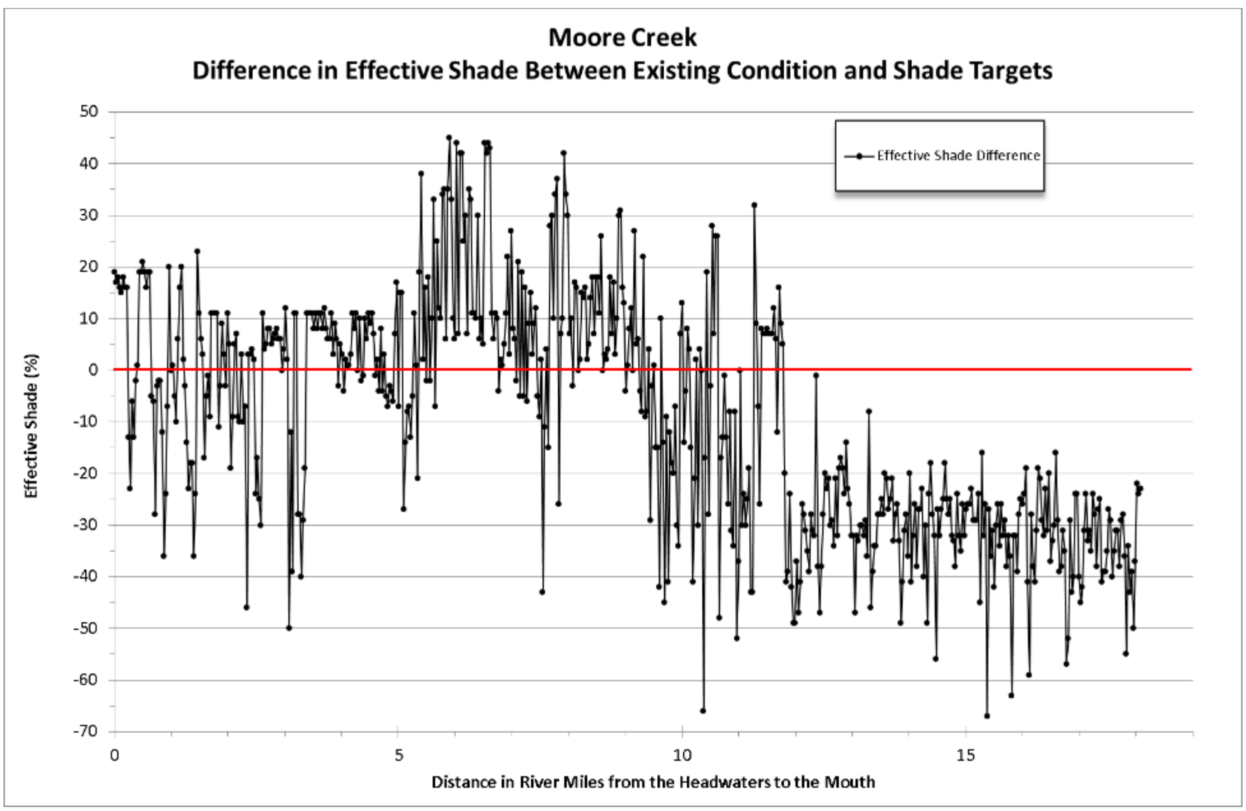

Figure 6-14. Difference in Effective Shade between Existing Condition and Shade Targets for Moore Creek

Channel Width/Depth Ratio

Channel width/depth ratio was measured at two sites along Moore Creek as a part of the data collection effort to assess sediment impairment (**Section 5.0**). Data collected by DEQ in 2014 indicate that Moore Creek is meeting the width/depth ratio targets at both of the monitoring sites (**Table 6-8**). Although this data was collected in two discrete locations, the locations of the monitoring sites were chosen because they are assumed to be representative of Moore Creek as a whole. It is possible that the width/depth ratio may be exceeding targets in areas along Moore Creek, especially in areas where land management practices are poor, but areas that have good land management practices in place should not be negatively affecting the width/depth ratio of Moore Creek.

Table 6-8. Moore Creek Calculated Width/Depth Ratios in Comparison to Width/Depth Ratio Targets

Reach/Site ID	Year Data Collected	Mean BFW (ft)	W/D Ratio Target	W/D Ratio
MOOR 09-01	2014	18.3	≤ 24	21.1
MOOR 09-04	2014	4.6	≤ 11	4.8

Instream Discharge (Streamflow Conditions)

As of February 4, 2020, a total of 10 entities held water rights on Moore Creek and its tributaries. In addition to these diversions, there is a small reservoir (Hacker Dam) located upstream of the town of Ennis. Moore Creek is a relatively small stream; therefore, any irrigation withdrawals could potentially have a significant impact on streamflow. Montana FWP holds a water right for an instream flow reservation of 1.4 cfs for the purpose of maintaining the resident trout population in Moore Creek; protecting important spawning habitat for the arctic grayling population that inhabits Ennis Lake and the channels of the Madison River below the town of Ennis; and to help protect the habitat of those wildlife species which depend upon the stream and its associated riparian zone for food, water, and shelter (Montana Department of Fish Wildlife and Parks 1989).

Qual2k Temperature Simulation and Implications for Fish Populations

Water temperature, flow, channel characteristics, and riparian shade data were incorporated into a QUAL2K water quality model to characterize existing temperature conditions and evaluate the effects of increases in shade and streamflow for Moore Creek (Chapra et al 2012). The model was developed for the warmest temperature day occurring during temperature logger deployment during summer 2013, which occurred on 7/3/2013.

The stream section modeled for this analysis included the section from the mouth of Moore Creek to approximately 12 miles upstream, which is near site 4-F on **Figure 6-11**. Within the model, water temperatures were predicted largely based on climate data from the Western Climate Center (https://wrcc.dri.edu/) Ennis Montana weather station. Estimates of riparian shade along the length of the study section were estimated using the Shade Tool (**Section 6.4.2.3**) in ArcGIS. Headwater temperature conditions were estimated using hourly temperature loggers deployed at monitoring sites in **Figure 6-11**. Channel characteristics were based on field measurements taken by Montana DEQ during discharge measurements and sediment surveys. Detailed boundary conditions and parameter used in the model can be found in **Appendix J**. The model is considered adequate for evaluating the potential impacts of increasing shade and stream flow on water temperature. However, it may not be suitable for all purposes.

The performance of the model was evaluated by comparing modeled temperatures at temperature loggers to actual temperatures collected on 7/3/2013 using the absolute relative error method, as described in **Appendix J**. Despite limited field data, the modeled maximum temperatures approximated measured maximum temperatures with an error rate of 2.7% (representing the average percent difference between modeled and actual conditions).

Existing data indicates that, during the hottest day of the year, Moore Creek becomes suitable for sensitive Westslope cutthroat trout and Arctic grayling starting at approximately 3 miles upstream from the mouth (**Appendix J**, Figure J-9). While Moore Creek does not currently contain Westslope cutthroat trout, this sensitive species is being introduced in the Madison drainage as part of recent efforts. Arctic grayling was introduced to Moore Creek in 2015 as part of a re-introduction initiative (Clancy and Lohrenz 2015).).

The potential management scenarios modeled as part of this exercise included an 15% increased flow scenario, an increased shade scenario to represent likely shade as a result of riparian restoration, and a scenario that included a combination of actions (15% increased flow, increased shade) The increased shade scenario was developed using predictions of natural vegetation for ecoregion IV and shade curves for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009; **Section 6.4.2.3** and **Appendix I**).

Results indicate that the increased flow scenario decreased modeled maximum temperatures at the most downstream site by 0.48˚C, the increased shade scenario decreased modeled maximum temperature by 2.1˚C, and the combination scenario decreased modeled maximum temperature by 2.4˚C (**Appendix J**, Table J-3). While an increase in shade had a bigger impact on stream temperatures, the combined scenario could decrease the temperature near the mouth to be at or just slightly above the 24-hour Lethal temperature for 10% of the population for Westslope cutthroat trout, and would potentially increase the overall length of stream available to these species during the warmest times by up to 3 miles (**Appendix J**; Figure J-9 to Figure J-12).

6.4.3 Summary of Madison TPA Stream Shade Conditions

Effective stream shade plays a crucial role in the temperature regime of a stream. To determine where Cherry Creek, Elk Creek, and Moore Creek are in relation to adequate stream shade, an effective stream shade net balance was calculated based on the magnitude of shade surplus or shade deficit at each 50-meter point along the length of the stream, using the data presented in **Figures 6-6, 6-10,** and **6-14**. These data were plotted in box plots for each stream, showing how close each stream is to meeting its shade targets (**Figure 6-15**). Box plots depict the smallest observation (sample minimum), 25th percentile, median, 75th percentile, and the largest observation (sample maximum). If the median value (dark line in the middle of the box) is above zero, then the stream has adequate shade in more places than it has deficient shade. If the median value is below zero, then the stream has deficient shade in more places than it has adequate shade. The magnitude above or below this line represents the amount of the shade deficit or surplus, which makes it easier to compare different streams. For example, Cherry Creek is much closer to meeting its shade targets than Elk Creek.

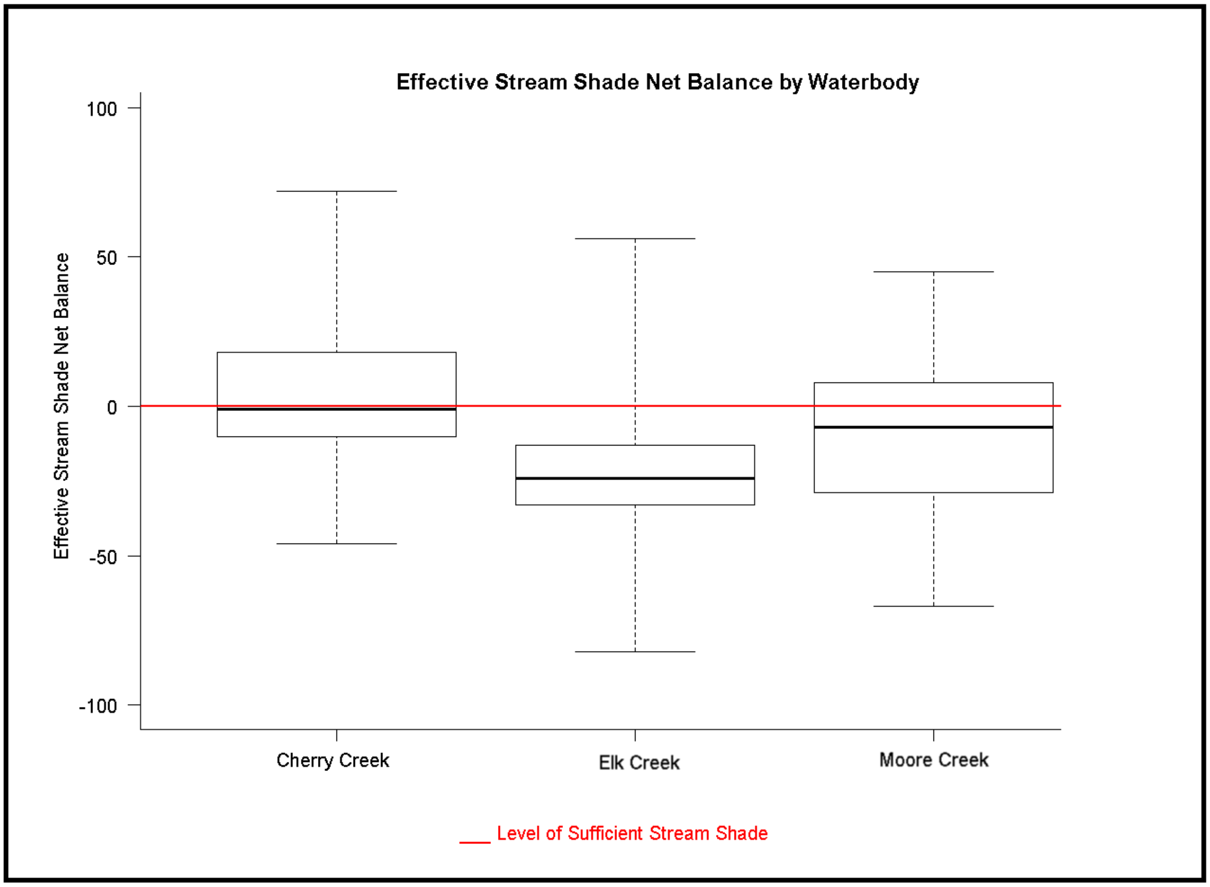

Figure 6-15. Box plot showing the effective stream shade net balance for Cherry Creek, Elk Creek, and Moore Creek

6.5 Total Maximum Daily Loads (TMDLs)

This section summarizes the approach used for TMDL development, and then presents the TMDLs, allocations, and estimated reductions necessary to meet water quality targets for the three temperature impaired streams. **Table 6-9** shows the temperature TMDLs developed in the Madison TPA.

Table 6-9. Temperature TMDLs developed in the Madison TMDL Planning Area

Stream Segment	Assessment Unit ID
Cherry Creek – headwaters to mouth (Madison River)	MT41F002_010
Elk Creek – headwaters to mouth (Madison River)	MT41F002_020
Moore Creek – springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130

Stream temperatures are continuously variable and dependent on multiple factors such as climate, riparian shade, and streamflow. However, temperature TMDLs for these streams are based on solar loading to a stream at an achievable condition in which the stream is meeting its targets for riparian shade. Daytime solar radiation is often the most significant temperature source and increased riparian vegetation (shade) can intercept solar radiation (Beschta, 1997). Nonetheless, even under ideal conditions, a stream might not be meeting its target at every single point along its length due to localized disturbances or other environmental factors and therefore, in evaluating targets it is important to look at overall shade health for a stream or specific reach.

While meeting shade targets is the ultimate method for determining if a stream is meeting its temperature TMDL, a daily load can be calculated by quantifying the amount of solar flux reaching the stream on the warmest day of the year, while under target shade conditions (**Equation 6-1**).

Equation 6-1: TMDL = (X) (Y) (20.4)

TMDL = Total maximum daily load in kcal/day

X = daily watts/ft^2 of solar flux to the stream surface for the stream reach under target shade conditions

Y = water surface area of stream reach in ft^2 (wetted width x length)

20.4 = conversion factor from watts to kcal/day

6.6 Source Assessment

This section provides the approach used for source assessment, which characterizes the type, magnitude, and distribution of sources contributing to temperature loading and establishes the approach used to develop TMDLs and allocations to specific source categories for each. Source characterization and assessment to determine the major sources in each of the temperature impaired watersheds was conducted by using monitoring data collected from the Madison TPA from 2009-2014, which represents the most recent data for determining existing conditions, and by using aerial photos, Geographic Information System (GIS) analysis, field work, and literature reviews. Assessment of existing temperature sources is needed to understand Load Allocations (LAs), and load reductions for different source categories. Source characterization links temperature sources, temperature loading to streams, and water quality response, and supports the formulation of the allocation portion of the TMDL.

Watersheds with temperature issues primarily consist of agricultural land uses (dryland and irrigated cropland, pasture, and rangeland), silviculture (timber harvest and forest roads), and residential development. These nonpoint sources may include a variety of discrete and diffuse pollutant inputs that have differing pathways to a waterbody. Ideally, monitoring efforts are conducted in a way that helps with the identification of these pathways. There are no permitted point source discharges to streams with temperature TMDLs developed in the Madison.

6.6.1 Description of Temperature Sources

The following sections give a general overview of temperature sources. More detailed source descriptions are included for each specific stream in **Sections 6.6.2** through **6.6.4.**

6.6.1.1 Point Source Discharges

There are no point sources with an active Montana Pollutant Discharge Elimination System (MPDES) permit in the Cherry Creek, Elk Creek, or Moore Creek watersheds

6.6.1.2 Agriculture

Agricultural sources of temperature can result from land use practices that remove riparian vegetation by cultivation or livestock grazing and practices that alter streamflow by the use of surface water diversions. Temperature contributions from specific agricultural activities are described below.

Irrigated and Dryland Cropping

Cropping in the watersheds of temperature impaired waterbodies in the Madison TPA is relatively minimal (**Figures 6-16,6-18**, and **6-20**). Cropland in these watersheds is predominately irrigated production of alfalfa hay and pasture/hay, with smaller acreages of irrigated and dryland cultivated cropland. Irrigated lands are usually in continuous production and have annual soil disturbance. Dryland cropping may have fallow periods of 16 to 22 months, depending on site characteristics and landowner management. Cropland may contribute temperature loading to streams when it encroaches on the riparian area, reducing the amount of shade producing woody vegetation, or by altering streamflow by irrigation withdrawals and irrigation return drains. Water withdrawals reduce the volume of water in a stream, which decreases the buffering capacity that stream has to handle solar radiation. Irrigation return flows are generally warmer in temperature than water that remains in the stream due to exposure to solar radiation in ditches and canals, which do not typically have shade producing woody vegetation on the banks.

Livestock Grazing

Grazing on rangeland and in pastures is common in the Madison TPA (**Figures 6-16,6-18**, and **6-20**). Cattle are allowed to roam and are generally not concentrated along the valley bottoms during the growing season when many pasture systems are hayed. Horses may also be allowed to roam and graze, though they have been mostly observed on small acreage lots that are fenced. Pastures are managed for hay production during the summer and for grazing during the fall through spring. Hay pastures are thickly vegetated in the summer; less so in the fall through spring. The winter grazing period is typically long (October–May), and trampling and feeding further reduce biomass when it is already low. Rangeland is typically grazed during the summer in the watershed. Rangeland differs from pasture in that rangeland has much less biomass.

Although no livestock grazing data were collected for private or state managed lands, grazing allotment data were collected from the BLM and USFS on the federally managed lands and were compiled per impaired waterbody watershed as total Animal Unit Months (AUM) per drainage. An assumption was made that livestock management on private and state lands is similar to the federally managed lands. The BLM does not make an annual “count” of the livestock that graze on BLM-managed lands because the actual number of livestock grazing on public lands on any single day varies throughout the year and livestock are often moved from one grazing allotment to another. Instead, the BLM compiles information on the number of AUMs used each year, which takes into account both the number of livestock and the amount of time they spend on public lands (U.S. Department of Interior, Bureau of Land Management 2017a).

Total AUMs were determined only for allotments that have some areas draining to an impaired waterbody. These numbers constitute the existing permits for grazing leases on public lands within grazing allotments and represent a maximum number of AUMs possible at any one time. AUMs are reported for public lands within each allotment. However, since allotment boundaries differ from the watershed boundaries, a distinction is made between grazing on public land within the entire allotment and on public land within the allotment that also lies within the sub-watershed boundary. This compilation is for coarse source assessment purposes only. Some attempt was made to obtain grazing reports of USFS allotments to verify grazing practices for Moore Creek and Cherry Creek, and this information is presented in the Agriculture portion of the source assessment.

6.6.1.3 Silviculture
A significant portion of the Madison TPA is on forested lands administered by the US Forest Service (USFS) specifically the Beaverhead-Deerlodge and Gallatin National Forests, and lands administered by the Bureau of Land Management (BLM). Silviculture practices inevitably cause some measure of downstream effects that may or may not be significant over time. Changes in land cover will alter 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 will also disrupt the hydrological cycle. The combination of these changes can alter water yield, peak flows, and water quality (Jacobson, 2004). In addition to changes in the hydrologic cycle, removal of riparian vegetation can result in decreased effective shade to the stream. The Montana Streamside Management Zone (SMZ) law, passed in 1991, prohibits timber harvest within 50 feet or 100 feet of a stream or lake depending on stream class and slope. Adjacent wetlands to the stream are also included within this protected zone, but a 50-foot buffer around the wetland is not required (MCA, 2017). If silvicultural activities follow the requirements of the SMZ law, there should not be a significant change in effective shade to the stream resulting from these activities.

