Rock Creek Watershed Total Maximum Daily Loads and Water Quality Improvement Plans

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYM LIST

Acronym	**Definition**
AAL	Acute Aquatic Life
AFDW	Ash Free Dry Weight
AFO	Animal Feeding Operation
AMB	Abandoned Mine Bureau
AML	Abandoned Mine Lands
ANFO	Ammonium Nitrate and Fuel Oil
ARD	Acid Rock Drainage
ARM	Administrative Rules of Montana
AUM	Animal Unit Month
BDNF	Beaverhead Deerlodge National Forest
BEHI	Bank Erosion Hazard Index
BFW	Bankful Width
BLM	Bureau of Land Management (Federal)
BMP	Best Management Practices
CAFO	Concentrated (or Confined) Animal Feeding Operations
CAL	Chronic Aquatic Life
CALA	Controlled Allocation of Liability Act
CECRA	[Montana] Comprehensive Environmental Cleanup and Responsibility Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CNMP	Comprehensive Nutrient Management Plans
CTM	Critical Thermal Maximum
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
DO	Dissolved Oxygen
DQO	Data Quality Objectives
EFRC	East Fork Rock Creek
EPA	Environmental Protection Agency (U.S.)
EQIP	Environmental Quality Initiatives Program
FS	Forest Service
FWP	Fish, Wildlife & Parks (Montana)
FWS	Fish & Wildlife Service (US)
GIS	Geographic Information System
GWIC	Groundwater Information Center
HBI	Hilsenhoff's biotic index
HDPE	high-density polyethylene
HH	Human Health
ICIS	Integrated Compliance Information System
INFISH	Inland Native Fish Strategy
IR	Integrated Report
IRMH	Integrated Riparian Monitoring Hydrology Report
LA	Load Allocation

Acronym	Definition
LWD	Large Woody Debris
MARS	Montana Aquatic Resources Services
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MCL	Maximum Contaminant Level
MDL	Maximum Detection Limit
MDT	Montana Department of Transportation
MFISH	Montana Fisheries Information System
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSL	Mean Sea Level
MSU	Montana State University
NAIP	National Agricultural Imagery Program
NBS	Near Bank Stress
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	National Resources Conservation Service
NWIS	National Water Information System
OIT	Office of Information Technology (DEQ)
OSM	Office of Surface Mining Reclamation and Enforcement
PEL	Probable Effects Levels
PIBO	PACFISH/INFISH Biological Opinion
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RAWS	Remote Automatic Weather Station
RIT/RDG	Resource Indemnity Trust/Reclamation and Development Grants Program
RSI	Riffle Stability Index
SAP	Sampling and Analysis Plan
SC	Specific Conductivity
SFAC	South Fork Antelope Creek
SILC	Satellite Imagery land Cover (Montana)
SMCRA	Surface Mining Control & Reclamation Act
SMES	Small Miner's Exclusion Statement
SMZ	Streamside Management Zone
SS	Sediment Sources
SSURGO	Soil Survey Geographic database
STORET	EPA STOrage and RETrieval database
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TPN	Total Persulfate Nitrogen
TSS	Total Suspended Solids
UILT	Upper Incipient Lethal Temperature

Acronym	Definition
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
VCRA	Voluntary Cleanup and Redevelopment Act
VFS	Vegetated Filter Strips
WCW	Wetted Channel Width
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan

DOCUMENT SUMMARY

This document presents a total maximum daily load (TMDL) and water quality improvement plans for 11 impaired tributaries in the Rock Creek watershed including: Antelope Creek, Basin Gulch, East Fork Rock Creek, Eureka Gulch, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, Sluice Gulch, South Fork Antelope Creek, West Fork Rock Creek (**Map A-1** found in **Appendix A)**.

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.

Rock Creek flows northwards from the Anaconda Range to its confluence with the Clark Fork River, near Clinton. The TMDL planning area (TPA) is located in the Clark Fork River Basin of western Montana, as shown on **Map A-2 (Appendix A)**. The majority of the TPA is within Granite County, with a minor percentage (near the mouth of Rock Creek) in Missoula County. The TPA is bounded by the John Long Mountains to the east, the Anaconda Range to the south, and the Sapphire Range to the west. The total area is 569,320 acres, or approximately 890 square miles.

DEQ determined that 11 tributaries do not meet the applicable water quality standards. The scope of the TMDLs in this document addresses problems with sediment, temperature, nutrients, and metals (see **Table DS-1**). In total, 33 TMDLs were written, addressing 34 waterbody pollutant combinations.

Sediment
Sediment was identified as impairing aquatic life in Antelope Creek, East Fork Rock Creek, Eureka Gulch, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, Sluice Gulch, South Fork Antelope Creek, and West Fork Rock Creek. Sediment is affecting designated uses in these streams by altering aquatic insect communities, reducing fish spawning success, and increasing turbidity. Water quality restoration goals 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 goals are met, all water uses currently affected by sediment will be restored.

Sediment loads are quantified for the following sources: bank erosion, hillslope erosion, and unpaved roads. The most significant sources include: bank and hillslope erosion from current and historical rangeland grazing and hay production in the riparian (streamside) area. The Rock Creek TPA sediment TMDLs indicate that reductions in sediment loads ranging from 9% to 56% will satisfy the water quality restoration goals.

Recommended strategies for achieving the sediment reduction goals are also presented in this plan. They include best management practices (BMPs) for grazing, cropland and irrigation. 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 and wetland vegetation.

Temperature
DEQ identified temperature-related effects as a cause of impairment on East Fork Rock Creek. Anthropogenic sources for temperature include reductions in riparian shade from riparian grazing and crop production. Additionally, in summer months, the majority of water in the creek is diverted to provide irrigation water for users in the Flint Creek watershed, thereby reducing stream volumetric heat capacity; where less stream water heats more rapidly from the same energy inputs.

Recommended strategies for reducing temperature include applying best management practices to improve shade producing riparian vegetation by improving grazing practices and providing vegetated riparian buffers between irrigated fields and the stream. Additionally, improved irrigation delivery and application efficiency could lead to water savings and that conserved water or some percentage of that conserved water should be allowed to flow down East Fork Rock Creek past the diversion during summer months. Improved irrigation management can be achieved through best management practices including irrigation scheduling, delivery upgrades, and equipment modification.

Nutrients
A total of 6 waterbody segments in the Rock Creek TPA appeared on the 2012 Montana 303(d) List for nutrient (phosphorus and/or nitrogen) impairments. These impairments occur on the East Fork of Rock Creek, South Fork of Antelope Creek, Scotchman's Gulch, Sluice Gulch and Flat Gulch. An overabundance of these nutrients in aquatic ecosystems accelerates the process known as eutrophication. Eutrophication is the enrichment of a waterbody, usually by nitrogen and phosphorus, leading to increased aquatic plant production (including algae). The increased aquatic plant or algal growth can reach nuisance levels and harm multiple beneficial uses of the waterbody. Water quality restoration goals for nutrients were established on the basis of Montana's established criteria for water quality, which include the narrative water quality standards for nutrients. DEQ believes that once these water quality targets are met, all water uses currently affected by nutrients will be restored.

Nutrient loads are quantified for the following sources: Agricultural activities, historical mining practices, silvicultural practices and natural background. The most significant source is agricultural activities. The Rock Creek TPA nutrient TMDLs indicate that reductions in nutrient loads ranging from 0% to 94% will satisfy the water quality restoration goals.

Recommended strategies for achieving the nutrient reduction goals are also presented in this plan. The goal of the nutrient restoration strategy is to reduce nutrient input to stream channels by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, and limiting the transport of nutrients from rangeland, cropland, and historically impacted areas.

Metals
A total of 7 waterbody segments in the Rock Creek TPA have been identified as being impaired for metals pollution. Eureka Gulch, Quartz Gulch, Sluice Gulch, and West Fork Rock Creek were included on the 2012 Montana 303(d) List of metal-impaired waters. Basin Gulch, Flat Gulch, and Scotchman Gulch were not; however, these three streams are considered impaired as a result of review of recent water quality data that indicates beneficial uses for these streams are impaired by elevated metals concentrations. Waterbodies with metals concentrations exceeding the aquatic life and/or human health standards are impairing several beneficial uses of surface water including aquatic life support, drinking water, and agriculture. Water quality restoration goals for metals were established on the basis of Montana's established criteria for water quality, which include the aquatic life and human health

standards. DEQ believes that once these water quality targets are met, all water uses currently affected by metals will be restored.

Metals loads are quantified for historical mining operations and naturally occurring metals sources. The most significant source is historical mining operations. The Rock Creek TPA metals TMDLs indicate that reductions in metals loads ranging from 0% to 99% will satisfy the water quality restoration goals.

Recommended strategies for achieving the metals reduction goals are also presented in this plan. Generally restoration programs and funding mechanisms are more applicable to metals sources instead of specific BMPs. A number of state and federal regulatory programs have been developed to address water quality problems stemming from historical mines and associated disturbances. These include the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the State of Montana Abandoned Mine Lands (AML) Reclamation Program, the Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA), which incorporates additional cleanup options under the Controlled Allocation of Liability Act (CALA) and the Voluntary Cleanup and Redevelopment Act (VCRA).

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

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

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Rock Creek TPA with Completed Sediment, Temperature, Nutrients and Metals TMDLs Contained in this Document

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
ANTELOPE CREEK, headwaters to mouth (Rock Creek)	Sediment	Sediment	Aquatic Life
BASIN GULCH, headwaters to mouth (Eureka Gulch)	Arsenic	Metals	Drinking Water
EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)	Sediment	Sediment	Aquatic Life
	Temperature	Temperature	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen	Nutrients	Aquatic Life and Primary Contact Recreation
EUREKA GULCH, confluence of Quartz Gulch and Basin Gulch to mouth (Un-Named Ditch)	Sediment*	Sediment	Aquatic Life
	Arsenic	Metals	Drinking Water
	Mercury		Drinking Water

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Rock Creek TPA with Completed Sediment, Temperature, Nutrients and Metals TMDLs Contained in this Document

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
FLAT GULCH, headwaters to mouth (Rock Creek)	Sediment	Sediment	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen		Aquatic Life and Primary Contact Recreation
	Aluminum	Metals	Aquatic Life
	Iron		Aquatic Life
MINERS GULCH, headwaters to mouth (Upper Willow Creek), T8N R15W S23	Sediment	Sediment	Aquatic Life
QUARTZ GULCH, headwaters to mouth (Eureka Gulch)	Sediment	Sediment	Aquatic Life
	Aluminum	Metals	Aquatic Life
	Lead		Drinking Water
SCOTCHMAN GULCH, headwaters to mouth (Upper Willow Creek)	Sediment	Sediment	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen		Aquatic Life and Primary Contact Recreation
	Aluminum	Metals	Aquatic Life
SLUICE GULCH, headwaters to mouth (Rock Creek)	Sediment	Sediment	Aquatic Life
	Total Nitrogen	Nutrients	Aquatic Life and Primary Contact Recreation
	Nitrate + Nitrite		Aquatic Life and Primary Contact Recreation
	Arsenic	Metals	Drinking Water
	Copper		Aquatic Life
SOUTH FORK ANTELOPE CREEK, headwaters to mouth (Antelope Creek), T6N R15W S22	Sediment	Sediment	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen	Nutrients	Aquatic Life and Primary Contact Recreation
	Nitrate + Nitrite	Nutrients	Aquatic Life and Primary Contact Recreation
WEST FORK ROCK CREEK, headwaters to mouth (Rock Creek)	Sediment	Sediment	Aquatic Life
	Aluminum	Metals	Aquatic Life

*This sediment TMDL addresses two impairment causes

1.0 INTRODUCTION

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for sediment, temperature, nutrients, and metals problems in the Rock Creek Watershed (also referred to throughout this document as the Rock Creek TMDL Planning Area). This document also presents a general outline for resolving these problems. **Map A-1**, found in **Appendix A,** shows a map of waterbodies in the Rock Creek TMDL Planning Area (TPA) with sediment, temperature, nutrients, and metals pollutant listings.

1.1 BACKGROUND

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

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

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

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

Montana's biennial IR identifies all the state's impaired waterbody segments. The 303(d) list portion of the IR includes all of those waterbody segments impaired by a pollutant, which require a TMDL, whereas TMDLs are not required for non-pollutant causes of impairments. **Table 1-1** in **Section 1.2** identifies all impaired waters for the Rock Creek TPA from Montana's 2012 303(d) List, includes non-pollutant impairment causes included in Montana's "2012 Water Quality Integrated Report," and identifies new impairment causes that will be included in the Montana "2014 Water Quality Integrated Report." **Table 1-1** provides the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

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

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

- Determining measurable target values to help evaluate the waterbody's condition in relation to the applicable water quality standards
- Quantifying the magnitude of pollutant contribution from their sources
- Determining the TMDL for each pollutant based on the allowable loading limits for each waterbody-pollutant combination
- Allocating the total allowable load (TMDL) into individual loads for each source

In Montana, restoration strategies and monitoring recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation.

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

1.2 Water Quality Impairments and TMDLs Addressed by this Document

Table 1-1 below lists all of the impairment causes from the "2012 Water Quality Integrated Report" that are addressed in this document (also see **Map A-1** in **Appendix A**). Each pollutant impairment falls within a TMDL pollutant category (e.g., sediment, temperature, nutrients, or metals), and this document is organized by those categories.

New data assessed during this project identified new sediment, total phosphorus, total nitrogen, arsenic, aluminum, iron, lead, and copper impairment causes. These impairment causes are also identified in **Table 1-1** and noted as not being on the 2012 303(d) List (within the integrated report). Instead, these waters will be documented within DEQ assessment files and incorporated into the 2014 IR.

TMDLs are completed for each waterbody – pollutant combination, and this document contains 35 TMDLs (**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 9**. **Sections 9** and **10** also provide 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 Rock Creek TPA

Waterbody & Location Description*	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status	Included in 2012 Integrated Report**
ANTELOPE CREEK, headwaters to mouth (Rock Creek)	MT76E002_061	Sedimentation/Siltation	Sediment	Sediment TMDL completed	No
BASIN GULCH, headwaters to mouth (Eureka Gulch)	MT76E002_080	Arsenic	Metals	Arsenic TMDL completed	No
		Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed within document (see **Sections 9** and **10**); not linked to a TMDL	Yes
BREWSTER CREEK, East Fork to mouth (Rock Creek)	MT76E002_050	Sedimentation/Siltation	Sediment	Not impaired based on updated assessment	Yes
		Total Phosphorous	Nutrients	Not impaired based on updated assessment	Yes
		Fish Passage Barrier	Not Applicable; Non-Pollutant	Addressed within document (see **Sections 9** and **10**); not linked to a TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed within document (see **Sections 9** and **10**); not linked to a TMDL	Yes
EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)	MT76E002_020	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Temperature, water	Temperature	Temperature TMDL completed	Yes
		Total Phosphorous (TP)	Nutrients	TP TMDL completed	No
		Total Nitrogen (TN)	Nutrients	TN TMDL completed	No
		Nitrogen, Nitrate (Equivalent to Nitrate + Nitrite)	Nutrients	Impairment cause replaced with TN	Yes
		Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed by sediment TMDL	Yes
		Chlorophyll-*a*	Not Applicable; Non-Pollutant	Addressed by TP	Yes

Table 1-1. Water Quality Impairment Causes for the Rock Creek TPA

Waterbody & Location Description*	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status	Included in 2012 Integrated Report**
EUREKA GULCH, confluence of Quartz Gulch and Basin Gulch to mouth (Un-Named Ditch)	MT76E002_090	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Solids		Addressed by sediment TMDL	Yes
		Arsenic	Metals	Arsenic TMDL completed	Yes
		Mercury		Mercury TMDL completed	Yes
		Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL	Yes
FLAT GULCH, headwaters to mouth (Rock Creek)	MT76E002_120	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Total Phosphorous	Nutrients	TP TMDL completed	Yes
		Total Nitrogen		TN TMDL completed	Yes
		Aluminum	Metals	Aluminum TMDL completed	No
		Iron		Iron TMDL completed	No
MINERS GULCH, headwaters to mouth (Upper Willow Creek), T8N R15W S23	MT76E002_160	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
QUARTZ GULCH, headwaters to mouth (Eureka Gulch)	MT76E002_070	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Aluminum	Metals	Aluminum TMDL completed	No
		Lead		Lead TMDL completed	No
		Mercury	Metals	Not impaired based on updated assessment	Yes
		Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL	Yes
SCOTCHMAN GULCH, headwaters to mouth (Upper Willow Creek)	MT76E002_100	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Total Phosphorous	Nutrients	TP TMDL completed	Yes
		Total Nitrogen		TN TMDL completed	No
		Aluminum	Metals	Aluminum TMDL completed	No

Table 1-1. Water Quality Impairment Causes for the Rock Creek TPA

Waterbody & Location Description*	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status	Included in 2012 Integrated Report**
SLUICE GULCH, headwaters to mouth (Rock Creek)	MT76E002_110	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Total Nitrogen	Nutrients	TN TMDL completed	No
		Nitrate + Nitrite		Nitrate + Nitrite TMDL completed	Yes
		Arsenic		Arsenic TMDL completed	Yes
		Copper		Copper TMDL completed	No
		Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL	Yes
SOUTH FORK ANTELOPE CREEK, headwaters to mouth (Antelope Creek), T6N R15W S22	MT76E002_060	Sedimentation/Siltation	Sediment	Sediment TMDL completed	Yes
		Temperature, water	Temperature	Not impaired based on updated assessment	Yes
		Total Phosphorous	Nutrients	TP TMDL completed	Yes
		Total Nitrogen	Nutrients	TN TMDL completed	No
		Nitrate + Nitrite	Nutrients	Nitrate + Nitrite TMDL completed	Yes
		Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by sediment TMDL	Yes
UPPER WILLOW CREEK, headwaters to mouth (Rock Creek)	MT76E002_040	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed within document (see **Sections 9** and **10**); not linked to a TMDL	Yes
		Low Flow Alterations	Not Applicable; Non-Pollutant	Addressed within document (see **Sections 9** and **10**); not linked to a TMDL	Yes
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed within document (see **Sections 9** and **10**); not linked to a TMDL	Yes
WEST FORK ROCK CREEK, headwaters to mouth (Rock Creek)	MT76E002_030	Sedimentation/Siltation	Sediment	Sediment TMDL completed	No
		Mercury	Metals	Not impaired based on updated assessment	Yes
		Aluminum	Metals	Aluminum TMDL completed	No

*All waterbody segments within Montana's Water Quality Integrated Report are indexed to the National Hydrography Dataset (NHD)
**Impairment causes not in the "2012 Water Quality Integrated Report" were recently identified and will be included in the 2014 Integrated Report.

1.3 Document Layout

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

Section 2.0 Rock Creek Watershed 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 Rock Creek watershed.

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

Sections 5.0 – 8.0 Sediment, Temperature, Nutrients, and Metals TMDL Components:
Each section includes (a) a discussion of the affected waterbodies and the pollutant's effect on designated beneficial uses, (b) the information sources and assessment methods used to evaluate stream health and pollutant source contributions, (c) water quality targets and existing water quality conditions, (d) the quantified pollutant loading from the identified sources, (e) the determined TMDL for each waterbody, (f) the allocations of the allowable pollutant load to the identified sources.

Section 9.0 Other Identified Issues or Concerns:
Describes other problems that could potentially be contributing to water quality impairment and how the TMDLs in the plan might address some of these concerns. This section also provides recommendations for combating these problems.

Section 10.0 Restoration Objectives and Implementation Plan:
Discusses water quality restoration objectives and presents a framework for implementing a strategy to meet the identified objectives and TMDLs.

Section 11.0 Monitoring for Effectiveness:
Describes a water quality monitoring plan for evaluating the long-term effectiveness of the "Rock Creek Watershed Total Maximum Daily Loads and Framework Water Quality Protection Plan."

Section 12.0 Public Participation & Public Comments:
Describes other agencies and stakeholder groups who were involved with the development of the plan and the public participation process used to review the draft document. Addresses comments received during the public review period.

2.0 ROCK CREEK WATERSHED DESCRIPTION

This watershed description provides a general overview of the physical and social characteristics of the Rock Creek watershed. Although certain information is not current up to 2013, 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 Rock Creek watershed.

2.1.1 Location

Rock Creek flows northwards from the Anaconda Range to its confluence with the Clark Fork River, near Clinton. The TPA is located in the Clark Fork River Basin of western Montana, as shown on **Map A-2 (Appendix A)**. The majority of the TPA is within Granite County, with a minor percentage (near the mouth of Rock Creek) in Missoula County. The TPA is bounded by the John Long Mountains to the east, the Anaconda Range to the south, and the Sapphire Range to the west. The total area is 569,320 acres, or approximately 890 square miles.

The TPA is located on the border between the Middle Rockies and the Idaho Batholith Level III Ecoregions. Five Level IV Ecoregions are mapped within the TPA (Woods et al., 2002). These include: Flint Creek – Anaconda Mountains (17am), Alpine (17h), Deer Lodge – Philipsburg – Avon Grassy Intermontane Hills and Valleys (17ak), Rattlesnake – Blackfoot – South Swan – Northern Garnet – Sapphire Mountains (17x) and Eastern Batholith (16a). Level IV Ecoregions are illustrated on **Map A-3 (Appendix A)**.

2.1.2 Topography

Elevations in the TPA range from 1,073 to 3,190 meters (3,520 - 10,463 feet) above mean sea level (**Map A-4, Appendix A**). The highest point in the watershed is Warren Peak, at 10,463 feet. The lowest point is the confluence of Rock Creek and the Clark Fork River.

The topography is characterized by alpine terrain to the south, and lower elevation mountains along the axis of Rock Creek. These exhibit rounded peaks and ridges with steep valley slopes.

2.1.3 Climate

As there are no climate stations within the TPA, the climate summary is based on the station at Philipsburg. Climate in the area is typical of mid-elevation intermontane valleys in western Montana. Summer highs exceed 90° and winter lows are commonly less than 0°. Precipitation is most abundant in May and June. Philipsburg receives an annual average of 14.8 inches. The mountains may exceed 40 inches average annual moisture (Voeller and Waren, 1997). See **Table 2-1** for climate summaries; **Map A-5 (Appendix A)** shows the distribution of average annual precipitation.

2.1.3.1 Climate Stations

There are no climate stations identified within the TPA. Two are located on divides bordering the TPA: one SNOTEL station (Skalkaho Summit) and one Bureau of Land Management (BLM) remote automatic weather station (RAWS) (Climate Station Welch-Gillispie). RAWS stations are primarily used to assess conditions related to fire hazard, and provide telemetry to the National Interagency Fire Center in Boise, Idaho. Climate data for the TPA is based upon the stations at Philipsburg (although it is located outside the TPA) and Clinton. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) operates four SNOTEL snowpack monitoring stations near the TPA margin: Daly Creek, Black Pine, Combination and Peterson Meadows.

Precipitation data is mapped by Oregon State University's PRISM Group, based on the records from National Oceanic and Atmospheric Administration (NOAA) stations (PRISM Group, 2004). Climate data is provided by the Western Regional Climate Center, operated by the Desert Research Institute of Reno, Nevada. **Map A-5 (Appendix A)** shows the locations of the NOAA and SNOTEL stations, in addition to average annual precipitation.

Table 2-1. Monthly Climate Summaries

Philipsburg, Montana (246470) Period of Record : 9/16/1903 to 10/12/1955													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Ave. Max. Temp (F)	30.8	35.2	42.2	53.7	61.6	69.3	80.5	79.2	68.7	57.4	43.5	33.9	54.7
Ave. Min. Temp. (F)	11.7	14.6	19.8	27.0	33.3	39.1	43.8	41.9	35.5	28.9	21.5	15.5	27.7
Ave Tot. Precip. (in.)	0.81	0.78	1.03	1.30	2.15	2.82	1.34	1.03	1.40	1.00	0.81	0.68	15.17
Ave. Snowfall (in.)	9.7	9.6	11.4	8.8	5.9	1.5	0.0	0.2	1.2	4.0	8.0	8.2	68.6
Ave Snow Depth (in.)	3	3	1	0	0	0	0	0	0	0	1	2	1
Philipsburg Ranger Station, Montana (246472) Period of Record : 10/13/1955 to 9/30/2010													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Ave. Max. Temp (F)	33.1	37.5	44.2	53.2	62.2	70.5	80.2	79.7	69.7	57.9	42.0	33.9	55.3
Ave. Min. Temp. (F)	13.4	16.0	20.4	26.3	33.0	39.6	42.6	41.3	34.4	28.0	20.4	14.5	27.5
Ave Tot. Precip. (in.)	0.64	0.47	0.84	1.37	2.26	2.46	1.24	1.51	1.33	1.07	0.73	0.64	14.55
Ave. Snowfall (in.)	8.9	5.1	7.3	4.3	1.3	0.0	0.0	0.0	0.2	1.3	4.8	5.6	38.9
Ave Snow Depth (in.)	3	3	1	0	0	0	0	0	0	0	1	2	1
Clinton 6 SE, Montana (241831) Period of Record : 10/1/2002 to 8/31/2008													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Ave. Max. Temp (F)	30.0	36.4	46.5	55.1	63.8	72.8	87.8	83.1	70.3	56.1	37.1	29.7	55.7
Ave. Min. Temp. (F)	13.3	17.1	23.7	28.3	35.7	42.2	47.7	44.8	37.3	29.9	19.6	14.8	29.5
Ave Tot. Precip. (in.)	1.25	1.11	1.73	1.82	2.62	2.22	0.54	1.36	1.97	1.47	1.78	1.09	18.97
Ave. Snowfall (in.)	13.0	12.5	15.3	4.1	0.8	0.3	0.0	0.0	0.1	1.3	12.7	10.2	70.3
Ave Snow Depth (in.)	8	9	7	1	0	0	0	0	0	0	2	5	3

2.1.4 Surface Water

Rock Creek drains from the Anaconda Range to the Clark Fork River near Clinton, a linear distance of approximately 55 miles. Rock Creek hydrography is illustrated on **Map A-6 (Appendix A)**. The United States Geological Survey (USGS) National Hydrography Dataset (NHD) maps 184.5 miles of streams in the TPA (at a medium resolution scale of 1:100,000).

Rock Creek has five significant tributaries: the East, Middle, Ross and West Forks of Rock Creek, and Upper Willow Creek. The drainage pattern is largely controlled by structure and lithology of the underlying bedrock

Forty-five lakes are present in the TPA (using the NHD 1:100,000), covering 810 acres. Of these, only 28 are named. The largest is East Fork Rock Creek Reservoir (described below). The other named lakes are generally tarns present in the higher portions of the Anaconda range.

2.1.4.1 Impoundments

The East Fork Rock Creek Reservoir (16,000 acre-feet) stores water for agricultural use within the east-adjacent Flint Creek watershed. Water from this reservoir is diverted via the Flint Creek Main Canal, built in 1938. This canal drains to Trout Creek, a tributary of Flint Creek (Voeller and Waren, 1997).

2.1.4.2 Stream Gaging Stations

The United States Geological Survey (USGS) maintains 2 gauging stations within the watershed. The USGS gauging stations are shown on **Map A-6 (Appendix A)**.