An assessment of timber harvest operations for the Cherry Creek, Elk Creek, and Moore Creek watersheds was made based on harvest data collected by the US Forest Service from 1820 to present, and by using the Montana Spatial Data Infrastructure (MSDI) geospatial land cover data layer. These data were used to better understand recent operations by scale and location in comparison with available water quality data. Based on this data, there has been no significant timber harvest in any of these watersheds. Therefore, silviculture is not classified as a major source contributing to temperature impairment in these watersheds.

6.6.1.4 Residential Development
Residential development in a watershed can contribute to temperature through encroachment on riparian areas by buildings, streets, and residential lawns. This encroachment reduces the amount of shade producing woody vegetation and can limit the extent for future riparian vegetation expansion. Residential development in the Madison watershed is concentrated around the Ennis area and Moore Creek. Cherry Creek and Elk Creek watersheds have relatively low levels of residential development.

6.6.1.5 Natural Background
Natural sources contributing to increased stream temperatures including riparian grazing and browsing by wildlife, geology that limits riparian expansion, thermal springs, and the effects of natural events such as flooding, fire, and beetle kill were accounted for in target development and represent the reference condition to which existing condition data were compared to.

6.6.2 Cherry Creek Source Assessment
Factors contributing to elevated stream temperatures in Cherry Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed) which are shown in **Figure 6-16**. There are no permitted point sources in the Cherry Creek watershed. DEQ identified the following source categories that contribute to elevated stream temperatures in the Cherry Creek watershed:

- Agriculture (irrigated cropping and livestock grazing)
- Natural background

Since stream shade is one of the primary temperature-influencing targets, areas lacking sufficient shade can be identified through the source assessment process as areas likely contributing to temperature impairment. **Figure 6-17** is a map displaying the difference between target shade and existing shade for each data point in the analysis. This map can be used to identify areas where stream shade conditions can likely be improved, thus improving in-stream temperature conditions.

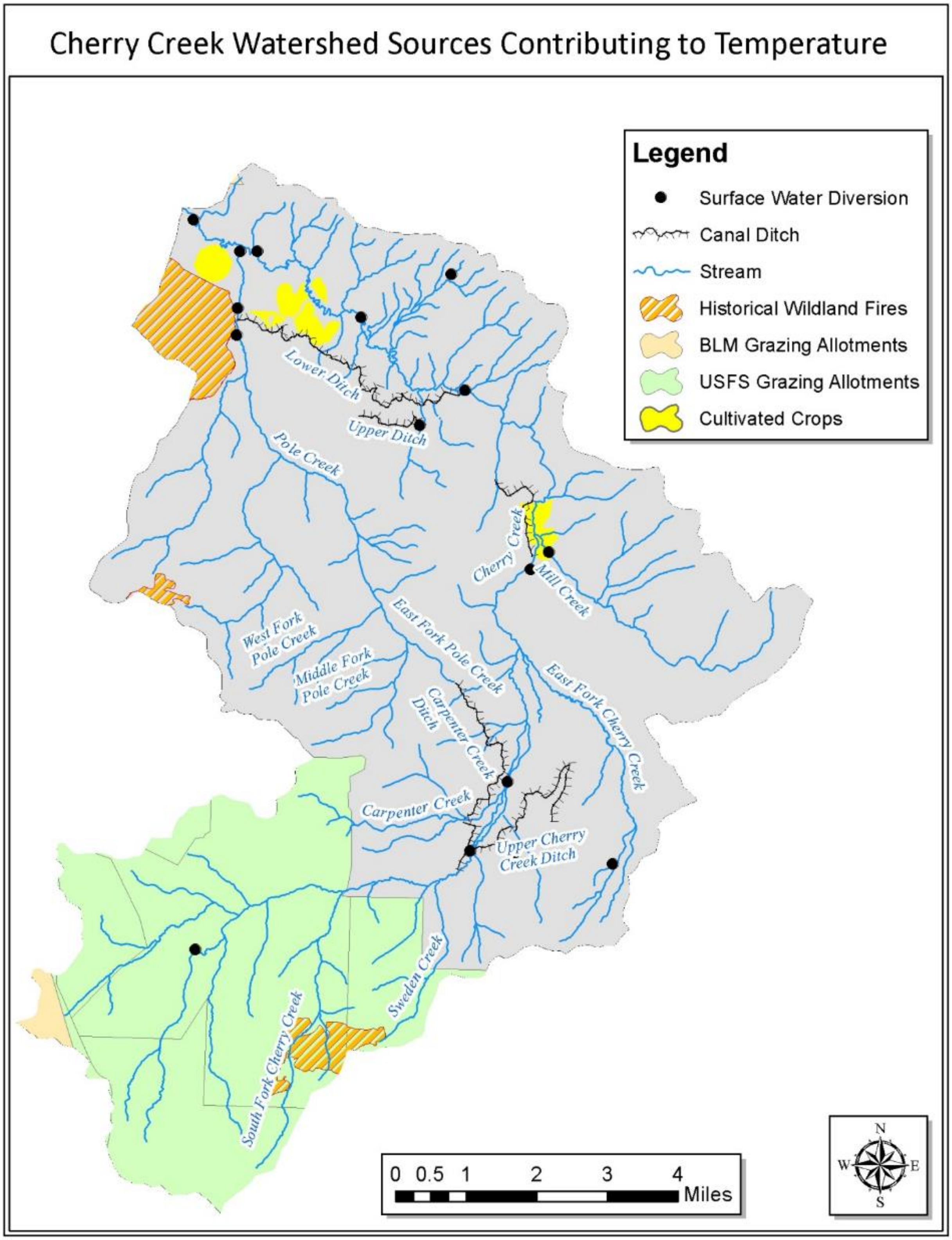

Figure 6-16. Map showing potential sources contributing to temperature impairment in Cherry Creek

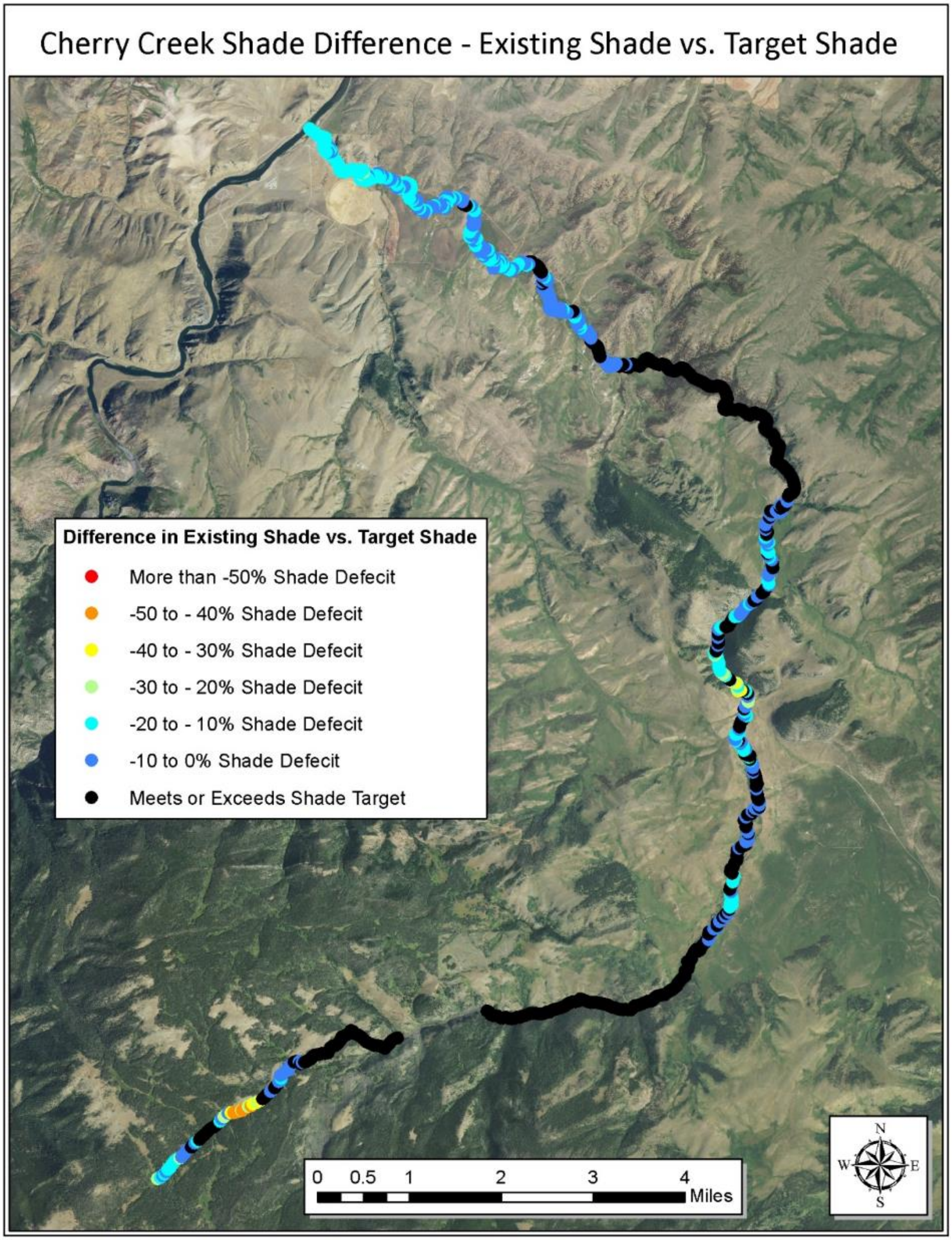

Figure 6-17. Map of Difference in Effective Shade between Existing Condition and Shade Targets for Cherry Creek

6.6.2.1 Agriculture

There are several possible ways that agriculture can contribute to stream temperatures as described in **Section 6.6.1.2** above. **Figure 6-16** shows the location of agricultural land and surface water diversions in the Cherry Creek watershed.

Irrigated Cropping

Cropland in the Cherry Creek watershed is primarily hay and pasture land, most of which is irrigated (U.S. Department of Agriculture, Montana Agricultural Statistics 2016) Several surface water diversion ditches shown in **Figure 6-16** are used to supply these irrigated hay fields and pastures. Areas downstream of these surface water diversions are generally lacking sufficient stream shade (**Figure 6-17**), indicating that agriculture is likely a significant factor in these areas not meeting shade targets. Hay fields encroaching in riparian areas and livestock grazing in riparian pastures can reduce the effectiveness of the existing shade-producing vegetation and prevent new shade producing vegetation from recolonizing in these riparian areas.

Livestock Grazing

Grazing on rangeland and pastures is common in the Cherry Creek watershed and occurs in a manner as described in **Section 6.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can potentially be contributing to a lack of effective stream shade by grazing and browsing riparian vegetation. In addition to private land grazing, there are several public land grazing allotments in the Cherry Creek watershed (**Figure 6-16**). The Red Knob allotment is the only U. S. Forest Service allotment that Cherry Creek flows through. Prior to 2003, this allotment was part of three allotments (Red Knob South, Red Knob North, and Cherry Creek) (U. S. Forest Service 2010), with the Cherry Creek and Red Knob South areas closed to grazing. In 2010, these three allotments were combined into the Red Knob North allotments and new riparian grazing standards were adopted. Extensive efforts were undertaken by the USFS to add riparian exclosures to improve riparian vegetation in the Red Knob North section. An implementation monitoring review in 2010 reported that extensive improvements were made in riparian vegetation growth since the exclosures were added. USFS also reported that all riparian grazing standards were met for Red Knob pastures in 2010, which had not occurred previously. However, some trespass grazing occurred as cattle were able step over the wire stands. As of the 2010 report, the USFS was working to improve these exclosures (U. S. Forest Service 2010).

6.6.2.2 Natural Background

Natural sources contributing to stream temperatures including riparian grazing and browsing by wildlife, geology that limits riparian expansion, thermal springs, and the effects of natural events such as flooding, fire, and beetle kill were accounted for in target development and represent the reference condition to which existing condition data were compared to. Riparian grazing and browsing by wildlife occurs in the watershed, but since much of the watershed is grazed by livestock, it was not possible to differentiate wildlife impacts from domestic livestock impacts. Several wildland fires have historically occurred in the Cherry Creek watershed and are shown in **Figure 6-16**, while **Table 6-10** shows the details of these fires. One area of upper Cherry Creek which experienced a conifer die-off appears to have either been burned by an unidentified wildland fire or had tree loss through disease. This area was excluded from the shade analysis because the die-off was caused by natural factors and it is expected that this area will return to mature shade producing vegetation on its own.

Table 6-10. Wildland Fires in the Cherry Creek Watershed

Fire Name	Acres Burned[1]	Year
Bear Trap 2	15372	2012
Bear Trap	148	2002
Cherry Creek	544	Not Reported

[1]Acres burned includes total acres for the fire which may include areas outside of the watershed

6.6.3 Elk Creek Source Assessment

Factors contributing to elevated stream temperatures in Elk Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed) which are shown in **Figure 6-18**. There are no permitted point sources in the Elk Creek watershed. DEQ identified the following source categories that contribute to elevated stream temperatures in the Elk Creek watershed:

- Agriculture (irrigated and dryland cropping and livestock grazing)
- Natural background

Since stream shade is one of the primary temperature-influencing targets, areas lacking sufficient shade can be identified through the source assessment process as areas likely contributing to temperature impairment. **Figure 6-19** is a map displaying the difference between target shade and existing shade for each data point in the analysis. This map can be used to identify areas where stream shade conditions can likely be improved, thus improving in-stream temperature conditions.

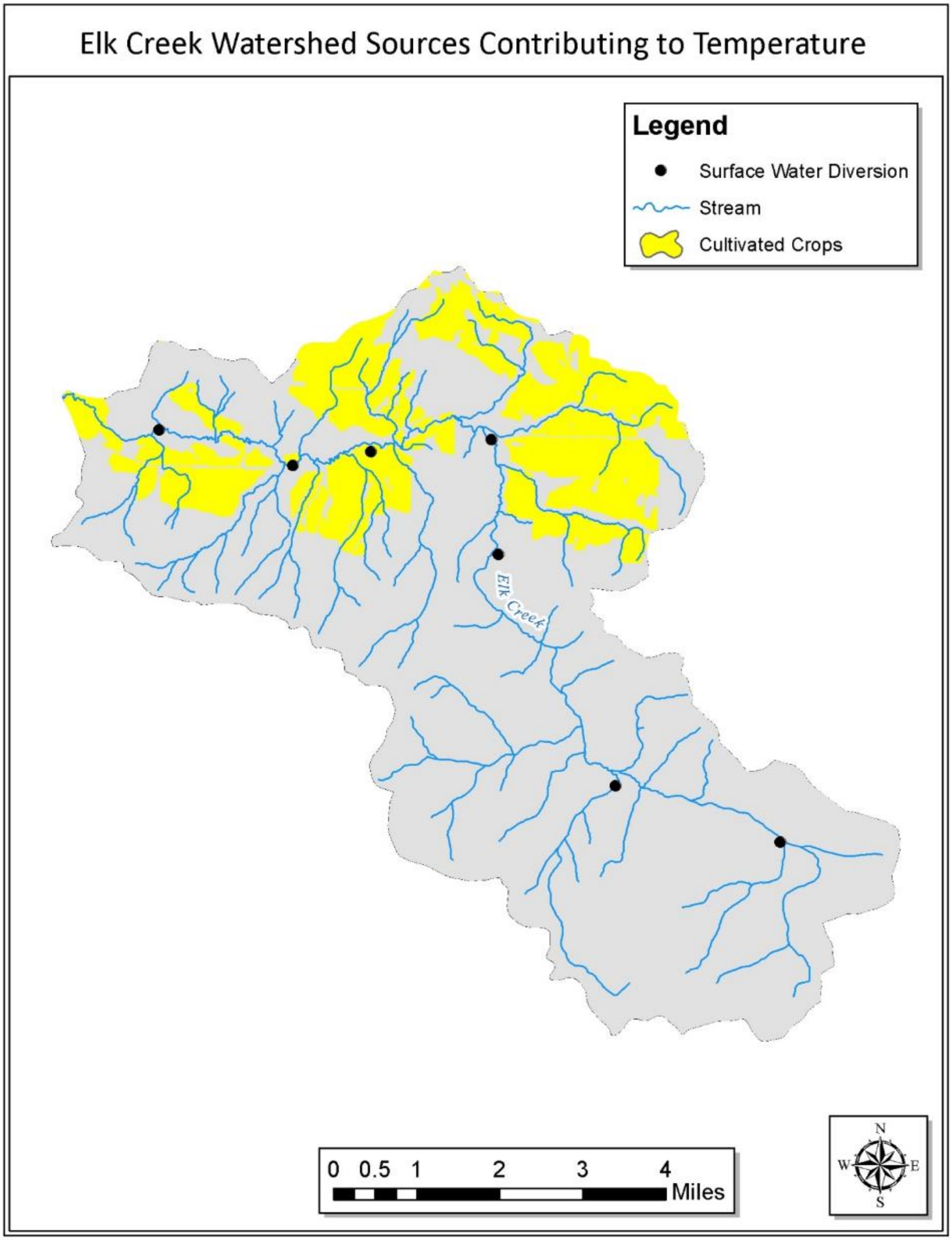

Figure 6-18. Map showing potential sources contributing to temperature impairment in Elk Creek

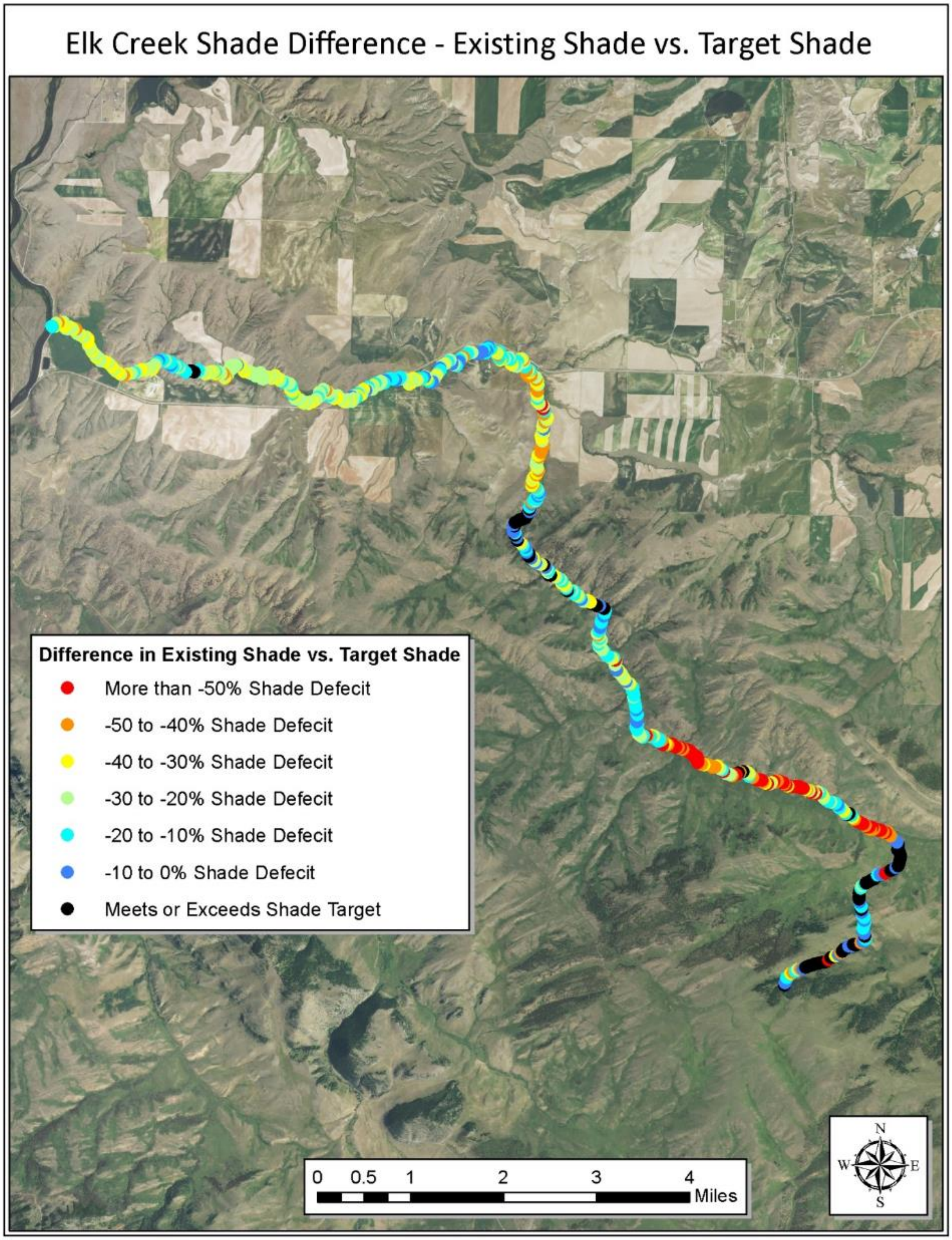

Figure 6-19. Map of Difference in Effective Shade Between Existing Condition and Shade Targets for Elk Creek

6.6.3.1 Agriculture

There are several possible ways that agriculture can contribute to stream temperatures as described in **Section 6.6.1.2** above. **Figure 6-18** shows the location of agricultural land and surface water diversions in the Elk Creek watershed.

Irrigated and Dryland Cropping

Cropland in the Elk Creek watershed is primarily dryland small grains production (specifically wheat and barley) and irrigated and dryland hay and pasture land (grass and alfalfa) (U.S. Department of Agriculture, Montana Agricultural Statistics 2016). Dryland cropping may have fallow periods, depending on site characteristics and landowner management. Several surface water diversions, shown in **Figure 6-18**, are used to supply these irrigated hay fields and pastures in the lower part of the watershed. Areas downstream of these surface water diversions are generally lacking sufficient stream shade (**Figure 6-19**), indicating that agriculture is likely a significant factor in these areas not meeting shade targets. Hay fields encroaching in riparian areas and livestock grazing in riparian pastures can reduce the effectiveness of the existing shade-producing vegetation and prevent new shade producing vegetation from recolonizing in these riparian areas.

Livestock Grazing

Grazing on rangeland and pastures is common in the Elk Creek watershed and occurs in a manner as described in **Section 6.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can potentially be contributing to a lack of effective stream shade by grazing and browsing riparian vegetation. There were no public land grazing allotments identified in the Elk Creek watershed. Portions of the headwater areas of Elk Creek had some of the most significant shade deficits, suggesting that livestock grazing in this these areas may be contributing to the lack of shade.

6.6.3.2 Natural Background

Natural sources contributing to stream temperatures including riparian grazing and browsing by wildlife, geology that limits riparian expansion, thermal springs, and the effects of natural events such as flooding, fire, and beetle kill were accounted for in target development and represent the reference condition to which existing condition data were compared to. Riparian grazing and browsing by wildlife occurs in the watershed, but since much of the watershed is grazed by livestock, it was not possible to differentiate wildlife impacts from domestic livestock impacts. There have not been any significant wildland fires in the Elk Creek watershed, so wildland fire is not expected to be a significant source causing increased instream water temperatures.

6.6.4 Moore Creek Source Assessment

Factors contributing to elevated stream temperatures in Moore Creek come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed) which are shown in **Figure 6-20**. There are no permitted point sources in the Moore Creek watershed. Ennis Hot Springs LLP previously held an MPDES permit to discharge unaltered groundwater to Moore Creek, but this permit (MT0028843) expired on September 30, 2016, and the facility has chosen to not renew the permit. Since the facility discharges unaltered groundwater, it is not required to have a permit to discharge; therefore, the facility may continue to discharge to Moore Creek without needing a permit.

DEQ identified the following source categories that contribute to elevated stream temperatures in the Moore Creek watershed:

- Agriculture (irrigated cropping and livestock grazing)
- Thermal springs
- Residential development
- Natural background

Since stream shade is one of the primary temperature-influencing targets, areas lacking sufficient shade can be identified through the source assessment process as areas likely contributing to temperature impairment. **Figure 6-21** is a map displaying the difference between target shade and existing shade for each data point in the analysis. This map can be used to identify areas where stream shade conditions can likely be improved, thus improving in-stream temperature conditions.

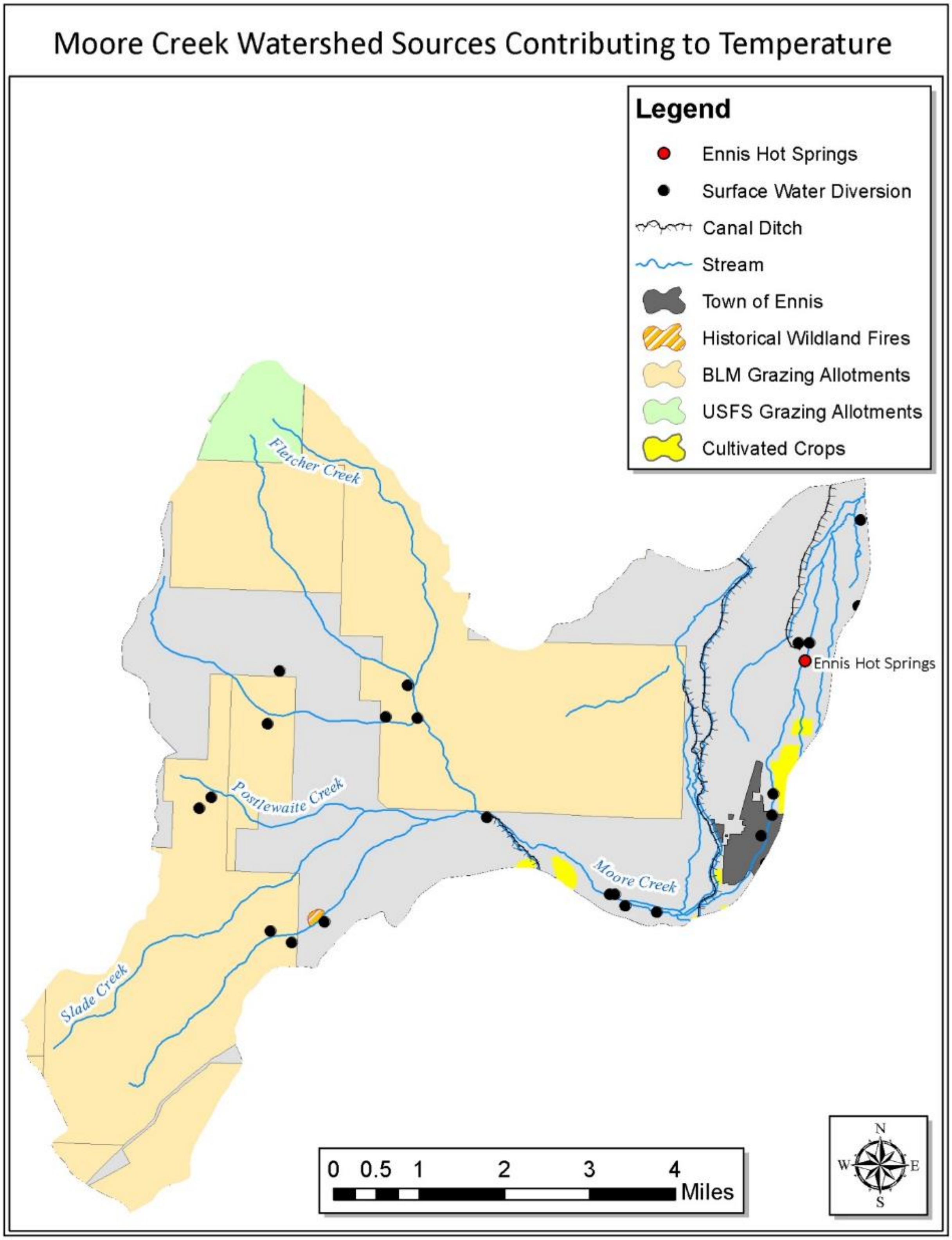

Figure 6-20. Map showing potential sources contributing to temperature impairment in Moore Creek

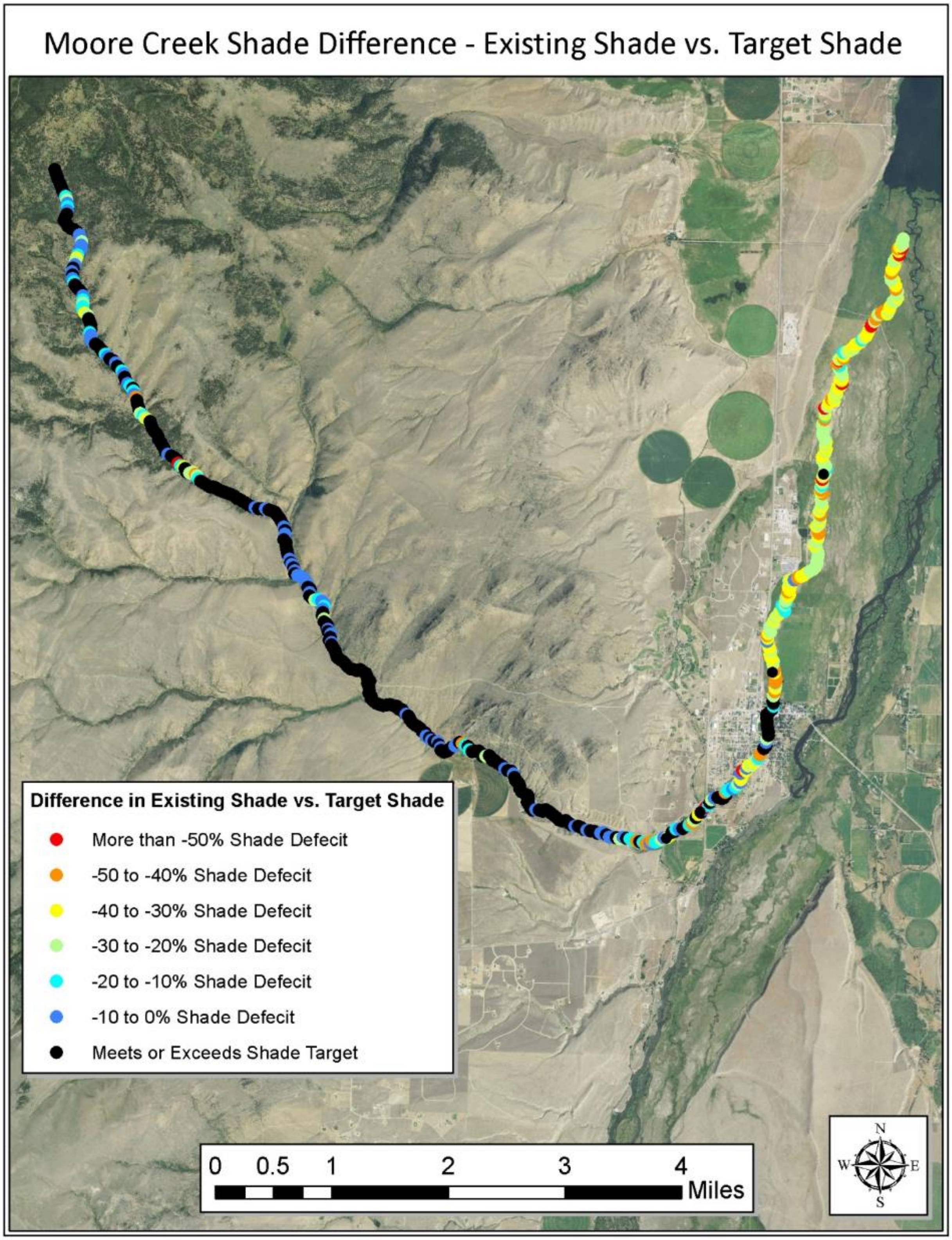

Figure 6-21. Map of Difference in Effective Shade Between Existing Condition and Shade Targets for Moore Creek

6.6.4.1 Agriculture

There are several possible ways that agriculture can contribute to stream temperatures as described in **Section 6.6.1.2** above. **Figure 6-20** shows the location of agricultural land and surface water diversions in the Moore Creek watershed.

Irrigated Cropping

Cropland in the Moore Creek watershed is primarily hay and pasture land with some small grains production, most of which is irrigated (U.S. Department of Agriculture and Montana Department of Agriculture 2016). Several surface water diversion ditches shown in **Figure 6-20** are used to supply these irrigated hay fields and pastures. Hay and pasture land in the Moore Creek valley bottom is irrigated using a combination of sprinkler, sub-irrigation and flood irrigation. Irrigated lands are supplied with water being diverted from Moore Creek in multiple locations and the Madison River via the West Madison Canal. Upstream of the town of Ennis, the West Madison Canal crosses Moore Creek. Further investigation indicated that this is a bypass structure, with check-boards to control the amount of any discharge from the canal into Moore Creek, with Moore Creek passing underneath the canal. It was discovered that some water from the West Madison Canal was mixing with Moore Creek via a headgate upstream of the intersection and some minor leakage through the check boards; see **Figure 6-22**. There was no temperature monitoring at this location, so the influence of the West Madison Canal on Moore Creek stream temperatures is unknown at this time, but is likely variable based on the amount of water being released through the check-boards. Upstream of the Town of Ennis, there is a small reservoir, Hacker Dam, which could be leading to increased water temperatures in Moore Creek due to a larger percentage of water surface area being exposed to solar radiation. DEQ collected continuous water temperature data below Hacker Dam, but was not able to collect water temperature upstream of the impoundment to quantify the impacts that this impoundment may have on the water temperatures in Moore Creek.

Dryland cropping, if present, may have fallow periods, depending on site characteristics and landowner management. Agricultural fields encroaching in riparian areas and livestock grazing in riparian pastures can reduce the effectiveness of the existing shade-producing vegetation and prevent new shade producing vegetation from recolonizing in these riparian areas.

Figure 6-22. Photo showing West Madison Canal crossing Moore Creek and mixing through leaky check-boards in the center of the photo. Headgate releases water into Moore Creek to the left of photo (off photo).

Livestock Grazing

Grazing on rangeland and pastures is common in the Moore Creek watershed and occurs in a manner as described in **Section 6.6.1.2**. Private land grazing occurs throughout the watershed, and in areas where livestock have direct access to the stream, they can potentially be contributing to a lack of effective stream shade by grazing and browsing riparian vegetation. Livestock grazing downstream of the town of Ennis is likely a significant contributor to the lack of shade producing woody vegetation in that area, but recent land management changes have been made, such as off-stream watering tanks and riparian fencing, which should allow the riparian vegetation to eventually return to a state where it is providing sufficient stream shade.

In addition to private land grazing, there are seven public land grazing allotments in the Moore Creek watershed, six on BLM managed lands and one on USFS managed lands (**Figure 6-20**). Moore Creek flows through three of these allotments, the South Meadow (USFS), Granite-Moore (BLM), and Fletcher-Moore (BLM). The BLM managed grazing allotments in the Moore Creek watershed fall within the 2007 South Tobacco Roots Watershed Assessment report. According to the report, in 2007 the Granite-Moore and Fletcher-Moore allotments were not meeting the standards for riparian wetlands and bio-diversity due to conifer encroachment, forest health (insects and/or disease), excessive fuel loads, and streambank impacts from livestock grazing. It was determined that livestock management was a significant factor in these standards not being met (U.S. Department of the Interior, Bureau of Land Management 2007). However, a new report using dated collected in 2012 indicated that the Granite-Moore allotment was meeting all health standards as a result of pastures being rested for five consecutive years (U.S. Department of the Interior, Bureau of Land Management 2017b). The Fletcher-Moore allotment also met health standards in 2012. A large part of the Fletcher-Moore allotment has been sold, and management of the remaining portion in BLM land was changed in 2012 to include a grazing rotation that reduces livestock during sensitive time periods, but has fewer years of rest (every 4th year versus every other year). The allotment is expected to continue to meet standards with this new rotation method.

The Allotment Management Plan for the USFS managed South Meadow Creek allotment indicates that this allotment is currently meeting USFS standards and no major changes have occurred since the plan was last updated in 1996 (U.S. Department of Agriculture, Forest Service 1997; Suzuki 2015).

It is likely that livestock grazing in the upper portions of the Moore Creek watershed is contributing to the lack of sufficient stream shade in those areas of Moore Creek as shown in **Figure 6-21**. There are however, portions of these allotments that are meeting shade targets, and the current levels of effective stream shade on these allotments are similar to the amount of effective stream shade found on nearby private lands.

6.6.4.2 Thermal Springs

Ennis Hot Springs is a developed thermal spring located downstream of Ennis, and flows into Moore Creek after passing through a cooling pond. Quarterly water temperature data exists on the spring from 2011-2015, and based on this data, the spring has minimal impact on the water temperature of Moore Creek, with a maximum measured increase of 0.1°F (**Table 6-11**). Other non-developed thermal springs may be located in this area, and are covered under the natural background source category.

Table 6-11. Quarterly temperature monitoring results for the Ennis Hot Springs discharge

Monitoring Period	Spring Discharge (cfs)	Spring Temperature After Cooling Pond (°F)	Upstream Temperature (°F)	Downstream Temperature (°F)	Net Change in Temperature (°F)
4th Quarter 2011	0.08	55.2	48.9	49	0.1
1st Quarter 2012	0.08	48.1	44.6	44.6	0
2nd Quarter 2012	0.08	65.3	54.9	54.9	0
3rd Quarter 2012	0.08	61.5	53.1	53.2	0.1
4th Quarter 2012	0.08	38.4	33.8	33.9	0.1
1st Quarter 2013	0.08	51.8	46.3	46.3	0
2nd Quarter 2013	0.08	68.8	58.6	58.7	0.1
3rd Quarter 2013	0.08	68.6	57.4	57.5	0.1
4th Quarter 2013	0.08	43.1	38.3	38.3	0
1st Quarter 2014	0.08	40.6	36.3	36.4	0.1
2nd Quarter 2014	0.08	61.5	55.2	55.2	0
3rd Quarter 2014	0.08	71.2	62.3	62.3	0
4th Quarter 2014	0.08	39.6	35.2	35.3	0.1
1st Quarter 2015	0.08	43.7	41.7	41.7	0
2nd Quarter 2015	0.08	64.8	53.4	53.5	0.1

6.6.4.3 Residential Development

Residential development in the Moore Creek watershed occurs in and around the Town of Ennis. Residential lawns can often encroach on riparian areas and the removal of woody vegetation in favor of grasses is common. In parts where the shade producing overstory remains intact, the effective shade is high, while in areas where the vegetation has been removed, the effective shade is quite low. Effective stream shade in these areas can be improved by maintaining existing shade producing woody vegetation and planting new shade producing woody vegetation (where possible). Homeowner and small acreage owner education and outreach can be a useful tool in achieving this.