Table 2-2. Stream Gages

Name	Number	Drainage Area	Agency	Period of Record
Rock Creek near Clinton	12334510	885 $miles^2$	USGS	1972-
Middle Fork Rock Cr nr Philipsburg MT	12332000	123 $miles^2$	USGS	1937-

2.1.4.3 Streamflow

Streamflow data is based on records from the USGS stream gages described above, and is available on the Internet from the USGS (United States Department of Interior, Geological Survey, 2011). Flows in Rock Creek and its tributaries vary considerably over a calendar year, and from one year to another.

The earliest recorded peak annual discharge in Rock Creek occurred on May 1 (1987), and the latest was June 26 (1998). Peak annual discharge in Rock Creek has ranged from 6,500 cubic feet per second (cfs; June 1, 1972) to 922 cfs (May 25, 1977). All annual peak discharges measured in the Rock Creek have occurred in May or June.

2.1.4.4 Surface Water Quality

Water quality and chemistry data is available from the Rock Creek near Clinton gauging station (12334510). Parameters include: pH, specific conductance, temperature, hardness as CaCO3; filtered and total recoverable inorganics: Ca, Mg, As, Cd, Cu, Fe, Pb, Mn, Zn; and suspended sediment.

2.1.5 Groundwater

2.1.5.1 Hydrogeology

Groundwater flow within the valleys of the Rock Creek TPA is presumed to be typical of intermontane basins. Groundwater flows towards the center of the basin from the head and sides, and then down valley along the central axis.

The average groundwater flow velocity in bedrock is probably several orders of magnitude lower than in the valley fill sediments. However, carbonate and siliciclastic sedimentary rocks in the mountains may have zones of significant permeability. The hydrologic role of the structural geology (faults and folds) is uncertain. Faults may act as flow conduits or flow barriers. No studies of the bedrock hydrogeology were identified.

Natural recharge occurs from infiltration of precipitation, stream loss and flow out of the adjacent bedrock aquifers. Flood irrigation also contributes to aquifer recharge.

2.1.5.2 Groundwater Quality

The Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC) program monitors and samples a statewide network of wells (Montana Bureau of Mines and Geology, 2008). Additionally, the GWIC program is engaged in a statewide characterization of aquifers and groundwater resources, by region. The TPA is in Region 5, the Upper Clark Fork River basin.

As of July 2008, the GWIC database reports 366 wells within the TPA (Montana Bureau of Mines and Geology, 2013). Water quality data are available for 14 of those wells. The locations of these data points are shown on **Map A-7 (Appendix A)**.

The water quality data include general physical parameters: temperature, pH and specific conductance, in addition to inorganic chemistry (common ions, metals and trace elements). MBMG does not analyze groundwater samples for organic compounds. Groundwater quality data are available from the GWIC database.

A review of GWIC data reports for agricultural chemical monitoring programs did not yield any data points for Granite County.

There are 3 public water supplies within the TPA. These are small transient, non-community systems (i.e. that serve a dynamic population of more than 25 persons daily) using groundwater for their supplies. These systems are all located near the mouth of Rock Creek. Water quality data is available from these utilities via the State Safe Drinking Water Information System database, although the data reflect the finished water provided to users, not raw water at the source.

2.1.6 Geology

Map A-8 (Appendix A) provides an overview of the geology, based on the most recent geologic map of the Butte and Dillon 1° x 2° quadrangles (Lewis, 1998; Ruppel et al., 1993). The geology of the Rock Creek area is complex, and has been considerably reinterpreted in recent years. Much of the debate and complexity is beyond the scope of this characterization.

In general, much of the TPA is underlain by a structural unit informally called the Sapphire Block (although no longer considered an intact body), which extends west to the Bitterroot detachment fault in the Bitterroot Valley (Lonn et al., 2003a). The 'Sapphire Block' may be considered a slab of Precambrian Belt Series rocks located between the Bitterroot and Flint Creek Valleys.

2.1.6.1 Bedrock

The 'Sapphire Block' includes the Sapphire Mountains and the John Long Mountains. Both ranges are composed of Middle Proterozoic (~1.5 billion years old) Belt Supergroup rocks. These rocks are interpreted as passive margin deposits, and the dominant lithologies are siltstone, sandstone and limestone (and their metamorphic equivalents). The total stratigraphic thickness of Belt Series rocks in this area exceeds 20,000 feet (Lonn et al., 2003b). These rocks are less resistant than the granitic rocks in surrounding mountain ranges, giving the Sapphire and John Long ranges their subdued topography and lower elevations (relative to the Anaconda or Flint Creek ranges).

Younger (Paleozoic) sedimentary rocks are limited in the TPA, found only along the northern margin of the Anaconda range. Mesozoic sedimentary rocks are not mapped in the TPA.

This package of sedimentary rocks has been intruded by several generations of Cretaceous and Tertiary igneous rocks. Metamorphism and hydrothermal activity associated with these rocks produced economically significant ores. Volcanic rocks of Tertiary age are also present, including the Rock Creek volcanic field, a rhyolitic flow that is the source of the eponymous sapphires. Pleistocene glaciation sculpted the Anaconda range, producing the rugged alpine geomorphology.

2.1.6.2 Basin Sediments

Unlike many valleys in western Montana that occupy fault-bounded basins between uplifted mountains, the Rock Creek Valley is located on the 'Sapphire Block.' Consequently, the valley is underlain by relatively shallow, continuous bedrock. This is responsible for the smaller size of the valley bottom in the TPA relative to surrounding watersheds.

Tertiary sediments are found mostly in the Upper Willow Creek drainage, and in the upper half of the TPA. These sediments are found on terraces and at higher elevations than the modern alluvium. The Tertiary sediments are not well described in available maps, but include a wide range of clast sizes, from clay to gravel, and are presumably similar in character to Tertiary sediments described in the Flint Creek and Bitterroot Valleys.

2.1.6.3 Glacial History

The glacial history of the watershed is presumably similar to that of the rest of the Central and Northern Rockies, although no detailed studies were identified. While evidence of earlier glaciations (before 150,000 years ago) is not well-preserved, there is widespread evidence for two recent episodes of significant glacial activity. The earlier (Bull Lake) is generally dated to ~130,000 years ago, and the later (Pinedale) to 23,000 – 16,000 years ago (Chadwick et al., 1997; Pierce et al., 1976). The dates are general; alpine glacial activity varied somewhat according to elevation and other local variables. Each period of glaciation included multiple advances and retreats.

Glacial deposits are widespread in the southern portion of the TPA, along the northern flank of the Anaconda Range (Lonn et al., 2003b). The nature of the sedimentary deposits varies according to the depositional environment. Areas underlain by till tend to be swampy and poorly drained due to the low permeability of these deposits. Springs are common. In contrast, kame deposits (stream sediments deposited by streams flowing on or adjacent to glaciers) tend to be well-drained due to the well-sorted and larger grained sediments.

2.1.7 Soils

The USGS Water Resources Division (Schwarz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the USDA Natural Resources Conservation Service (NRCS) STATSGO soil database. The STATSGO data is 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 Soil Survey Geographic database (SSURGO) data. The soil attributes considered in this characterization are erodibility and slope.

2.1.7.1 Erodibility

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 on **Map A-9 (Appendix A)**, 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. No values greater than 0.4 are mapped in the TPA.

Low susceptibility soils comprise 39% of the TPA; moderate susceptibility soils comprise 53% of the TPA, and the remaining 8% is mapped with moderate-high susceptibility soils. No high susceptibility soils are mapped in the TPA.

Low susceptibility soils are associated with the Sapphire batholith and other granitic plutons, as well as the higher-elevation areas of the Anaconda and Sapphire Ranges. Moderate-high susceptibility soils also show a preferred distribution, and are strongly associated with Tertiary sediments.

2.1.7.2 Slope
Below the confluence with Upper Willow Creek, the Rock Creek watershed is considerably steeper, with slopes of greater than 30° common. Above Upper Willow Creek, the TPA exhibits broader valleys, with steep slopes on the flank of the Anaconda Range. A map of soil slope is provided on **Map A-10 (Appendix A)**.

2.2 Ecological Parameters

2.2.1 Vegetation
The primary cover in the uplands is conifer forest. Conifers are dominated by Lodgepole pine, giving way to Douglas fir at lower elevations, and to subalpine fir and spruce at higher elevations. The valleys are characterized by grassland and irrigated agricultural land, with minor shrublands. Landcover is shown on **Maps A-11 and A-12 (Appendix A)**. Data sources include the University of Montana's Satellite Imagery land Cover (SILC) project (University of Montana, 2002), and USGS National Land Cover Dataset (NLCD) mapping (United States Geological Survey, 2011).

2.2.2 Aquatic Life
Native fish species present in the TPA include: bull trout, westslope cutthroat trout, mountain whitefish, longnose dace, redside shiner, slimy scuplin, northern pike minnow, largescale sucker and longnose sucker. Bull trout and westslope cutthroat trout are designated "Species of Concern" by Montana Department of Fish, Wildlife and Parks (FWP). Bull trout are further listed as "threatened" by the US Fish and Wildlife Service (US FWS). Seventy-five miles of Rock Creek and its tributaries (**Map A-13, Appendix A)** have been designated critical habitat for bull trout (50 CFR Part 17, 2005).

Introduced species are also present, including: brook, rainbow and brown trout.

Data on fish species distribution are collected, maintained and provided by FWP (Montana Department of Fish, Wildlife and Parks,2006). Fish species distribution is shown on **Map A-13 (Appendix A)**.

2.2.3 Fires
The TPA has experienced several significant burns in the last 13 years. Nearly 66,450 acres burned in 2007, and over 24,000 acres burned in 2000. Overall, a total of 113,728 acres are mapped burned; according to the most recent fire data provided by United States Forest Service (USFS) Region 1 (includes fire history from 1835 to 2009). Burned areas are shown on **Map A-14 (Appendix A)**.

2.3 SOCIAL PROFILE

The following information describes the social profile of the Rock Creek watershed.

2.3.1 Population

There are no large population centers in the TPA. An estimated 552 persons lived within the TPA in 2010. Population estimates are derived from census data (United States Census Bureau, 2010) and based on spatial analysis of census blocks. Census data are shown on **Map A-15 (Appendix A)**.

2.3.2 Transportation

The principal transportation route in the TPA is Montana Highway 38. Highway 38 connects Philipsburg to Hamilton, via Skalkaho Pass. Granite County Road 102 runs from Highway 38 to Clinton, along Rock Creek. The network of unpaved roads on public and private lands will be further characterized as part of the source assessment. No active or abandoned railways are present in the TPA.

2.3.3 Land Ownership

Over 80% of the TPA is administered by the USFS (**Table 2-3**). Private landowners own 16% of the TPA. Plum Creek Timber Company lands are limited to 2,667 acres at the northeastern edge of the TPA. The remainder is State of Montana or US Bureau of Land Management (BLM) land (**Map A-16, Appendix A**).

Table 2-3. Land Ownership

Owner	Acres	Square Miles	% of Total
US Forest Service	459,204	717.5	80.7%
Private	91,722	143.3	16.1%
US Bureau of Land Management	10,867	17.0	1.9%
State Trust Land	6,815	10.6	1.2%
Total*	569,320	890	—

*includes water and right-of-way acreage

2.3.4 Land Use

Land use within the TPA is dominated by forest and agriculture (**Table 2-4**). Agriculture in the valley is primarily related to the cattle industry: irrigated hay and dry grazing. Information on land use is based on mapping completed by the USGS in the 1980s and on county assessments (Montana Department of Natural Resources and Conservation, 2008b). The USGS data is at 1:250,000 scale. Agricultural land use is illustrated on **Map A-17 (Appendix A)**. Potential sources of human impacts (abandoned mines, livestock feeding areas, and Montana Pollution Discharge Elimination System (MPDES)-permitted discharge sites) are illustrated on **Map A-18 (Appendix A)**.

Table 2-4. Land Use & Land Cover

Land Use	Acres	Square Miles	% of Total
Evergreen Forest	430,988	673.4	75.71%
Grasslands/Herbaceous	88,819	138.8	15.60%
Shrubland	41,005	64.1	7.20%
Pasture/Hay	2,262	3.54	0.40%
Woody Wetlands	1,880	2.94	0.33%
Transitional	1,167	1.82	0.21%
Open Water	901	1.41	0.16%
Deciduous Forest	867	1.36	0.15%

Table 2-4. Land Use & Land Cover

Land Use	Acres	Square Miles	% of Total
Bare Rock/Sand/Clay	760	1.19	0.13%
Emergent Herbaceous Wetlands	426	0.666	0.07%
Commercial/Industrial/Transportation	95.7	0.150	0.02%
Perennial Ice/Snow	55.0	0.086	0.010%
Row Crops	23.1	0.036	0.004%
Small Grains	20.6	0.032	0.004%
Mixed Forest	18.0	0.028	0.003%
Urban/Recreational Grasses	0.2	0.000	0.000%

Information on agricultural land use can be obtained from Department of Revenue data. The Department of Revenue assigns an agricultural use only if more than 50% of a given parcel is so used. Nearly 3,000 acres of irrigated land are reported in the TPA. Irrigation infrastructure includes interbasin diversions and impoundments as described above in **Section 2.5**. Berkas et al. (2005) report that diversions from Rock Creek irrigate nearly 16,100 acres, but this number presumably includes land in the Flint Creek watershed that is irrigated via interbasin diversion from the East Fork Rock Creek Reservoir.

2.3.5 Mining

The Rock Creek TPA includes portions of 7 mining districts: Rock Creek, Moose Lake, Frog Pond Basin, Alps, Antelope Creek, Welcome Creek and Woodman. The TPA was the scene of considerable mining activity. Like many other mining districts, metal production began with gold placers. Lode mines were developed later, but never became as productive as the mines in the nearby Philipsburg and Combination districts. However, the Rock Creek district was (and remains) a major producer of sapphires.

MBMG completed an environmental survey of 119 abandoned mining sites in the Rock Creek and Flint Creek watersheds in the mid-1990s (Metesh et al., 1995). Of these sites, 35 are located in the Rock Creek TPA. Eight sites were found to have potential environmental problems, although these were generally limited to the immediate vicinity of the site. The study was limited to sites on Beaverhead-Deer Lodge National Forest property.

Milling was performed at many locations within the TPA. Waste rock and tailings are still present in many locations. DEQ Remediation Division data on abandoned mine locations are plotted on **Map A-18 (Appendix A)**. Active mining is currently limited to the sapphire operations.

2.3.6 Livestock Operations

The Montana Pollution Discharge Elimination System (MPDES) does not include any regulated concentrated animal feeding operations (CAFOs) within the Rock Creek watershed. Aerial photograph inspection (1-meter resolution, natural color, circa 2005) did not reveal any likely livestock confinement areas.

2.3.7 Wastewater

There are no large population centers in the TPA. Accordingly, no municipal wastewater treatment systems are present. Wastewater treatment needs are met by individual onsite septic tanks and drainfields.

3.0 MONTANA WATER QUALITY STANDARDS

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

Montana’s water quality standards and water quality standards in general include three main parts:
1. Stream classifications and designated uses
2. Numeric and narrative water quality criteria designed to protect designated uses
3. Nondegradation provisions for existing high-quality waters

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

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

3.1 ROCK CREEK TPA STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Waterbodies are classified based on their designated uses. All Montana waters are classified for multiple uses. All streams within the Rock Creek watershed are classified as B-1, which specifies that the water must be maintained suitable to support all of the following uses:
- Drinking, 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 some of the waterbodies might not actually be used for a designated use (e.g., drinking water supply), their water quality still must be maintained suitable for that designated use. More detailed descriptions of Montana’s surface water classifications and designated uses are provided in Appendix B. DEQ’s 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. For streams in Western Montana, the most sensitive use assessed for sediment is aquatic life; for temperature is aquatic life; for metals is drinking water and/or aquatic life; and for nutrients is aquatic life and primary contact recreation. DEQ determined that 11 tributaries do not meet the applicable water quality standards (**Table 3-1**).

Table 3-1. Impaired Waterbodies and their Impaired Uses* in the Rock Creek TPA

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
ANTELOPE CREEK, headwaters to mouth (Rock Creek)	Sedimentation/Siltation	Sediment	Aquatic Life
BASIN GULCH, headwaters to mouth (Eureka Gulch)	Arsenic	Metals	Drinking Water
EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)	Sedimentation/Siltation	Sediment	Aquatic Life
	Temperature, water	Temperature	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen	Nutrients	Aquatic Life and Primary Contact Recreation
EUREKA GULCH, confluence of Quartz Gulch and Basin Gulch to mouth (Un-Named Ditch)	Sedimentation/Siltation	Sediment	Aquatic Life
	Solids		Aquatic Life
	Arsenic	Metals	Drinking Water
	Mercury		Drinking Water
FLAT GULCH, headwaters to mouth (Rock Creek)	Sedimentation/Siltation	Sediment	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen		Aquatic Life and Primary Contact Recreation
	Aluminum	Metals	Aquatic Life
	Iron		Aquatic Life
MINERS GULCH, headwaters to mouth (Upper Willow Creek), T8N R15W S23	Sedimentation/Siltation	Sediment	Aquatic Life
QUARTZ GULCH, headwaters to mouth (Eureka Gulch)	Sedimentation/Siltation	Sediment	Aquatic Life
	Aluminum	Metals	Aquatic Life
	Lead		Drinking Water
SCOTCHMAN GULCH, headwaters to mouth (Upper Willow Creek)	Sedimentation/Siltation	Sediment	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen		Aquatic Life and Primary Contact Recreation
	Aluminum	Metals	Aquatic Life
SLUICE GULCH, headwaters to mouth (Rock Creek)	Sedimentation/Siltation	Sediment	Aquatic Life
	Total Nitrogen	Nutrients	Aquatic Life and Primary Contact Recreation
	Nitrate + Nitrite		Aquatic Life and Primary Contact Recreation
	Arsenic		Drinking Water
	Copper		Aquatic Life

Table 3-1. Impaired Waterbodies and their Impaired Uses* in the Rock Creek TPA

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)
SOUTH FORK ANTELOPE CREEK, headwaters to mouth (Antelope Creek), T6N R15W S22	Sedimentation/Siltation	Sediment	Aquatic Life
	Total Phosphorous	Nutrients	Aquatic Life and Primary Contact Recreation
	Total Nitrogen	Nutrients	Aquatic Life and Primary Contact Recreation
	Nitrate + Nitrite	Nutrients	Aquatic Life and Primary Contact Recreation
WEST FORK ROCK CREEK, headwaters to mouth (Rock Creek)	Sedimentation/Siltation	Sediment	Aquatic Life
	Aluminum	Metals	Aquatic Life

*Only pollutant impairments are listed

3.2 WATER QUALITY STANDARDS

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria that protect the designated uses. Numeric criteria define the allowable concentrations of specific pollutants so as not to impair designated uses. Narrative criteria are more "free from" descriptions, or statements, of unacceptable conditions. **Appendix B** defines both the numeric and narrative water quality criteria for the Rock Creek TPA.

Numeric standards apply to pollutants that are known to have adverse effects on human health or aquatic life (e.g., metals, organic chemicals, and other toxic constituents). Human health standards are set at levels that protect against long-term (lifelong) exposure, as well as short-term exposure through direct contact such as swimming. Numeric standards for aquatic life include chronic and acute values. Chronic aquatic life standards prevent long-term, low level exposure to pollutants. Acute aquatic life standards protect from short-term exposure to pollutants.

Narrative standards are developed when there is insufficient information to develop specific numeric standards. Narrative standards describe either the allowable condition or an allowable increase of a pollutant above "naturally occurring" conditions. DEQ uses the naturally occurring condition, called a "reference condition," to determine whether or not narrative standards are being met (see **Appendix B**).

Reference defines the condition a waterbody could attain if all reasonable land, soil, and water conservation practices were put in place. Reasonable land, soil, and water conservation practices usually include, but are not limited to, best management practices (BMPs).

The specific sediment, temperature, nutrient, and metals water quality standards that apply to the Rock Creek TPA are summarized in **Appendix B.**

4.0 Defining TMDLs and Their Components

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

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

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

A TMDL is expressed by the equation:

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

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

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

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

Development of each TMDL has four major components:

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

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

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

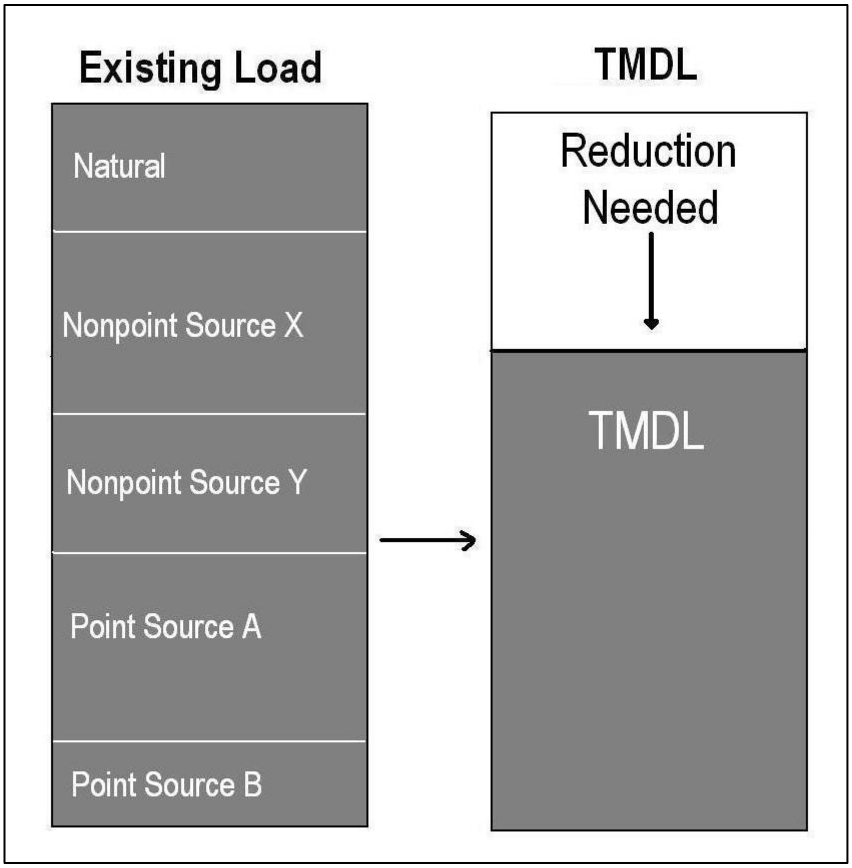

Figure 4-1. Schematic Example of TMDL Development

4.1 Developing Water Quality Targets

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

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

4.2 Quantifying Pollutant Sources

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

A pollutant load is usually quantified for each point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Nonpoint sources are quantified by source categories (e.g., unpaved roads) and/or by land uses (e.g., crop production or forestry). These source categories and land uses can be divided further by ownership, such as federal, state, or private. Alternatively, most, or all, pollutant sources in a sub-watershed or source area can be combined for quantification purposes. Because all potentially significant sources of the water quality problems must be evaluated, source assessments are conducted on a watershed scale. The source quantification approach may produce reasonably accurate estimates or gross allotments, depending on the data available and the techniques used for predicting the loading (40 CFR Section 130.2(I)). Montana TMDL development often includes a combination of approaches, depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 Establishing the Total Allowable Load

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

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

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

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

4.4 Determining Pollutant Allocations

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

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

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

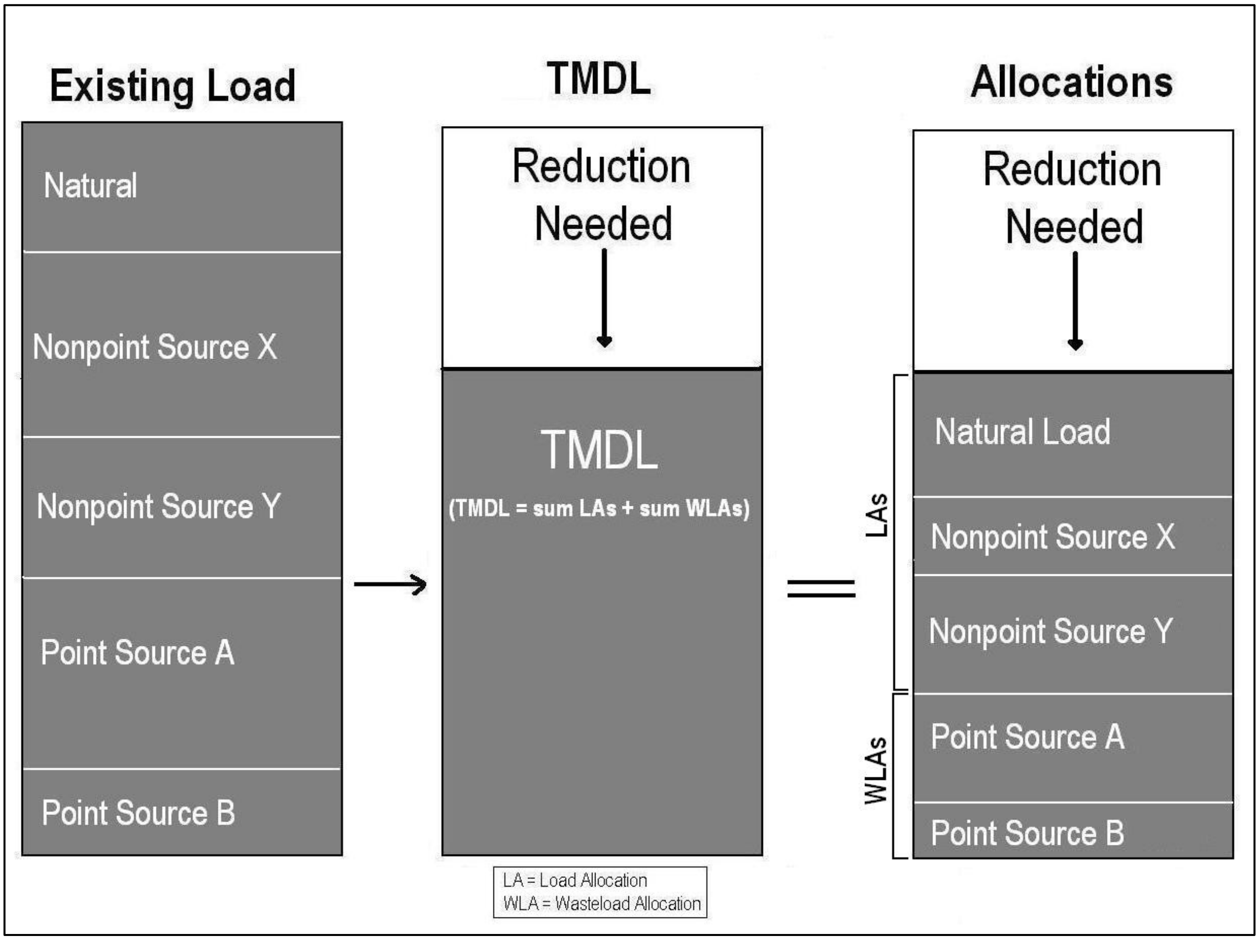

Figure 4-2. Schematic Diagram of a TMDL and its Allocations

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

4.5 Implementing TMDL Allocations

The Clean Water Act (CWA) and Montana state law (Section 75-5-703 of the Montana Water Quality Act) require wasteload allocations to be incorporated into appropriate discharge permits, thereby providing a regulatory mechanism to achieve load reductions from point sources. Nonpoint source reductions linked to load allocations are not required by the CWA or Montana statute, and are primarily implemented through voluntary measures. This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 10.0** discusses a restoration and implementation strategy by pollutant group and source category, and provides recommended best management practices (BMPs) per source category (e.g., grazing, cropland, urban, etc.). **Section 10.5** discusses potential funding sources that stakeholders can use to implement BMPs for nonpoint sources. Other site specific pollutant sources are discussed throughout the document, and can be used to target implementation activities. DEQ's Watershed Protection Section helps to coordinate nonpoint implementation throughout the state and provides resources to stakeholders to assist in nonpoint source BMPs. Montana's Nonpoint Source Management Plan (available at http://www.deq.mt.gov/wqinfo/nonpoint/nonpointsourceprogram.mcpx) further discusses nonpoint source implementation strategies at the state level.