6.6.4.4 Natural Background

Natural sources contributing to stream temperatures including riparian grazing and browsing by wildlife, geology that limits riparian expansion, thermal springs, and the effects of natural events such as flooding, fire, and beetle kill were accounted for in target development and represent the reference condition to which existing condition data were compared to. Riparian grazing and browsing by wildlife occurs in the watershed. There has been one small documented wildland fire in the Moore Creek watershed, the Bobcat fire, which burned 15 acres on Frieler Creek in 1999. Due to the size and age of this fire, it is not anticipated that there are any current stream temperature impacts from this fire.

6.7 Approach to TMDL Allocations

As discussed in **Section 4.0**, the temperature TMDLs for applicable impaired waterbodies consist of the sum of load allocations (LAs) to individual sources and source categories (**Table 6-12**). There are no point sources in the Cherry Creek, Elk Creek, or Moore Creek watersheds, therefore the entire allowable load is allocated to natural and human-caused nonpoint sources of temperature and will be presented as a composite load allocation ($LA_{composite}$). Since the TMDL is based on a reference stream shade condition, improvements in effective stream shade can be made regardless of the source (human-caused or natural) to achieve the goals of the TMDL. Because the TMDLs for each stream consist of a composite load allocation to natural background and human-caused nonpoint sources with no wasteload allocations, the TMDL equals $LA_{composite}$ (**Equation 6-2**). An implicit margin of safety (MOS) is applied such that the MOS in the TMDL equation is equal to zero as discussed in **Section 4.0**.

Table 6-12. Temperature Source Categories and Descriptions for the Madison TPA

Source Category	Source Descriptions
Natural Background	• local geology • naturally occurring thermal springs • wild animal grazing and browsing of riparian vegetation • effects from natural events such as fire, beetle kill, drought, etc.
Human-Caused Nonpoint Sources	• agriculture • silviculture • residential development • human-influenced thermal springs

Equation 6-2: TMDL = $LA_{composite}$ = (X) (Y) (20.4)

TMDL = Total maximum daily load in kcal/day

$LA_{composite}$ = Load allocation to natural background and human-caused nonpoint sources in kcal/day

X = daily watts/ft^2 of solar flux to the stream surface for the stream reach under target shade conditions
Y = water surface area of stream reach in ft^2 (wetted width x length)
20.4 = conversion factor from watts to kcal/day

6.7.1 Total Existing Load

To estimate a total existing load for the purpose of estimating a required load reduction, **Equation 6-3** will be used. **Equation 6-3** uses similar calculations as used for the TMDL, but uses the daily watts/m^2 of solar flux under existing shade conditions instead of target shade conditions.

Equation 6-3: Total existing load = (X) (Y) (20.4)
Total existing load = Total existing load in kcal/day
X = daily watts/ft^2 of solar flux to the stream surface for the stream reach under existing shade conditions
Y = water surface area of stream reach in ft^2 (wetted width x length)
20.4 = conversion factor from watts to kcal/day

6.7.2 Load Reductions

Loads greater than the TMDL require load reductions to meet the TMDL. Existing effective shade in excess of shade targets decreases the existing solar load at a particular point, while deficit shade increases the existing solar load at that point. In areas where existing effective shade is in excess of shade targets, a load reduction is not required to meet the TMDL. Equation 6-3 and **Equation 6-4** were used to calculate temperature load reductions for stream segments in the Madison TPA:

Equation 6-4: % Load Reduction = (1 - (TMDL/Total Existing Load)) *100
*TMDL = Total maximum daily load in kcal/day (**Equation 6-1**)*
*Total Existing Load = calculated total existing load in kcal/day (**Equation 6-3**)*

Stream sections with high wetted widths have larger surface are and greater potential for solar load. Therefore, data permitting, wetted widths were decreased to reflect wetted widths that could be achieved through restoration or re-vegetation efforts. Using aerial photograph, wetted width was estimated for each stream segment based on aerial photography and adjusted to reflect wetted widths that would occur if width: depth target ratios were not exceeded. For sections with estimated wetted widths greater than the accepted range, the wetted width was reduced to reflect target conditions as part of the solar load reduction scenario.

Although a 15% increase in flow is also recommended as a target to improve temperatures, this target was not addressed in the load reduction scenario. A sensitivity performed to determine relative effects of increases in shade versus 15% flow augmentation on temperature targets illustrated the potential effects of such an increase in flow (see **Sections 6.4.2.1, 6.4.2.2**, and **6.4.2.3**)

6.8 TMDLs and Allocations by Stream

The below sections establish TMDLs and composite LAs to identified sources. These sections additionally provide temperature loading estimates to temperature-impaired stream segments, and estimate reductions necessary to meet water quality targets for the following streams:

- Cherry Creek
- Elk Creek
- Moore Creek

The total existing loads, as discussed above in **Section 6.7.1**, are used to estimate load reductions by comparing them to the allowable (TMDL) load and computing a required percent reduction to meet the TMDL. The temperature TMDLs for Cherry Creek, Elk Creek, and Moore Creek represent a condition on these streams in which all reasonable land, soil, and water conservation practices are in place. This condition can be measured by using temperature-influencing factors such as effective shade and channel width/depth ratio as surrogates for stream temperature conditions. Meeting targets for effective shade and channel width/depth ratio, and applying all reasonable land, soil, and water conservation practices will equate to meeting the TMDL.

Each stream was divided into segments based on land cover and land use for purposes of identifying general areas where effective stream shade is sufficient and areas where stream shade can be improved. To calculate a load reduction by using stream shade as a surrogate, the difference between percent target shade and percent existing shade was averaged for each segment. This equates to meeting the shade targets for that segment, therefore when all segments of a stream are meeting shade targets, it is assumed that all reasonable land, soil, and water conservation practices are in place and that stream is meeting the TMDL.

6.8.1 Cherry Creek TMDL and Allocations

This section describes the temperature TMDL for Cherry Creek.

6.8.1.1 Cherry Creek Temperature TMDL, Allocations, and Current Loading

The TMDL for temperature is based on **Equation 6-1** and the TMDL allocations are based on **Equation 6-2.** The value of the temperature TMDL is a function of the water surface area exposed to solar flux, and the modeled solar energy load in kilocalories (kcal) per day.

To estimate the reduction in solar load needed to meet the TMDL, the solar load was adjusted for the amount of shade that would be present during natural conditions under the shade surrogate model. Field data indicated that Cherry Creek met width:depth targets at the subset of sites sampled (**Table 6-5**). Because too few estimates of width: depth ratio were made in the field to estimate width: depth ratios at unsampled sites, adjustments for wetted width were not included in the load reduction scenario. In cases where human activities have increased wetted widths beyond expected natural conditions, riparian restoration or revegetation efforts could be implemented to reduce wetted widths and resulting solar load.

The following is the Cherry Creek temperature TMDL for the mouth of Cherry Creek at river mile 26.5 (RM 26.5).

TMDL at the mouth (RM 26.5) = (32.8 ft) (164 ft) (530 Watts/ft^2) (20.4 Kilocalories/Watt) = 58,159,910 Kilocalories/day

The total existing load at the mouth (RM 26.5) is based on **Equation 6-3**, and is calculated as follows:

Total existing load at the mouth (RM 26.5) = (32.8 ft) (164 ft) (613 Watts/ft^2) (20.4 Kilocalories/Watt) = 67,267,971 Kilocalories/day

Results for each stream segment can be found in **Appendix I**. The TMDL and total existing load presented in the equations above and in the table below (**Table 6-13**) are an expression of the modeled existing load and the TMDL at the mouth of Cherry Creek (RM 26.5). Since the TMDL and total existing load are based on stream surface area, target shade, and existing shade at that particular point in the stream, this number is dynamic in relation to location on the stream, and therefore the TMDL presented in **Table 6-13** is applicable only to that particular location on the stream. To provide a better picture of the overall stream temperature (shade) conditions in Cherry Creek, the shade surrogate TMDL presented in **Table 6-13** should be used for TMDL implementation purposes. **Figure 6-23** contains a map displaying the location of the breakouts for each segment identified in the shade surrogate TMDL

Table 6-13. Cherry Creek temperature TMDL at the mouth (RM 26.5) and shade surrogate TMDL

Temperature TMDL at the Mouth of Cherry Creek (RM 26.5)			
<u>TMDL</u>	*Total Maximum Daily Load in kcal/day*	*Existing Load in kcal/day*	*Load Reduction Needed to Meet the TMDL (%)*
	58,159,910	67,267,971	14%
<u>Allocations</u> • $LA_{composite}$	*Load Allocation in kcal/day*	*Existing Load in kcal/day*	*Load Reduction Needed to Meet the Allocation (%)*
	58,159,910	67,267,971	14%
Shade Surrogate TMDL for Cherry Creek			
Stream Segment[1]	*Average Target Effective Shade (%) (TMDL)*	*Average Existing Effective Shade (%)*	*Effective Shade Increase Needed to Meet TMDL (%)*
Headwaters (RM 0) to RM 7	70%	76%	0% - Meets Shade Targets
RM 7 to RM 11.5	35%	47%	0% - Meets Shade Targets
RM 11.5 to RM 13.2	44%	41%	3%
RM 13.2 to RM 14.8	33%	37%	0% - Meets Shade Targets
RM 14.8 to RM 17.7	30%	65%	0% - Meets Shade Targets
RM 17.7 to Mouth (RM 26.5)	22%	16%	6%

[1]Stream segments are divided by land cover and land use and are displayed by river mile (RM)

The source assessment of the Cherry Creek watershed indicates that agriculture is the most likely source of temperature in Cherry Creek; load reductions should focus on limiting and controlling temperature loading from those sources. Meeting LAs for Cherry Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 9.0**.

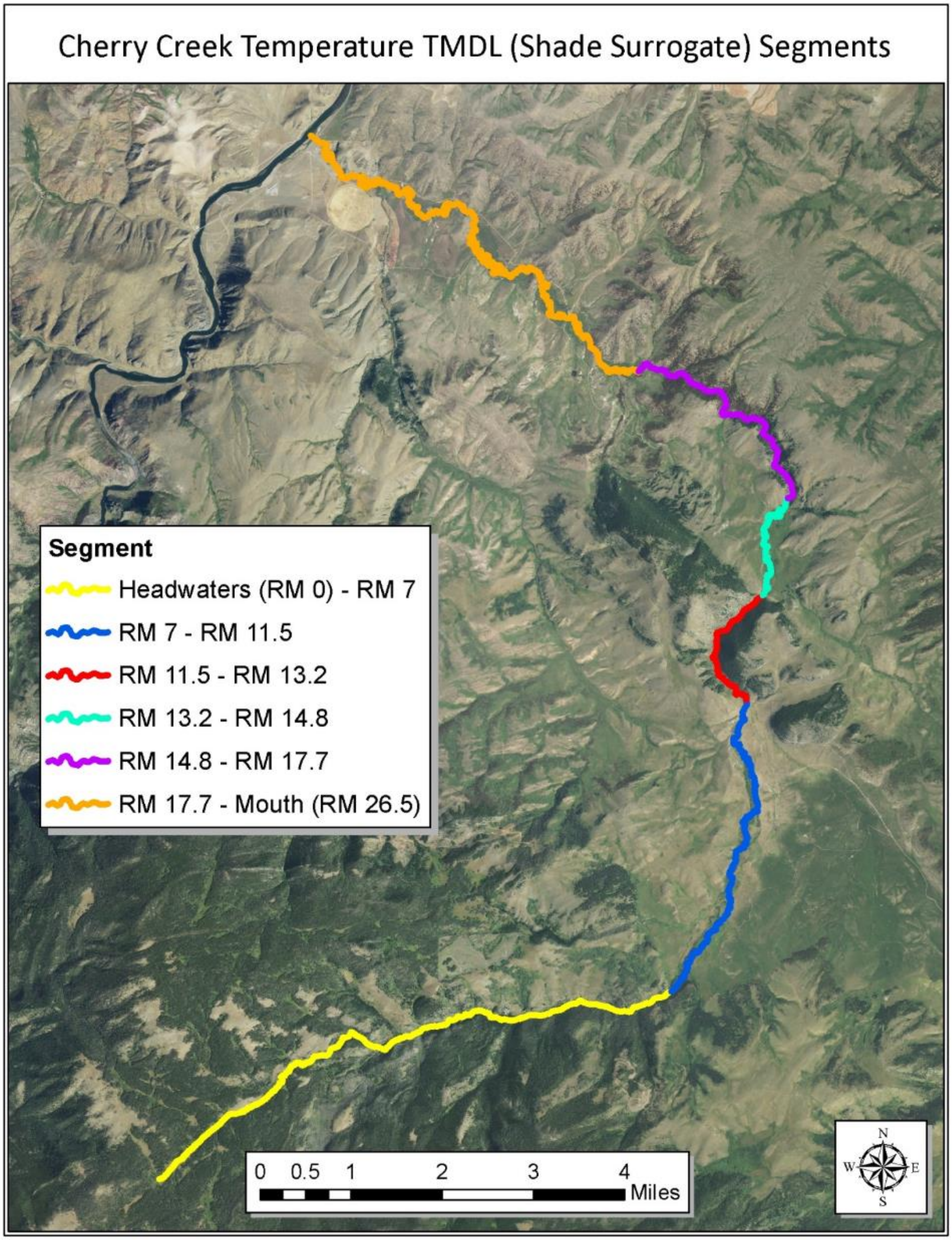

Figure 6-23. Map displaying the location of the stream segment breakouts by river mile (RM) for the shade surrogate TMDL for Cherry Creek

6.8.2 Elk Creek TMDL and Allocations

This section describes the temperature TMDL for Elk Creek.

6.8.2.1 Elk Creek Temperature TMDL, Allocations, and Current Loading

The TMDL for temperature is based on **Equation 6-1** and the TMDL allocations are based on **Equation 6-2**. The value of the temperature TMDL is a function of the water surface area exposed to solar flux, and the modeled solar energy load in kilocalories (kcal) per day.

The solar load was adjusted for the amount of shade that would be present under the shade model. Adjustments were also made to the wetted width portion of equation 6-1 for sites estimated to not meet width: depth targets. Based on field data, sites not meeting width: depth targets typically had a wetted width of >8 feet. Therefore, based on aerial photos, any stream sections with wetted widths > 8.5 feet were given the value of 8.5 feet for the solar energy load calculation under the solar load reduction scenario. Riparian restoration or revegetation efforts could be implemented to reduce wetted widths in these sections.

The following is the Elk Creek temperature TMDL for the mouth of Elk Creek at river mile 22.4 (RM 22.4).

TMDL at the mouth (RM 22.4) = (417 Watts/ft^2) (164ft) (9.84 ft) (20.4 Kilocalories/Watt) = 10,304,180 Kilocalories/day

The total existing load at the mouth (RM 22.4) is based on **Equation 6-3**, and is calculated as follows:

Total existing load at the mouth (RM 22.4) = (313 Watts/ft^2) (164 ft) (9.84 ft) (20.4 Kilocalories/Watt) = 13,727,934 Kilocalories/day

Results for each stream segment can be found in **Appendix I**. The TMDL and total existing load presented in the equations above and in the table below (**Table 6-14**) are an expression of the modeled existing load and the TMDL at the mouth of Elk Creek (RM 22.4). Since the TMDL and total existing load are based on stream surface area, target shade, and existing shade at that particular point in the stream, this number is dynamic in relation to location on the stream, and therefore the TMDL presented in **Table 6-14** is applicable only to that particular location on the stream. To provide a better picture of the overall stream temperature (shade) conditions in Elk Creek, the shade surrogate TMDL presented in **Table 6-14** should be used for TMDL implementation purposes. **Figure 6-24** contains a map displaying the location of the breakouts for each segment identified in the shade surrogate TMDL.

Table 6-14. Elk Creek temperature TMDL at the mouth (RM 22.4) and shade surrogate TMDL

Temperature TMDL at the Mouth of Elk Creek (RM 22.4)			
TMDL	*Total Maximum Daily Load in kcal/day*	*Existing Load in kcal/day*	*Load Reduction Needed to Meet the TMDL (%)*
	13,727,934	**10,304,180**	25%
Allocations • $LA_{composite}$	*Load Allocation in kcal/day*	*Existing Load in kcal/day*	*Load Reduction Needed to Meet the Allocation (%)*
	13,727,934	**10,304,180**	25%

Shade Surrogate TMDL for Elk Creek			
Stream Segment[1]	*Average Target Effective Shade (%) (TMDL)*	*Average Existing Effective Shade (%)*	*Effective Shade Increase Needed to Meet TMDL (%)*
Headwaters (RM 0) to RM 2.5	88%	82%	6%
RM 2.5 to RM 8.3	63%	28%	35%
RM 8.3 to RM 11	50%	43%	7%
RM 11 to Mouth (RM 22.4)	42%	17%	25%

[1]Stream segments are divided by land cover and land use and are displayed by river mile (RM)

The source assessment of the Elk Creek watershed indicates that agriculture is the most likely source of temperature in Elk Creek; load reductions should focus on limiting and controlling temperature loading from those sources. Meeting LAs for Elk Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 9.0**.

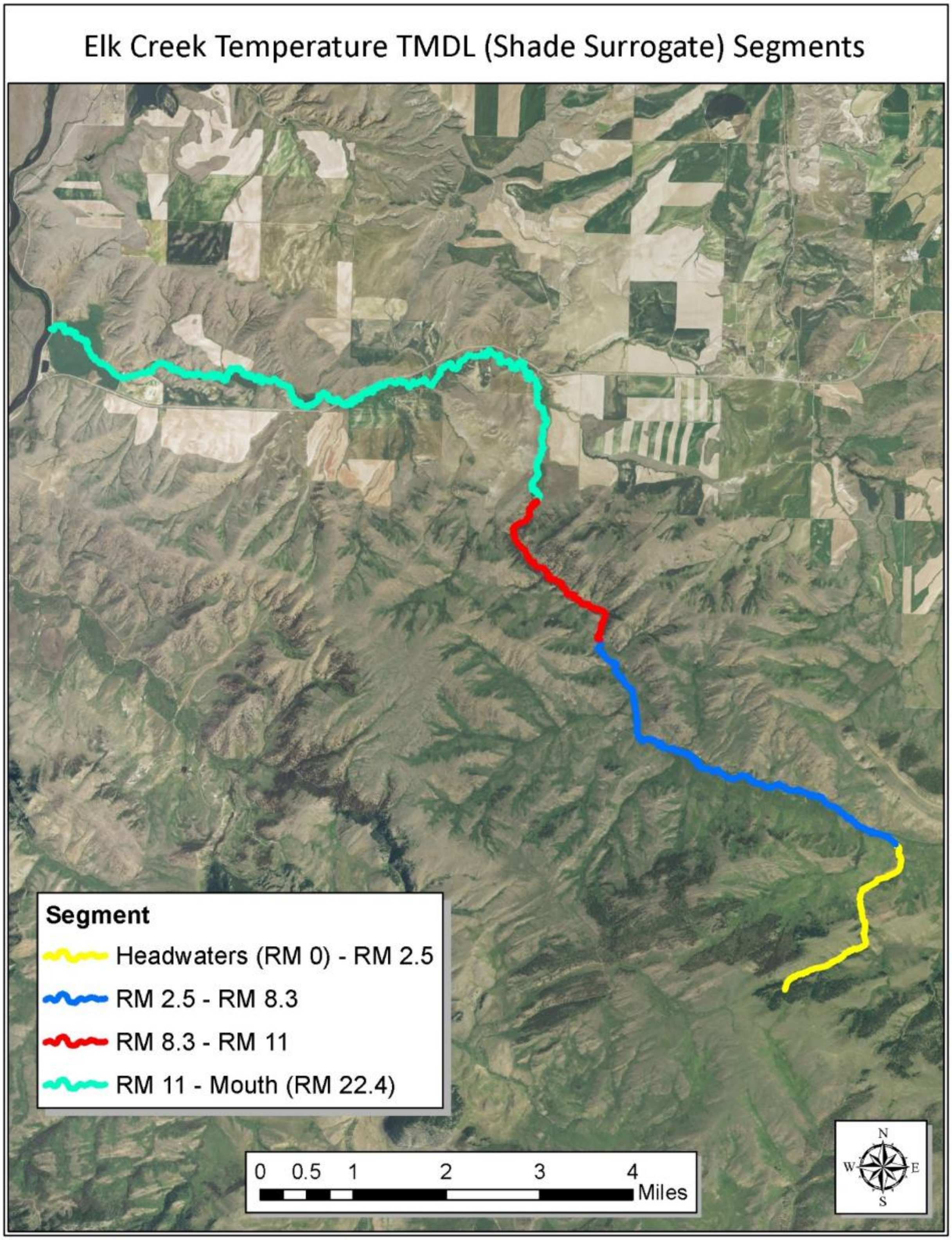

Figure 6-24. Map displaying the location of the stream segment breakouts by river mile (RM) for the shade surrogate TMDL for Elk Creek

6.8.3 Moore Creek TMDL and Allocations

This section describes the temperature TMDL for Moore Creek.

6.8.3.1 Moore Creek Temperature TMDL, Allocations, and Current Loading

The TMDL for temperature is based on **Equation 6-1** and the TMDL allocations are based on **Equation 6-2**. The value of the temperature TMDL is a function of the water surface area exposed to solar flux, and the modeled solar energy load in kilocalories (kcal) per day. The following is the Moore Creek temperature TMDL for the mouth of Moore Creek at river mile 18.1 (RM 18.1).

The solar load was adjusted for the amount of shade that would be present under the shade model. Based on sampled sections and aerial photography, all sections were predicted to meet width: depth targets, and wetted widths were therefore not adjusted in the solar load TMDL calculation. However, it is possible that sections with high wetted widths are present in Moore Creek, and this could be determined through further field reconnaissance. Riparian restoration or revegetation efforts could be implemented to reduce wetted widths in sections that have high wetted widths due to land use activities.

TMDL at the mouth (RM 18.1) = (9.84 ft) (164 ft) (483.7 Watts/ft^2) (20.4 Kilocalories/Watt) = 15,923,745 Kilocalories/day

The total existing load at the mouth (RM 18.1) is based on **Equation 6-3**, and is calculated as follows:

Total existing load at the mouth (RM 18.1) = (9.84 ft) (164 ft) (654.8 Watts/ft^2)(20.4 Kilocalories/Watt) = 21,556,476 Kilocalories/day

The TMDL and total existing load presented in the equations above and in the table below (**Table 6-15**) are an expression of the modeled existing load and the TMDL at the mouth of Moore Creek (RM 18.1). Since the TMDL and total existing load are based on stream surface area, target shade, and existing shade at that particular point in the stream, this number is dynamic in relation to location on the stream, and therefore the TMDL presented in **Table 6-15** is applicable only to that particular location on the stream. To provide a better picture of the overall stream temperature (shade) conditions in Moore Creek, the shade surrogate TMDL presented in **Table 6-15** should be used for TMDL implementation purposes. **Figure 6-25** contains a map displaying the location of the breakouts for each segment identified in the shade surrogate TMDL. In addition, the load reduction targets for each segment can be found in **Appendix I**.

Table 6-15. Moore Creek temperature TMDL at the mouth (RM 18.1) and shade surrogate TMDL

Temperature TMDL at the Mouth of Moore Creek (RM 18.1)			
TMDL	*Total Maximum Daily Load in kcal/day*	*Existing Load in kcal/day*	*Load Reduction Needed to Meet the TMDL (%)*
	15,923,745	21,556,476	26%
Allocations • $LA_{composite}$	*Load Allocation in kcal/day*	*Existing Load in kcal/day*	*Load Reduction Needed to Meet the Allocation (%)*
	15,923,745	21,556,476	26%
Shade Surrogate TMDL for Moore Creek			
Stream Segment[1]	*Average Target Effective Shade (%) (TMDL)*	*Average Existing Effective Shade (%)*	*Effective Shade Increase Needed to Meet TMDL (%)*
Headwaters (RM 0) to RM 4.2	83%	82%	1%
RM 4.2 to RM 10.4	65%	71%	0% - Meets Shade Targets
RM 10.4 to RM 11.8	67%	59%	8%
RM 11.8 to Mouth (RM 18.1)	49%	17%	32%

[1]Stream segments are divided by land cover and land use and are displayed by river mile (RM)

The source assessment of the Moore Creek watershed indicates that agriculture and residential development are the most likely sources of temperature in Moore Creek; load reductions should focus on limiting and controlling temperature loading from those sources. Meeting LAs for Moore Creek may be achieved through a variety of water quality planning and implementation actions which are identified in **Section 9.0**.

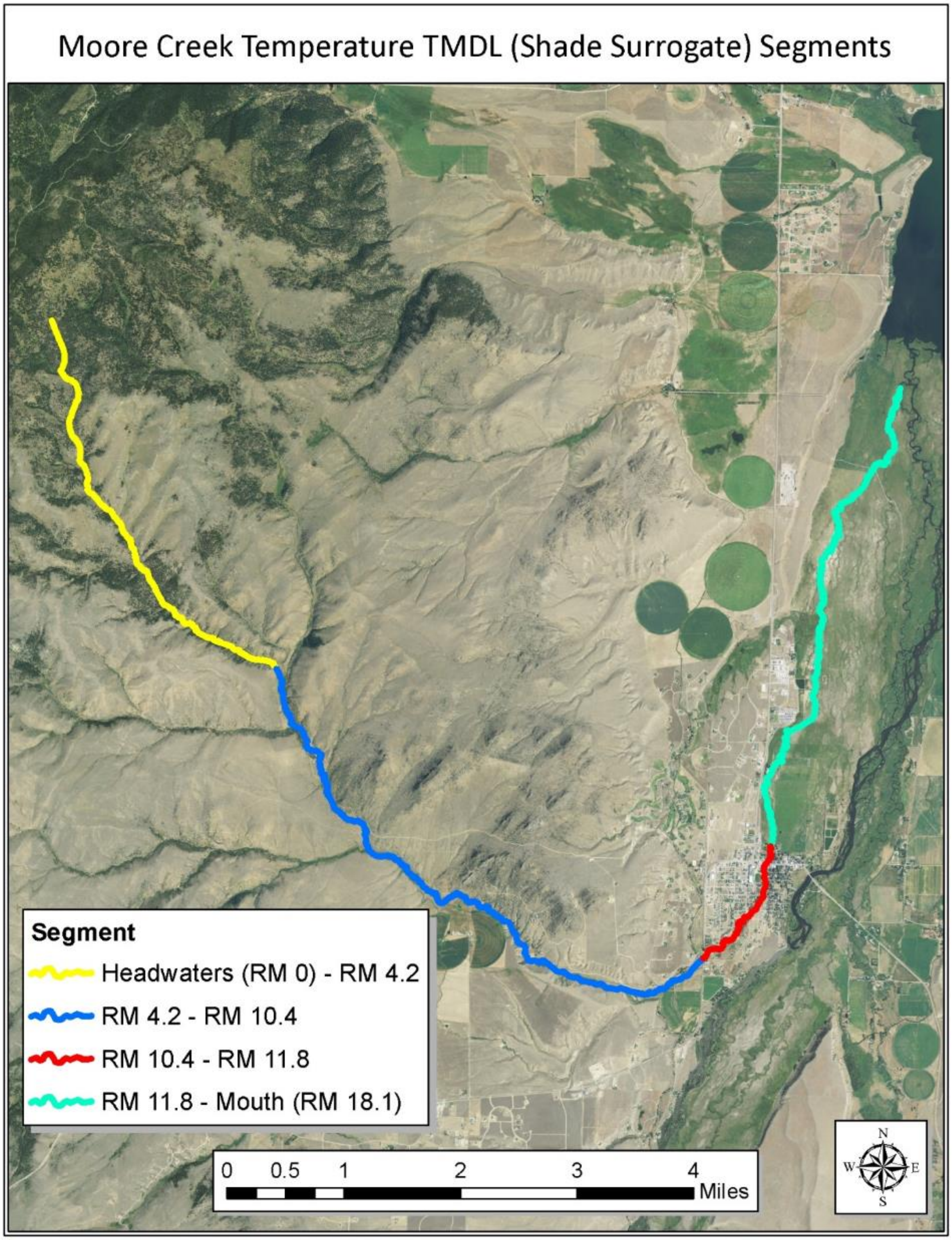

Figure 6-25. Map displaying the location of the stream segment breakouts by river mile (RM) for the shade surrogate TMDL for Moore Creek

6.8.4 Summary of Madison TPA Temperature Load Reduction Requirements

The shade surrogate temperature TMDLs developed for streams in the Madison TPA, the existing effective shade, and the percent effective shade increase needed to meet these TMDLs are summarized below in **Table 6-16**.

Table 6-16. Summary of the Madison TPA shade surrogate Temperature TMDLs, and Percent Effective Shade Increase Needed to Meet Each TMDL

Waterbody Name	Stream Segment	Average Target Effective Shade (%) (TMDL)	Average Existing Effective Shade (%)	Effective Shade Increase Needed to Meet TMDL (%)[1]
Cherry Creek	Headwaters (RM 0) to RM 7	70%	76%	0% - Meets Shade Targets
	RM 7 to RM 11.5	35%	47%	0% - Meets Shade Targets
	RM 11.5 to RM 13.2	44%	41%	**3%**
	RM 13.2 to RM 14.8	33%	37%	0% - Meets Shade Targets
	RM 14.8 to RM 17.7	30%	65%	0% - Meets Shade Targets
	RM 17.7 to Mouth (RM 26.5)	22%	16%	**6%**
Elk Creek	Headwaters (RM 0) to RM 2.5	88%	82%	**6%**
	RM 2.5 to RM 8.3	63%	28%	**35%**
	RM 8.3 to RM 11	50%	43%	**7%**
	RM 11 to Mouth (RM 22.4)	42%	17%	**25%**
Moore Creek	Headwaters (RM 0) to RM 4.2	83%	82%	**1%**
	RM 4.2 to RM 10.4	65%	71%	0% - Meets Shade Targets
	RM 10.4 to RM 11.8	67%	59%	**8%**
	RM 11.8 to Mouth (RM 18.1)	49%	17%	**32%**

[1]Bolded values indicate temperature reductions (shade increases) are needed to meet the TMDL

6.9 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), Wasteload Allocations (WLAs) (if applicable) and Load Allocations (LAs). TMDL development must also incorporate a margin of safety (MOS) 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. This section describes seasonality and MOS in the Madison TPA temperature TMDL development process.

6.9.1 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:

- Temperature monitoring occurred during the summer period, which is the warmest time of the year and when temperature-related impacts to aquatic life are most likely to occur

- Shade model development was based on the day in which water temperatures reached their maximum, based on water temperature data collected (See **Appendix G**)
- Temperature targets, the TMDLs, and the allocations apply year-round, but exceedances are most likely to occur during the summer period.
- Physical factors such as riparian vegetation and channel width/depth ratio targets, once met, will not likely change seasonally and will contribute year-round benefits to temperature loading

6.9.2 Margin of Safety

A margin of safety (MOS) is a required component of TMDL development. The MOS 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, 1999). This plan addresses MOS implicitly in a variety of ways:

- Riparian areas are an excellent indicator of overall health of a stream. By using shade as a surrogate for temperature, for a waterbody to meet its target shade, all reasonable land, soil, and water conservation practices must be in place to sustain the health of that riparian area. When good land management is in place, it is unlikely that riparian health will worsen unless management practices change.
- Shade model development was based on the day in which water temperatures reached their maximum, therefore if shade requirements are met for that most critical day, they would also be met for all other days in which water temperatures are cooler.
- Seasonality (discussed above) and variability in temperature loading is considered in target development, monitoring design, and source assessment.
- An adaptive management approach (discussed below) is recommended to evaluate target attainment and allow for refinement of load allocations, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development over time.

6.10 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, temperature targets, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. Therefore, mitigation and reduction of uncertainties through adaptive management approaches is a key component 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 methods of assessing temperature sources and needed reductions. The main sources of uncertainty are summarized below.

6.10.1 Water Quality Conditions

It was assumed that sampling data for each waterbody segment are representative of conditions in each segment. Future monitoring **would help** reduce the uncertainty regarding data representativeness, improve the understanding of the effectiveness of Best Management Practice (BMP) implementation, and increase the understanding of the load reductions needed to meet the TMDLs.

Uncertainties may arise in aerial photo interpretation of vegetation, and reference condition selection for each stream. Aerial photos provide a point in time snapshot of an area, and interpretation is dependent on what year and season the photos were taken. These can be verified by on the ground data collection, and if there are discrepancies between the aerial photo-interpretation and the data collected, the variables in the Shade Tool can be adjusted to reflect the actual condition. Each stream analyzed as a part of this study had multiple field verification sites to assist with ground-truthing aerial assessments.

6.10.2 Source Assessment

Source characterization and assessment to determine the major sources in each of the temperature impaired waterbodies was conducted by using monitoring data collected from the Madison TPA from 2009-2014, which represents the most recent data for determining existing conditions, and by using aerial photos, Geographic Information System (GIS) analysis, field work, and literature reviews. Uncertainties in source assessment can occur by using data that does not reflect the current condition of the waterbody, the misinterpretation of aerial photos, using outdated GIS data, and using field data that may not be representative of the overall condition of the waterbody.

Water quality monitoring data used for source assessment includes the time period from 2009-2014. Sources of pollutants or the level of contribution from those sources may have changed since data collection, and therefore there is some uncertainty that the data used is reflective of the current conditions of a particular waterbody. An assumption was made that the data used are representative of current conditions. Data collected on a waterbody accurately characterizes that particular site, but there is some uncertainty as to whether or not that site is representative of the overall waterbody conditions. To address this, monitoring site locations were selected to generate the most representative samples.

When using aerial photography and GIS data, uncertainty may occur through the misinterpretation of aerial photos and using GIS data that may either be inaccurate or outdated. To reduce uncertainty, multiple years of aerial photos were analyzed and only GIS data containing complete metadata and generated from reliable sources were used for source assessment.

6.10.3 Loading Estimates

Loading estimates are based on currently available data, and are only representative of the pollutant load at the time of data analysis. It is important to recognize that pollutant loads are not static and can therefore be different than the loads reported in this document. This brings some uncertainty into load reductions, as achieving the load reductions stated in this document may or may not result in meeting in-stream water quality targets based on current conditions. To account for this, shade was used as a surrogate for temperature, and therefore, meeting the shade targets for a stream will equate to meeting the temperature TMDL at any given solar load. Adaptive management can address uncertainties related to loading estimates through the re-evaluation of water quality conditions as BMPs are installed, land uses change, or pollutant sources and their contribution levels change.

7.0 Public Participation and Public Comments

Stakeholder and public involvement is a component of total maximum daily load (TMDL) planning required by Montana state law which directs the Department of Environmental Quality (DEQ) to consult with a watershed advisory group and local conservation districts during the TMDL development process. Technical advisors, stakeholders, state and federal agencies, interest groups, and the public were solicited to participate in differing capacities throughout the TMDL development process for this project in the Madison TMDL Planning Area.

7.1 Participants and Their Roles

Throughout completion of the sediment and temperature TMDLs in this document, DEQ worked to keep stakeholders apprised of project status and solicited input from a TMDL watershed advisory group. A description of the participants and their roles in the development of the TMDLs in this document is contained below.

Montana Department of Environmental Quality
The Montana Water Quality Act (75-5-703, Montana Code Annotated (MCA)) 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 has worked with other state and federal agencies to gather data and conduct technical assessments.

United States Environmental Protection Agency
EPA is the federal agency responsible for administering and coordinating requirements of the Clean Water Act. Section 303(d) of the Clean Water Act directs states to develop TMDLs (see **Section 1.1**), and EPA has developed guidance and programs to assist states in that regard. EPA has provided funding and technical assistance to Montana's overall TMDL program and is responsible for reviewing and evaluating TMDLs to see that they meet all federal requirements.

Local Conservation Districts
DEQ consulted with the Madison and Gallatin conservation districts during development of the TMDLs in this document, which included opportunities to provide comment during the various stages of TMDL development and an opportunity for participation in the watershed advisory group described below.

Madison TMDL Planning Area Watershed Advisory Group
The Madison TMDL Planning Area TMDL Watershed Advisory Group consisted of selected resource professionals who possess a familiarity with water quality issues and processes in the Madison River watershed, and representatives of applicable interest groups. All members were solicited to participate and work with DEQ in an advisory capacity per Montana state law. DEQ requested participation from the interest groups defined in 75-5-704 MCA and included local city and county representatives; livestock-oriented and farming-oriented agriculture representatives; conservation groups; watershed groups; hydroelectric industry representatives; state and federal land management agencies; and representatives of fishing, recreation, and tourism interests. The advisory group also included additional state and federal agency professionals, local action groups, and stakeholders with an interest in maintaining and improving water quality and riparian resources.

Advisory group involvement was voluntary, and the level of involvement was at the discretion of the individual members. Members had the opportunity to attend meetings organized by DEQ for soliciting feedback on project planning. Communication with advisory group members was conducted through a series of group meetings, video calls, and e-mails. Draft documents, project status updates, and meeting agendas and presentations were made available both via e-mail and through DEQ's wiki for water quality planning projects (http://mtwaterqualityprojects.pbworks.com/). Opportunities for review and comment were provided for participants at varying stages of TMDL development, including a two-week review and comment period for a draft version of this TMDL document prior to the public comment period. Member's comments were incorporated into this version of the document. The draft TMDLs were also presented to and discussed with the group at a virtual meeting in June 2020.

7.2 Response to Public Comments

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

The public comment period for this document was initiated on July 22, 2020 and closed on August 20, 2020. A virtual public informational meeting was held August 05, 2020 at 5:00 p.m. via Zoom. At the meeting, DEQ provided an overview of the TMDL document, answered questions, and solicited input and comment on the document. The public comment period and public meeting were announced in a July 22, 2020 press release from DEQ which was published on DEQ's website and was distributed to multiple media outlets across Montana. A public notice advertising the public comment period and public meeting was published in the following newspapers: Bozeman Daily Chronicle, The Madisonian, Lone Peak Lookout. Additionally, the announcement was distributed to the project's TMDL watershed advisory group, the Statewide TMDL Advisory Group, and other additional contacts via e-mail.