DEQ uses an adaptive management approach to implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 11.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute (see **Section 11.2**). TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

5.0 SEDIMENT TMDL DEVELOPMENT

This portion of the document focuses on sediment as an identified cause of water quality impairments in the Rock Creek TMDL Planning Area (TPA). It includes: 1) the mechanisms by which sediment can impair beneficial uses, 2) the specific stream segments of concern, 3) the presently available data pertaining to sediment impairment characterization in the watershed, including target development and a comparison of existing water quality to targets, 4) quantification of the various contributing sources of sediment based on recent studies, and 5) identification of and justification for the sediment TMDLs and the TMDL allocations.

5.1 MECHANISM OF 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. Riparian and wetland vegetation and natural instream barriers such as large woody debris (LWD), beaver dams, or overhanging vegetation help trap sediment and build channel and floodplain features. When these barriers are absent or excessive sediment loading 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 not naturally characterized by high levels of fine sediment.

More specifically, sediment may block light and cause a decline in primary production, and it may also interfere with fish and macroinvertebrate survival and reproduction. Fine sediment deposition reduces availability of suitable spawning habitat for salmonid fishes and can smother eggs or hatchlings. 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 overwidening (which may lead to additional sediment loading and/or increased temperatures). This larger sediment can also reduce or eliminate flow in some stream reaches where sediment aggrades 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 instance, high concentrations of suspended sediment in streams can also cause water to appear murky and discolored, negatively impacting recreational use, and excessive sediment can increase filtration costs for water treatment facilities that provide safe drinking water.

5.2 STREAM SEGMENTS OF CONCERN

A total of 9 waterbody segments in the Rock Creek TPA appeared on the 2012 Montana 303(d) List due to sediment impairments (**Table 5-1**). These include: Brewster Creek, East Fork Rock Creek, Eureka Gulch, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, South Fork Antelope Creek, and Sluice Gulch. As shown in **Table 5-1**, many of the waterbodies with sediment impairments are also listed for habitat and flow alterations, which are non-pollutant forms of pollution frequently 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.

There are three other streams segments of concern in the TPA (**Table 5-1**). Upper Willow Creek (MT76E002_040) and West Fork Rock Creek (MT76E002_030) were not on the 303(d) list for sediment, but do have habitat alterations that are potentially linked to sediment and therefore were also evaluated as part of TMDL development. Antelope Creek (MT76E002_61) was also evaluated as part of TMDL development because of observations of sediment sources during field reconnaissance in June of 2011.

Table 5-1. Waterbody Segments of Concern for Sediment in the Rock Creek TPA

Stream Segment	Waterbody ID	Sediment Pollutant Listing	Non-Pollutant Causes of Impairment Potentially Linked to Sediment Impairment
Antelope Creek, headwaters to mouth (Rock Creek)	MT76E002_061		
Brewster Creek, East Fork to mouth (Rock Creek)	MT76E002_050	Sedimentation/ Siltation	Low flow alterations
East Fork Rock Creek, East Fork Reservoir to mouth (Middle Fork Rock Creek)	MT76E002_020	Sedimentation/ Siltation	Alteration in streamside or littoral vegetative covers & low flow alterations
Eureka Gulch, confluence of Quartz Gulch and Basin Gulch to mouth (Un-Named Ditch)	MT76E002_090	Sedimentation/ Siltation & Solids (Suspended/ Bedload)	Alteration in streamside or littoral vegetative covers
Flat Gulch, headwaters to mouth (Rock Creek)	MT76E002_120	Sedimentation/ Siltation	
Miners Gulch, headwaters to mouth (Upper Willow Creek)	MT76E002_160	Sedimentation/ Siltation	
Quartz Gulch, headwaters to mouth (Eureka Gulch)	MT76E002_070	Sedimentation/ Siltation	Alteration in streamside or littoral vegetative covers
Scotchman Gulch, headwaters to mouth (Upper Willow Creek)	MT76E002_100	Sedimentation/ Siltation	
Sluice Gulch, headwaters to mouth (Rock Creek)	MT76E002_110	Sedimentation/ Siltation	Alteration in streamside or littoral vegetative covers
South Fork Antelope Creek, headwaters to mouth (Antelope Creek)	MT76E002_060	Sedimentation/ Siltation	Alteration in streamside or littoral vegetative covers
Upper Willow Creek, headwaters to mouth (Rock Creek)	MT76E002_040		Alteration in streamside or littoral vegetative covers, low flow alterations, & physical substrate
West Fork Rock Creek, headwaters to mouth (Rock Creek)	MT76E002_030		

5.3 Information Sources and Assessment Methods to Characterize Sediment Conditions

For TMDL development, information sources and assessment methods fall within two general categories. The first category, discussed within this section, is focused on characterizing overall stream health with focus on sediment and related water quality conditions. The second category, discussed within **Section 5.6**, is focused on quantifying sources of sediment loading within the watershed.

5.3.1 Summary of Information Sources

To characterize sediment conditions for TMDL development purposes, a sediment and habitat assessment was completed during 2011. The below listed data sources represent the primary information used to characterize water quality and/or develop TMDL targets (**Figure 5-1**).

- DEQ assessment files
- 2011 DEQ sediment and habitat assessment
- 2011 DEQ macroinvertebrate and periphyton data collection
- 2009/2010 Beaverhead Deerlodge National Forest (BDNF) Integrated Riparian Monitoring Hydrology Report
- PIBO data (PACFISH/INFISH Biological Opinion Effectiveness)
- Beaverhead Deerlodge regional reference data
- GIS data layers and publications regarding historical land usage, channel stability, and sediment conditions

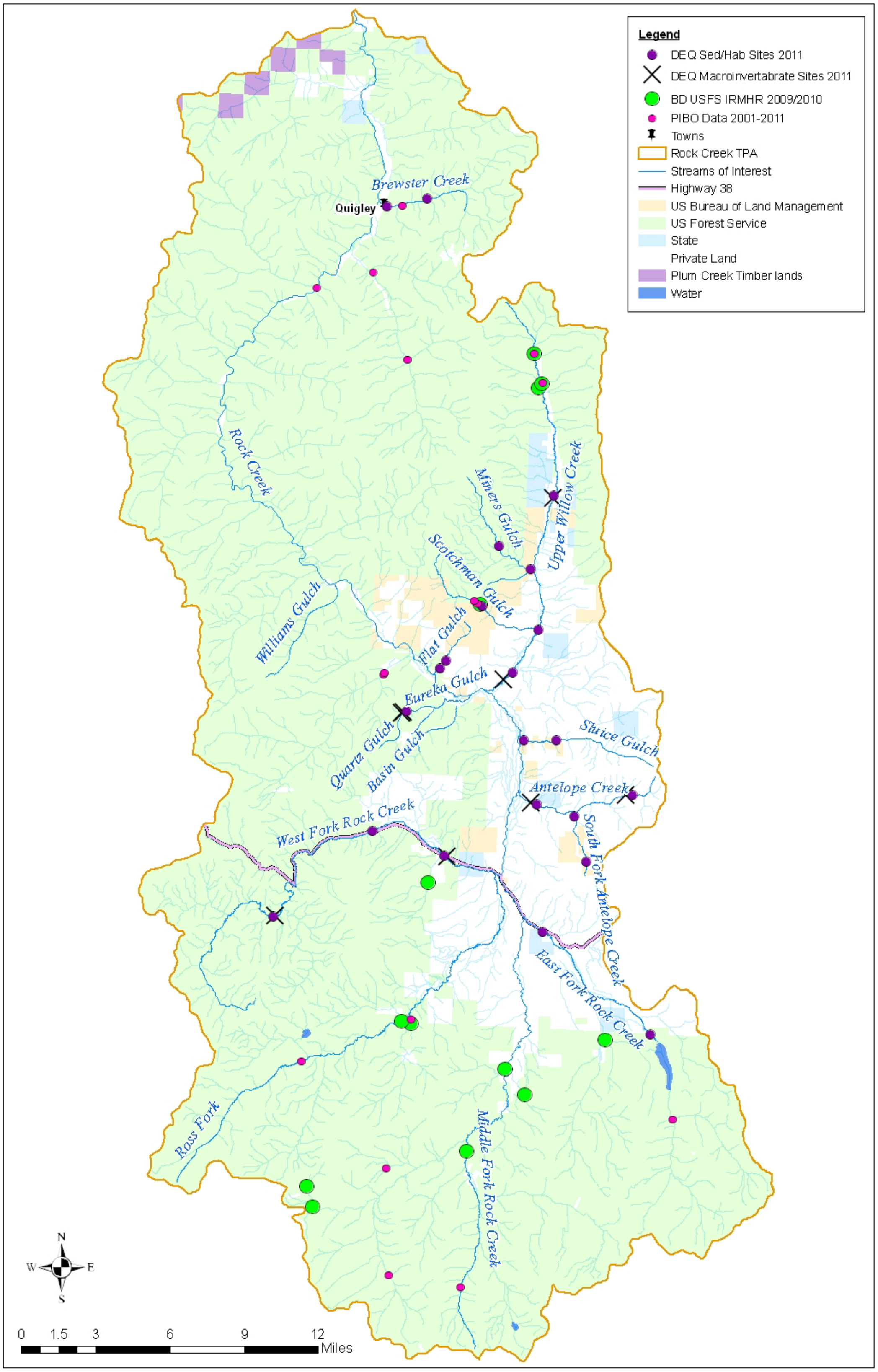

Figure 5-1. Reaches Assessed by DEQ in 2011 and Other Sources of Information

5.3.2 DEQ Assessment Files and Reference Sites

The DEQ assessment files contain information used to make the existing sediment impairment determinations. The files include a summary of physical, biological, and habitat data collected by DEQ on most waterbodies between 1990 and 2009 as well as other historical information collected or obtained by DEQ. The most common quantitative data that will be incorporated from the assessment files are pebble counts and macroinvertebrate index scores. The files also include information on sediment water quality characterization and potentially significant sources of sediment, as well as information on non-pollutant impairment determinations and associated rationale. Files are available electronically on DEQ's Clean Water Act Information Center website: http://cwaic.mt.gov/. Four DEQ reference sites exist in the Rock Creek TPA, however, sediment and habitat data has not yet been collected at these sites.

5.3.3 DEQ's 2011 Sediment and Habitat Assessments

Field measurements of channel morphology and riparian and instream habitat parameters (Montana Department of Environmental Quality, 2012b) were collected in August 2012 from 22 sites on 11 waterbody segments to aid in TMDL development (**Figure 5-1**). Although Eureka Gulch is listed, no sites were assessed on the stream during the sediment and habitat data collection in 2011 because access was not granted.

Streams are delineated into waterbody segments by the DEQ. Initially, all waterbody segments of interest underwent an aerial assessment procedure by which reaches were characterized by four main attributes not affected by human activity: stream order, valley gradient, valley confinement, and ecoregion. These four attributes represent main factors influencing stream morphology, which in turn influences sediment transport and deposition. The next step in the aerial assessment involved identification of near-stream land uses since land management practices can have a significant influence on stream morphology and sediment characteristics. The resulting product was a stratification of waterbody segments into reaches that allow for comparisons among those reaches of the same natural morphological characteristics, while also indicating stream reaches where land management practices may further influence stream morphology. The waterbody stratification, along with field reconnaissance, provided the basis for selecting the monitoring sites located within a reach. Each monitoring site, ranging from 500 feet to 1500 feet (depending on the channel bankfull width) is broken into five individual and equally-sized cells.

Monitoring sites were chosen with the goal of being representative of various reach characteristics, land use category, and anthropogenic influence. There was a preference toward sampling those sites where anthropogenic influences would most likely lead to impairment conditions since it is a primary goal of sediment TMDL development to further characterize sediment impairment conditions. Thus, it is not a random sampling design intended to sample stream reaches representing all potential impairment and non-impairment conditions. Instead, it is a targeted sampling design that aims to assess a representative subset of reach types while ensuring that reaches within each [sediment] 303(d) listed waterbody with potential impairment conditions are incorporated into the overall evaluation. Typically, the effects of excess sediment are most apparent in low gradient, unconfined streams larger than 1st order (i.e., having at least one tributary). However, many of the reach types within the Rock Creek TPA are higher gradient first order streams (**Table 5-2**); therefore, a range of gradients and stream orders were sampled.

The field parameters assessed in 2011 include standard measures of stream channel morphology, fine sediment, stream habitat, riparian vegetation, and streambank erosion. Channel morphology, stream habitat, riparian, and bank erosion measures were performed in all five cells, while fine sediment measures were performed in four of the cells. Field parameters are briefly described in **Section 5.4**, and summaries of all field data are contained in the 2012 monitoring summary report (**Appendix C**).

Table 5-2. Stratified Reach Types and Sampling Site Representativeness within the Rock Creek TPA

Reach Type*	Number of Reaches	Sites Monitored
MR_0_3_U	45	ANTE 21-01
		BREW 06-01
		UWIL 11-05
		WFRK 14-03
		WFRK 27-03
		WFRK 30-02
MR_0_4_U	9	EFRK 03-03
		UWIL 15-01
MR_2_1_U	9	SCOT 08-01
MR_2_2_C	8	SLUI 14-01
MR_2_2_U	18	MINE 14-02
		SLUI 18-02
MR_2_3_U	15	BREW 05-01
		EFRK 01-02
MR_4_1_C	25	QUTZ 09-01
MR_4_1_U	40	FLAT 12-01
		MINE 10-02
		SCOT 16-02
MR_4_2_C	10	SFAN 06-01
MR_4_2_U	12	ANTE 07-01
		SFAN 13-01
MR_10_1_U	20	FLAT 13-01

* Per DEQ's stratification methodology: MR= Middle Rockies; the first number in the series refers to stream gradient: 0=0-2%, 2=2-4%, 4=4-10%, and 10=>10%; the next number in the series refers to Strahler stream order, 1 through 7; and finally U = Unconfined & C = Confined

5.3.4 DEQ Macroinvertebrate and Periphyton Collection 2011

DEQ contracted with Watershed Consulting, LLC to in 2011 to collect and analyze macroinvertebrate and periphyton data in 8 reaches on four streams: Antelope Creek, Quartz Creek, Upper Willow Creek, and West Fork Rock Creek. Additional data collected included aquatic vegetation composition, amount, color and condition; water chemistry indicators such as dissolved oxygen (DO), pH, specific conductivity (SC), and air and water temperature; and digital photos upstream, downstream and across each reach. The full report is available in **Appendix D**.

5.3.5 Beaverhead Deerlodge NF Sediment and Habitat Assessment 2009/2010

In 2009 and 2010, the Beaverhead Deerlodge National Forest (BDNF) surveyed twelve streams (13 sites) in the Rock Creek Watershed for their Integrated Riparian Monitoring Hydrology Report (IRMH). Two of the streams surveyed by BDNF, Upper Willow Creek and Scotchman Gulch, are also streams that were surveyed by the DEQ during the 2011 sediment and habitat assessment for TMDL development. The primary objectives associated with the BDNF sites were to document riparian/stream condition and to evaluate trends based on future management at the allotment level. Sites were distributed across the Forest and were most commonly located where livestock directly influenced channel and/or riparian conditions. Three cross section measurements, bank erosion hazard index (BEHI) ratings, particle size distribution, sinuosity, slope, channel width/depth measurements, discharge, pictures and field notes were collected at each monitoring location.

5.3.6 PIBO Data

The PACFISH/INFISH Biological Opinion Effectiveness (PIBO) monitoring program collects data from reference and managed (i.e., non-reference) stream sites on United States Forest Service (USFS) and Bureau of Land Management (BLM) land within the Rock Creek watershed. Reference sites are defined as having catchment road densities less than 0.5 km/km^2, riparian road densities less than 0.25 km/km^2, no grazing within 30 years, and no known in-channel mining upstream of the site. Within the Rock Creek TPA, data were collected on reference sites in 2001 and 2002 on Ranch Creek; in 2004 and 2009 on Middle Fork Rock and East Fork Rock creeks; and in 2007 on Welcome Creek (**Figure 5-1**). Data were also collected on managed (non-reference) sites in the Rock Creek TPA between 2002 and 2009 on 10 other streams. The four reference sites in the Rock TPA are located within the Middle Rockies Level IV ecoregion, and because four reference sites provides a small dataset for target development, and ecoregion is a primary stratification category, all PIBO reference data from the Middle Rockies ecoregion between 2001 and 2011 were used for target development. Data was collected following protocols described in *"Effectiveness Monitoring for Streams and Riparian Areas within the Pacific Northwest: Stream Channel Methods for Core Attributes"* (U.S. Department of Agriculture, Forest Service, 2006). Relevant data collected during these assessments include width/depth ratios, residual pool depths, pool frequency, LWD frequency, pebble counts, and the percentage of fine sediment in pool tails <6mm via grid toss.

5.3.7 Beaverhead Deerlodge Regional Reference Data

Regional reference data are available from the BDNF. BDNF data were collected between 1991 and 2002 from approximately two hundred reference sites: seventy of the sites are located in the Greater Yellowstone Area and the remaining sites are in the BDNF, which is also located in southwestern Montana (Bengeyfield, 2004). Applicable reference data are width/depth ratios, entrenchment ratios, and fine sediment <6mm from pebble counts.

5.4 Water Quality Targets and Comparison to Existing Conditions

The concept of water quality targets was presented in **Section 4.1**, but this section provides the rationale for each sediment-related target parameter, discusses the basis of the target values, and then presents a comparison of those values to available data for the stream segments of concern in the Rock Creek TPA (**Table 5-1**). Although placement onto the 303(d) list indicates impaired water quality, a comparison of water quality targets to existing data helps define the level of impairment and establishes a benchmark to help evaluate the effectiveness of restoration efforts.

In developing targets, natural variation throughout the river channel must be considered. As discussed in more detail in **Section 3** and **Appendix B**, 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 utilizing reference site data, but modeling, professional judgment, and literature values may also be used. The 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 historical and current land use activities. Although sediment water quality targets typically relate most directly to the aquatic life use, the targets are protective of all designated beneficial uses because they are based on the reference approach, which strives for the highest achievable condition. Waterbodies used to determine reference conditions are not necessarily pristine. The reference condition approach is intended to accommodate natural variations due to climate, bedrock, soils, hydrology and other natural physiochemical differences yet allow differentiation between natural conditions and widespread or significant alterations of biology, chemistry or hydrogeomorphology due to human activity.

The basis for the value for each water quality target varies depending on the availability of reference data and sampling method comparability to the 2010/11 DEQ data. As discussed in **Appendix B**, 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. For example, if low values are desired, the sampled streams are assumed to be severely degraded, and there is a high degree of confidence in the reference data, the 75th percentile of the reference dataset or the 25th percentile of the sample dataset (if reference data are not available) is typically used. However, percentiles may be used differently depending on whether a high or low value is desirable, the representativeness and range of variability of the data, the severity of human disturbance to streams within the watershed, and size of the dataset. For each target, descriptive statistics were generated relative to any available reference data (e.g., BDNF or PIBO) as well as for the entire sample dataset. The preferred approach for setting target values is to use reference data, where preference is given towards the most protective reference dataset. Additionally, the target value for some parameters may apply to all streams in the Rock Creek TPA, whereas others may be stratified by bankfull width, reach type characteristics (i.e., ecoregion, gradient, stream order, and/or confinement), or by Rosgen stream type if those factors are determined to be important drivers for certain target parameters. Although the basis for target values may differ by parameter, the goal is to develop values that incorporate an implicit margin of safety (MOS) and are achievable. The MOS is discussed in additional detail in **Section 5.8.2**.

5.4.1 Water Quality Targets

The sediment water quality targets for the Rock Creek TPA are summarized in **Table 5-3** and described in detail in the sections that follow. Sediment-related targets for the Rock Creek TPA are based on a combination of reference data from the BDNF, from the Middle Rockies portion of the Montana PIBO dataset, and sample data from the DEQ 2011 sampling effort. **Appendix C** provides a summary of the DEQ 2011 sample data and a description of associated field protocols.

Consistent with EPA guidance for sediment TMDLs (U.S. Environmental Protection Agency, 1999), water quality targets for the Rock Creek TPA are comprised of a combination of measurements of instream siltation, channel form, biological health, 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 and biological indices).

Target parameters and values are based on the current best available information, but they 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. 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 supports impairment; the degree to which one or more targets are exceeded are taken into account (as well as the current 303(d) listing status), and 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, natural conditions, and flow alterations within a watershed may warrant the selection of unique indicator values that differ slightly from those presented below, or special interpretation of the data relative to the sediment target values.

Table 5-3. Sediment Targets for the Rock TPA

Parameter Type	Target Description	Target Value
Fine Sediment	Percentage of fine surface sediment ≤ 6mm in riffles via pebble count (reach average)	≤ 13% (excludes E channels) ≤ 30% (E channels only)
	Percentage of fine surface sediment ≤ 2mm in riffles via pebble count (reach average)	≤ 11% (excludes E channels) E channels: No target
	Percentage of fine surface sediment < 6mm in pool tails via grid toss (reach average)	≤ 9% (excludes E channels) E channels: No target
Channel Form and Stability	Bankfull width/depth ratio (reach average)	B stream type: < 16
		C stream type: < 23
		E & A stream types: < 12
	Entrenchment ratio (reach median)	A stream type: < 1.4
		B stream type: 1.4-2.2
		C and E stream types: > 2.2
Pool Features	Residual pool depth (reach average)	< 15' bankfull width : > 0.7 (ft)
		> 15' bankfull width : > 1.4 (ft)
	Pools/mile	< 15' bankfull width : ≥ 117
		> 15' bankfull width : ≥ 52
Riparian Health	Percent of streambank with understory shrub cover (reach average)	≥ 60% understory shrub cover (where potential exists)
	Percent of streambank with bare ground	1% (recent ground disturbance excluding water gaps or other BMPs)
	Percent of streambank with hummocking	0% (hummocking in water gap areas is excluded)
Sediment Supply	Riffle stability index	<70 for B stream types
		>45 and <75 for C stream types
Biological Index	Macroinvertebrate bioassessment threshold	O/E ≥ 0.80

5.4.1.1 Fine Sediment

The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a streambed and is directly linked to the support of the coldwater fish and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival, clog spawning redds, and smother fish eggs by limiting oxygen availability (Irving and Bjorn, 1984; Weaver and Fraley, 1991; Shepard et al., 1984; Suttle et al., 2004). Excess fine sediment can also decrease macroinvertebrate abundance and taxa richness (Mebane, 2001; Zweig and Rabeni, 2001). Because similar concentrations of sediment can cause different degrees of impairment to different species, and even age classes within a species, and because the particle size defined as "fine" is variable and some assessment methods measure surficial sediment while others measure subsurface fine sediment, literature values for harmful fine sediment thresholds are highly variable. Some studies of salmonid and macroinvertebrate survival found an inverse relationship between fine sediment and survival (Suttle et al., 2004) whereas other studies have concluded the most harmful percentage falls within 10 to 40 percent fine sediment (Bjorn and Reiser, 1991; Mebane, 2001; Relyea et al., 2000). Bryce, et al. (2010) evaluated the effect of surficial 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. Literature values are taken into consideration during fine sediment target development, but because increasing concentrations of fine sediment are known to be harmful to aquatic life, targets are developed using a conservative statistical approach consistent with **Appendix B**, and consistent with Montana's water quality standard for sediment as described in **Section 3.2**.

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

Surface fine sediment measured in riffles by the modified (Wolman, 1954) pebble count indicates the particle size distribution across the channel width is an indicator of aquatic habitat condition that can point to excessive sediment loading. Pebble counts in 2011 were performed in four riffles per sampling reach for a total of at least 400 particles.

Less than 6mm

The BDNF reference data and the Montana Middle Rockies PIBO reference data were examined for fine sediment < 6 mm during the development of these targets. The BDNF reference data for pebble count was collected using the "zigzag" method, which includes both riffles and pools. The PIBO pebble count data are also a composite of riffle and pool particles. Both of these methods of collection likely result in a higher percentage of fines than a riffle pebble count, which was the method used for TMDL related data collection in the Rock Creek TPA, and because of this difference in methodology, the median statistic is applied (as discussed in **Section 5.4**) to reflect the desired condition. The PIBO reference dataset contains a large sample size and therefore targets for fine sediment < 6 mm are set at less than or equal to the median of the PIBO reference dataset **(bold** in **Table 5-4)**. Due to an inherently high percentage of fines typical in Rosgen Type E channels, E channel values were examined separately. Because of the large amount of data available for E channels from the BDNF reference dataset, E channel targets for percent fines < 6mm are set at ≤ 30. Target values should be compared to the reach average value from pebble counts.

Less than 2 mm

For fine sediment <2 mm, PIBO is the only reference data currently available. As mentioned in the above paragraph, PIBO pebble count data are a composite of riffle and pool particles, which are likely to result in higher fines than the DEQ riffle-only pebble count, and therefore the median is used to reflect the desired condition. Again, because there is a larger sample size for the PIBO dataset, targets for fine sediment < 2 mm are set a less than or equal to the median of the PIBO reference dataset (**Table 5-5**). Target values should be compared to the reach average value from pebble counts.

Table 5-4. PIBO Reference Dataset, BDNF IRMH selected sites, and 2011 Rock Creek TPA DEQ Data Summary Percent Fine Sediment < 6 mm.

Target values are indicated in bold.

Data Source	Sample Size (n)	Parameter	Summary
PIBO reference data (Montana only)	64	Median	**13**
2011 DEQ Sample Data (all data)	22	25th	10
BDNF reference (E channels only)	113	Median	**30**

Table 5-5. PIBO Reference Dataset, BDNF IRMH selected sites, and 2011 Rock Creek TPA DEQ Data Summary Percent Fine Sediment < 2 mm.

Target values are indicated in bold.

Data Source	Sample Size (n)	Parameter	Summary
PIBO reference data (Montana only)	64	Median	**11**
2011 DEQ Sample Data (all data)	22	25th	4

5.4.1.1.2 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. A 49-point grid toss (Kramer et al., 1993) was used to estimate the percent surface fine sediment < 6mm in pool tails in the Rock Creek TPA, and three tosses, or 147 points, were performed and then averaged for each assessed pool.