One formal, written comment was received and is summarized below, along with DEQ's response to this comment. DEQ evaluates comments and related information to ensure no critical information was excluded from the document. The original comment submission is in the TMDL project files at DEQ and may be reviewed upon request.

Comment: Were Jack and Grayling creeks evaluated for inclusion in the lists of sediment and temperature impaired streams? Jack Creek experiences significant sediment inputs from adjacent roads upstream of the Madison Valley as well as degraded habitat from overgrazing and a poor riparian zone in much of the stream near the Madison River. I am surprised it did not meet the sediment thresholds to be included in this document. The habitat in Grayling Creek is generally in better condition than Jack Creek, but habitat alterations near Hebgen Reservoir have decreased habitat quality to some extent.

> **Response:** Several methods were used to identify waterbodies in the Madison TMDL Planning Area to be monitored for sediment and/or temperature parameters. Waterbodies previously listed by DEQ for sediment, habitat, and temperature impairments were identified first, which included Jack Creek. Additional waterbodies were selected based on recommendations from Montana Fish, Wildlife & Parks fisheries biologists, the U.S. Forest Service, and the Madison Conservation District. Unimpaired, major tributaries to the Madison River were also included. Grayling Creek was not identified for inclusion; however, two sites were monitored for sediment on Jack Creek. Section B3.5 in **Appendix B** presents the monitoring results, provides a comparison to water quality targets, and a summary of the TMDL development determination.

Using the data collected in 2014, a water quality beneficial use support assessment determined Jack Creek was not impaired for sediment, and therefore, a sediment TMDL was not written for Jack Creek. Jack Creek is, however, listed as impaired for “alteration in stream-side or littoral vegetative covers” and “flow regime modification,” which are further described in **Section 8.0**. Water quality improvement measures that address these two impairments will also address excess sediment inputs to Jack Creek.

PART 3
WATER QUALITY IMPROVEMENT RECOMMENDATIONS

GLOSSARY OF WATER QUALITY TERMINOLOGY

Term	Definition or Description
Anthropogenic	Human-caused, or human-influenced. Water quality pollution originating from human activity.
Aquatic Life	Fish and aquatic bugs (macroinvertebrates)
Beneficial Use(s)	Beneficial uses, or designated uses, are simply the ways that we use water, and are the uses of water that we protect with water quality standards. They may include support of drinking water, recreation, fish and aquatic life, agricultural uses, and industrial uses. All surface waters in Montana are classified with, or assigned, a group of beneficial uses they must support, based on the potential of the waterbody to support those uses.
Best Management Practice (BMP)	Appropriate management practices designed and implemented for a specific purpose and include management methods as well as actual physical structures. In the case of water quality, BMPs are practices designed to protect or improve the physical, chemical, or biological characteristics of surface water and groundwater resources.
Buffer	Also referred to as a “riparian buffer” or “buffer strip.” In the context of this document, a buffer is a strip of vegetation that filters pollutants from entering the water. It can also be defined as the distance between a waterbody and the adjacent uplands, which includes the riparian area/zone.
Floodplain	Floodplains are the areas adjacent to streams, and sometimes to lakes and reservoirs, which are subject to periodic flooding. Often, they are defined by whether they would be inundated during a flood with a given probability of occurrence, such as a 100-year flood, which has a 1% chance of happening in any given year.
Habitat, Instream or Aquatic	Fish habitat within a waterbody (stream channel, lake, or reservoir).
Habitat, Streamside or Riparian	Wildlife habitat adjacent to a waterbody (stream channel, lake, or reservoir) and within the riparian zone.
Hummocking	Formation of grass mounds in a knob-like shape due to livestock access to soft ground in the riparian area or in a wetland. The mounds of grass or wetland vegetation are typically surrounded by bare soil.
Impaired	An unhealthy water or waterbody for which water quality data shows that the waterbody is failing to achieve compliance with applicable water quality standards and is not fully supporting one or more of its designated beneficial uses. DEQ maintains a list of impaired waters.
Nonpoint Source Pollution	Polluted runoff that comes from a variety of land-use activities. Common nonpoint source pollutants include sediment (dirt), nutrients (nitrogen and phosphorus), water temperature changes, metals, pesticides, pathogens, and salinity (salt). Nonpoint source pollution is the largest contributor of water quality problems in Montana, when compared to point sources of pollution in the state.

Term	Definition or Description
Non-Pollutant	Non-pollutants are human-induced alterations in the health of a water and have a harmful effect on any living thing that drinks or uses or lives in the water. For example, a human-induced alteration is the removal of streamside vegetation that results in the alteration of aquatic and wildlife habitat in and along the stream, which may subsequently increase stream temperatures and negatively affect the shape of the stream channel.
Point Source Pollution	Water pollution that requires a permit, usually from a single, traceable location. Note that agricultural stormwater discharges and return flows from irrigated agriculture are considered nonpoint sources and do not require a permit.
Pollutant	A pollutant is any substance that is introduced into a water, naturally or by human activities, that adversely affects the water quality. Common water pollutants include nutrients (nitrogen and phosphorus), sediment (dirt), pathogens, temperature, and metals (e.g., aluminum, arsenic, cadmium, copper, iron, lead, nickel, mercury, zinc).
Residual Pool Depth	A pool is defined as a depression in the streambed that is concave in profile. The “residual” pool is identified by visualizing the shape of the pool and evaluating where standing water would remain if all the flowing water were drained from the stream. The residual pool is defined as the portion of the pool that is deeper than the riffle crest forming the downstream end of the pool, and is calculated by subtracting the maximum depth at the riffle crest from the maximum pool depth.
Riparian	Riparian areas are typically vegetated zones along a waterbody and are usually transitional areas between the waterbody and upland habitat. Riparian areas have one or both of the following characteristics: • Distinctly different vegetative species than adjacent areas • Species similar to adjacent areas but exhibiting more vigorous or robust growth forms
Stakeholder	A person or entity with a direct interest in, or concern with, this project, usually local to the Madison River watershed.
Stormwater	Snowmelt and rainfall that does not infiltrate into the ground and runs off the land; also referred to as runoff or overland flow.
Total Maximum Daily Load (TMDL)	The maximum amount of a pollutant that a stream or waterbody can receive and still meet water quality standards. Think of it as a pollution diet or pollution budget. **Section 4.0** in Part 1 of this document further defines a TMDL and the TMDL development process.
Upland	Land outside of the riparian zone, usually higher than, or elevated above, the riparian.

Term	Definition or Description
Waterbody	A water; a stream, creek, river, lake, or reservoir. Also referred to as an assessment unit for water quality impairment assessments/determinations, which can be the full length, or partial segment of the length or area, of a waterbody.
Watershed	A geographic area drained by a river or stream; also referred to as a drainage basin, which is any area of land where precipitation collects and drains into a common outlet, such as into a river, bay, or other body of water.
Wetland	Wetlands are transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. Wetlands are typically defined as those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils.
Width/Depth Ratio	A number calculated by dividing the width of a stream channel by the depth of the stream channel, which is measured along what is called a cross-section or transect.

8.0 NON-POLLUTANT IMPAIRMENTS

This section discusses non-pollutant impairments in the Madison TMDL Planning Area (TPA). This section is included for informational purposes to help with development of overall watershed management goals and objectives and prioritization of restoration projects in the Madison TPA.

8.1 NON-POLLUTANT IMPAIRMENTS

A waterbody may be on Montana's list of impaired waters, but does not require a TMDL if it is not impaired for a pollutant, such as sediment, temperature, a nutrient, or metal. Non-pollutant causes of impairment such as "alteration in stream-side or littoral vegetative covers" do not require a TMDL. Non-pollutant causes of impairment are often associated with a pollutant cause of impairment; however, in some cases, non-pollutant impairments are causing a deleterious effect on beneficial uses without a clearly defined quantitative measurement or direct linkage to a pollutant.

The Montana Department of Environmental Quality (DEQ) recognizes that non-pollutant impairments can limit a waterbody's ability to fully support all beneficial uses and these impairment causes are important to consider when improving water quality conditions in both individual streams, and the Madison TMDL Planning Area as a whole. **Table 8-1** shows the non-pollutant impairments for waterbodies in the Madison TPA on Montana's 2018 list of impaired waters. They are summarized in this section to increase awareness of the non-pollutant impairment definitions and typical sources, and should be considered during planning of watershed-scale restoration efforts.

It is important to note that water quality issues are not limited to waterbodies that have identified pollutant and non-pollutant impairments. In some cases, streams have not yet been reviewed through DEQ's water quality assessment process and do not appear on Montana's list of impaired waters even though they may not be fully supporting all their beneficial uses.

Table 8-1. Waterbody Segments with Non-Pollutant Impairments in the 2018 Water Quality Integrated Report

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Impairment Cause	Addressed by a TMDL in This Document
Antelope Creek, Headwaters to mouth (Cliff Lake)	MT41F004_140	Alteration in stream-side or littoral vegetative covers	Yes (sediment TMDL)
		Flow Regime Modification	No
Blaine Spring Creek, Headwaters to mouth (Madison River, T7S R1W S6)	MT41F004_010	Flow Regime Modification	No
Elk Creek, Headwaters to mouth (Madison River)	MT41F002_020	Alteration in stream-side or littoral vegetative covers	Yes (sediment and temperature TMDLs)
Hot Springs Creek, Headwaters to mouth (Madison River)	MT41F002_030	Flow Regime Modification	No
Indian Creek, Lee Metcalf Wilderness boundary to mouth (Madison River)	MT41F004_040	Alteration in stream-side or littoral vegetative covers	No
		Flow Regime Modification	No

Table 8-1. Waterbody Segments with Non-Pollutant Impairments in the 2018 Water Quality Integrated Report

Waterbody (Assessment Unit)	Waterbody ID (Assessment Unit ID)	Impairment Cause	Addressed by a TMDL in This Document
Jack Creek, Headwaters to mouth (Madison River, T5S R1W S23)	MT41F004_050	Alteration in stream-side or littoral vegetative covers	No
		Flow Regime Modification	No
Moore Creek, Springs to mouth (Fletcher Channel), T5S R1W S15	MT41F004_130	Alteration in stream-side or littoral vegetative covers	Yes (sediment and temperature TMDLs)
North Meadow Creek, Headwaters to mouth (Ennis Lake)	MT41F004_060	Flow Regime Modification	No
O'Dell Spring Creek, Headwaters to mouth (Madison River)	MT41F004_020	Alteration in stream-side or littoral vegetative covers	No
		Other anthropogenic substrate alterations	No
		Physical substrate habitat alterations	No
Red Canyon Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_020	Alteration in stream-side or littoral vegetative covers	Yes (sediment TMDL)
		Flow Regime Modification	No
Ruby Creek, Headwaters to mouth (Madison River)	MT41F004_080	Flow Regime Modification	No
Watkins Creek, Headwaters to mouth (Hebgen Lake)	MT41F006_030	Alteration in stream-side or littoral vegetative covers	Yes (sediment TMDL)
		Flow Regime Modification	No

8.2 Non-Pollutant Impairment Cause Descriptions

Non-pollutants are often used as a probable cause of impairment when available data at the time of a water quality assessment do not provide a direct, quantifiable linkage to a specific pollutant. In some cases, the pollutant and non-pollutant categories are linked and appear together in the list of impairment causes for a waterbody; however, a non-pollutant impairment cause may appear independently of a pollutant cause. The following discussion provides some rationale for the application of the identified non-pollutant causes to a waterbody, and thereby provides additional insight into possible factors in need of additional investigation and potential restoration.

Alteration in Stream-side or Littoral Vegetative Covers

"Alteration in stream-side or littoral vegetative covers" refers to circumstances where practices along the stream channel have altered or removed riparian vegetation and subsequently affected channel geomorphology and/or stream temperature. Such instances may be riparian vegetation removal for a road or utility corridor, or overgrazing by livestock along the stream. As a result of altering the streamside vegetation, destabilized banks from loss of vegetative root mass could lead to over-widened stream channel conditions, elevated sediment and/or nutrient loads, and the resultant lack of canopy cover can lead to increased water temperatures.

Physical Substrate Habitat Alterations and Other Anthropogenic Substrate Alterations

"Physical substrate habitat alterations" generally describe cases where the stream channel has been physically altered or manipulated, such as straightening of the channel or human-influenced channel downcutting, resulting in a reduction of morphological complexity and loss of habitat (riffles and pools) for fish and aquatic life. For example, this may occur when a stream channel has been straightened to accommodate roads, agricultural fields, or placer mine operations. "Other anthropogenic substrate alterations" (human-caused modifications) may include channel alterations due to new infrastructure such as highways, roads, and bridges; and construction of dams or impoundments.

Flow Regime Modification

Flow modification refers to a change in the flow characteristics of a waterbody relative to natural conditions. An impairment listing caused by flow regime modification could be associated with changes in runoff and streamflow due to activities such as urban development, road construction, and timber harvest. Changes in runoff are commonly linked to elevated peak flows, which can also cause excess sedimentation by increasing streambank erosion and channel scour. Road crossings, particularly where culverts are undersized or inadequately maintained, can also alter flows by causing water to back-up upstream of the culvert.

Streams can also be listed as impaired for flow regime modification when irrigation withdrawal management leads to base flows that are too low to support the beneficial uses designated for that system. This could result in dry channels or extreme low flow conditions unsupportive of fish and aquatic life. Low flow conditions absorb thermal radiation more readily and increase stream temperatures, which in turn creates dissolved oxygen conditions too low to support some species of fish.

It should be noted that while Montana law requires monitoring and assessment to identify impaired waterbodies (75-5-702, Montana Code Annotated (MCA)) and to subsequently develop TMDLs for these waterbodies (75-5-703, MCA), the law also states that these requirements may not be construed to divest, impair, or diminish any legally-recognized water right (75-5-705, MCA). The identification of flow regime modification as a probable cause of impairment, related to probable sources of agriculture and irrigated crop production, should not be construed to divest, impair, or diminish a water right. Instead, it should be considered an opportunity to characterize the impacts of flow alterations, and pursue solutions that can result in improved streamflows during critical periods, while at the same time ensuring no harm to water rights. These same considerations apply to flow-related targets applied to temperature TMDLs in this document. It is up to local users, agencies, and entities to voluntarily improve instream flows through water and land management, which may include irrigation efficiency improvements and/or instream water leases that result in reduced amounts of water diverted from streams.

8.3 Monitoring and Best Management Practices for Non-Pollutant Affected Streams

Table 8-1 above indicates whether the non-pollutant impairment causes are addressed by a sediment and/or temperature TMDL in this document. It is likely that meeting the sediment and temperature TMDL targets (**Sections 5.4** and **6.4**) will also equate to addressing the habitat and flow regime modification impairment conditions in the streams listed in the table above. For streams with habitat alteration or flow regime modification impairments that do not have a sediment or temperature TMDL, meeting the sediment targets applied to streams of similar size will likely equate to addressing the habitat impairment condition for each stream.

Streams with non-pollutant impairments should be considered when developing watershed management goals and plans and when prioritizing restoration projects. Additional sediment and/or temperature information should be collected where data is insufficient for pollutant impairment determinations and the linkage between probable cause, non-pollutant listing, and effects to the beneficial uses is not well defined. The monitoring and restoration strategies that follow in **Sections 9.0** and **10.0** are presented to address both pollutant and non-pollutant issues for streams in the Madison TMDL Planning Area with TMDLs in this document, and they are equally applicable to streams listed for the above non-pollutant impairment causes. The strategies also apply to the entire Madison River watershed.

9.0 Water Quality Improvement Plan

There are many approaches to implementing a total maximum daily load (TMDL) and improving water quality, often with the majority of approaches linked to voluntary measures by landowners (including homeowners), particularly those located along an impaired stream or a tributary to an impaired stream. Landowners may independently choose to implement conservation measures (i.e., best management practices (BMPs)) with or without technical assistance offered by a variety of agency and other professionals (see **Section 9.2**), and with or without financial assistance offered via many available water quality improvement programs (see **Section 9.7**).

Equally important toward improving water quality is the continuation and maintenance of those land management activities that may already be incorporating conservation practices or other approaches toward limiting sediment loading and increases in water temperature, as well as limiting instream and streamside habitat alterations. **Section 9.5** discusses applicable BMPs.

While certain land uses and human activities are identified as sources and causes of water quality impairment, this document does not advocate for the removal of land and water uses to achieve the water quality restoration objectives discussed in this document. Changes to current and future land management practices that will improve and maintain water quality are instead the intended goal.

In addition to the information provided in this section, a document of stream summaries was compiled to provide a succinct description of each stream monitored for this TMDL project. These summaries include a general description of prominent sources of pollution to the stream and general recommendations to combat these problems. A location map showing monitoring locations is also provided for each stream. The stream summaries can be found on Montana DEQ's TMDL webpage, alongside this TMDL document.

9.1 Purpose of this Water Quality Improvement Plan and Support It Provides for Watershed Restoration Plan Development

This section provides an overall strategy and specific on-the-ground measures designed to restore water quality beneficial uses and attain water quality standards in the Madison TMDL Planning Area. This strategy includes general measures for reducing loading from identified nonpoint sources of pollutants (i.e., pollution that originates from a diffuse area, such as an agricultural field or an unpaved road adjacent to a stream).

To help promote and achieve water quality improvements linked to a TMDL document, the Montana Department of Environmental Quality (DEQ) endorses and provides technical support toward a collaborative watershed approach that involves development of what is called a "watershed restoration plan" (WRP). While this document section does not serve as a watershed restoration plan, it should assist local stakeholders in developing a WRP, which is a locally-developed plan providing more specific restoration goals for the Madison TMDL Planning Area, and the WRP may encompass broader goals than the water quality improvement information outlined in this document. The intent of a WRP for the Madison 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. A 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 U.S. Environmental Protection Agency's nine minimum elements for a WRP 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

The 2020 Madison Stream Summaries document (found on DEQ's TMDL website with this TMDL document) succinctly aids with elements 1, 2, and 8 for waterbodies that received a sediment and/or temperature TMDL in this document. This document section (**Section 9.0**) can assist with element 3 for all waterbodies prioritized within the WRP, and **Section 10.0** can provide technical assistance for element 9. DEQ TMDL and nonpoint source pollution program staff can provide technical assistance for development of all nine of the required elements, including assistance with sources of funding (**Section 9.7**); staff contacts and WRP planning assistance documents can be found on the DEQ website at http://deq.mt.gov.

9.2 Role of DEQ, Other Agencies, and Stakeholders

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. In addition to DEQ, specific stakeholders and agencies that will likely be vital to restoration efforts for streams discussed in this document include:

- Madison Conservation District
- Gallatin Conservation District
- U.S. Environmental Protection Agency (EPA)
- U.S. Forest Service (USFS)
- Natural Resources and Conservation Service (NRCS)
- U.S. Fish & Wildlife Service (USFWS)
- Montana Department of Natural Resources and Conservation (DNRC)
- Montana Fish, Wildlife and Parks (FWP)

- Montana Department of Transportation
- Montana Bureau of Mines and Geology
- Northwestern Energy
- Trout Unlimited: Madison-Gallatin Chapter
- Local City and County Representatives
- Gallatin Local Water Quality District
- Madison Valley Ranchlands Group
- Jack Creek Preserve Foundation

Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include:

- Montana Water Center (at Montana State University)
- University of Montana Watershed Health Clinic
- Montana Aquatic Resources Services
- Montana State University Extension Water Quality Program

9.3 Water Quality Restoration Objective

The water quality restoration objective for the Madison TMDL Planning Area is to reduce pollutant loads, as identified throughout this document, to meet the water quality standards and TMDL targets for full recovery of beneficial uses for all impaired streams. Meeting the TMDLs provided in this document, as well as in the 2019 nutrient, pathogen, and metals TMDL document (DEQ 2019), will achieve this objective for all identified pollutant-impaired streams. Based on the assessment provided in both TMDL documents, the TMDLs can be achieved through proper implementation of best management practices and using the appropriate technology to treat wastewater (both private and municipal). However, this section focuses on BMPs for nonpoint sources.