Grid toss reference data for pool tails are available from the PIBO dataset. The 75th percentile of the PIBO reference data for pool tails is 16% and the median is 9% (**Table 5-6**). PIBO performs three grid tosses at every pool encountered, and DEQ performs three grid tosses in each scour pool encountered where appropriate sized spawning gravels have been identified and the potential for spawning exists. Given that the DEQ performs a grid toss only in pools where spawning gravels exist, the resulting fines may be higher in pools found in the PIBO reference dataset, and because of this difference, the median statistic of the PIBO reference data is applied (as discussed in **Section 5.4**) to reflect the desired condition. The pool grid toss target for fine sediment less than 6 mm is set at 9%, using the median of the reference dataset. Due to an inherently high percentage of fines in Rosgen Type E channels, and the lack of reference pool grid toss data specific to E channel types, no target value is set for E channels.

Table 5-6. PIBO Reference and 2011 Rock Creek TPA DEQ Data Percentiles for Percent Fine Sediment < 6 mm via Grid Toss in Pool Tails.
Target values are indicated in bold.

Data Source	Sample Size (n)	Parameter	Summary
PIBO Pool Tail	76	Median	**9**
		75th	16
DEQ 2011 Sample Data Pool Tail	20	Median	9
		25th	2

5.4.1.2 Channel Form and Stability
5.4.1.2.1 Width/Depth Ratio and Entrenchment Ratio
The width/depth ratio and the entrenchment ratio are dimensionless values representing fundamental aspects of channel morphology. Each provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e., riffles, pools, and near bank zones). Changes in both the width/depth ratio and entrenchment ratio can be used as indicators of change in the relative balance between the sediment load and the transport capacity of the stream channel. As the width/depth ratio increases, streams become wider and shallower, suggesting an excess coarse sediment load (MacDonald et al., 1991). As sediment accumulates, the depth of the stream channel decreases, which is compensated for by an increase in-channel width as the stream attempts to regain a balance between sediment load and transport capacity. Conversely, a decrease in the entrenchment ratio signifies a loss of access to the floodplain. Low entrenchment ratios signify that stream energy is concentrated in-channel during flood events versus having energy dissipation on the floodplain. Accelerated bank erosion and an increased sediment supply often accompany an increase in the width/depth ratio and/or a decrease in the entrenchment ratio (Rosgen, 1996; Knighton, 1998; Rowe et al., 2003). Width/depth and entrenchment ratios were calculated for each 2011 assessment reach based on 5 riffle cross section measurements.

Width/Depth Ratio Target Development
There is reference riffle width/depth ratio data for both the BDNF and PIBO datasets. The 2011 Rock Creek TPA dataset is primarily comprised of B and C channels and on average B channels tend to have a

smaller width/depth ratio than C channels (Rosgen, 1996). The target value for width/depth ratio is based on the BDNF reference dataset, which is stratified by Rosgen channel type. The width/depth ratio target for Rock Creek TPA B & C channel types is set at less than or equal to the 75th percentile of the reference value; and for A & E channels is set at less than 12 based on Rosgen stream type classification (**Table 5-7**).

Table 5-7. The 75th Percentiles of Reference Data used for Width/Depth Ratio Target Development

Data Source	Category	Sample Size (n)	Parameter	Summary
BDNF Reference	B channel type	30	75th	**16**
BDNF Reference	C channel type	40	75th	**23**

Entrenchment Ratio Target Development
Delineative criteria based on Rosgen stream type classification for entrenchment gives guidance of <1.4 for A, F and G streams, 1.4-2.2 for B streams, and >2.2 for C, E streams. These literature values will serve as the target ranges for entrenchment in the Rock Creek TPA **(Table 5-8)**.

Table 5-8. Entrenchment Targets for the Rock Creek TPA Based on the 25th Percentile of BDNF Reference Data

Rosgen Stream Type	Target Value
A, F, G	<1.4
B	1.4-2.2
C,E	>2.2

5.4.1.3 Pool Features
Pools are stream features characterized by slow moving, deep sections of the stream. These important components aid the balance between flow and sediment load by reducing stream velocity and storing water and sediment. The measure and comparison of pool features can have direct links to sediment load increases and its effect on stream form and function, as well as biological integrity. Pool features play an important role for aquatic life and fisheries by providing refuge from warm water, high velocity, and terrestrial predators. However, when sediment loads are excessive, pool habitat quality and frequency is often diminished as pools fill with sediment. When this happens, velocities increase, stream channels widen, and sediment is transported to other areas of the stream where it may be deposited into areas that have an additional impact on fisheries and aquatic life.

5.4.1.3.1 Residual Pool Depth
Residual pool depth, defined as the difference between the pool maximum depth and the pool tail crest depth, is a discharge-independent measure of pool depth and an indicator of the quality of pool habitat. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods (Nielson et al., 1994; Bonneau and Scarnecchia, 1998; Baigun, 2003). Similar to channel morphology measurements, residual pool depth integrates the effects of several stressors; pool depth can be decreased as a result of filling with excess sediment (fine or coarse), a reduction in-channel obstructions (such as LWD), and changes in-channel form and stability (Bauer and Ralph, 1999). A reduction in pool depth from channel aggradation may not only alter surface flow during the critical low flow periods, but may also impair fish condition by altering habitat, food availability, and productivity (May and Lee, 2004; Sullivan and Watzin, 2010). Residual pool depth is typically greater in larger systems.

The definition of pools for the PIBO protocol is fairly similar to the definition used for the 2011 Rock Creek TPA sample dataset; both define a pool as having its maximum depth greater than or equal to 1.5 times the pool tail crest depth. However, the DEQ dataset could potentially have a greater pool frequency and more pools with a smaller residual pool depth because the DEQ protocol records all pools encountered, whereas the PIBO protocol only counts pools greater than half the wetted channel.

Because of the variance between the PIBO and DEQ methods of counting pools, the residual pool depth target is equal to or greater than the PIBO median value (**bold** in **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 2011 as a baseline. Future monitoring should document an improving trend (i.e. deeper pools) at sites which fail to meet the target criteria, while a stable trend should be documented at established monitoring sites that are currently meeting the target criteria.

Table 5-9. PIBO Reference and 2011 DEQ Sample Data Percentiles for Residual Pool Depth (ft).
Targets are shown in bold.

Category	PIBO Reference			DEQ Sample Data		
	n	**Median**	**25th**	**n**	**Median**	**75th**
< 15 ft bankfull width	12	**0.7**	0.6	14	0.5	0.6
> 15 ft bankfull width	66	**1.4**	1.2	7	1.3	1.7

5.4.1.3.2 Pool Frequency

Pool frequency is another indicator of sediment loading that relates to changes in-channel geometry and is an important component of a stream's ability to support the fishery beneficial use for many of the same reasons associated with the residual pool depth discussed above and also because it can be a major driver of fish density (Muhlfeld and Bennett, 2001; Muhlfeld et al., 2001). Sediment may limit pool habitat by filling in pools with fines. Alternatively, aggradation of larger particles may exceed the stream's capacity to scour pools, thereby reducing the prevalence of this critical habitat feature. Pool frequency generally decreases as stream size (i.e., watershed area) increases.

Again, because of the difference between the PIBO and DEQ pool identification, the median statistic of the PIBO reference data is applied (as discussed in **Section 5.4**) to reflect the desired condition. The pool frequency target is equal to or greater than the PIBO median value (**bold** in **Table 5-10).** Pools per mile should be calculated based on the number of measured pools per reach and then scaled up to give a frequency per mile.

Table 5-10. PIBO Reference and 2011 DEQ Sample Data Percentiles for Pool Frequency (pools/mile) and INFISH Riparian Management Objective Values.
Targets are shown in bold.

Category	PIBO Reference			DEQ Sample Data		
	n	**Median**	**25th**	**n**	**Median**	**75th**
≤ 15 ft bankfull width	12	**117**	84	15	127	158
> 15 ft bankfull width	66	**52**	24	7	40	56

5.4.1.4 Riparian Health

Although the following categories are not a direct measure of sediment, they do provide insight into the overall riparian quality. Riparian condition is often associated with factors that may be leading to increased sediment loads and the reduction of instream habitat.

During the 2011 DEQ sediment and habitat data collection, a riparian assessment method (ie, Greenline) (Montana Department of Environmental Quality, 2012b) was used to conduct a coarse survey of the riparian corridor and its general vegetation composition. The results are used here to infer riparian corridor health and bank stability.

5.4.1.4.1 Riparian Understory Shrub Cover

Interactions between the stream channel and the riparian vegetation along the streambanks are a vital component in the support of the beneficial uses of coldwater fish and aquatic life. Riparian vegetation provides organic material used as food by aquatic organisms and supplies LWD that influences sediment storage and channel morphology. Riparian vegetation helps filter sediment from upland runoff, stabilize streambanks, and it can provide shading, cover, and habitat for fish. During DEQ assessments conducted in 2011, ground cover, understory vegetation and overstory vegetation were cataloged at 10 to 20 foot intervals along the greenline at the bankfull channel margin along both sides of the stream channel for each monitoring reach. The percent of understory shrub cover is of particular interest in valley bottom streams historically dominated by willows and other riparian shrubs. While understory cover is important for stream health, not all reaches have the potential for dense understory shrub cover or they may have the potential for a dense riparian community of a different composition, such as wetland vegetation or mature pine forest.

At the 2011 assessment sites, the 75th percentile of understory shrub cover was 60%. Based on the 75th percentile, a target value of ≥ 60% is established for understory shrub cover in the Rock Creek TPA. This target value should be assessed based on the reach average greenline understory shrub cover value. For any reaches that do not meet the target value, the greenline assessment results will be more closely examined to evaluate the potential for dense riparian understory shrub cover.

5.4.1.4.2 Bare Ground along Greenline

Percent bare ground is an important indicator of erosion potential, as well as an indicator of land management influences on riparian habitat. Bare ground was noted in the greenline inventory in cases where recent ground disturbance was observed, leaving bare soil exposed, excluding water gaps and other BMPs. Bare ground is often caused by trampling from livestock or wildlife, fallen trees, recent bank failure, new sediment deposits from overland or overbank flow, or severe disturbance in the riparian area, such as from past mining, road-building, or fire. Ground cover on streambanks is important to prevent sediment recruitment to stream channels. Sediment can wash in from unprotected areas due to snowmelt, storm runoff, or flooding. Bare areas are also much more susceptible to erosion from hoof shear. Most stream reaches have a small amount of naturally-occurring bare ground. As conditions are highly variable, this measurement is most useful when compared to reference values from best available conditions within the study area or literature values.

At the 2011 assessment sites, the 25th percentile and median of bare ground throughout all reaches was zero percent, and the median of this data set would typically be used; however, because the median value is zero percent and many streams may have a small amount of naturally-occurring recently disturbed bare ground, a target value of 1% is established for bare ground along the greenline for streams in the Rock Creek TPA. This does not apply to disturbed bare ground associated with water gaps or other BMPs.

5.4.1.4.3 Hummocking along Greenline

Hummocking occurs when hoof action associated with overgrazing in riparian areas creates pedestals of soil and vegetation surrounded by troughs of muddy areas. Overgrazing practices in the riparian area can significantly impact vitality and cover of principal native riparian and wetland species and can lead to soil compaction and erosion (U.S. Department of the Interior, Bureau of Land Management, 2001). Hummocking can lead to streambank instability, channel sloughing, increased fine sediment input, stream widening and bank compaction (U.S. Department of the Interior, Bureau of Land Management, 2006). Stream channels in narrow valley bottoms are particularly susceptible to the effects of overgrazing, as livestock tend to concentrate in these areas, rather than on steep upland slopes. Limiting the grazing intensity, frequency, or season of use in these highly sensitive areas provides opportunity to encourage plant vigor, regrowth, and minimize compaction of soils.

During the green line assessment at the 2011 sites (many of which have grazing occurring within the reach) the 25th percentile, median, and 75th percentile of all reaches show 0% hummocking. Therefore a target value of 0% is established for hummocking along the greenline for streams in the Rock Creek TPA. This target does not apply to hummocking in areas associated with water gaps or other BMPs.

5.4.1.5 Sediment Supply

Riffle Stability Index

The Riffle Stability Index (RSI) is an estimate of sediment supply in a watershed. RSI target values are established based on values calculated by Kappesser (2002), who found that RSI values between 40 and 70 in B channels indicate that a stream's sediment transport capacity is in dynamic equilibrium with its sediment supply. Values between 70 and 85 indicate that sediment supplies are moderately high, while values greater than 85 suggest that a stream has excessive sediment loads. The scoring concept applies to any streams with riffles and depositional bars. Additional research on RSI values in C streams types was conducted in the St. Regis River watershed and applied in the St. Regis TMDL, for which a water quality target of greater than 45 and less than 75 was established based on Kappesser's research and local reference conditions for least-impacted stream segments. For the Rock Creek TPA an RSI target value of < 70 is established for B streams, while values of > 45 and < 75 are established for C streams. The target should be compared with the mean of measurements within a sample reach. Streams types other than B and C will need to be reviewed on a case-by-case basis.

5.4.1.6 Biological Indices

Macroinvertebrates

Siltation exerts a direct influence on benthic macroinvertebrates assemblages by filling in spaces between gravel and by limiting attachment sites. Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessment scores are an assessment of the macroinvertebrate assemblage at a site, and DEQ uses one bioassessment methodology to evaluate stream condition and aquatic life beneficial-use support. Aquatic insect assemblages may be altered as a result of different stressors such as nutrients, metals, flow, and temperature, and the biological index values must be considered along with other parameters that are more closely linked to sediment.

The macroinvertebrate assessment tool used by DEQ is the Observed/Expected model (O/E). The rationale and methodology for the index is presented in the DEQ Benthic Macroinvertebrate Standard Operating Procedure (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2006). The O/E model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled and is expressed as a ratio of the Observed/Expected taxa (O/E value). However, scores in excess of 1.2 may not reflect the effects of sediment in the stream if there is an abundance of nutrients or a condition beyond the experience of the model, such as a large river system or a reference site not used to build the model. An O/E score of > 0.80 is established as a sediment target in the Rock Creek TPA, keeping in mind that scores over 1.2 may indicate excess nutrients or a condition beyond the experience of the model.

An index score greater than the threshold value is desirable, and the result of each sampling event is evaluated separately. Because index scores may be affected by other pollutants or forms of pollution such as habitat disturbance, they will be evaluated in consideration of more direct indicators of excess sediment. In other words, not meeting the biological target does not automatically equate to sediment impairment. Additionally, because the macroinvertebrate sample frequency and spatial coverage is typically low for each watershed and because of the extent of research showing the harm of excess sediment to aquatic life, meeting the biological target does not necessarily indicate a waterbody is fully supporting its aquatic life beneficial use. For this reason, measures that indicate an imbalance in sediment supply and/or transport capacity will also be used for TMDL development determinations.

Periphyton

Periphyton-based biometrics are presented in this document as supporting information for TMDL development; however no target is set for this parameter. Periphytonare algae that live attached to or in close proximity to the stream bottom. Algae are ubiquitous in Montana surface waters, easy to collect, and represented by large numbers of species. Different species are differentially sensitive to a variety of pollutants, and have been found to be useful indicators of nutrient and clean-sediment impacts. Measures of the structure of algal associations, such as species diversity and dominance, can be sensitive and useful indicators of water-quality impacts and ecological disturbance.

DEQ has used a variety of periphyton-based biometrics to help interpret stream water quality. DEQ's current approach uses pollutant-diagnosing biometrics based on stressor-specific increaser diatom taxa, as described in Teply (2010a; 2010b) and earlier documents (Bahls et al., 2008; Teply, 2010a; Teply and Bahls, 2006). Currently there are increaser-taxa biometrics available for nutrients and sediment in both the mountainous and plains regions of the state. The rationale and methodology for the periphyton-based biometrics is presented in the DEQ Periphyton Standard Operating Procedure (Montana Department of Environmental Quality, 2011).

5.4.2 Existing Condition and Comparison to Water Quality Targets

This section presents summaries and evaluations of relevant water quality data for Rock Creek TPA waterbodies appearing on the Montana 2012 303(d) List. The weight-of-evidence approach described earlier in **Section 4.1**, using a suite of water quality targets, has been applied to each of the listed water quality impairments. Data presented in the section comes primarily from sediment and habitat assessments performed by DEQ during summer of 2011. Results of the 2011 assessment are supported by additional data collected by DEQ in the DEQ Assessment Files and by data supplied by the BDNF. However, this section is not intended to provide an exhaustive review of all available data.

5.4.2.1 Antelope Creek MT76E002_061

Antelope Creek was not listed for sedimentation/siltation on the 2012 303(d) List; however, because of observations of sediment sources during field reconnaissance in June of 2011, the stream was assessed by the DEQ. Antelope Creek flows 7.2 miles from its headwaters to Rock Creek.

Physical Condition and Sediment Sources

In 2011, DEQ performed sediment and habitat assessments at two monitoring sites on Antelope Creek. The upstream site (ANTE 07-01) was located on private land. The site was inhabited by cattle, the riparian vegetation was grazed to stubble, and banks were heavily trampled and hummocky (**Figure 5-2**). A vegetation exclosure existed approximately 30 feet downstream of the site for a solar powered watering trough. The confined reach upstream of the sample site was also grazed and trampled. A dry stream channel started at station 380 and continued upstream into the confined reach. A dirt road existed approximately 100 feet from the stream on river left. The upper watershed mostly contained grassy slopes with some forest.

Stream channel measurements at the upper site resembled Rosgen type B4. Stream channel conditions at the site included B-type entrenchment, low width/depth ratios, poor riffle/pool development, and a gravel bottom with fines in low gradient areas. No LWD existed within the bankfull margin of the channel. Pool tails had spawning sized gravels, but the entire stream was trampled and not suitable for spawning. Silt accumulated in slow areas and on aquatic vegetation. No wetland species were found on banks; only grass species. The site had minimal understory with some cinquefoil and sage, but most were browsed. No overstory existed within the site. Many noxious weeds were noted above bankfull including mullein, thistle, and dock-leafed smartweed.

Figure 5-2. Riparian stubble and hummocky banks in ANTE 07-01

The downstream site on Antelope Creek (ANTE 21-01) was located on Montana State Trust Lands. Evidence of overgrazing existed throughout the site, although it appeared that no grazing had occurred for several months prior to sampling. Weeds were prevalent, and no understory or overstory existed. Multiple diversions existed above and below the sampled site. Evidence of channel manipulation occurred in places. A dirt road paralleled the stream, but only directly impacted the stream in a few places.

The downstream site resembled an E5 type channel with little entrenchment and low width/depth ratio; but did not have the sinuosity of an E type channel. The potential stream type is a small C4 type channel. The channel had long poorly developed riffles, abundant fine sediment, and very few pools (which were formed by sloughing bank material). The channel had no woody debris. Eroding banks were generally low and trampled, with hummocking along the entire channel on both sides. Clumps of grass had sheared into the stream in places. Banks were composed of fine material (<2 mm).

Comparison to Water Quality Targets

The existing data in comparison to the targets for Antelope Creek are summarized in **Table 5-11** (See **Figure 5-3** for map)**.** Macroinvertebrate scores and periphyton summaries are found in **Table 5-12**. All bolded cells represent conditions where target values are not met.

Table 5-11. Existing Sediment-Related Data for Antelope Creek Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
ANTE 07-01	B4	3.4	1.1	2.7	**17**	9	4	**8.3**	**2.7**	**0.20**	127	**2**	**2**	**71**
ANTE 21-01	C4	1.2	1.4	7.0	**56**	**36**	8	12.8	24.0	**0.36**	**42**	**0**	1	N/R*

* Not recorded - Although hummocking values were not recorded along the greenline in site ANTE 21-01, field notes and photos indicate that the entire site had hummocky banks.

Table 5-12. Antelope Creek Macroinvertebrate and Periphyton Summary

Site ID - DEQ	Sample Date	Macroinvertebrates		Periphyton	
		O/E Score	Pass/Fail	Impairment Probability	Impairment Class
ANTE 08-01	8/10/11	**0.37**	**Fail**	72.45%	Impaired
ANTE 21-03	8/12/11	**0.28**	**Fail**	55.66%	Impaired

Figure 5-3. Antelope Creek DEQ Assessment Sites

Summary and TMDL Development Determination

Both sites exceeded < 6mm fine sediment targets in riffles and the lower site exceeded the <2 mm fine sediment target value. The upper site failed to meet channel form targets. The lower site did not meet the pool frequency target. Both sites failed to meet residual pool depth and most riparian health targets. Both sites failed to meet the O/E macroinvertebrate score and periphyton samples showed impairment. Current and historical grazing practices contribute to high fine sediment percentages within the stream, which is likely limiting its ability to support fish and aquatic life. Fine sediment values were more than double the target values in riffles in the lower site, pool habitat targets were not met at the lower site, and all greenline targets were not met at either site. Because of these factors and obvious sediment sources, a sediment TMDL will be written for Antelope Creek.

5.4.2.2 Brewster Creek MT76E002_050

Brewster Creek is listed for sedimentation/siltation on the 2012 303(d) List. In addition, Brewster Creek is also listed for low flow alterations; which is a non-pollutant form of pollution commonly linked to sediment impairment. Brewster Creek flows 4.6 miles from the East Fork of Brewster Creek to the mouth (Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed sediment and habitat assessments at two monitoring sites. The upstream site (BREW 05-01) was located on USFS land. The site was located in forest adjacent to USFS road approximately 10 feet from the stream in places. The upper watershed had historically been logged and mined. Evidence of historical logging existed within the riparian area (stumps). No evidence of grazing existed.

The upstream site resembled a B4 type stream, but was similar to an F4b in areas with entrenchment. Stream had a gravel bed with poor riffle development, and long runs and drops created by LWD. Several split channels existed with obvious aggradation. One split channel occurred below a large wood jam. Few fines existed throughout the channel. Pool tails had good spawning sized gravels. Pools were formed by LWD and lateral scour. Eroding banks were well vegetated and undercut with a lot of cobble; and were located on outside meander bends. Erosion was possibly influenced by road encroachment in places, but most erosion appeared to be natural. The site had a very dense understory of birch, currants and raspberry bushes. Some grasses occurred on banks but were mostly forbs. Grass may have been shaded out by dense canopy of tall birch, ponderosa pine and spruce. Some wetland vegetation occurred in the lower part of site and a few weeds (thistle) were noted. Riparian vegetation appears lush and in good health (**Figure 5-4**).

Figure 5-4. Healthy riparian area on Brewster Creek

The downstream site on Brewster Creek (BREW 06-01) was located on private land. Only 800 feet of this site could be surveyed due to access. The site was in a rural residential area, where two homes were within the surveyed site and many residences were upstream (permanent and recreational). Several small bridges existed within the channel (above bankfull). Two diversions existed within the site. Vegetation had been cleared on the left bank adjacent to a residence. A rock wall existed on the same left bank, where a cabin sits 20 feet from the stream. A small pond was present on river right, approximately 25 feet from stream. Historical logging and mining has occurred upstream.

The downstream site resembled an F4 type channel with entrenchment, long runs, poor riffles, and several large plunge/dam pools. Most pools were created by lateral scour. Hand-built rock dams on cell 4 created some pool habitat, but these dams have the potential to be blown out during high flows. A lot of LWD occurred within bankfull, although woody vegetation had been cleared in places adjacent to residences. This site had well vegetated banks with high density roots. A few taller eroding banks existed where downcutting occurs. All banks were slowly eroding, with root mass providing stabilization. The worst eroding banks occurred near bridges. The banks had good grass cover, but no wetland vegetation. A thick understory existed of dogwood, willow, birch, currants and others. A thick overstory existed with cottonwoods and spruce.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Brewster Creek are summarized in **Table 5-13** (See **Figure 5-5** for map). Macroinvertebrate scores are found in **Table 5-14.** All bolded cells represent conditions where target values are not met.

Table 5-13. Existing Sediment-Related Data for Brewster Creek Relative to Targets

					Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
BREW 05-01	B4	2.3	1.3	11.8	10	6	0	13.0	1.9	0.98	**63**	98	0	0
BREW 06-01	B4	2.0	1.4	10.8	6	3	3	**10.8**	1.4	1.36	**59**	85	**42**	0

Table 5-14. Brewster Creek Macroinvertebrate Summary

Site ID - DEQ	Sample Date	Macroinvertebrates	
		O/E Score	Pass/Fail
C02BRWSC10	8/3/04	0.87	Pass

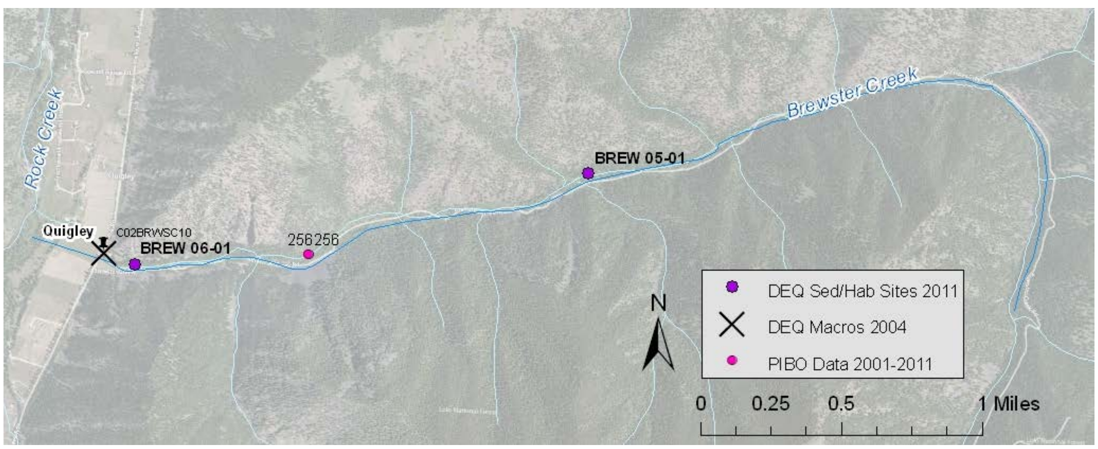

Figure 5-5. Brewster Creek DEQ Assessment Sites

Summary and TMDL Development Determination

Neither site exceeded fine sediment targets in riffles or pools. The lower site failed to meet the width to depth ratio target and the percent bare ground target. Both sites failed to meet pool frequency targets. Macroinvertebrates sampled in 2004 on Brewster Creek met the O/E target score. The upper site on Brewster Creek, despite its location paralleling the road and its historical logging, appeared to be recovering and did not exhibit a sediment impairment. The channel and streamside vegetation at the lower site had been modified by landowners adjacent to the site, with bridges, rip-rap, clearing of the riparian area, and creation of pools by damming. Although the stream appeared to have habitat alterations in areas close to residences on the lower site, there did not appear to be a sediment impairment within the stream and therefore, no sediment TMDL will be written for Brewster Creek. However, additional habitat alterations could lead to a sediment impairment, and therefore a sediment TMDL may be warranted in the future.