9.4 Restoration Approaches by Pollutant

TMDLs were completed for 13 waterbody segments for sediment and three waterbody segments for temperature. Other streams in the planning 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. Details specific to each stream, and therefore which of the following strategies may be most appropriate, are found within **Sections 5.0** and **6.0** and the 2020 Madison Stream Summaries document found on DEQ's TMDL website.

Many of the BMPs discussed involve what is often referred to as soft, or passive, approaches. These include situations where impacts along a stream are often reduced due to changes in grazing management and nature is allowed to 'run her course' over time via establishment of healthy riparian vegetation and other conditions that improve water quality and overall stream function. These are often the most practical and least expensive approaches, although full recovery can take years. In some situations, it can be advantageous to take a more aggressive or active approach which can be as simple as planting willows along the stream to help hold banks together, versus waiting for willows to naturally repopulate. In more extreme cases, particularly where channel form and function have been significantly altered and passive approaches could take decades, an active approach could involve reconfiguring a whole reach of a stream along with creation of stream meander patterns and planting of willows or other appropriate riparian vegetation.

9.4.1 Sediment Restoration Approach

The goal of the sediment restoration strategy is to limit the availability, transport, and delivery of excess sediment by a combination of minimizing sediment delivery, reducing the rate of runoff, and intercepting sediment transport. Monitoring data used to develop targets and determine impairments are described in **Section 5.0** and in **Appendix B**, Sediment and Habitat Data Collection Methods. Sediment restoration activities on impaired stream segments will help reduce the amount of fine sediment, reduce width/depth ratio, increase residual pool depths, increase pool frequency, increase riparian understory shrub cover, reduce impacts of human-caused sediment sources, and restore appropriate macroinvertebrate assemblages. These are indicators of successful restoration activities targeted toward sediment reduction and need to be considered together and within the context of stream potential in comparison to appropriate reference sites. For example, pool frequency tends to decline as stream size increases; therefore, indicators for these parameters will vary. General targets for these indicators are summarized in **Table 5-2**.

Streamside riparian and wetland vegetation restoration and long-term management are crucial to achieving the sediment TMDLs. Native streamside riparian and wetland vegetation provides root mass, which hold streambanks together. Suitable root mass density ultimately slows bank erosion. Riparian and wetland vegetation filter pollutants from upland runoff. Therefore, improving riparian and wetland vegetation will decrease streambank erosion by improving streambank stability and will also reduce pollutant delivery from upland sources. Suspended sediment is also deposited more effectively in healthy riparian zones and wetland areas during flooding because water velocities slow in these areas enough for excess sediment to settle out. Restoration recommendations involve the promotion of riparian and wetland recovery through improved grazing and land management (including the timing and duration of grazing, the development of multi-pasture systems that include riparian pastures, and the development of off-site watering areas), application of timber harvest best management practices, floodplain and streambank stabilization, revegetation efforts, and instream channel and habitat restoration where necessary. Appropriate BMPs will differ by location and are recommended to be included and prioritized as part of a comprehensive watershed scale plan (e.g., a WRP).

In areas where stormwater is accelerating sediment loading to streams, the sediment restoration strategy will be achieved by BMPs that promote infiltration of runoff and lessen its volume and the timing of delivery to surface water. Smart growth and low impact development are two closely related planning strategies that help reduce stormwater volume, slow its transport to surface waterbodies, and improve groundwater recharge.

Although unpaved roads may be a small source of sediment at the watershed scale, sediment derived from roads may cause significant localized impact in some stream reaches. Restoration approaches for unpaved roads near streams primarily include measures that divert water to ditches before it enters the stream. The diverted water should be routed through natural healthy vegetation, which will act as filter zones for the sediment laden runoff before it enters streams. In addition, routine maintenance of unpaved roads (particularly near stream crossings) and proper sizing and maintenance of culverts, regardless of road use status, are crucial components to limiting sediment production from roads.

9.4.2 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 temperature in Cherry Creek, Elk Creek, and Moore Creek is increasing riparian shade. Secondarily, recovery of over widened stream channels to a more natural morphology and increasing instream flow during summer months may also aid in reducing temperatures.

Increase 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 serving as a stabilizing component to streambanks to reduce bank erosion, slow lateral river migration, and buffer 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.

Specific targets for instream summer flow are provided for Cherry, Elk, and Moore creeks in **Sections 6.4.1.4** and **6.4.1.5**. 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. This TMDL document cannot, nor is it intended to, prescribe limitations on individual water rights owners and users. However, it is understood that increased summer instream flows could improve summer water temperatures, and in addition, improve quality and connectivity among instream features used by aquatic life. Local water users should work collectively and with local, state, and federal resource management professionals to review water use options and available assistance programs.

Recovery of stream channel morphology in most cases will occur slowly over time and follow the improvement of riparian condition, stabilization of streambanks, and reduction in overall sediment load. For smaller streams, there may be discrete locations or portions of reaches that demand a more rapid intervention through physical restoration, but size, scale, and cost of restoration in most cases are limiting factors to applying a constructed remedy.

The above approaches give only the broadest description of activities to help reduce water temperatures. The temperature assessments described in **Section 6.0** 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, but site-specific analysis and detailed review of current land management and water use practices was not included in the assessment. Therefore, it is not suggested that every operator and water user in the Madison River watershed need to change their practices to reduce stream temperatures; there may be some who currently manage their land and water use consistent with all reasonable land, soil, and water conservation practices, and there may be others for whom changing their practices at this stage is not a viable option due to economic or other constraints. Nevertheless, it is strongly encouraged that resource managers and land owners continue to work to identify all potential areas of improvement and develop projects and practices to reduce stream temperatures in Cherry, Elk, and Moore creeks and the West Fork Madison River.

9.4.3 Non-Pollutant Restoration Approach

Although TMDL development is not required for non-pollutant causes of impairment, they are frequently linked to pollutants, and addressing non-pollutant causes is an important component of TMDL implementation. Non-pollutant impairment causes within the Madison TMDL Planning Area include alteration in streamside or littoral vegetative covers, physical substrate habitat alterations, other anthropogenic substrate alterations, and flow regime modification, and are described in **Section 8.0**. Typically, habitat impairments are addressed during implementation of associated pollutant TMDLs. Although flow modifications have the most direct link with temperature, adequate flow is also critical for downstream sediment transport and improving the assimilative capacity of streams for sediment and nutrient inputs. Therefore, if restoration goals within the Madison TMDL Planning Area are not also addressing non-pollutant impairments, additional non-pollutant related BMP implementation should be considered.

9.5 Restoration Approaches by Source

General management recommendations are outlined below for the major sources of human-caused pollutant loads in the Madison TMDL Planning Area: agricultural sources, riparian and wetland vegetation removal, forestry and timber harvest, and roads. Applying and maintaining BMPs is the core of the nonpoint source pollutant reduction strategy, but are only part of a watershed restoration strategy. Restoration activities may also address other current pollution-causing uses and management practices. In some cases, efforts beyond implementing new BMPs may be required to address key pollutant sources. In these cases, BMPs are usually identified as a first effort and further monitoring and evaluation of activities and outcomes, as part of an adaptive management approach, will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is an important part of the restoration process, and monitoring recommendations are outlined in **Section 10.0**.

The information provided in the 2020 Madison Stream Summaries document found on DEQ's TMDL website with this TMDL document, should be used to help determine restoration priorities and which restoration approaches below should be applied for each stream. In recognition that noxious weeds are a problem throughout Montana and may be associated with any of the following source categories, noxious weed control should be actively pursued whenever BMPs are being implemented.

9.5.1 Agriculture Sources

Reduction of pollutants from upland agricultural sources can be accomplished by limiting the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil and runoff before it enters a waterbody. The main BMP recommendations for the Madison TMDL Planning Area are riparian buffers, wetland restoration, and vegetated filter strips, where appropriate. These methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept pollutants. Filter strips and buffers are even more effective for reducing upland agricultural-related sediment when used in conjunction with BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, and strip-cropping. Additional BMP information, design standards and effectiveness, and details on the suggested BMPs can be obtained from your local USDA Agricultural Service Center and in Montana's Nonpoint Source Management Plan (DEQ 2017).

An additional benefit of reducing sediment input to the stream is a decrease in sediment-bound nutrients. Reductions in sediment loads may help address some nutrient-related problems. Nutrient management considers the amount, source, placement, form, and timing of plant nutrients and soil amendments. Conservation plans should include the following information (NRCS Conservation Practice Standard 590 and 590-1, Nutrient Management (United States Department of Agriculture, Natural Resources Conservation Service, 2019):

- Field maps and soil maps
- Planned crop rotation or sequence
- Results of soil, water, plant, and organic materials sample analysis
- Realistic expected yields
- Sources of all nutrients to be applied
- A detailed nutrient budget
- Nutrient rates, form, timing, and application method to meet crop demands and soil quality concerns
- Location of environmentally sensitive areas, including streams, wetlands, springs, or other locations that deliver surface runoff to groundwater or surface water
- Guidelines for operation and maintenance

9.5.1.1 Grazing

Grazing has the potential to increase sediment and nutrient loads, as well as stream temperatures (by altering channel width and riparian vegetation), but these effects can be mitigated with appropriate management. Development of riparian grazing management plans should be a goal for any landowner who operates livestock and does not currently have such plans. Private land owners may be assisted by state, county, federal, and local conservation groups to establish and implement appropriate grazing management plans. Note that riparian grazing management does not necessarily eliminate all grazing in riparian corridors. In some areas however, a more limited management strategy may be necessary for a period of time in order to accelerate reestablishment of a riparian community with the most desirable species composition and structure.

Every livestock grazing operation should have a grazing management plan. The NRCS Prescribed Grazing Conservation Practice Standard (Code 528) recommends the plan include the following elements (Natural Resource Conservation Service, 2010):

- A map of the operation showing fields, riparian and wetland areas, winter feeding areas, water sources, animal shelters, etc.
- The number and type of livestock
- Realistic estimates of forage needs and forage availability
- The size and productivity of each grazing unit (pasture/field/allotment)
- The duration and time of grazing
- Practices that will prevent overgrazing and allow for appropriate regrowth
- Practices that will protect riparian and wetland areas and associated water quality
- Procedures for monitoring forage use on an ongoing basis
- Development plan for off-site watering areas

Reducing grazing pressure in riparian and wetland areas and improving forage stand health are the two keys to preventing nonpoint source pollution from grazing. Grazing operations should use some or all of the following practices:

- Minimizing or preventing livestock grazing in riparian and wetland areas
- Providing off-stream watering facilities or using low-impact water gaps to prevent ‘loafing’ in wet areas

- Managing riparian pastures separately from upland pastures
- Installing salt licks, feeding stations, and shelter fences in areas that prevent 'loafing' in riparian areas and help distribute animals
- Replanting trodden down banks and riparian and wetland areas with native vegetation (this should always be coupled with a reduction in grazing pressure)
- Rotational grazing or intensive pasture management that takes season, frequency, and duration into consideration

The following resources provide guidance to help prevent pollution and maximize productivity from grazing operations:

- USDA, Natural Resources Conservation Service
  The office serving Madison County is the Sheridan Service Center (find your local USDA Agricultural Service Center listed in your phone directory or at www.nrcs.usda.gov)
- Montana State University Extension Service (www.musextension.org)
- DEQ Watershed Protection Section, Nonpoint Source Program: Nonpoint Source Management Plan (http://deq.mt.gov/Water/SurfaceWater/npspollution)

The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian and wetland vegetation and minimize disturbance of the streambank and channel. The primary recommended BMPs for the Madison TMDL Planning Area are limiting livestock access to streams and stabilizing the stream at access points, providing off-site watering sources when and where appropriate, planting native stabilizing vegetation along streambanks, and establishing and maintaining riparian buffers. Although bank revegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation.

9.5.1.2 Animal Feeding Operations

Animal feeding operations (AFOs) can pose a number of risks to water quality and public health if the animal manure and wastewater they generate contaminates nearby waters. To minimize water quality and public health concerns from AFOs and land applications of animal waste, the USDA and EPA released the Unified National Strategy for AFOs in 1999 (USDA and U.S. EPA, 1999). This strategy encouraged owners of AFOs of any size of number of animals to voluntarily develop and implement site-specific Comprehensive Nutrient Management Plans (CNMPs). A CNMP is a written document detailing manure storage and handling systems, surface runoff control measures, mortality management, chemical handling, manure application rates, schedules to meet crop nutrient needs, land management practices, and other options for manure disposal.

An AFO that meets certain specified criteria is referred to as a Concentrated Animal Feeding Operation (CAFO), and may be required to obtain a Montana Pollution Discharge Elimination System (MPDES) permit as a point source. Montana's AFO compliance strategy is based on federal law and has voluntary, as well as, regulatory components. If voluntary efforts can eliminate discharges to state waters, in some cases no direct regulation is necessary through a permit.

Operators of AFOs may take advantage of effective, low cost practices to reduce potential runoff to state waters. In addition to water quality benefits, these practices may help increase property values and operation productivity. Properly installed vegetative filter strips, in conjunction with other practices to reduce wasteloads and runoff volume, are very effective at trapping and detaining sediment and reducing transport of nutrients and pathogens to surface waters, with removal rates approaching 90 percent (USDA, NRCS 2005). Other options may include clean water diversions, roof gutters, berms, sediment traps, fencing, structures for temporary manure storage, shaping, and grading. Animal health and productivity also benefit when clean, alternative water sources are installed to prevent contamination of surface water.

Opportunities for financial and technical assistance (including comprehensive nutrient management plan development) in achieving voluntary AFO and CAFO compliance are available from conservation districts, NRCS field offices, or the Montana DEQ Watershed Protection Section. Further information may be obtained from the DEQ website at: http://deq.mt.gov/Water/permits.

Montana's nonpoint source pollution control strategies for addressing AFOs are summarized in the bullets below:

- Work with producers to prevent nonpoint source pollution from AFOs
- Promote use of State Revolving Fund for implementing AFO BMPs
- Collaborate with Montana State University (MSU) Extension Service, NRCS, and agriculture organizations in providing resources and training in whole farm planning to farmers, ranchers, conservation districts, watershed groups and other resource agencies
- Encourage inspectors to refer farmers and ranchers with potential nonpoint source discharges to DEQ watershed protection staff for assistance with locating funding sources and grant opportunities for BMPs that meet their needs (this is in addition to funds available through NRCS and the Farm Bill)
- Develop early intervention of education and outreach programs for small farms and ranches that have potential to discharge nonpoint source pollutants from animal management activities. This includes assistance from the DEQ Permitting Division, as well as external entities such as DNRC, local watershed groups, conservation districts, and MSU Extension.

9.5.1.3 Water Management and Irrigation

Flow modification and dewatering are commonly considered water quantity rather than water quality issues. However, changes to streamflow can have a profound effect on the ability of a stream to attenuate pollutants, especially nutrients, metals, and heat. Flow reduction may increase water temperature, allow pollutants to accumulate in stream channels, reduce available habitat for fish and other aquatic life, and may cause the channel to respond by changing in size, morphology, meander pattern, rate of migration, bed elevation, bed material composition, floodplain morphology, and streamside vegetation if flood flows are reduced (Andrews and Nankervis, 1995; Schmidt and Potyondy, 2004). Implementation strategies recognize the need for specific flow regimes, and may suggest flow-related improvements as a means to achieve full support of beneficial uses. However, local coordination and planning are especially important for flow management because Montana state law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (75-5-705, Montana Code Annotated).

Irrigation management is a critical component of attaining both coldwater fishery conservation and TMDL goals. Understanding irrigation water, groundwater, and surface water interactions is an important part of understanding how irrigation practices will affect streamflow during specific seasons. Improvements should focus on how to reduce the amount of stream water diverted during July and August, while still maintaining healthy crops or forage. It may also be desirable to investigate irrigation practices earlier in the year that promote groundwater return during July and August, and September.

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:

- 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.

9.5.1.4 Small Acreages

Throughout Montana, the number of small acreages is growing rapidly, and many small acreage owners own horses or cattle. Animals grazing on small acreages can lead to overgrazing and a shortage of grass cover, leaving the soil subject to erosion and runoff to surface waters. General BMP recommendations for small acreage lots with animals include creating drylots, developing a rotational grazing system, and maintaining healthy riparian buffers. Small acreage owners should collaborate with MSU Extension Service, NRCS, conservation districts and agriculture organizations to develop management plans for their lots. Further information may be obtained from the Montana Nonpoint Source Management Plan (DEQ, 2017) or the MSU extension website at: http://animalrangeextension.montana.edu/range/small-acreages.html

9.5.1.5 Cropland

The primary strategy of the recommended cropland BMPs is to reduce sediment inputs. The major factors involved in decreasing sediment loads are reducing the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil before it enters waterbodies. The main BMP recommendations for the Madison TMDL Planning Area are vegetated filter strips and riparian buffers. Both methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept sediment. Effectiveness is typically about 70% for the filter strips (Arora 1996) and 50% for the buffers (Liu 2008). Filter strips and buffers are most effective when used in conjunction with agricultural BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, strip cropping, and precision farming. Filter strips along streams should be composed of natural vegetative communities. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in Appendix A of Montana's Nonpoint Source Management Plan (DEQ 2017).

9.5.2 Riparian Areas, Wetlands, and Floodplains

Healthy and functioning riparian areas, wetlands, and floodplains are critical for wildlife habitat, groundwater recharge, reducing the severity of floods and upland and streambank erosion, and filtering pollutants from runoff. The performance of these functions is dependent on the connectivity of riparian areas, wetlands, and floodplains to both the stream channel and upland areas. Human activities affecting the quality of these transitional habitats or their connectivity can alter their performance and greatly affect the transport of water, sediments, and contaminants (e.g., channelization, increased stream power, bank erosion, and habitat loss or degradation). Therefore, restoring, maintaining, and protecting riparian areas, wetlands, and floodplains within the watershed should be a priority of TMDL implementation in the Madison TMDL Planning Area.

Reduction of riparian and wetland vegetative cover by various land management activities is a principal cause of water quality and habitat degradation in watersheds throughout Montana. Although implementation and maintenance of passive BMPs that allow riparian and wetland vegetation to recover at natural rates is typically the most cost-effective approach, active restoration (e.g., plantings) may be necessary in some instances. The primary advantage of riparian and wetland plantings is that installation can be accomplished with minimum impact to the stream channel, existing vegetation, and private property. Weed management should also be a dynamic component of managing riparian areas.