5.4.2.3 East Fork Rock Creek MT76E002_020

East Fork Rock Creek is listed for sedimentation/siltation on the 2012 303(d) List. In addition, East Fork Rock Creek is listed for alterations in streamside or littoral vegetative covers and low flow; which are non-pollutant forms of pollution commonly linked to sediment impairment. The East Fork Rock Creek segment flows 9.7 miles from the outlet of the East Fork Rock Reservoir to the mouth (Middle Fork Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed sediment and habitat assessments at two monitoring sites on East Fork Rock Creek. The upper site (EFRK 01-02) was located mostly on USFS land, downstream of the East Fork Rock Creek Reservoir and diversion. The site had rural residents at the lower end and a USFS campground at the upper end. Evidence of rock dams existed across the stream in multiple locations. A pool created for filling water trucks existed near the campground. Hiking and other recreational use existed along banks, including a few constructed crossings.

The upper site was a C-type channel with some entrenchment into F-type channel. Riffles were well developed, while pools were long and wide with cobbles in pool-tails, especially where man-made dams were present. Spawning gravels were in good abundance, but non-typical, and generally occurred on sides of pools, even in dammed pools. Some small lateral scour pools occurred by large wood and willow bunches. Many fish were noted. Most eroding banks were stable, slowly eroding, well-vegetated, undercut, and located on outside meander bends; with patches of bare banks where undercuts had sloughed. Small recreational trails near the USFS campsite had caused patches of eroding banks, which had the potential to expand. Sedges and rushes were abundant along the stream edge with a willow understory and some young conifers. Grass species occurred in abundance upgradient from the stream edge. Weeds were lacking throughout the site.

The downstream site (EFRK 03-03) was located on private property in an agricultural valley. Evidence of historical grazing existed, but the site was likely not grazed in the year the field work occurred. Multiple diversions existed along the valley edge. A headgate and rock dam was located at station 876 with approximately 8 CFS of flow. A bridge existed at the bottom of the site. Moderate recreational use from fishing existed along the banks. Some return flows were noted along the channel, which could be an indication of old side channels. East Fork Reservoir and siphon diversion (the East Fork Irrigation Canal) exist upstream, which affected the flow regime in the stream at the site. An irrigation diversion (dam with tarp) existed just upstream of the site.

The downstream site had a low slope, with riffle dominated habitat, long runs, and minimal pool habitat. Pools were typically formed on inside meander bends or from cobbles and boulders. Existing channel type was a C4. Minimal spawning gravels were noted, typically occurring on inside slope of pools. A split channel existed from station 350 to 410. No wood was noted within the channel. Significant filamentous algae existed and fine substrate accumulated in the dense aquatic vegetation. Most eroding banks were well vegetated, undercut, and located on outside meander bends. Some evidence of past grazing existed, but most banks were sloughing into channel and recovering with strong-rooted wetland vegetation. Some bare banks also occurred where overland flow was entering into the stream channel. The stream edge was dominated by sedges with intermixed rushes. Grass existed on outside bends where sloughing has occurred. Site had no overstory and minimal understory vegetation. Very little willow was noted, with no mature species. Upland grasses were smooth brome, timothy, and canary reed grass. Bull thistle and mustard were also observed.

Comparison to Water Quality Targets

The existing data in comparison to the targets for East Fork Rock Creek are summarized in **Table 5-15** (See **Figure 5-6** for map). Macroinvertebrate scores are found in **Table 5-16.** All bolded cells represent conditions where target values are not met.

Table 5-15. Existing Sediment-Related Data for East Fork Rock Creek Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
EFRK 01-02	C4	0.1	1.7	24.6	6	3	1	22.1	**1.3**	**0.91**	84	**34**	**5**	0
EFRK 03-03	C4	0.9	1.3	21.4	8	3	1	14.3	3.6	**0.96**	**37**	**13**	1	0

Table 5-16. East Fork Rock Creek Macroinvertebrate Summary

Site ID - DEQ	Sample Date	Macroinvertebrates	
		O/E Score	Pass/Fail
C02ROCEF20	7/26/04	**0.33**	**Fail**

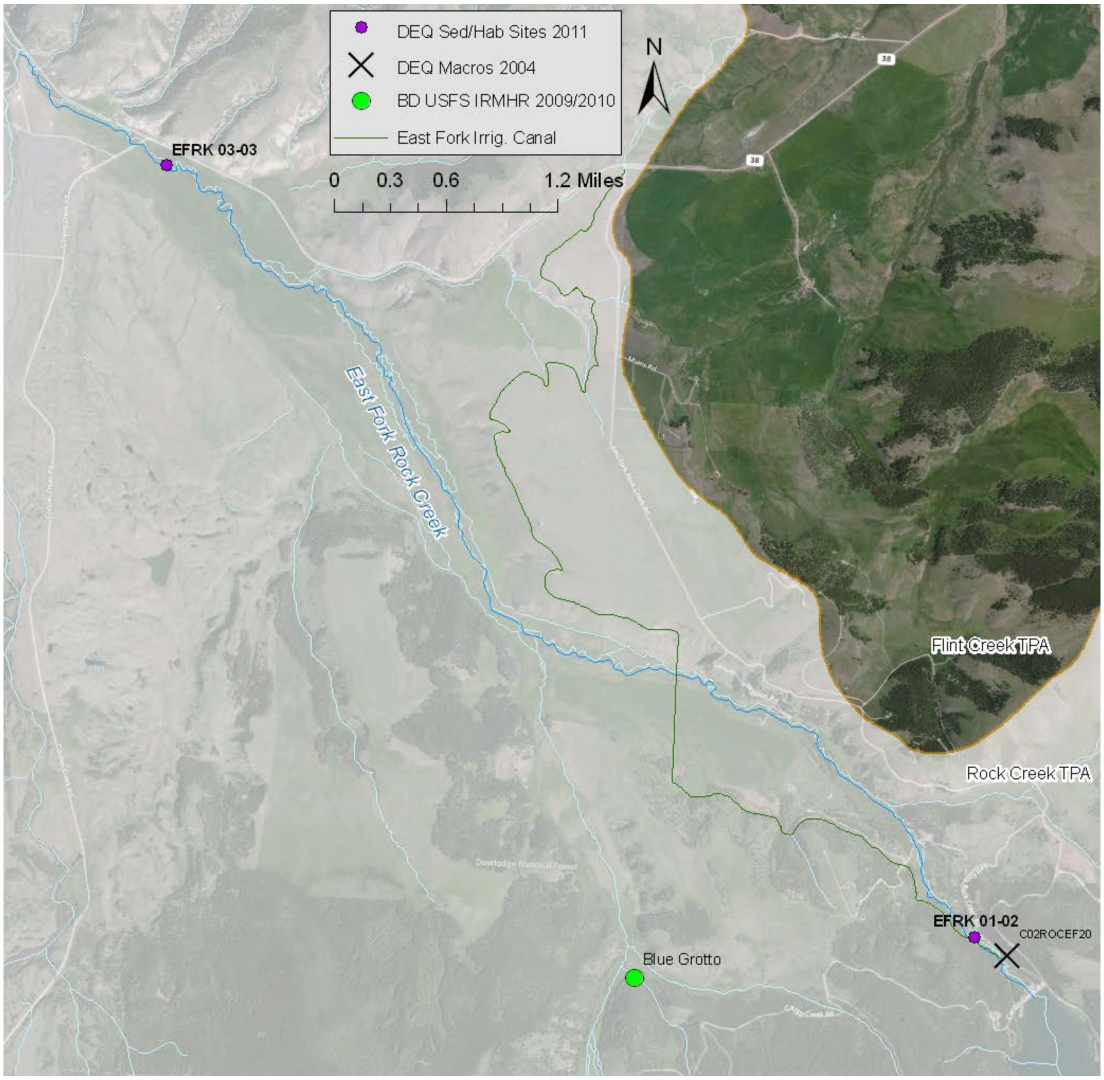

Figure 5-6. East Fork Rock Creek DEQ Assessment Sites

Summary and TMDL Development Determination
Both sites met fine sediment targets in riffles and in pools. Both sites met width to depth ratio targets, but the upper site failed to meet the entrenchment target. Both sites failed to meet residual pool depth and riparian shrub cover. The upper site failed to meet bare ground targets. However, the upstream site did meet the pool frequency target. The macroinvertebrate sample taken in 2004 failed to meet the O/E target score. Both the affected habitat from human manipulation of the stream channel at the upstream site (irrigation, recreation, residential) and grazing along the riparian area are contributing to sediment loading, which is likely limiting its ability to support fish and aquatic life; therefore a sediment TMDL will be written for East Fork Rock Creek.

5.4.2.4 Eureka Gulch MT76E002_090
Eureka Gulch is listed for sedimentation/siltation and solids on the 2012 303(d) List. In addition, Eureka Gulch is listed for alterations in streamside or littoral vegetative covers; which is a non-pollutant form of pollution commonly linked to sediment impairment. Eureka Gulch flows 0.6 miles from the confluence of Basin and Quartz gulches to the mouth (un-named ditch to Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ requested access to perform a sediment and habitat assessment on Eureka Gulch, but was denied access. Therefore, observations from previous assessments and aerial photos (**Figure 5-7**) will be used to evaluate the stream.

Figure 5-7. Aerial Photo of Eureka Gulch

In 1996 and 1997, DEQ visited the Small Miners Exclusion Operation located on Eureka Gulch during high flows in April. The entire gulch bottom was disturbed from the mining operations. According to field notes, water was flowing like chocolate milk (see **Figure 5-8**). An extremely turbid plume of sediment was observed in the receiving waterbody on the T-Heart Ranch, which went from clear to opaque below Eureka Gulch. The lower settling pond was completely full and overflowing in the channel. The upper pond was full of turbid water, but not overflowing. The channel was extremely unstable and cutting vertically, where a diversion existed. Above the mine pit there was a very large amount of aggradation occurring with multiple channels cutting through the recently deposited substrate material. It appeared the material may have washed down from Quartz or Basin gulches.

Figure 5-8. Eureka Gulch in high flows 1997 – both leaving the pond and crossing Rock Creek Rd.

In 2004, DEQ revisited Eureka Gulch. The field crew noted that the whole valley bottom had been placer mined and all that was left was gravel and two ponds. No active mining was observed at the time of the visit. The two ponds were still present with an unstable channel connecting the two. There was very little vegetative growth across the valley bottom, mostly noxious weeds. Both ponds had significant amounts of algae growth. In the summer of 2005, a sediment catch basin was installed. The vegetation was taking some time to re-grow and there were still a lot of weeds present. Eureka Gulch is ephemeral and carries water only during spring runoff. How effective the catch basin has been throughout the last 7 years is unknown and no data or observations were collected at the time of sampling in 2011 due to denial of access to the site.

Comparison to Water Quality Targets

Turbidity was collected during the high flows in 1996 and 1997 and found to be very high, but the extent compared to natural is unknown. Total Suspended Solids (TSS) and turbidity were collected together in 1996. Assuming these TSS concentrations persisted for one week, a score of 9 on the Newcombe and Jensen Scale was achieved." Without associated TSS data from 1997, the impacts are unknown. It can be assumed by using the relative turbidity in 1996, that TSS levels were much higher for a duration in 1997 and were having detrimental effects on aquatic life. In the summer of 2004, the only flow observed was for a very short, spring fed section above the mine pit. The water was very cold and flow was estimated to be 0.3 cfs.

Because there is no existing sediment and habitat data to compare to targets set for the Rock Creek TPA, it is unclear if target values are being met. However, based on what is known about the stream, target values for a B4 channel with a bankfull width less than 15 will apply.

Summary and TMDL Development Determination

In June of 2012, Potentate Mining, LLC started work under Exploration License #00739 to test for placer gold. They are currently placer mining under SMES #46-144. The operation is approved to disturb 2.6 acres and has about $3,500 in obligated bond. They also have just under $6,500 in unobligated bond to draw on if they plan to expand their mining disturbance. This area was historically mined, most recently in the 90's, and because the channel was unstable and contributing large loads of sediment in high runoff events, a new sediment catch basin was installed in 2005. Since access was denied at the time of sampling, it is unclear if conditions in Eureka Gulch have improved. Because of this, the DEQ assumes that conditions are comparable to what they were in the 2004 reassessment and that the gulch has the potential to carry a high sediment load in a heavy spring runoff event; therefore, a sediment TMDL will be written. Eureka Gulch is also listed for solids (suspended bedload), which is a pollutant that falls within the sediment pollutant category. In developing the sediment TMDL, it is assumed that solids are also addressed since satisfying the sediment TMDL targets and sediment allocations addressing both fine and coarse sediment, will result in conditions consistent with reference or naturally occurring conditions.

5.4.2.5 Flat Gulch MT76E002_120

Flat Gulch is listed for sedimentation/siltation on the 2012 303(d) List. Flat Gulch flows approximately 3 miles from its headwaters to the mouth (Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at two monitoring sites on Flat Gulch. The upper site (FLAT 12-01), was located on private property. Cattle grazing was actively occurring within the site. The entire section was heavily trampled with pugging and hummocking along the banks, low grasses, weeds, and browsed alder. A road crossing existed approximately 80 feet upstream of the top of site. Upper hillslopes were bare and were historically logged with many large stumps showing. The stream was trampled throughout, with poor feature development.

The upper site would likely be a B-type channel if grazing were excluded. The channel had some spawning size gravels at cattle crossings and areas without trampling, but mostly fine substrate dominated throughout the channel. LWD was primarily alder bunches with individual pieces smaller than 6 inches in diameter. Trampled eroding banks were found along the entire site, except at browsed alders where cattle could not access the stream, and grasses along banks were grazed down. Upland areas had many noxious weeds including thistle and mullein. Sparse understory consisted of alder and a few small aspen, which had been browsed by cattle. The only overstory consisted of one tall cottonwood and one aspen in the upper part of the site.

The downstream site on Flat Gulch (FLAT 13-01) may have been historically moved from the original channel. Extensive cattle grazing occurred upstream. Logging has historically occurred upstream and within the riparian area. A dirt road parallels within 50 feet of the stream, with a steep bank as a buffer.

At the downstream site, the stream was a B4a type channel with many fines, likely contributed from upstream. The channel had large gravel substrate covered by a layer of fine silt, and a steep slope (around 10% in some locations), with some step-pool development. Riffles were poorly developed throughout the channel. Pools were poor quality scour and LWD dam pools, with many fines and organic debris. A large amount of LWD occurred within the channel, with some aggregates in the stream channel. Banks were stable, with some small vegetated slowly-eroding banks. Some influence from past placer mining and grazing was evident with berms along the channel and hummocky banks. The banks were covered in grass, with some wetland vegetation. A good understory existed with raspberry and alder. Many forbs occurred throughout the site, including some weed species (thistle, mullein, and knapweed). Good overstory occurred throughout the site, with tall firs and a few small conifers.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Flat Gulch are summarized in **Table 5-17** (See **Figure 5-9** for map). Macroinvertebrate scores are found in **Table 5-18.** All bolded cells represent conditions where target values are not met.

Table 5-17. Existing Sediment-Related Data for Flat Gulch Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
FLAT 12-01	B4a	5.1	1.3	2.7	**42**	**31**		**7.0**	**5.1**		**0**	**39**	0	**83**
FLAT 13-01	B4a	5.0	1.2	3.3	**49**	**44**		**11.8**	**4.2**	**0.28**	**84**	63	0	0

Table 5-18. Flat Gulch Macroinvertebrate Summary

Site ID - DEQ	Sample Date	Macroinvertebrates	
		O/E Score	Pass/Fail
C02FLATG01	8/7/09	**0.35**	**Fail**
C02FLATG01	9/11/09	**0.50**	**Fail**
C02FLATG02	8/6/09	**0.50**	**Fail**
C02FLATG02	9/10/09	**0.43**	**Fail**
C02FLATG10	8/7/09	**0.56**	**Fail**
C02FLATG10	9/12/09	**0.56**	**Fail**

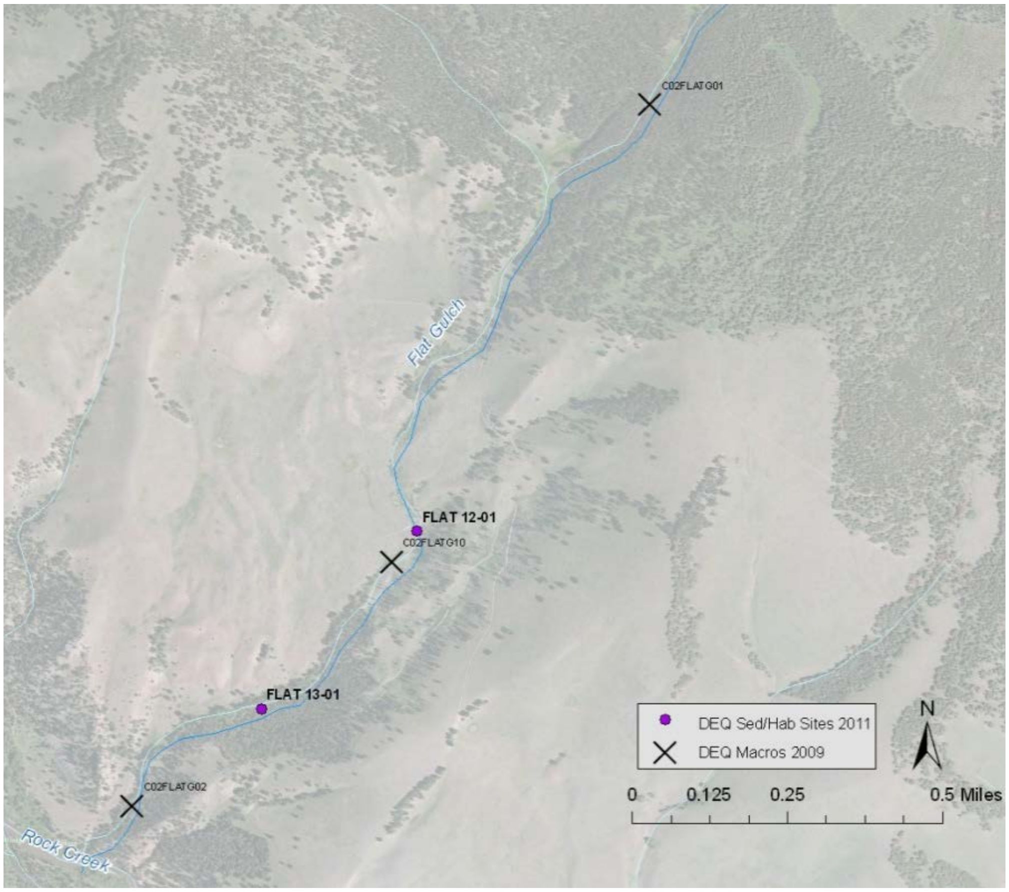

Figure 5-9. Flat Gulch DEQ Assessment Sites

Summary and TMDL Development Determination

Fine sediment targets were well exceeded in riffles. Pool frequency and residual pool depth failed to meet target values in the lower site and no pools were found in the upper site due to a trampled channel. Riparian health throughout the upper site was compromised because of recent browse. All six sites sampled in 2009 for macroinvertebrates failed to meet the O/E macroinvertebrate target score. Current and historical grazing practices contribute to high fine sediment percentages within the stream, which is likely limiting its ability to aquatic life. Because fine sediment targets were more than triple the target values in riffles; and pool habitat targets were not met, a sediment TMDL will be written for Flat Gulch.

5.4.2.6 Miners Gulch MT76E002_160

Miners Gulch is listed for sedimentation/siltation on the 2012 303(d) List. Miners Gulch flows 5.4 miles from its headwaters to the mouth (Upper Willow Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at two monitoring sites on Miners Gulch. The upper site (MINE 10-02), was located USFS land. The site had been logged historically and more recently up to the stream channel. Evidence of past mining existed at the site (small closed adits). The forest road was approximately 100 meters upslope from the channel. Many fines existed throughout the site. There was no evidence of grazing.

The stream at the upper site was a type B4 channel, with a step-pool system and poor riffle development. Pools were formed by boulders and LWD (dam pools), with few lateral scour pools. Many fines existed in pools and throughout the channel. Few spawning-sized gravels were noted. Abundant LWD occurred in the channel, with a mix of individual pieces and alder bunches. Several fish were seen in the stream (4-6 inches in length). The channel had slowly eroding vegetated banks with high root density and mostly natural sources of bank erosion. Despite past logging and mining in the area, banks appeared stable due to dense root mass. Riparian vegetation was thick with alder and currant up to 15 feet tall. Some overstory existed with lodgepole pine, Douglas fir and spruce; although lodgepole appear to be dying. Banks were well vegetated with grasses and sedges. A few weeds occurred in the riparian area, including thistle.

At the downstream site on Miners Gulch (MINE 14-02), historical mining and logging occurred upstream of the site, but there was no evidence of recent activity. The site was in open agricultural land that was historically logged. Hayfields occurred downstream on Upper Willow Creek, but not at the Miners Gulch site. Old cabins and structures existed just upstream of the site.

The stream channel at the downstream site resembled an E4 type channel, with slight entrenchment and a very low width to depth ratio, but lacked the sinuosity of an E-type channel. The channel had poor riffle and pool development. Decent spawning gravels existed, but riffles were somewhat embedded. Pool tails had good spawning gravels, without embeddedness. Pools were mostly lateral scour or dammed by LWD, and were shallow and not well defined. Stable banks occurred throughout the channel, except for two small actively eroding banks. Many slowly eroding banks occurred, but were stabilized with wetland vegetation. All bank erosion sources were natural. Hay grasses (brome and garrison) and wetland vegetation occurred on banks. Many willows existed throughout the site, but there was almost no overstory. The forest canopy existed upstream of the site on BLM land.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Miners Gulch are summarized in **Table 5-18** (See **Figure 5-10** for map). Macroinvertebrate scores are found in **Table 5-20.** All bolded cells represent conditions where target values are not met.

Table 5-19. Existing Sediment-Related Data for Miners Gulch Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
MINE 10-02	B4	4.0	1.0	6.1	**37**	**14**	**14**	**5.8**	**9.2**	**0.65**	158	89	0	0
MINE 14-02	C4	1.5	1.2	6.4	**25**	**13**	**9**	**6.4**	2.2	**0.56**	137	70	0	0

Table 5-20. Miners Gulch Macroinvertebrate Summary

Site ID - DEQ	Sample Date	Macroinvertebrates	
		O/E Score	Pass/Fail
C02MNRSG10	8/2/04	0.70	**Fail**
C02MNRSG20	8/3/04	0.79	**Fail**

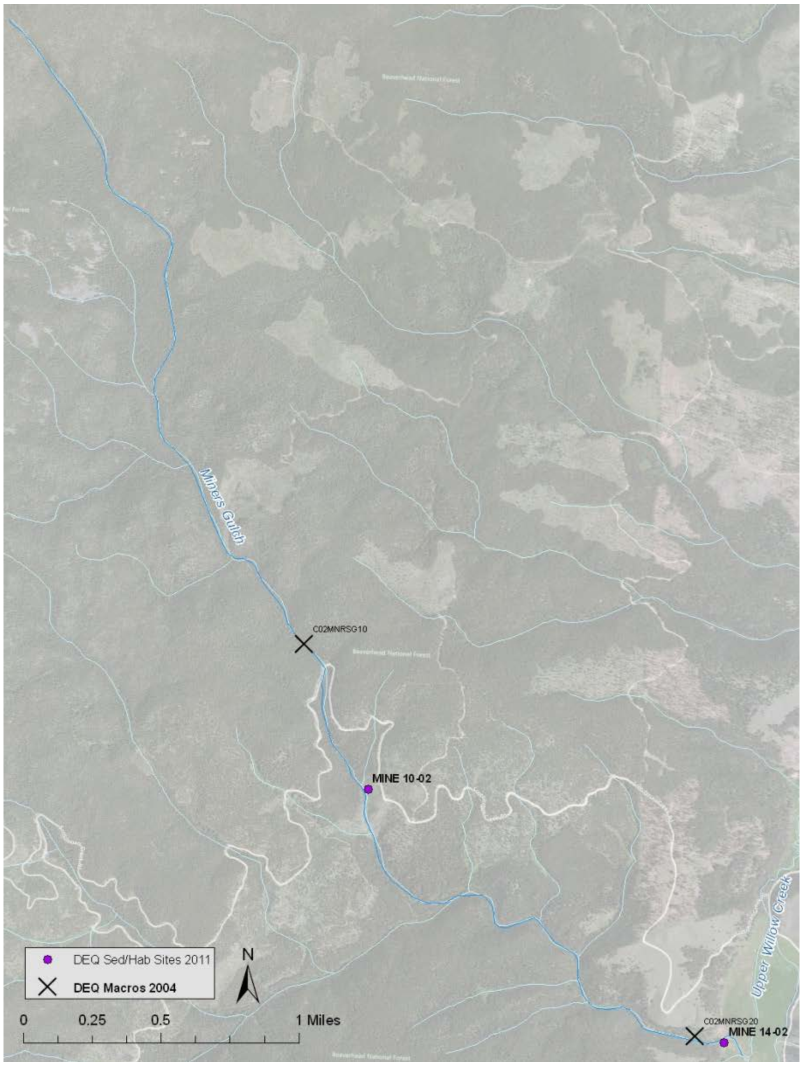

Figure 5-10. Miners Gulch DEQ Assessment Sites

Summary and TMDL Development Determination

Fine sediment targets were exceeded in riffles and pools at both sites. Width to depth ratios failed to meet target values at both sites, and the upper site did not meet the target value for entrenchment. Although pool frequency was good at both sites, residual pool depth at both sites failed to meet the target value. Macroinvertebrates sampled on Miners Gulch did not meet the O/E target score. All greenline targets were met at both sites. Although the stream channel seems to be recovering, the data show a fine sediment issue, which is likely limiting its ability to support fish and aquatic life. Because fine sediment targets were not met in riffles or pools and residual pool depth targets were not met, a sediment TMDL will be written for Miners Gulch.

5.4.2.7 Quartz Gulch MT76E002_070

Quartz Gulch is listed for sedimentation/siltation on the 2012 303(d) List. In addition, Quartz Gulch is listed for alterations in streamside or littoral vegetative covers; which is a non-pollutant form of pollution commonly linked to sediment impairment. Quartz Gulch flows 3.4 miles from its headwaters to the mouth (Eureka Gulch).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at one monitoring site on Quartz Gulch. The site (QUTZ 09-01), was located on USFS land. The site was in a forested section just downstream of a constructed settling pond. The site appeared to have had restoration work, with cut LWD in the upper part of the site and geotextile fabric near the settling pond. The upland slopes had been logged recently, with a large clearcut upstream. Mining had occurred upstream and downstream of the site. An obliterated forest road ended at the top of the site near the settling pond. Some evidence of cattle grazing existed including cow manure and hummocky banks. A staff gage, with peak flow indicator, was located in cell 3. The seasonal peak flow measured approximately 0.4 to 0.5 feet on the gage.

At the site, the stream channel was entrenched throughout, with a riffle/pool sequence dominated by 32-45 mm size gravels and few fines. The low bankfull elevation (0.4 feet above the water surface) was likely buffered by the settling pond upstream of the site. Good riffles existed, with some point bar development. Pools were mostly dammed and plunge pools with LWD. Good spawning gravels existed in pool tails, with few fines. The lower cells (1-3) had a lower gradient than the upper cells (4-5). Well vegetated slowly-eroding banks occurred on outside meander bends, as the stream downcut and moved. Erosion created sloughed banks that became part of the active channel. Riparian vegetation was mostly grass and forbs on banks, with wetland vegetation on low banks. Large amounts of LWD occurred in the stream channel. The understory was composed of diverse willow, small conifers, raspberry, and chokecherry. Some small aspen were observed. Canopy was dense with old tall aspen, spruce, and Douglas fir.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Quartz Gulch are summarized in **Table 5-21 (**See **Figure 5-11** for map). Macroinvertebrate scores are found in **Table 5-22.** All bolded cells represent conditions where target values are not met.

Table 5-21. Existing Sediment-Related Data for Quartz Gulch Relative to Targets

					Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health			Sediment supply
Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking	RSI
QUTZ 09-01	A4	4.3	1.2	4.7	**14**	6	**18**	**12.6**	1.4	**0.52**	158	83	0	0	71

Table 5-22. Quartz Gulch Macroinvertebrate and Periphyton Summary

Site ID	Sample Date (DEQ)	Macroinvertebrates		Periphyton	
		O/E Score	Pass/Fail	Impairment Probability	Impairment Class
QUTZ 08-01 (U.S.)	8/9/11	**0.78**	**Fail**	72.45%	Impaired
QUTZ 08-01 (D.S)	8/9/11	0.85	Pass	95.00%	Impaired

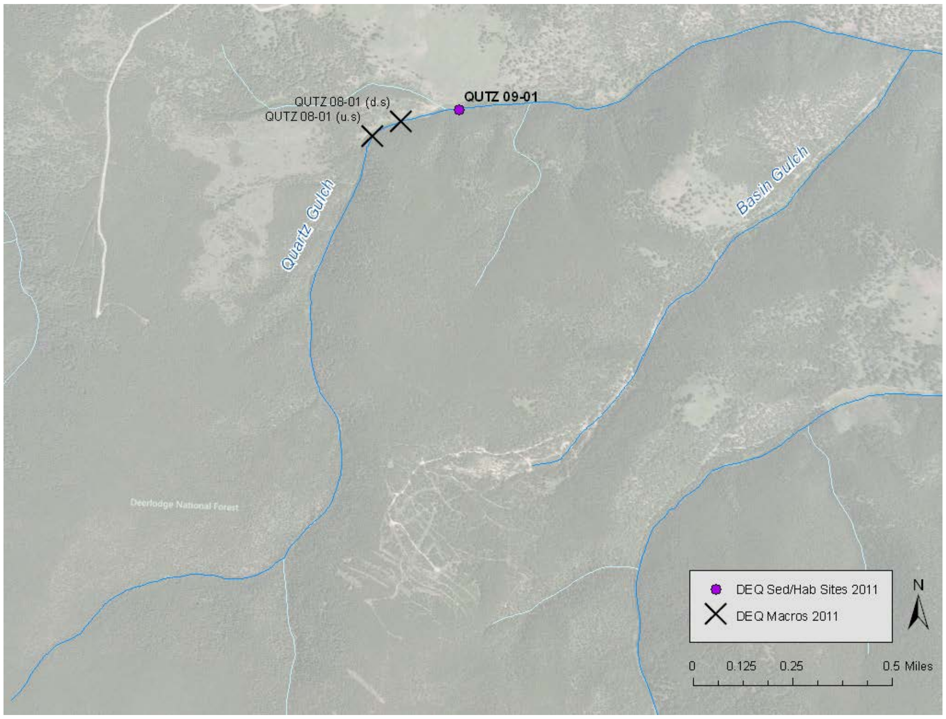

Figure 5-11. Quartz Gulch DEQ Assessment Site

Summary and TMDL Development Determination

Fine sediment in the channel exceeded the target values for percent less than 6 mm in riffles and in pools. Both the width to depth ratio and residual pool depth failed to meet target values. Historical placer mining in the gulch, timber harvest, and grazing impacts have contributed sediment to the stream. Macroinvertebrates did meet target scores at the downstream site, and just failed to meet target values at the upstream site. Although some restoration work has occurred and the stream seems to be in a state of recovery; fine sediment targets were exceeded in both riffles and pools, and width to depth ratio and residual pool depth targets were not met. Therefore, a sediment TMDL will be written for Quartz Gulch.

5.4.2.8 Scotchman Gulch MT76E002_100

Scotchman Gulch is listed for sedimentation/siltation on the 2012 303(d). Scotchman Gulch flows 6.9 miles from its headwaters to the mouth (Upper Willow Creek).

In 2011, DEQ performed sediment and habitat assessments at two monitoring sites on Scotchman Gulch. The first site (SCOT 08-01), was located on USFS land. At the upper site (SCOT 08-01); the lower portion of the site appeared to be modified by mining, and overwidened in places. The entire site was recently fenced around the riparian area, with solar electric fence installed (August 2011). A good riparian buffer existed on both sides of channel. Recent restoration may have occurred. Young willows were flagged in meadow sections of cells 4 and 5. Hummocky banks throughout the site suggested past grazing, but no recent evidence existed.

The stream channel at the upper site was in forest in the bottom three cells and in open meadow in the upper two cells. Large boulders existed in cell 3. No riffles existed in the meadow cells. Many fines were observed, with few spawning gravels. Pools were primarily lateral scour and LWD dam pools. Some LWD existed in the stream channel within the forested section. Eroding banks were primarily slowly-eroding vegetated banks that were recovering from heavy grazing. Many were overhanging and sloughing into the stream. The lower section of the site had berms from historical placer mining. The site had good overstory and understory in the bottom forested cells. Alder and willow made up the understory; with old aspen, Douglas fir, and lodgepole pine in the canopy. A few young aspens existed, but not many mid-aged aspens were found. Cattle exclusion (riparian fencing) could have been helping aspen recruitment. The meadow section had primarily grass (brome, timothy) and some young willows. The bottom of the site had some wetland vegetation, but grasses occurred throughout most of channel.

The lower site (SCOT 16-02) was located up from the mouth of stream in the middle of a hay field. Hay was cut within 10 feet of the stream channel. Upstream from the site the land was historically logged and mined. A small culvert occurred within the channel at station 370-380 for movement of hay equipment, but the culvert appeared to have little effect on stream morphology. A road crossing and small cabin existed just upstream of the site.

The stream at the lower site was engulfed in tall uncut hay grass and formed a stable channel with steep well vegetated banks. Bankfull was located at the top of the bench at the base of grasses. The stream channel was not entrenched and had access to the floodplain within hay grasses. The channel consisted of a crude step-pool type system, with no true riffles and some run-type features below pools. An abundance of fine sediment occurred within larger substrate, which was well embedded. Lower cells had lateral scour pools with no spawning gravels. The upper cells had rock dam pools with some spawning gravels. No LWD occurred within the channel. Slowly-eroding well-vegetated banks occurred on both sides of the stream. Undercut banks existed on meander bends. Thick hay grasses engulfed the entire stream channel. Some forbs were interspersed, but rare. One willow occurred at the bottom of the site, but hay grasses dominated throughout the site.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Scotchman Gulch are summarized in **Table 5-23** (See **Figure 5-12** for map). Macroinvertebrate scores are found in **Table 5-24.** All bolded cells represent conditions where target values are not met.

Table 5-23. Existing Sediment-Related Data for Scotchman Gulch Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
SCOT 08-01	B4	2.6	1.1	6.6	**55**	**22**	**79**	**9.7**	1.9	**0.68**	158	**40**	0	0
SCOT 16-01	E4b	3.8	1.2	2.3	**59**	**45**	**26**	2.8	167.7	**0.43**	190	**7**	0	0

Table 5-24. Scotchman Gulch Macroinvertebrate Summary

Site ID - DEQ	Sample Date	Macroinvertebrates	
		O/E Score	Pass/Fail
C02SCTMG10	8/1/04	**0.77**	**Fail**
C02SCTMG20	8/2/04	0.87	Pass
C02SCTMG01	8/5/09	0.81	Pass
C02SCTMG01	9/15/09	0.81	Pass
C02SCTMG02	8/5/09	**0.56**	**Fail**
C02SCTMG02	9/13/09	**0.63**	**Fail**
C02SCTMG10	8/7/09	**0.77**	**Fail**
C02SCTMG10	9/14/09	0.84	Pass
C02SCTMG20	8/6/09	0.87	Pass
C02SCTMG20	9/12/09	**0.58**	**Fail**

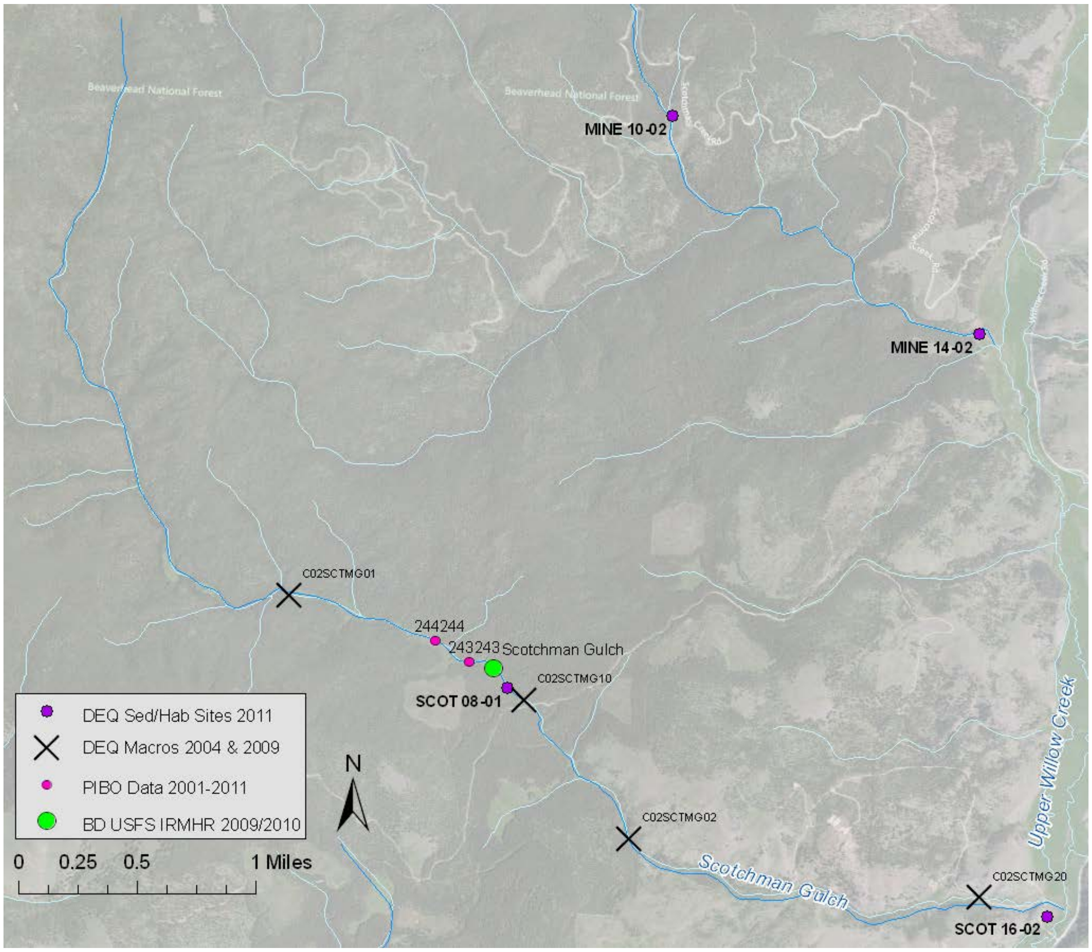

Figure 5-12. Scotchman Gulch DEQ Assessment Sites

Summary and TMDL Development Determination

Both sites far exceeded target values for fine sediment in riffles and pools. The upper site failed to meet width to depth ratios. Both sites failed to meet residual pool depth targets and understory shrub cover. The field measurements and observations indicate that fine sediment liberated from banks due to grazing (both historical and recent activities) and historical placer mining operations have contributed excess sediment loading to the stream that is likely limiting its ability to support fish and aquatic life; therefore, a sediment TMDL will be prepared for Scotchman Gulch.

5.4.2.9 Sluice Gulch MT76E002_110

Sluice Gulch is listed for sedimentation/siltation on the 2012 303(d) List. In addition, Sluice Gulch is listed for alterations in streamside or littoral vegetative covers; which is a non-pollutant form of pollution commonly linked to sediment impairment. Sluice Gulch flows 6.3 miles from the headwaters to the mouth (Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at two monitoring sites on Sluice Gulch. At the upper site (SLUI 14-01) some evidence of historical grazing existed within the riparian area. A forest road paralleled the channel on river left; although, it did not appear to directly impact the stream. An old road grade existed closer to stream on river left, but it had been re-vegetated and contained many weeds.

The upper site was riffle dominated and moderately steep, with very few pools. Some entrenchment existed from downcutting, although much of the channel resembled a B4 type stream. The substrate was mainly gravel and cobbles. Pools were on steep outside meander bends or caused by LWD, which was lacking throughout the channel (only 2 individual pieces). Banks were relatively stable and recovering from historic grazing. Eroding banks were slowly eroding and well vegetated with grasses and weeds and had abundant surface protection from cobble. Eroding banks mainly occurred on outside meander bends. Some juniper understory existed, but was mostly lacking throughout the site. Mature aspen were found in the upper portion of the site, and ponderosa pine, spruce and juniper were encroaching upon the stream channel in the lower part of the site. Several weed species were noted; including thistle, mullein, and dock leafed smartweed.

Historical mining occurred both upstream from and at the lower site (SLUI 18-02). Tailings and placer workings were noted and the channel appeared to have been manipulated and channelized. The latest NHD high and mid resolution GIS layers show the stream in a different location than where it existed at the time of sampling. Some cattle grazing occurred along the riparian area, with animal crossings noted. Weeds were prevalent throughout the site.

The stream at the lower site had poorly developed features. Riffles were not well defined and a high amount of fines were noted. Pools were formed by lateral scour, with poorly developed pool tails. Some spawning gravels were noted in pool tails. Abundant algae and debris existed within the channel. The banks were stable and well vegetated, with tall grasses on both sides of the channel. Signs of grazing existed from the past year, which had created hummocky banks; however, at the time of sampling they were covered with tall grasses and appeared to be recovering. Grasses trapped silt that was released into the stream when banks were stepped on. The tall grasses and wetland vegetation covering the banks were primarily timothy grass and sedges. Some willows were present at the lower end of the site. One mature spruce tree and one mature cottonwood in the upper cells were the only canopy cover within the site. Several weed species were noted, including thistle and knapweed in the upper part of the site.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Sluice Gulch are summarized in **Table 5-25**. (See **Figure 5-13** for map). Macroinvertebrate scores are found in **Table 5-26.** All bolded cells represent conditions where target values are not met.

Table 5-25. Existing Sediment-Related Data for Sluice Gulch Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
SLUI 14-01	B4a	2.5	1.3	6.9	**14**	2	**10**	**11.2**	1.9	**0.37**	**63**	**5**	0	0
SLUI 18-02	C4	2.0	1.2	6.9	**50**	**25**	**10**	13.6	**16.0**	**0.49**	158	**1**	0	0

Table 5-26. Sluice Gulch Macroinvertebrate Summary

Site ID - DEQ	Sample Date	Macroinvertebrates	
		O/E Score	Pass/Fail
C02SLUCG03	8/2/11	**0.78**	**Fail**
C02SLUCG02	8/2/11	**0.51**	**Fail**
C02SLUCG01	8/2/11	**0.43**	**Fail**

Figure 5-13. Sluice Gulch DEQ Assessment Sites

Summary and TMDL Development Determination

Fine sediment targets were exceeded for percent less than 6mm at riffles and pools at both sites and for fines less than 2mm in riffles at the lower site. The width to depth ratio at the upper site did not meet the target value. Residual pool depth targets were not met at either site; and the pool frequency target at the upper site was not met. Greenline understory shrub cover targets were not met at either site. Macroinvertebrates failed to meet the O/E target score. Current and historical grazing and channel manipulation on Sluice Gulch have contributed fine sediment to the stream which is likely limiting its ability to support fish and aquatic life. Because fines were notably high in field observations and field measurements showed that fine sediment targets were not being met, a sediment TMDL will be written for Sluice Gulch.

5.4.2.10 South Fork Antelope Creek MT76E002_060

South Fork Antelope Creek is listed for sedimentation/siltation on the 2012 303(d) List. In addition, South Fork Antelope Creek is listed for alterations in streamside or littoral vegetative; which is a non-pollutant form of pollution commonly linked to sediment impairment. South Fork Antelope Creek flows 2.9 miles from its headwaters to the mouth (Antelope Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at two monitoring sites on South Fork Antelope Creek. The upper site (SFAN 06-01), was located on private land. The site was in a forested area with significant grazing impacts. Hummocky banks occurred throughout the channel. Cattle were actively grazing upstream of the site. An old road existed approximately 5 to 30 feet from the stream. Upper hillslopes had been logged within the last 10 years, with some burnt slash piles just upstream of the site. Old cabins existed upstream in the grazed area.

The stream at the upper site resembled a C4b or E4b stream type, but did not have the sinuosity of an E-type stream and had a relatively high slope (4.5%). The potential stream type is likely C4b or B4. Pools were short and generally plunge type pools with LWD or boulders. Few spawning gravels existed. The stream mostly had long riffle/run sections, but resembled more of a step-pool type system in steeper sections. The lower site (cells 1 and 2) had a 4% slope, but the gradient increased to 8% in the steep middle section and was 3% in cell 5 (the flat portion of upper site). Abundant fine sediment occurred in most areas. Some LWD appeared mobile, but bigger pieces were anchored below bankfull depths. Both sides of the stream were heavily trampled by cattle throughout the entire channel, except for one section on river right between stations 244 and 356 where the bank was naturally armored with rock from a cliff above. Banks were held together with grasses and were very hummocky. This site had mostly grasses on banks but some wetland species (rushes and sedges) existed in the upper cells. A few forbs were noted, including cinquefoil in the upper site. The canopy had approximately 25% cover with lodgepole pine and spruce. Weeds were noted throughout the site, including thistle, knapweed and mullein.

The lower site (SFAN 13-01) was heavily trampled from cattle grazing. Hummocky banks existed throughout the channel, with short grazed grasses and shrubs. A culvert and road crossing existed at the bottom of the site. Slopes above the site had been logged and evidence of recent fire existed in the upper site.

The stream at the lower site was a steep (5+% slope) C4b/C5b type channel. The potential stream type was likely a B4. The channel was heavily trampled with poor riffle and pool features. Many fines existed throughout the channel. Some plunge type drops created some pool habitat. Few to minimal spawning gravels existed throughout the channel. Some LWD occurred in the form of willow clumps and dead logs from fire. Riffles were overwidened from grazing. Despite the human impacts on the stream, several fish were noted at time of sampling. Eroding banks were slowly-eroding and well-vegetated, with dense root mass. Heavy riparian grazing along the stream caused hummocky banks, which allowed the banks to slough off in places and cause fine sediment to enter the stream. Sedges were dominant throughout the site, with rushes in the upper portion. Recruitment of shrubby cinquefoil and aspen were noted in the lower cells, however, all plants were less than 2 feet tall and showed evidence of browsing by cattle. Many weeds occurred in upland areas, including thistle, knapweed and mullein.

Comparison to Water Quality Targets

The existing data in comparison to the targets for the South Fork Antelope Creek are summarized in **Table 5-27** (See **Figure 5-14** for map). All bolded cells represent conditions where target values are not met.

Table 5-27. Existing Sediment-Related Data for South Fork Antelope Creek Relative to Targets

Site ID	Target Stream Type	Field Slope (Percent)	Calculated Sinuosity	Mean BFW (ft)	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health		
					% < 6mm (mean)	% < 2mm (mean)	Pool % < 6mm (mean)	Width/Depth Ratio (mean)	Entrenchment Ratio (median)	Residual Pool Depth (ft)	Pools / Mile	Greenline % Shrub Cover	Greenline % Bare Ground	Greenline % Hummocking
SFAN 06-01	B4	4.5	1.1	3.6	**29**	10	**11**	**11.6**	**5.3**	**0.37**	211	**8**	0	**95**
SFAN 13-01	B4	5.3	1.1	6.5	**41**	**18**	**21**	12.2	**4.4**	**0.48**	**116**	**11**	0	**7**

Figure 5-14. South Fork Antelope Creek DEQ Assessments

Summary and TMDL Development Determination

Fine sediment targets were exceeded for percent less than 6mm at riffles and pools at both sites and for fines less than 2mm in riffles at the lower site. The width to depth ratio target at the upper site failed to meet the target value and the entrenchment ratio at both sites did not fall within the target range. Residual pool depth targets were not met at either site; and the pool frequency target was not met at the lower site. Both sites failed to meet understory shrub target and hummocking target vales. Both instream pool habitat targets were not met. Current grazing is contributing a significant amount of fines to South Fork Antelope Creek, which is likely limiting its ability to fully support fish and aquatic life. Because fines were notably high in field observations and field measurements showed that fine sediment targets were not being met, a sediment TMDL will be written for South Fork Antelope Creek.

5.4.2.11 Upper Willow Creek MT76E002_040

Upper Willow Creek was not listed for sedimentation/siltation on the 2012 303(d) List. However, because of observations of potential sediment sources during field reconnaissance and because Upper Willow Creek is listed for alterations in streamside or littoral vegetative covers, low flow alterations, and physical substrate (which are non-pollutant forms of pollution commonly linked to sediment impairment), the stream was assessed by the DEQ. Upper Willow Creek flows 21.7 miles from its headwaters to the mouth (Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at two monitoring sites on Upper Willow Creek. The upper site (UWIL 11-05) was located on private land. The channel at the upper site was in a hayfield with approximately 100 feet of uncut grass buffer on each side. Beaver had been eradicated from the area. The site was historically logged upstream and up to the stream channel. No evidence of recent grazing existed, but the site may have historically been grazed.

The stream at the upper site was a C4 type channel with some point bar development and dominated by riffle/run type habitat. Large gravels existed throughout the channel, with few fines noted. The substrate was not embedded. Few quality pools and spawning gravels existed. The channel appeared to be slightly straightened. LWD was mostly dead mature willow bunches browsed by beaver. New willows were establishing within the dead willow bunches. Eroding banks were mostly slowly-eroding and well-vegetated. Some actively eroding banks were stratified with a cobble layer below a clay layer. The banks were dominated by grass species (primarily garrison) with some wetland species (rushes and sedges). A few small willow bunches existed, with no overstory.

The lower site (UWIL 15-02) was in a hayfield, with hay cut 10 feet from the channel in places and up to 50 feet of uncut buffer in other locations. Some signs of grazing occurred at the site. Hummocky banks, sloughing, and low benches occurred in places. Upstream land use was mostly hay fields, with recent and historical logging and mining in tributary streams. A paved highway existed approximately 300 feet from the stream on river left. A bridge for hay equipment existed approximately 200 feet downstream of the bottom of the site.

At the lower site, the stream was a typical C4 type channel, with some point bar development and a consistent riffle/pool sequence. Substrate was not embedded, with few fines. Some good spawning gravels existed in pool tails. LWD was mostly comprised of willow bunches on banks. Riffles were mostly transverse-type riffles on corners, and pools were typically lateral scour. Two eroding bank types occurred, both on outside meander bends. One was an actively eroding type, with sloughing banks. The other type was a well vegetated undercut bank. Sources of erosion were cropland, grazing, and natural.

Hay grasses (brome and garrison) and reed canary grass occurred on banks throughout the site. Some understory and taller canopy of willows existed. Grasses on banks were dense, but a short (10 foot) buffer existed in places where hay was cut close to stream.

Comparison to Water Quality Targets

The existing data in comparison to the targets for Upper Willow Creek are summarized in **Table 5-28**. The macroinvertebrate bioassessment data for Upper Willow Creek is located in **Table 5-29** (See **Figure 5-15** for map). All bolded cells represent conditions where target values are not met.

Table 5-28. Existing Sediment-Related Data for Upper Willow Creek Relative to Targets

					Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health			Sediment Supply
Site ID	**Target Stream Type**	**Field Slope (Percent)**	**Calculated Sinuosity**	**Mean BFW (ft)**	**% < 6mm (mean)**	**% < 2mm (mean)**	**Pool % < 6mm (mean)**	**Width/Depth Ratio (mean)**	**Entrenchment Ratio (median)**	**Residual Pool Depth (ft)**	**Pools / Mile**	**Greenline % Shrub Cover**	**Greenline % Bare Ground**	**Greenline % Hummocking**	**RSI**
UWIL 11-05	C4	1.6	1.1	19.7	9	7		17.1	4.4	**1.08**	**32**	**18**	0	0	
UWIL 15-01	C4	0.5	2.3	21.1	11	7	**14**	16.5	10.2	2.11	74	**36**	0	0	**80**

Table 5-29. Upper Willow Creek Macroinvertebrate and Periphyton Summary

Site ID - DEQ	Sample Date	Macroinvertebrates		Periphyton	
		O/E Score	Pass/Fail	Impairment Probability	Impairment Class
UWIL 11-05	8/8/11	**0.57**	**Fail**	55.14%	Impaired
UWIL 15-01	8/8/11	**0.6**	**Fail**	37.43%	Unimpaired

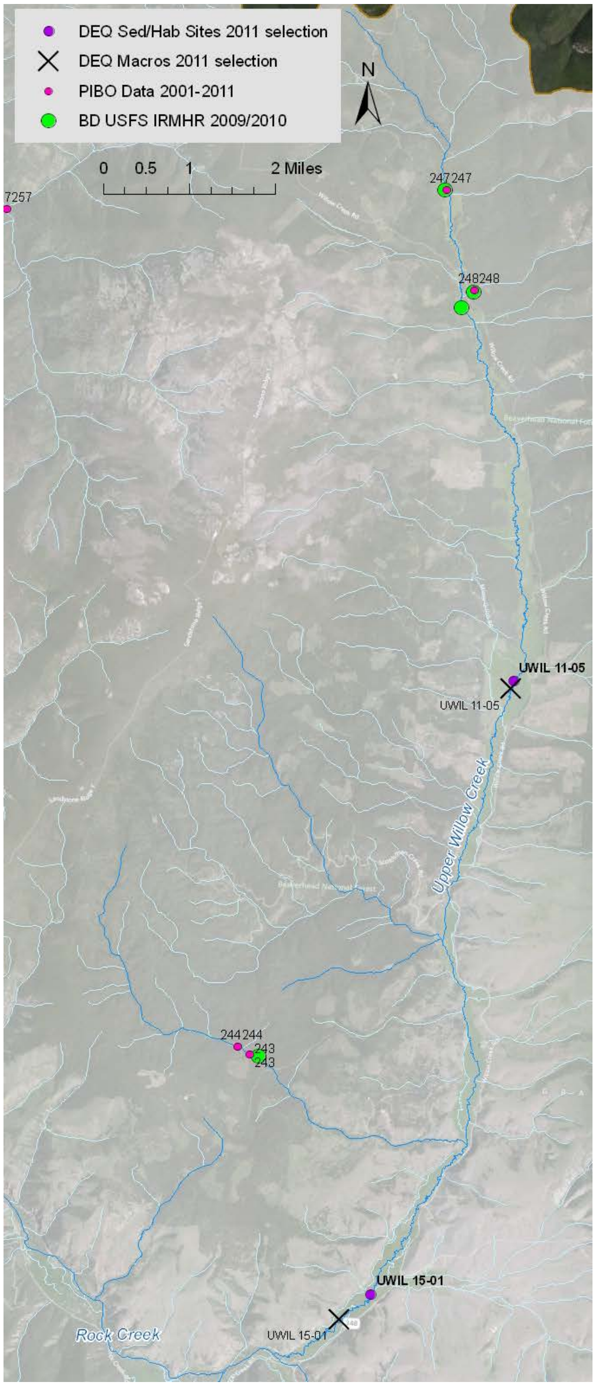

Figure 5-15. Upper Willow Creek DEQ Assessment Site and Macro Sites

Summary and TMDL Development Determination

Upper Willow Creek met most of the fine sediment targets, except for pool fines less than 6mm in the lower site. The upper site did not meet residual pool depth and pool frequency targets. Both sites did not meet the greenline understory shrub cover targets. And the lower site did not meet the RSI target. Macroinvertebrate O/E scores did not meet target values. Although Upper Willow Creek does appear to have some issues with instream and riparian habitat, the stream does not appear to have a sediment issue, therefore, a sediment TMDL will not be written for Upper Willow Creek.