Factors influencing the appropriate riparian and wetland restoration would include severity of degradation, site-potential for various species, and availability of local sources for native transplant materials. In general, riparian and wetland plantings would promote establishment of functioning stands of native species. The following recommended restoration measures would allow for stabilization of the soil, decrease sediment delivery to the stream, and increase absorption of nutrients from overland runoff:

- Harvesting and transplanting locally available sod mats with an existing dense root mass provides immediate promotion of bank stability and filtering nutrients and sediments
- Seeding with native graminoids (grasses and sedges) and forbs is a low-cost activity at locations where lower bank shear stresses would be unlikely to cause erosion
- Transplanting mature native shrubs, particularly willows (*Salix* sp.), provides rapid restoration of instream habitat and water quality through overhead cover and stream shading, as well as uptake of nutrients
- Willow sprigging expedites vegetative recovery, but involves harvest of dormant willow stakes from local sources

Note: Before transplanting *Salix* from one location to another it is important to determine the exact species so that we do not propagate the spread of non-native species. There are several non-native willow species that are similar to our native species and commonly present in Montana watersheds.

In addition to the benefits described above, it should be noted that in some cases, wetlands act as areas of shallow subsurface groundwater recharge and/or storage areas. The captured water via wetlands is then generally discharged to the stream later in the season and contributes to the maintenance of base flows and stream temperatures. Restoring ditched or drained wetlands can have a substantial effect on the quantity, temperature, and timing of water returning to a stream, as well as the pollutant filtering capacity that improved riparian and wetlands provide. 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/water/surfacewater/wetlands.

9.5.3 Bank Hardening/Riprap/Revetment and Floodplain Development

The use of riprap or other "hard" approaches is not recommended and is not consistent with water quality protection or implementation of this plan. Although it may be necessary in some instances, these “hard” approaches generally redirect channel energy and exacerbate erosion in other places. Bank armoring should be limited to areas with a demonstrated infrastructure threat. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of the upper bank, reduce stream scouring energy, and provide shading and cover habitat. Limit threats to infrastructure by reducing floodplain development through local land use planning initiatives.

As discussed above, passive riparian restoration is preferable, but in areas where stream channels are unnaturally unstable or streambanks are eroding excessively, additional active restoration approaches, such as channel design, woody debris and log vanes, bank sloping, seeding, and shrub planting may be desired to speed up the rate of recovery. Bank stabilization using natural channel design techniques can provide both bank stability and aquatic habitat potential. The primary recommended structures include natural or “natural-like” structures, such as large woody debris jams. These natural arrays can be constructed to emulate historical debris assemblages that were introduced to the channel by the adjacent cottonwood-dominated riparian community types. When used together, woody debris jams and straight log vanes can benefit the stream and fishery by improving bank stability, reducing bank erosion rates, adding protection to fillslopes and/or embankments, reducing near-bank shear stress, and enhancing aquatic habitat and lateral channel margin complexity.

Initiatives to protect riparian areas and floodplains will help protect property, increase channel stability, and buffer waterbodies from pollutants. However, in areas with a much smaller buffer or where historical vegetation removal and development have shifted the riparian vegetation community and limited its functionality, a tiered approach for restoring stream channels and adjacent riparian vegetation should be considered that prioritizes areas for restoration based on the existing condition and potential for improvement. In non-conifer dominated areas, the restoration goals should focus on restoring natural shrub cover on streambanks.

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. 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 (DEQ 2017).

9.5.4 Beaver Populations

Historic heavy trapping of beavers throughout Montana has likely had an effect on sediment yields in watersheds in the western areas of the state. Before the removal of beavers, many streams had a series of catchments that moderated flow, with smaller un-incised multiple channels and frequent flooding. Now some of these streams have incised channels and are no longer connected to the floodplain. This results in more bank erosion because high flows scour streambanks to a greater extent instead of flowing onto the floodplain. Beaver ponds capture and store sediment and can result in large reductions in total suspended solids (TSS) concentrations below a beaver impoundment in comparison to TSS concentrations above the beaver impoundment (Bason, 2004). Management of streams should include consideration of beaver habitat in appropriate areas currently lacking the beaver complexes that can trap sediment, reduce peak flows, and increase summer low flows. Allowing for existing and even increased beaver habitat is considered consistent with the sediment TMDL water quality goals.

9.5.5 Unpaved Roads

Unpaved roads contribute sediment (as well as nutrients and other pollutants) to streams in the Madison TMDL Planning Area. The road sediment reductions in this document represent a gross estimation of the sediment load that will remain once appropriate road BMPs are applied and maintained at all locations, assuming no current BMPs are in place. In general, a road with associated BMPs assumes contributing road treads, cutslopes, and fillslopes were reduced to 200 feet from each side of a crossing and 500 feet from each parallel road segment. This distance is selected as an example to illustrate the potential for sediment reduction through BMP application and is not a formal goal at every crossing. For example, many roads may easily allow for a smaller contributing length, while others may not be able to meet a 200-foot goal.

Achieving this reduction in sediment loading from roads may occur through a variety of methods at the discretion of local land managers and restoration specialists. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana's Nonpoint Source Management Plan (DEQ 217). Examples include:

- Providing adequate ditch relief up-grade of stream crossings
- Constructing waterbars, where appropriate, and up-grade of stream crossings
- Instead of cross pipes, using rolling dips on downhill grades with an embankment on one side to direct flow to the ditch. When installing rolling dips, ensure proper fillslope stability and sediment filtration between the road and nearby streams.
- Insloping roads along steep banks with the use of cross slopes and cross culverts
- Outsloping low traffic roads on gently sloping terrain with the use of a cross slope
- Using ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches
- For maintenance, grade materials to the center of the road and avoid removing the toe of the cutslope
- Preventing disturbance to vulnerable slopes
- Using topography to filter sediments; flat, vegetated areas are more effective sediment filters
- Where possible, limit road access during wet periods when drainage features could be damaged
- Limit new road stream crossings and the length of near-stream parallel segments to the extent practicable

9.5.5.1 Culverts and Fish Passage

Undersized and improperly installed and maintained culverts can be a substantial source of sediment to streams, and a barrier to fish and other aquatic organisms. There are many factors associated with culvert failure and it is difficult to estimate the true at-risk load. The allocation strategy for culverts is that, regardless of road use status, there should be no loading from culverts as a result of being undersized, improperly installed, or inadequately maintained. It is recommended that culverts be assessed so that a priority list may be developed for culvert replacement. As culverts fail, they should be replaced by culverts that pass a 100 year flood on fish-bearing streams and at least 25 year events on non-fish bearing streams. Some road crossings may not pose a feasible situation for upgrades to these sizes because of road bed configuration; in those circumstances, the largest size culvert feasible should be used. If funding is available, culverts should be prioritized and replaced prior to failure.

Another consideration for culvert upgrades should be fish and aquatic organism passage. Each culvert that is deemed a fish barrier should be assessed individually to determine if it functions as an invasive species and/or native species barrier. These two functions should be weighed against each other to determine if each culvert acting as a fish passage barrier should be mitigated. Montana Fish, Wildlife & Parks can aid in determining if a fish passage barrier should be mitigated, and, if so, can aid in culvert design.

9.5.5.2 Traction Sand

Severe winter weather and mountainous roads in the Madison TMDL Planning Area will require the continued use of relatively large quantities of traction sand. Nevertheless, closer evaluation of and adjustments to existing practices should be done to reduce traction sand loading to streams to the extent practicable. The necessary BMPs may vary throughout the watershed and particularly between state and private roads but may include the following:

- Use a snow blower to directionally place snow and traction sand on cut/fillslopes away from sensitive environments
- Increase the use of chemical deicers and decrease the use of road sand, as long as doing so does not create a safety hazard or cause undue degradation to vegetation and water quality
- Improve maintenance records to better estimate the use of road sand and chemicals, as well as to estimate the amount of sand recovered in sensitive areas
- Continue to fund Montana Department of Transportation research projects that will identify the best designs and procedures for minimizing road sand impacts to adjacent bodies of water and incorporate those findings into additional BMPs
- Street sweeping and sand reclamation
- Identify areas where the buffer could be improved, or structural control measures may be needed
- Improved maintenance of existing BMPs
- Increase availability of traction sand BMP training to both permanent and seasonal MDT employees, as well as private contractors

9.5.6 Forestry and Timber Harvest

Currently, active timber harvest is not significantly affecting sediment the Madison TMDL Planning Area and no load allocations were allocated directly to timber harvests. Timber harvesting will likely continue in the future within the Beaverhead-Deer Lodge National Forest, and on private land. Therefore, future timber 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, Montana Code Annotated). The Montana Forestry BMPs cover timber harvesting, site preparation, and road building including culvert design, 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 should be applied to numerous land management activities (e.g., timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana Department of Natural Resources and Conservation. 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.

In addition to the BMPs identified above, effects that timber harvest may have on yearly streamflow levels, such as peak flow, should be considered. Timber harvest plans should evaluate the potential for cumulative effects on water yield and peak flow increases and implement BMPs to reduce sediment and nutrients loading. Finally, noxious weed control should be actively pursued in all harvest areas.

9.6 Nonpoint Source Pollution Education

Because most nonpoint source pollution (NPS) is generated by individuals, a key factor in reducing NPS pollution is increasing public awareness through education. Local watershed groups can provide educational opportunities to both students and adults through water quality workshops and informational meetings. Continued education is key to an ongoing understanding of water quality issues in the Madison TMDL Planning Area, and to the support for implementation and restorative activities.

9.7 Potential Funding 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. Note that some programs or funding sources summarized below may be discontinued in the future, and new sources of funding could possibly become available. Be sure to inquire with these agencies and organizations for the most current information.

In addition to the information presented below, 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 (DEQ 2017) and information regarding additional funding opportunities can be found at https://www.epa.gov/nps/funding-resources-watershed-protection-and-restoration.

Section 319 Nonpoint Source Grant Program

DEQ issues a call for proposals every year to award federal 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. To receive funding, projects must directly implement a DEQ-accepted watershed restoration plan (**Section 9.2**) and funds may only be used for planning and implementing restoration projects. The recommended range for 319 funds per project proposal is $50,000 to $300,000. 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/Water/SurfaceWater/319Projects.

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 Madison 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/.

Renewable Resource Project Planning Grants

The DNRC administers watershed grants to pay for contracted costs associated with the development of a watershed assessment. Grant are available for a maximum of $75,000 per project. Eligible applicants include conservation districts and irrigation districts, among many others. For additional information about the program and how to apply, please visit: http://dnrc.mt.gov/grants-and-loans.

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/.

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 Madison River watershed, please visit: http://www.fws.gov/mountain-prairie/pfw/montana/.

Wetland Reserve Easements

The NRCS provides technical and financial assistance to private landowners and Indian tribes to restore, enhance, and protect wetlands through permanent easements, 30-year easements, or term easements. Land eligible for these easements includes farmed or converted wetland that can be successfully and cost-effectively restored. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/easements/acep/.

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/water/surfacewater/wetlands.

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.

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/.

10.0 Monitoring for Effectiveness

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

The monitoring strategy presented in this section provides a starting point for the development of more detailed planning efforts regarding monitoring needs; it does not assign monitoring responsibility. Monitoring recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet the water quality improvement goals outlined in this document. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on funding opportunities and stakeholder priorities for restoration. Once restoration measures have been implemented for a waterbody with an approved TMDL and given time to take effect, the Department of Environmental Quality (DEQ) will conduct a formal evaluation of the waterbody's impairment status and whether TMDL targets and water quality standards are being met. Based on this evaluation, DEQ will make recommendations on the next steps to take toward meeting water quality goals (**Section 10.2**).

The objectives for future monitoring in the Madison TMDL Planning Area include: 1) tracking and monitoring restoration activities and evaluating the effectiveness of individual and cumulative restoration activities, 2) baseline and impairment status monitoring to assess attainment of water quality targets and identify long-term trends in water quality, and 3) refining the source assessments. Each of these objectives is discussed below.

10.1 Adaptive Management and Uncertainty

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 for sediment and temperature, 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 as well as 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.

The analysis presented in this document assumes that the load reductions proposed for each of the listed streams will enable the streams to meet target conditions and that meeting target conditions will ensure full support of all beneficial uses (and attainment of water quality standards). Much of the monitoring proposed in this section of the document is intended to validate this assumption. If it looks like greater reductions in loading or improved performance is necessary to meet targets, then updated TMDL(s) and/or allocations will be developed based on achievable reductions via application of reasonable land, soil, and water conservations practices. Additionally, as new stressors are added to the watershed and additional data are collected, new water quality targets may need to be developed or existing targets/allocations may need to be modified.

10.2 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, watershed-scale monitoring may be valuable in determining if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in fine sediment deposition and channel substrate embeddedness, changes in channel cumulative width/depths, improvements in streambank 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 watershed, monitoring should be conducted prior to and after project implementation to help evaluate the effectiveness of specific practices or projects. Monitoring activities should be selected such that they directly investigate those subjects and pollutants that the project is intended to effect, and when possible, linked to targets and allocations in the TMDL.

For sediment, which has no numeric standard, and temperature, which was evaluated using a Qual2k water quality modeling approach, loading reductions and BMP effectiveness may be estimated using the approaches used within this document. However, tracking BMP implementation, maintenance, and project-related measurements will likely be most practical for sediment and temperature. For instance, for road improvements, it is not anticipated that post-project sediment loads will be measured. Instead, documentation of the BMP, reduced contributing length, and before and after photos documenting the presence and effectiveness of the BMP will be most appropriate. For installation of riparian fencing, photo point monitoring (before and after photo documentation) of riparian vegetation and streambank conditions, and a measurement such as “greenline” that documents the percentage of bare ground and shrub cover, may be most appropriate.

Evaluating instream parameters used for sediment targets will be one of the tools used to gauge the success of implementation when DEQ conducts a formal assessment, but may not be practical for most projects since the sediment effects within a stream represent cumulative effects from many watershed scale activities and because there is typically a lag time between project implementation and instream improvements (Meals et al., 2010). DEQ TMDL and nonpoint source staff can help local stakeholders determine the most practical and effective monitoring techniques.

If sufficient implementation progress is made within a watershed, DEQ will conduct a TMDL Implementation Evaluation. During this process, DEQ compiles recent data, conducts monitoring (if necessary), may compare data to water quality targets, summarizes BMP implementation that has occurred since TMDL development, and evaluates data to determine if the TMDL is being achieved or if conditions are trending one way or another. If conditions indicate the TMDL is being achieved, the waterbody will be recommended for reassessment and may be removed from the list of impaired waters if assessment results show that water quality standards are being met. If conditions indicate the TMDL is not being achieved, according to Montana State Law (75-5-703(9), MCA), the evaluation must determine if:

- The implementation of a new or improved phase of voluntary reasonable land, soil, and water conservation practices is necessary,
- Water quality is improving, but more time is needed for compliance with water quality standards, or
- Revisions to the TMDL are necessary to achieve applicable water quality standards.

10.3 Baseline and Impairment Status Monitoring

In addition to effectiveness monitoring, watershed scale monitoring should be conducted to expand knowledge of existing conditions and to provide data that can be used during the TMDL implementation evaluation. 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.

Although DEQ is the lead agency for conducting impairment status monitoring, other agencies or entities may collect and provide compatible data. Wherever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent with DEQ methodology to allow for comparison to TMDL targets and track progress toward meeting TMDL goals. The information in this section provides general guidance for future impairment status monitoring.

10.3.1 Sediment Monitoring and Data Collection Methodology

Each of the sediment streams of interest for this TMDL project was stratified into unique reaches based on physical characteristics and anthropogenic (human) influence. The sites assessed in the field represent only a percentage of the total number of stratified reaches. Sampling additional monitoring locations could provide additional data to assess existing conditions, and provide more specific information on a per stream basis as well as the TMDL planning area as a whole.

Sediment and habitat assessment protocols consistent with DEQ field methodologies, and that serve as the basis for sediment targets and assessment within this TMDL document, should be implemented whenever possible. Current protocols are identified within Standard Operating Procedure for Sediment Beneficial Use Assessment Monitoring: Wadeable Streams in Mountainous and Transitional Ecoregions (Makarowski, 2020). It is acknowledged that various agencies and entities have differing objectives, as well as time and resources available to achieve those objectives. However, when possible, it is recommended that at a minimum the following parameters be collected to allow for comparison to TMDL targets:

- Riffle Cross Section, using Rosgen methodology
- Riffle Pebble Count, using Wolman Pebble Count methodology
- Residual Pool Depth Measurements
- Greenline Assessment, using NRCS methodology

Prior to conducting this type of monitoring, DEQ TMDL and nonpoint source staff should also be contacted to discuss appropriate monitoring techniques and methods.

Additional monitoring information will undoubtedly be useful and assist DEQ with TMDL effectiveness monitoring and impairment status evaluations in the future. Examples of additional useful information may include total suspended solids; identifying percentage of eroding streambanks, human sediment sources, and areas with a high background sediment load; macroinvertebrate studies; McNeil core sediment samples; and fish population surveys and redd counts.

An important part of impairment determination and adaptive management is determining when a stream has fully recovered from past management practices, and where recovery is still occurring from historical improvements in management but recent BMPs were not applied. Particularly within the Beaverhead-Deerlodge National Forest, ongoing PIBO monitoring can provide critical insight into the extent of recovery from past practices via comparisons between reference and managed sites.

10.3.2 Temperature Monitoring and Data Collection Methodology

For temperature investigation in the Madison TMDL Planning Area, data loggers were deployed throughout Cherry, Elk, and Moore creeks and the West Fork Madison River, and shade sampling was distributed spatially along each waterbody to best delineate shade condition. If additional water temperature data 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 method.

10.4 Source Assessment Refinement

In the Madison TMDL Planning Area, the identification of sources was conducted largely through watershed field tours, aerial assessment, the incorporation of GIS information, available data and literature review, with limited field verification and on-the-ground analysis. In many cases, assumptions were made based on overall planning area conditions and extrapolated throughout the watershed. As a result, the level of detail often does not provide specific areas by which to focus restoration efforts, only broad source categories to reduce sediment loads from each of the discussed subwatersheds. Strategies for strengthening sediment and temperature source assessments are outlined below.

Sediment

- Field surveys of unpaved roads and road crossings to identify specific contributing road crossings, their associated loads, and prioritize those road segments/crossings of most concern

- Review of land use practices specific to subwatersheds of concern to determine where the greatest potential for improvement and likelihood of sediment reduction can occur for the identified major land use categories
- More thorough examinations of bank erosion conditions and investigation of related contributing factors for each subwatershed of concern through site visits and subwatershed scale bank assessments. Additionally, the development of bank erosion retreat rates specific to the Madison TMDL Planning Area would provide a more accurate quantification of sediment loading from bank erosion. Bank retreat rates can be determined by installing bank pins at different positions on the streambank at several transects across a range of landscapes and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions.

Temperature

- Assessment of irrigation network in Cherry, Elk Creek, and Moore Creeks, other streams in the watershed impacted by irrigation water use, to better understand irrigation efficiency and needs
- Temperature and flow monitoring in additional streams of the Madison TMDL Planning Area not covered by this TMDL
- Continued monitoring of flow and temperature with future changes in climate and water use
- Field surveys to better identify riparian area conditions and potential for improvement throughout the streams covered by this TMDL, as well as those not included
- Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use in the valley
- Assessment of water use in the Madison TMDL Planning Area and potential for improvements in water use that would result in increased instream flows
- Continued monitoring of arctic grayling and westslope cutthroat trout distributions in the Madison TMDL Planning Area in relation to temperature and flow
- Flow measurements at all temperature data locations at the time of data collection

10.5 Watershed Wide Analysis

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

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