5.4.2.12 West Fork Rock Creek MT76E002_030

West Fork Rock Creek was not listed for sedimentation/siltation on the 2012 303(d) List; however, because of observations of sediment sources during field reconnaissance in June of 2011, the stream was assessed by the DEQ. West Fork Rock Creek flows 25.2 miles from its headwaters to the mouth (Rock Creek).

Physical Condition and Sediment Sources

In 2011, DEQ performed a sediment and habitat assessment at three monitoring sites on West Fork Rock Creek. The upstream site (WFRK 14-03), was located on USFS land. The channel had been subjected to previous restoration attempts with numerous large logs and wood structures within the stream channel. Deep pools all had constructed wood structures that were anchored with large boulders. Many large cut logs had also been placed in the stream, some with metal rebar. The site appeared to have been historically grazed, but no evidence of grazing existed in the year of sampling. Logging and mining has likely occurred in the watershed above the sample site. A campsite existed at the lower end of the site, and debris was noted throughout the channel, including cans, bullet casings, and clay pigeons.

At the upstream site, the stream was an F5 type channel with low entrenchment values, high width/depth ratio, poor riffles, long compound pools connected by short runs, and a coarse sandy bottom (weathered granite) with some exposed gravels. Numerous pieces of LWD existed in the stream, but very few appeared natural. Some spawning sized gravels were noted. Old oxbows were evident outside of the channel. Man-made wood structures within the stream appeared to provide little benefit. More fine substrate was noted in the upper cells of the site. Streambanks were recovering from past grazing. Bank heights ranged from 1.7 to 4.6 feet and were all well vegetated, undercut and slowly eroding. There were many spots where overhanging banks had sloughed off in to the channel, leaving behind exposed banks. One large eroding bank may have been created by excavation outside of the stream channel on river right. Sedges existed on most banks, except where banks have sloughed into the channel and created grassy banks. The understory was composed of some small lodgepole pine and willow. No mature willows were noted within the site. The canopy was composed of one individual lodgepole pine. A good mix of forbs and grasses were noted outside of the stream channel.

The middle site (WFRK 27-02) was located in a forested area downstream of a bridge located on Skalkaho Road. A cabin existed on river left approximately 200 feet from the stream in cell 4. Evidence of recent grazing existed with short grasses and fresh cow dung in the upland area. The cabin area had a rock wall approximately 30 feet from the stream, with some clearing of vegetation. The site received some recreational use from fishermen. Logging had occurred in the upper watershed, and mining and ranching occurred downstream of the site.

The stream at the middle site was a B3 type channel with moderate entrenchment. At the upper cells, a step-pool system existed, but it became complicated by LWD jams and split channels in the middle cells. Compound pool habitat existed around wood jams, with short fast runs and poor riffles. Many large boulders existed with some fines accumulating in pocket water behind boulders. Pools tails did not contain many good spawning gravels. Abundant algae and vegetation were noted on rocks. The banks were well vegetated on both sides and had been undercut, allowing large trees to fall into the river during high flow. Sand had accumulated where trees have fallen into the channel. One tall bank on river left was actively eroding, but it was well armored by large cobble and boulders at the bottom of the bank. Banks were generally covered with sedges and rushes throughout the site. Many forb species were noted in the middle cells. The understory consisted of alder, birch, dogwood, and small conifers. The forest canopy consisted of mature fir and spruce, with abundant deadfall.

The downstream site (WFRK 30-02) was located on USFS land in the valley bottom. The upper cells were adjacent to the highway and had been channelized. The upper watershed (along Skalkaho Road) had been logged and mined both historically and recently. A highway bridge was within 500 feet of the top of the site. The site may have historically been grazed but showed no evidence of recent grazing. The site received minor recreational use from fishermen.

The stream at the downstream site was a typical C4b type channel in lower cells with good point bar development, good riffles, large pools, and some LWD (mostly willow clumps). The upper cells were encroached by the highway and more entrenched, similar to an F4b type channel. The stream appeared to be downcutting along the highway. Features in upper cells were not as well defined, with runs instead of riffles and increased fines. Considerable growth of aquatic vegetation and algae was noted. Eroding banks were mostly well-vegetated undercut banks, with a stratified cobble layer eroding on outside meander bends. As the cobble layer eroded and undercut, the top layer of vegetated bank slumped over and was eventually reforming banks. Banks ranged in height from 2 to 4 feet, which prevented establishment of wetland vegetation and made banks more prone to erosion. There were a few actively eroding banks with steep bank angles. The banks were well vegetated with grass species. Good understory existed with small and large willow clumps. Good wetland vegetation occurred on benches and sloughed banks, but tall banks prevented establishment of wetland vegetation, especially in entrenched areas. Some overstory existed from tall willows. Vegetation appeared stable and robust. A few noxious weeds were noted, including thistle, mullein and knapweed.

Comparison to Water Quality Targets

The existing data in comparison to the targets for West Fork Rock Creek are summarized in **Table 5-30** (See **Figure 5-16** for map). Macroinvertebrate scores are found in **Table 5-31**. All bolded cells represent conditions where target values are not met.

Table 5-30. Existing Sediment-Related Data for West Fork Rock Creek Relative to Targets

					Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat		Riparian Health			Sediment Supply
Site ID	**Target Stream Type**	**Field Slope (Percent)**	**Calculated Sinuosity**	**Mean BFW (ft)**	**% < 6mm (mean)**	**% < 2mm (mean)**	**Pool % < 6mm (mean)**	**Width/Depth Ratio (mean)**	**Entrenchment Ratio (median)**	**Residual Pool Depth (ft)**	**Pools / Mile**	**Greenline % Shrub Cover**	**Greenline % Bare Ground**	**Greenline % Hummocking**	**RSI**
WFRK 14-03	C4	1.5	3.0	28.8	**45**	**13**	**20**	22.7	**1.3**	1.66	**32**	**24**	**8**	0	
WFRK 27-02	B3	2.0	1.1	35.5	**13**	1		**21.3**	1.9	1.51	**42**	**31**	**13**	0	
WFRK 30-02	C3	1.8	1.3	44.2	7	3	0	**30.1**	**1.9**	1.73	**14**	**52**	0	0	66

Table 5-31. West Fork Rock Creek Macroinvertebrate and Periphyton Summary

Site ID - DEQ	Sample Date	Macroinvertebrates		Periphyton	
		O/E Score	Pass/Fail	Impairment Probability	Impairment Class
WFRK 14-03	8/10/11	**0.4**	**Fail**	25.49%	Unimpaired
WFRK 30-02	8/10/11	**0.43**	**Fail**	32.50%	Unimpaired

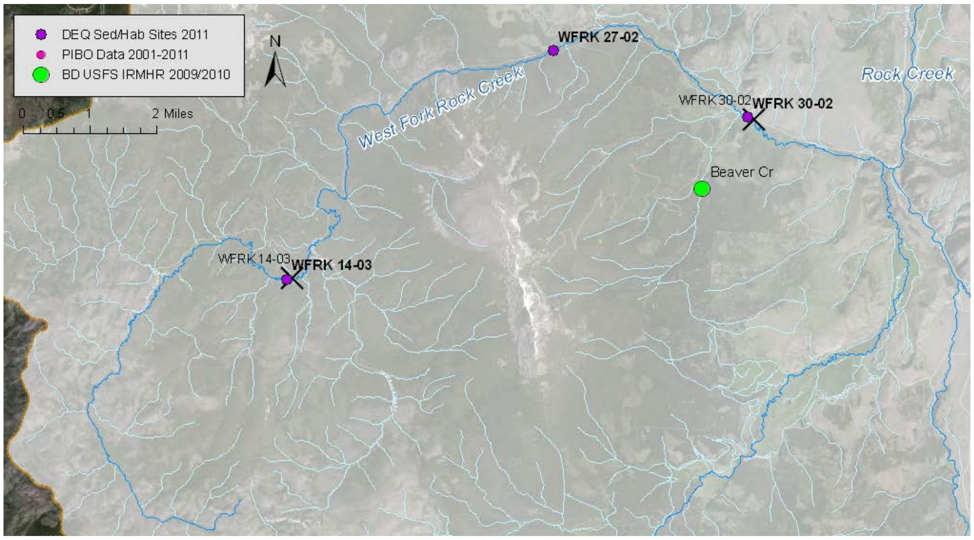

Figure 5-16. West Fork Rock Creek DEQ Assessment Site

Summary and TMDL Development Determination

Fine sediment targets were exceeded in both riffles and pools in the upstream site and fine sediment targets for percent less than 6mm were exceeded in the middle site. Width to depth ratio targets were not met in the middle and downstream sites and entrenchment ratio targets were not met in the upstream and downstream sites. Pool frequency and greenline understory shrub cover targets were not met in any of the sites. Greenline bare ground targets were exceeded in the upper and middle sites. Macroinvertebrate O/E scores also failed to meet target values. Because fines were notably high in field observations in the upper site and the existence of many sources of sediment that could continue to have a negative impact on habitat and sediment input to the stream, a sediment TMDL will be written for West Fork Rock Creek.

5.5 TMDL DEVELOPMENT SUMMARY

Based on the comparison of existing conditions to water quality targets, 10 sediment TMDLs will be developed in the Rock Creek TPA. **Table 5-32** summarizes the sediment TMDL development determinations and corresponds to **Table 1-1**, which contains the TMDL development status for listed waterbody segments in the Rock Creek TPA on the 2012 303(d) List.

Table 5-32. Summary of TMDL Development Determinations

Stream Segment	Waterbody ID	TMDL Development Determination (Y/N)
Antelope Creek*, headwaters to mouth (Rock Creek)	MT76E002_061	Y
Brewster Creek, East Fork to mouth (Rock Creek)	MT76E002_050	N
East Fork Rock Creek, East Fork Reservoir to mouth (Middle Fork Rock Creek)	MT76E002_020	Y
Eureka Gulch, confluence of Quartz and Basin gulches to mouth (un-named ditch)	MT76E002_090	Y
Flat Gulch, headwaters to mouth (Rock Creek)	MT76E002_120	Y
Miners Gulch, headwaters to mouth (Upper Willow Creek)	MT76E002_160	Y
Quartz Gulch, headwaters to mouth (Eureka Gulch)	MT76E002_070	Y
Scotchman Gulch, headwaters to mouth (Upper Willow Creek)	MT76E002_100	Y
Sluice Gulch, headwaters to mouth (Rock Creek)	MT76E002_110	Y
South Fork Antelope Creek, headwaters to mouth (Antelope Creek)	MT76E002_060	Y
Upper Willow Creek, headwaters to mouth (Rock Creek)	MT76E002_040	N
West Fork Rock Creek*, headwaters to mouth (Rock Creek)	MT76E002_030	Y

* Antelope Creek and West Fork Rock Creek were not on Montana's 2012 303(d) List for sediment

5.6 Source Assessment

This section summarizes the assessment approach, current sediment load estimates, and rationale for load reductions within the streams in the Rock Creek TPA that will have a sediment TMDL developed. There are no point sources in the Rock Creek TPA and therefore the focus is on the three potentially significant sediment source categories listed below and the associated controllable human-caused loading associated with each of these sediment source categories.

- streambank erosion
- upland erosion
- roads

EPA sediment TMDL development guidance for source assessments states that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the waterbody and using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (U.S. Environmental Protection Agency, 1999). Additionally, regulations allow that loadings "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)). The source assessments evaluated loading from the primary sediment sources using standard DEQ methods, but the sediment loads presented herein represent relative loading estimates within each source category, and, as no calibration has been conducted, should not be considered as actual loading values. Rather, relative estimates provide the basis for percent reductions in loads that can be accomplished via improved land management practices for each source category. These estimates of percent reduction provide a basis for setting load or wasteload allocations. As better information becomes available and the linkages between loading and instream conditions improve, the loading estimates presented here can be further refined in the future through adaptive management.

For each impaired waterbody segment, sediment loads from each source category were estimated based on field surveys, watershed modeling, and load extrapolation techniques (described below). The results include a mix of sediment sizes, particularly for bank erosion that involves both fine and coarse sediment loading to the receiving water; whereas loads from roads and upland erosion are predominately fine sediment.

The complete methods and results for source assessments for upland erosion, roads, and streambank erosion are located in **Appendices E, F,** and **G.** The following sections provide a summary of the load assessment results along with the basis for load reductions via improved land management practices. This load reduction basis provides the rationale for the TMDL load allocations defined in **Section 5.7**.

5.6.1 Eroding Streambank Sediment Assessment

Streambank erosion was assessed in 2011 at 22 assessment reaches discussed in **Section 5.3** to help obtain a representative dataset of existing loading conditions, causes, and the potential for loading reductions associated with improvements in land management practices. Sediment loading from eroding streambanks was assessed by performing Bank Erosion Hazard Index (BEHI) measurements and evaluating the Near Bank Stress (NBS) (Rosgen, 2006) along monitoring reaches in 2011. BEHI scores were determined at each eroding streambank based on the following parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. In addition to BEHI data collection, the source of streambank erosion was evaluated based on observed human-caused disturbances and the surrounding land-use practices based on the following near-stream source categories:

- transportation
- riparian grazing
- cropland
- mining
- silviculture
- irrigation-shifts instream energy
- natural sources
- other (typically refers to disturbance from past human activity that is not easily discernible due to elapsed time)

Based on the aerial assessment process (described in **Section 5.3**) in which each assessed stream segment is divided into different reaches, streambank erosion data from each 2011 monitoring site was used to extrapolate data and provide load estimates to the stream reach, stream segment and sub-watershed scales. Sediment load reductions were based on reducing BEHI values, assuming that implementing riparian best management practices (BMPs) practices will lead to improved streambank stability; and therefore achieve the naturally occurring condition. A more detailed description of the bank erosion assessment can be found in *Streambank Erosion Source Assessment,* which is included as **Appendix E**.

Assessment Summary

Based on the source assessment, streambank erosion contributes an estimated 7,101 tons of sediment within the streams in the Rock Creek TPA that will have a sediment TMDL developed. It is estimated that this sediment load can be reduced to 4,854 tons per year, which is a 32% reduction in sediment load from streambank erosion. Sediment loads due to streambank erosion range from 25 tons/year in Eureka Gulch to 2,880 tons per year in West Fork Rock Creek. The desired load is the estimate of the naturally occurring condition (the condition a waterbody could attain if all reasonable land, soil, and water conservation practices were put in place). The largest contribution of sediment loads due to streambank erosion in the Rock Creek TPA comes from natural sources, however, current and historical riparian grazing is the greatest anthropogenic contributor of sediment loads for most assessed sites in the Rock

Creek TPA. Bank erosion from transportation was the second largest anthropogenic contributor in many sites, where roads were confining the stream. Mining is the major source contributing to bank erosion in Eureka Gulch, but is not a primary source throughout the TPA. **Appendix E** contains additional information about sediment loads from eroding streambanks in the Rock Creek TPA by subwatershed, including all that were assessed. **Table 5-33** provides a summary of the bank erosion loads by each watershed where TMDLs are being developed in this document. **Table 5-33** also includes sediment load reduction information based on the application of BMPs. The load reduction approach and associated assumptions are described in **Appendix E**.

Table 5-33. Bank Erosion Results; Estimated Load Reduction Potential; and Resulting Loads after Application of Best Management Practices

Watershed	Total Bank Erosion Load (tons/year)	Estimated Load Reduction	Load After Application of BMPs (tons/year)
Antelope Creek (includes SF Antelope Creek)	691	40%	416
East Fork Rock Creek	984	9%	896
Eureka Gulch (includes Basin and Quartz gulches)	712	43%	407
Flat Gulch	280	58%	116
Miners Gulch	473	7%	439
Quartz Gulch	526	38%	324
Scotchman Gulch	683	31%	470
Sluice Gulch	398	46%	213
South Fork Antelope Creek	158	45%	87
West Fork Rock Creek	2880	34%	1897

5.6.2 Upland Erosion and Riparian Buffering Capacity

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE). Sediment delivery to the stream was predicted using a sediment delivery ratio, taking into account riparian buffering. The Rock TPA riparian health assessment was used to develop a riparian health score based on the sediment reduction percentage for each individual stream segment subwatershed (See **Appendix F**). This value represents the percent reduction in sediment delivery from a nominal 100 foot wide riparian buffer under existing conditions. For the BMP scenario, it was assumed that the implementation of BMPs on those activities that affect the overall health of the vegetated riparian buffer will increase riparian health. The potential to improve riparian health was evaluated for each reach based on best professional judgment through a review of color aerial imagery from 2009 and on-the-ground reconnaissance. The USLE results are useful for source assessment as well as for determining allocations to human-caused upland erosion. This model provided an estimate of existing sediment loading from upland sources and an estimate of potential sediment loading reductions that could be achieved by applying BMPs in the uplands and in the near stream riparian area.

The sediment load allocation strategy for upland erosion sources provides for a potential decrease in loading through BMPs applied to upland land uses, as well as those land management activities that have the potential to improve the overall heath and buffering capacity of the vegetated riparian buffer. The allocation to these sources includes both present and past influences and is not meant to represent only current management practices; many of the restoration practices that address current land use will reduce pollutant loads that are influenced from historical land uses. A more detailed description of the assessment can be found in **Appendix F**.

Assessment Summary

Based on the source assessment, upland erosion contributes approximately 3,683 tons per year to the streams in the Rock Creek TPA that will have a sediment TMDL developed. The assessment indicates that rangeland grazing and hay production within the near stream riparian buffer are the most significant contributors to accelerated upland erosion. Sediment loads due to upland erosion range from 26 tons/year in the Quartz Gulch sub-watershed to 1,181 tons/year in the lower East Fork Rock Creek sub-watershed. Since this assessment was conducted at the sub-watershed scale, it is expected that larger watersheds will have greater sediment loads. A significant portion of the sediment load due to upland erosion is contributed by natural sources. **Appendix F** contains additional information about sediment loads from upland erosion in the Rock Creek TPA by subwatershed, including all 6th code HUCs in the TPA. In order to facilitate reporting of the upland sediment loading information following the allocation strategy specific to this source category the data from each sub-watershed located in the appendix was further manipulated by:

- All sources that generate < 1 ton of sediment per year were considered insignificant and were removed;
- Land use categories were lumped into these classes;
- Forest – Evergreen Forest, Wetlands, Transitional
- Range – Shrub / Scrub, Grassland / Herbaceous
- Agricultural – Pasture / Hay, Cultivated Crops
- Other – Mixed land use
- All sediment loads were rounded to the nearest ton

Table 5-34 below reports the existing loads and resulting loads after applying the BMP reductions**.** This information can be used as a basis for setting TMDL load allocations. (See **Appendix F** for more detailed information).

Table 5-34. Existing Upland Sediment Loads and Estimated Load Reduction Potential after Application of Upland and Riparian BMPs

Watershed	Estimated Existing Upland Sediment Load (tons/year)	Estimated Load Reduction Potential (% reduction)	Modeled Load After Application of Best Management Practices
Antelope Creek (includes SF Antelope Creek)	868	60%	350
East Fork Rock Creek	1181	66%	403
Eureka Gulch (includes Basin and Quartz gulches)	50	38%	31
Flat Gulch	34	38%	21
Miners Gulch	65	18%	53
Quartz Gulch	26	23%	20
Scotchman Gulch	42	33%	28
Sluice Gulch	530	60%	211
South Fork Antelope Creek	51	37%	32
West Fork Rock Creek	913	25%	689

5.6.3 Road Sediment Assessment

5.6.3.1 Erosion from Unpaved Roads

An assessment of the road network within the Rock TPA was performed as part of the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. This assessment employed GIS, field data collection, and sediment modeling to assess sediment inputs from the unpaved road network. Prior to field data collection, GIS data layers representing land ownership, road network, stream network, watersheds, and ecoregions were used to identify road crossings throughout the Rock TPA. Through GIS analysis, 339 road crossings were identified within the Rock TPA; 207 of which were identified as unpaved road crossings (gravel or native material) based on attribute information contained in the roads database (**Table 2-1**). During this initial GIS analysis, 125 crossings were identified with an 'unknown' surface type. Following the initial GIS analysis, road surface types were assigned to the 125 crossings with an 'unknown' surface type based on an assessment of proximal road segments located within the vicinity of each crossing lacking road surface type information. A total of 45 unpaved road crossings were randomly selected prior to field data collection. Thirty-four pre-selected and 7 alternative sites were visited in the field in October of 2011. Out of the 41 sites visited, 30 of the sites had a true road crossing and therefore field forms were completed at 30 sites. During field data collection, sediment inputs to stream channels from parallel road segments were not observed. Thus, no field data was collected along parallel road segments in the Rock TPA. For each unpaved crossing, a series of measurements were performed to characterize road design, maintenance level, condition, culvert size, and sediment loading potential.

Sediment loading from unpaved road crossings was estimated using the WEPP:Road soil erosion model version 2011.12.20. The WEPP:Road model was used to evaluate existing conditions at each road crossing based on the field collected data. The WEPP:Road model was also used to estimate the potential to reduce sediment loads through the application of BMPs. During field data collection, the location of potential BMPs, such as water bars and rolling dips, were identified and the distance to the stream crossing was measured. During the BMP modeling scenario, the contributing road length was reduced from the existing length to the potential BMP length based on the field measured values. A more detailed description of this assessment can be found in **Appendix G**.

Assessment Summary

Based on the source assessment, unpaved roads are contributing 1.8 tons of sediment per year to the streams in the Rock Creek TPA that will have a sediment TMDL developed. Sediment loads are all < 1 ton/year in each sub-watershed. Factors influencing sediment loads from unpaved roads at the watershed scale include the overall road density within the watershed, watershed size, and the configuration of the road network, along with factors related to road construction and maintenance. **Table 5-35** contains annual sediment loads from unpaved road crossings from the watersheds where TMDLs are developed within this document. **Table 5-35** also includes the percent load reduction by watershed based on the contributing road length BMP scenario which is further defined within **Appendix G**.

Table 5-35. Annual Sediment Load (tons/year) from Unpaved Road Crossings

Watershed	Total Estimated Existing Load (tons/year)	Percent Load Reduction After BMP Application	Total Sediment Load After BMP Application
Antelope Creek (includes SF Antelope Creek)	0.091	57%	0.039
East Fork Rock Creek	0.541	67%	0.181
Eureka Gulch (includes Basin and Quartz gulches)	0.020	50%	0.010
Flat Gulch	0.053	72%	0.015
Miners Gulch	0.199	67%	0.066
Quartz Gulch	0.013	69%	0.004
Scotchman Gulch	0.015	60%	0.006
Sluice Gulch	0.080	71%	0.023
South Fork Antelope Creek	0.021	62%	0.008
West Fork Rock Creek	0.790	62%	0.300

5.6.3.2 Culvert Failure and Fish Passage Analysis

Undersized or improperly installed culverts may be a chronic source of sediment to streams or a large acute source during failure, and they may also be passage barriers to fish. Therefore, during the roads assessment, the flow capacity and potential to be a fish passage barrier was evaluated for a subset of culverts. The flow capacity culvert analysis was performed on 27 culverts and incorporated bankfull width measurements taken upstream of each culvert to determine the stream discharge associated with different flood frequencies (e.g., 2, 5, 10, 25, 50, and 100 year) and measurements for each culvert to estimate its capacity and amount of fill material. Flood frequency refers to the probability that a flood of a certain magnitude for a given river will occur in a certain period of time. For example, a “100-year flood” event has a 1 in 100 probability of occurring in any given year or in other words, a 1% chance in any given year.

Though culvert failure represents a potential load of sediment to streams, a yearly load estimate is not incorporated into the TMDL due to the uncertainty regarding estimating the timing of such failures and a lack of monitoring information to track the occurrence of these failures.

Fish passage assessments were performed on 27 culverts. The assessment was based on the methodology defined in **Appendix G**, which is geared toward assessing passage for juvenile salmonids. Considerations for the assessment include streamflow, the culvert slope, culvert perch/outlet drop, culvert blockage, and constriction ratio (i.e., culvert width to bankfull width). The assessment is intended to be a coarse level evaluation of fish passage that quickly identifies culverts that are likely fish passage barriers and those that need a more in-depth analysis. Culverts with fish passage concerns may have elevated road failure concerns since fish passage is often linked to undersized culvert design.

Assessment Summary

Within the Rock Creek TPA, 23 of the 27 culverts assessed in the field (85%) are capable of passing the two-year flood event, while only nine of these culverts (33%) pass a 100-year flood event (see **Appendix G** for more details).

In the Rock Creek TPA, none of the culverts allowed fish passage, while 26 culverts (96%) were classified as fish passage barriers (**Appendix G**). No estimated annual load was incorporated into the TMDL due to an uncertainty of failure events and deficient monitoring information.

5.6.4 Point Sources

As of November 1, 2012, there were no Montana Pollutant Discharge Elimination System (MPDES) permitted point sources within the Rock Creek TPA.

5.7 Sediment TMDLs and Allocations

This section is organized by the following topics:

- Application of Percent Reduction and Yearly Load Approaches
- Development of Sediment Allocations by Source Categories
- Allocations and TMDLs for Each Stream
- Meeting the Intent of TMDL Allocations

5.7.1 Application of Percent Reduction and Yearly Load Approaches

The sediment TMDLs for the Rock Creek TPA will be based on a percent reduction approach discussed in **Section 4.** This approach will apply to the loading allocated among sources as well as each individual waterbody TMDLs. An implicit margin of safety will be applied as further discussed in **Section 5.8**. Cover and others (Cover et al., 2008) observed a correlation between sediment supply and instream measurements of fine sediment in riffles and pools; it is assumed that a decrease in sediment supply, particularly fine sediment, will correspond to a decrease in the percent fine sediment deposition within the streams of interest and result in attainment of the sediment related water quality standards. A percent-reduction approach is preferable because there is no numeric standard for sediment to calculate the allowable load and because of the uncertainty associated with the loads derived from the source assessment (which are used to establish the TMDL), particularly when comparing different load categories such as road crossings to bank erosion. Additionally, the percent-reduction TMDL approach is more applicable for restoration planning and sediment TMDL implementation because this approach helps focus on implementing water quality improvement best practices (i.e., BMPs), versus focusing on uncertain loading values.

An annual expression of the TMDLs was determined as the most appropriate timescale because sediment generally has a cumulative effect on aquatic life or other designated uses, and all sources in the watershed are associated with periodic loading. Each sediment TMDL is stated as an overall percent reduction of the average annual sediment load that can be achieved after summing the individual annual source allocations and dividing them by the existing annual total load. EPA encourages TMDLs to be expressed in the most applicable timescale but also requires TMDLs to be presented as daily loads (Grumbles, Benjamin, personal communication 2006). Daily loads are provided in **Appendix H**.

5.7.2 Development of Sediment Allocations by Source Categories

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 **Section 5.6** and associated appendices, and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Sediment loading reductions can be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. Sediment loading was evaluated at the watershed scale and associated sediment reductions are also applied at the watershed scale based on the fact that many sources deliver sediment to tributaries that then deliver the sediment load to the impaired waterbodies.

The following subsections present additional allocation details for each sediment source category.

5.7.2.1 Streambank Erosion
Sediment loads associated with bank erosion were identified by separate source categories (e.g., transportation, grazing, natural) in **Appendix E**. Because of the inherent uncertainty in extrapolating this level of detail to the watershed scale, and also because of uncertainty regarding impacts from historical land management activity, all sources of bank erosion were combined for the purpose of expressing the TMDL and allocations. Streambank stability and erosion rates are very closely linked to the health of the riparian zone; reductions in sediment loading from bank erosion are expected to be achieved by applying BMPs within the riparian zone.

5.7.2.2 Upland Erosion
No reductions were allocated to natural sources, which are a significant portion of all upland land use categories. The allocation to upland sources includes application of BMPs to present land use activities as well as recovery from past land use influences such as riparian harvest. For all upland sources, the largest percent reduction will be achieved via riparian improvements.

5.7.2.3 Roads
The unpaved road allocation can be met by incorporating and documenting that all road crossings with potential sediment delivery to streams have the appropriate BMPs in place. Sediment loads delivered to streams from road crossings are minor and efforts in the Rock TPA to control sediment should focus on bank and upland erosion BMPs. However, routine maintenance of road BMPs is also necessary to ensure that sediment loading remains consistent with the intent of the allocations. At some locations, road closure or abandonment alone may be appropriate and, due to very low erosion potential linked to native vegetation growth on the road surface, additional BMPs may not be necessary.

5.7.3 Allocations and TMDLs for Each Stream
The following subsections present the existing quantified sediment loads, allocations and TMDL for each waterbody.

Allocation Assumptions
Sediment load reductions are given at the watershed scale, and are based on the assumption that the same sources that affect a listed stream segment affect other streams within the watershed and that a similar percent sediment load reduction can be achieved by applying BMPs throughout the watershed. However, it is acknowledged that conditions are variable throughout a watershed, and even within a 303(d) stream segment, and this affects the actual level of BMPs needed in different areas, the practicality of changes in some areas (e.g. considering factors such as public safety and cost-effectiveness), and the potential for significant reductions in loading in some areas. Also, as discussed in **Section 4.4**, note that BMPs typically correspond to all reasonable land, soil, and water conservation practices, but additional conservation practices above and beyond BMPs may be required to achieve compliance with water quality standards and restore beneficial uses.

Progress towards TMDL and individual allocation achievement can be gaged by adherence to point source permits, BMP implementation for nonpoint sources, and improvement in or attainment of water quality targets defined in **Section 5.4**. Any effort to calculate loads and percent reductions for purposes of comparison to TMDLs and allocations in this document should be accomplished via the same methodology and/or models used to develop the loads and percent reductions presented within this document.

The sediment TMDLs for all streams and stream segments presented below are expressed as a yearly load, and a percent reduction in the total yearly sediment loading achieved by applying the load allocation reductions identified in the associated tables (**Tables 5-36** through **5-45).** Each impaired segment's TMDL consists of any upstream allocations.

5.7.3.1 Antelope Creek (MT76E002_061)

Table 5-36. Sediment Source Assessment, Allocations and TMDL for Antelope Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.091	0.039	57%
Eroding Banks	691	416	40%
Upland Erosion	868	350	60%
Total Sediment Load	**1,559**	**766**	**51%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.2 East Fork Rock Creek (MT76E002_020)

Table 5-37. Sediment Source Assessment, Allocations and TMDL for East Fork Rock Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.541	0.181	67%
Eroding Banks	984	896	9%
Upland Erosion	1181	403	66%
Total Sediment Load	**2,166**	**1,299**	**40%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.3 Eureka Gulch (MT76E002_090)

Table 5-38. Sediment Source Assessment, Allocations and TMDL for Eureka Gulch

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.02	0.01	50%
Eroding Banks	712	407	43%
Upland Erosion	50	31	38%
Total Sediment Load	**762**	**438**	**43%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.4 Flat Gulch (MT76E002_120)

Table 5-39. Sediment Source Assessment, Allocations and TMDL for Flat Gulch

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.053	0.015	72%
Eroding Banks	280	116	59%
Upland Erosion	34	21	38%
Total Sediment Load	**314**	**137**	**56%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.5 Miners Gulch (MT76E002_160)

Table 5-40. Sediment Source Assessment, Allocations and TMDL for Miners Gulch

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.199	0.066	67%
Eroding Banks	473	439	7%
Upland Erosion	65	53	18%
Total Sediment Load	**538**	**492**	**9%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.6 Quartz Gulch (MT76E002_070)

Table 5-41. Sediment Source Assessment, Allocations and TMDL for Quartz Gulch

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.013	0.004	69%
Eroding Banks	526	324	38%
Upland Erosion	26	20	23%
Total Sediment Load	**552**	**344**	**38%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.7 Scotchman Gulch (MT76E002_100)

Table 5-42. Sediment Source Assessment, Allocations and TMDL for Scotchman Gulch

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.015	0.006	60%
Eroding Banks	683	470	31%
Upland Erosion	42	28	33%
Total Sediment Load	**725**	**498**	**31%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.8 Sluice Gulch (MT76E002_110)

Table 5-43. Sediment Source Assessment, Allocations and TMDL for Sluice Gulch

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.08	0.023	71%
Eroding Banks	398	213	46%
Upland Erosion	530	211	60%
Total Sediment Load	**928**	**424**	**54%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.9 South Fork Antelope Creek (MT76E002_060)

Table 5-44. Sediment Source Assessment, Allocations and TMDL for South Fork Antelope Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.021	0.008	62%
Eroding Banks	158	87	45%
Upland Erosion	51	32	37%
Total Sediment Load	**209**	**119**	**43%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.3.10 West Fork Rock Creek (MT76E002_030)

Table 5-45. Sediment Source Assessment, Allocations and TMDL for West Fork Rock Creek

Sediment Sources	Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Load Allocations (% Reduction)
Roads	0.79	0.3	62%
Eroding Banks	2880	1897	34%
Upland Erosion	913	689	25%
Total Sediment Load	**3,794**	**2,586**	**32%**

Sediment loads and percent reductions were rounded and may not exactly match the loads presented in the appendices.

5.7.4 Meeting the Intent of TMDL Allocations

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 example, a landowner or land manager that negatively impacts an existing healthy riparian area might increase sediment loading in a manner that is not consistent with the bank erosion and/or upland sediment load allocations that apply throughout the watershed.

Additional information regarding the implementation of the allocations and associated BMPs is contained in **Sections 6** and **7**.

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 Rock Creek 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 as described below.

- The applicable narrative water quality standards (**Appendix B**) 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 Rock Creek 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.

- TMDL development was pursued for all listed streams evaluated (except for Brewster Creek), even though some streams were close to meeting all target values. This approach addresses some of the uncertainty associated with sampling variability and site representativeness, and recognizes that sediment source reduction capabilities exist throughout the watershed.
- By using standards, targets, and TMDLs that 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** and in **Sections 6** and **7**).
- By using naturally occurring sediment loads as described in ARM 17.30.602(17) (see **Appendix B**) to establish the TMDLs and allocations based on reasonably achievable load reductions for each source category. Specifically, each major source category must meet percent reductions to satisfy the TMDL because of the relative loading uncertainties between assessment methodologies.
- TMDLs are developed at the watershed scale addressing all potentially significant human related sources beyond just the impaired waterbody segment scale. This approach should also reduce loading and improve water quality conditions within other tributary waterbodies throughout the watershed.

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 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 Rock Creek 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 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 a section focused on TMDL implementation, monitoring and adaptive management (**Section 6**). Furthermore, state law (ARM 75-5-703), requires monitoring to gage progress toward meeting water quality standards and satisfying TMDL requirements. These TMDL implementation monitoring reviews 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 C**. 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, 2012b). 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 (SAP) 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 SAP, and was based on a stratification process described in **Appendix C**. 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 most representative statistic was used to develop each target parameter consistent with the reference approach framework outlined in **Appendix B**. 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 DEQ data for the Rock Creek TPA. These differences were acknowledged within the target development discussion and taken into consideration during target setting. For each target parameter, DEQ stratified the Rock Creek 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 comparison characteristics.

The established targets are meant to apply under median conditions of natural background and natural disturbance. It is recognized 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. The goal, under these conditions, is to ensure that management activities are undertaken in a way that the achievement of targets is not significantly delayed in comparison to the natural recovery time. Also, human activity should not significantly increase the extent of water quality impacts from natural events. For example, extreme flood events can cause a naturally high level of sediment loading that could be significantly increased from a large number of road crossing or culvert failures.

Because sediment target values are based on statistical 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 the flexibility to refine targets as necessary to ensure protection of the resource and to adapt to new information concerning target achievability.

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 (BEHI) as defined within **Appendix E**. Field data collection was by trained environmental professionals per a standard DEQ procedure (Montana Department of Environmental Quality, 2012b). Prior to any sampling, a SAP 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 SAP, and was based on a stratification process described in **Appendix C**. The results were then extrapolated across the Rock Creek watersheds as defined in **Appendix E** to provide an estimate of the relative bank erosion loading from various streams and associated stream reaches.

Even with the above quality controls, there is uncertainty regarding the bank retreat rates, which directly influence loading rates, since it was necessary to apply bank retreat values established from Colorado by Rosgen. 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 BEHI 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 Rock Creek 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 Rock Creek watershed.

Upland Erosion

A professional modeler determined upland erosion loads applying a standard erosion model as defined in **Appendix F**. 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. For example, the model only allows one vegetative condition per land cover type (i.e., cannot reflect land management practices that change vegetative cover from one season to another), so an average condition is used for each scenario in the model. To minimize uncertainty regarding existing conditions and management practices, model inputs were reviewed by stakeholders familiar with the watershed.

The upland erosion model integrates sediment delivery based on riparian health, with riparian health evaluations linked to the stream stratification work discussed above. The potential to reduce sediment loading was based on modest 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. Also, the reductions in sediment delivery from improved riparian health also introduces some uncertainty, particularly in forested areas where there is uncertainty regarding the influence that historical riparian logging has on upland sediment delivery. 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 the Rock Creek watershed.

Roads

As described in **Appendix G**, 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. A total of 30 unpaved road crossings were evaluated in the field, representing about 9% of the total population of unpaved road crossings in the watershed. The results from these sites were extrapolated to the whole population of roads stratified by precipitation zones. 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.

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 an identified cause of water quality impairment in the Rock Creek TMDL Planning Area (TPA). It describes: (1) the mechanisms by which temperature affects beneficial uses of streams; (2) the specific stream segments of concern; (3) information sources used for temperature TMDL development; (4) temperature target development; (5) assessment of sources contributing to excess thermal loading; (6) TMDL development determination (7) the temperature TMDLs and allocations; (8) seasonality and margin of safety; and (9) uncertainty and adaptive management.

6.1 Temperature (Thermal) Effects on Beneficial Uses

Human influences that reduce stream shade, increase stream channel width, add heated water, or decrease the ability of the stream to regulate solar heating all increase stream temperatures. Warmer temperatures can negatively affect aquatic life and fish that depend upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increase metabolism and reduce the amount of available oxygen in the water. In turn, 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. Also, elevated temperatures can boost the ability of non-native fish to outcompete native fish if the latter are less able to adapt to warmer water conditions (Bear et al., 2007). Assessing thermal effects upon a beneficial use is an important initial consideration when interpreting Montana's water quality standard (**Appendix B**) and subsequently developing temperature TMDLs.

6.2 Stream Segments of Concern

Two waterbody segments in the Rock Creek TPA appeared on the 2012 Montana impaired waters list as having temperature limiting a beneficial use: East Fork Rock Creek (from the outlet of the reservoir to the mouth) and South Fork Antelope Creek (**Figures 6-1 and 6-2**). As discussed in **Section 3.1**, both segments are classified as B-1, which requires that the streams be maintained suitable for several uses, including salmonid fishes and associated aquatic life.

6.2.1 East Fork Rock Creek

The segment of concern is 9.74 miles long and extends from the outlet of East Fork Reservoir to the mouth (**Figure 6-1**). This stream originates in the high elevations of the Pintler Range (more than 8,000 feet above mean sea level [MSL]) and flows approximately 6 miles through the Beaverhead Deerlodge National Forest. The creek transitions from relatively steep, mountainous, coniferous forest in the headwater to more gentle, open, scrub/shrub/grassland in the lower reaches of the watershed. This transition occurs fairly dramatically just below the East Fork Reservoir, an impoundment constructed in 1938.

A siphon and a transfer pipeline were also constructed in 1939 to facilitate irrigation in the adjacent Flint Creek watershed. The Montana Department of Natural Resources and Conservation (DNRC) manages the reservoir, siphon, and transfer pipeline. Up to 200 cfs is released from the reservoir during irrigation season for diversion into the main canal. A small amount of additional flow is released from the reservoir during irrigation season to provide a minimum flow of 5 cfs in East Fork Rock Creek below the diversion. The segment (MT76E002-020) addressed in this document begins at the outlet of the dam on

East Fork Reservoir and ends at the mouth of East Fork Rock Creek (its confluence with Middle Fork Rock Creek).

The upper half of the East Fork Rock Creek watershed is primarily forested. Most of the valley bottom below the East Fork Reservoir is irrigated pasture or hay land. The 2006 National Land Cover Dataset (NLCD) erroneously identifies areas of irrigated hay and pasture as cultivated crops. The upland areas in the lower watershed are predominantly open rangeland (scrub/shrub and native grasslands).

The U.S. Forest Service owns and manages much of the watershed. The upper reaches of the East Fork Rock Creek watershed are in the Anaconda-Pintler Wilderness. Historically, timber harvest has occurred outside the wilderness area, predominantly in the Meadow Creek subwatershed, which drains to the impaired segment of East Fork Rock Creek. With the exception of two small areas in the lower half of the watershed under state ownership, the lower watershed is privately owned.

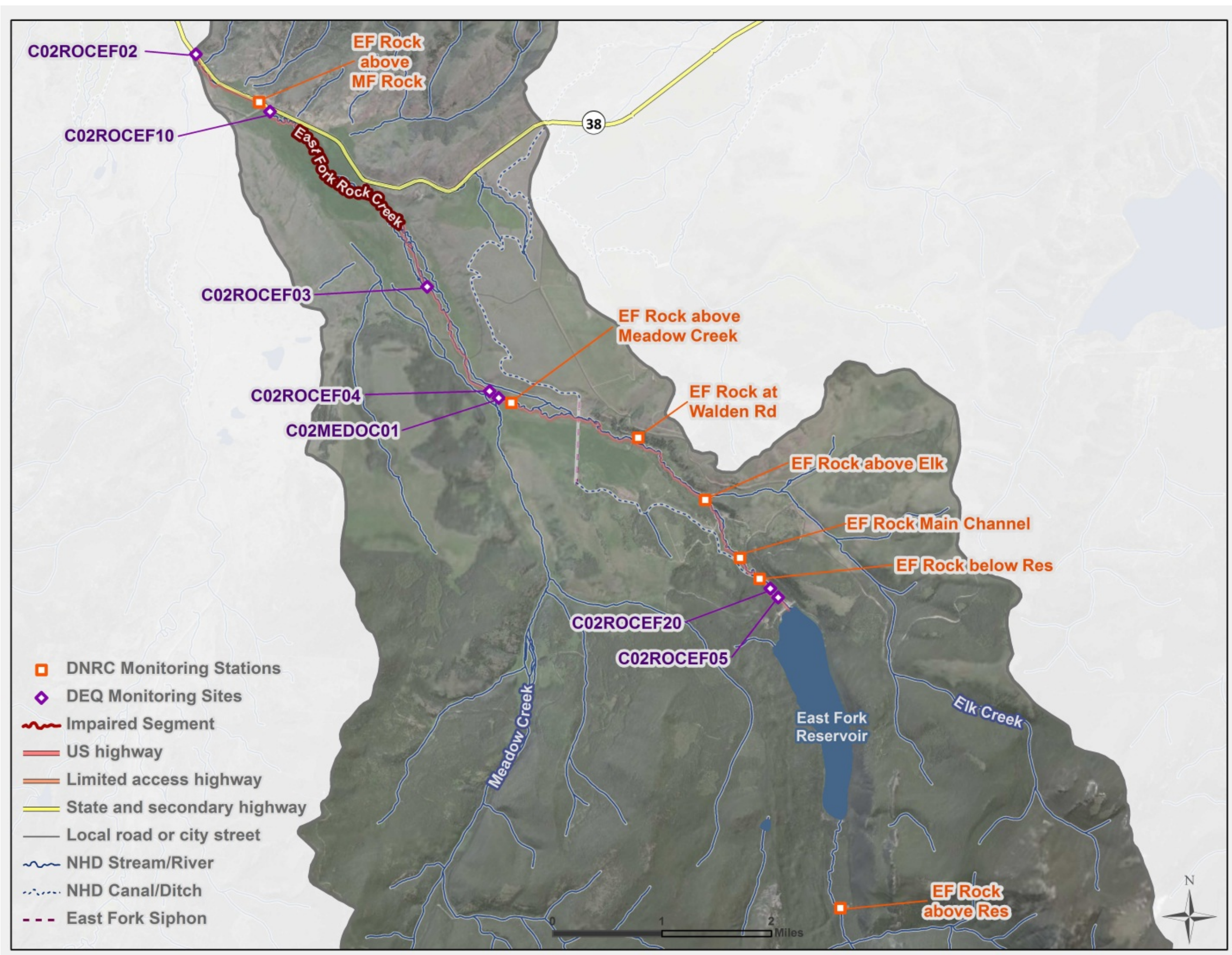

Figure 6-1. East Fork Rock Creek

6.2.2 South Fork Antelope Creek

The segment of concern is 2.9 miles long and extends from the headwaters to the mouth (**Figure 6-2**). Roughly half of the South Fork Antelope Creek watershed is forested. The remaining area is either shrub or grassland, exhibiting various stages of regrowth from timber harvesting. Approximately two-thirds of the watershed is privately owned. The remainder is owned by the U.S. Bureau of Land Management.

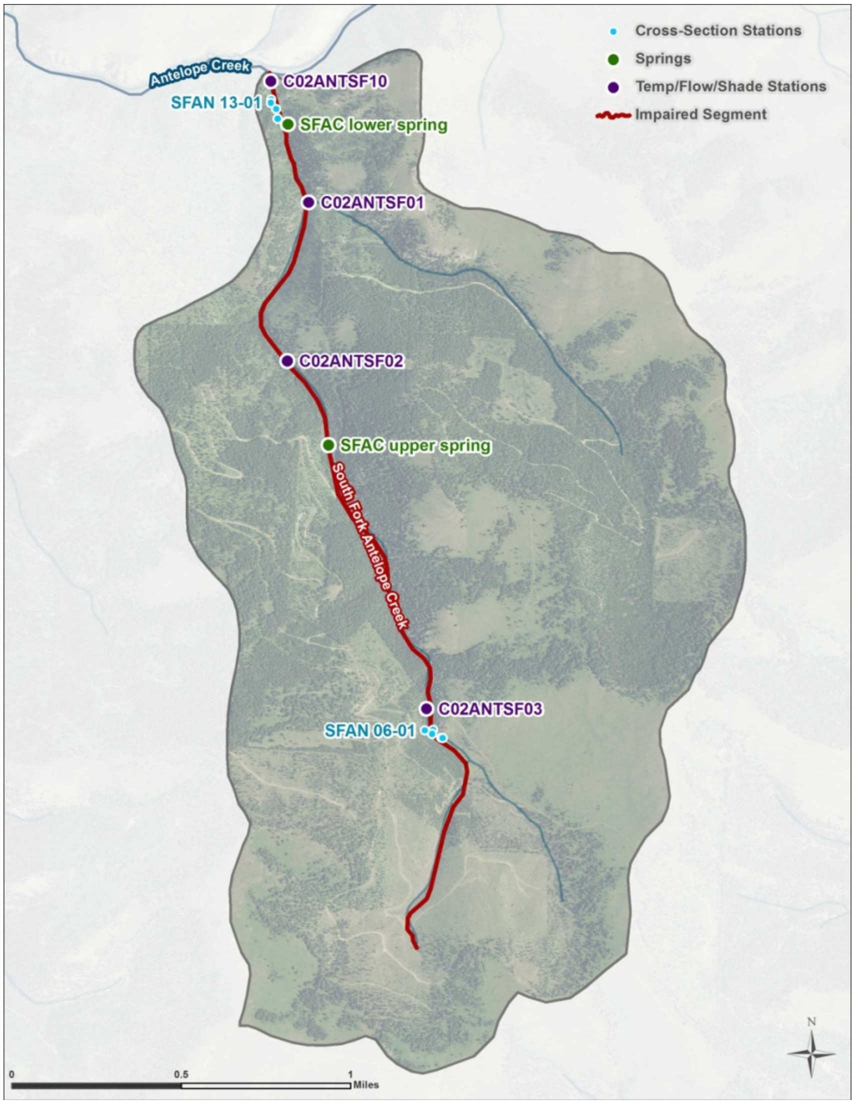

Figure 6-2. South Fork Antelope Creek watershed

6.3 Information Sources and Data Collection

As part of this TMDL project, DEQ used several information and data sources to analyze and assess the stream segments of concern.

6.3.1 Fish Populations & Specific Temperatures of Concern

To help understand potential thermal effects on aquatic life, information on fish populations along with information on temperatures that may cause harm to these fish populations was collected and is summarized below.

6.3.1.1 Fish Populations in East Fork Rock and South Fork Antelope Creeks

Based on a query of Montana Fisheries Information System (MFISH), brook trout, brown trout, and sculpin are year round residents in East Fork Rock Creek below the reservoir. Additionally, bull trout, westslope cutthroat trout, rainbow trout, and mountain whitefish are all common resident populations in East Fork Rock Creek. Longnose sucker are rare and longnose dace are also present in the stream with an unknown abundance. During shade monitoring and sediment and habitat field work, many fish were noted throughout East Fork Rock Creek.

According to a query of MFISH, South Fork Antelope Creek contains an abundant and year round resident population of native westslope cutthroat trout. Several 6” trout were observed at the confluence of South Fork Antelope and Antelope Creeks during a site visit on 8/1/2011.

6.3.1.2 Temperature Levels of Concern

Bull trout are listed as threatened under the U.S. Endangered Species Act. upper incipient lethal temperature (UILT) for Bull Trout is 68.5°F (20.3°C) (Selong et al., 2001). The LD10 for bull trout is 74°F (23.4°C) (McCullough and Spalding, 2002). Bull trout have maximum growth near 59.5°F (15.3°C) (McCullough and Spalding, 2002).

Special temperature considerations are warranted for the westslope cutthroat trout, which are listed in Montana as a species of concern. Research by Bear et al., (2007) found westslope cutthroat maximum growth around 56.5° F (13.6° C) with an optimum growth range, based on 95% confidence intervals, from 50.5° F to 62.6° F (10.3-17.0° C). 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 cutthroat trout, with growth significantly better at temperatures above 44.2° F and below 69.4° F (6.8-20.8° C), possibly allowing for increased competition with cutthroat trout in lower-elevation (warmer) streams.

Additionally, the average 60 day UILT for westslope cutthroat trout is 67.5° F (20.0° C). The 7-day UILT was found to be 75.4° F (Bear et al., 2007). The UILT is the temperature considered to be survivable indefinitely by 50% of the population over a specified time period. The lethal concentration (LD10) for westslope cutthroat is 73.0° F (22.8° C), which is the temperature that, on a sustained basis, will kill 10% of the population in a 24-hour period (Lines and Graham, 1988).

Brown trout better tolerate temperature increases than the native westslope cutthroat species; however, high temperatures can negatively affect the brown trout population as well. Studies conducted by Elliott (1981) and Brett (1952) found a range of 7-day UILT between 76.5° and 80.1° F. The upper lethal concentration for juvenile brown trout is 75.4° F, as presented in Beschta et al. (1987). The critical thermal maximum (CTM) is the arithmetic mean of collected thermal points at which locomotor activity becomes disorganized such that the organism loses its ability to escape lethal conditions (Cowells and Bogert, 1944). The CTM for brown trout, according to Elliott and Elliott (1995), is 85.8° F.

6.3.2 DEQ Assessment Files

DEQ maintains assessment files that provide a summary of available water quality and other existing condition information, along with a justification for impairment determinations. This information was compiled in 2006 during DEQ’s most recent formal assessment of streams in the Rock Creek TPA. Below is a short review and general characterization of stream conditions in relation to temperature impairment determinations DEQ made in 2006.

6.3.2.1 East Fork Rock Creek

The most recent assessment performed by the DEQ’s Monitoring and Assessment section for East Fork Rock Creek (EFRC) occurred in 2006. According to the records in the assessment file:

EFRC contains bull trout, westslope cutthroat trout, rainbow trout, brook trout, brown trout, sculpin, mountain whitefish, longnose sucker, and longnose dace. EFRC is an Northwest Power & Conservation Council fisheries protected area because it is essential spawning habitat for Rock Creek. This stretch of EFRC contains high infection rates of whirling disease and very high numbers of tubifex worms. The macroinvertebrate fauna collected in EFRC in 2005 suggested low diversity; nutrient enrichment; potentially elevated temperatures; excess fine sediment deposition; and simplified instream habitats at the local and reach scales. DEQ derived mountain metric scores indicated nonsupport of aquatic life. Chlorophyll-*a* was sampled at two locations in 2004; results at both locations suggested excess algal growth limiting beneficial uses.

Fine sediment levels were observed to be appropriate below the dam where flows were adequate, but near the mouth the stream channel was clogged with fine sediments. Percent grid fines in pool tails were 37%, fines in riffles less than 2mm comprised 29%, and fines in riffles less than 6mm comprised 31%. RSI indexes were calculated in 2004 and found to be ~70% below the dam, denoting riffles on the threshold of dynamic equilibrium and intermediate state, with riffles somewhat loaded with sediment. Near the mouth, the RSI was ~98%; indicative of riffles with increased loading of excess sediment, reducing pool volume and relative pool abundance. Width to depth and entrenchment ratios increased in the downstream direction. The majority of the reach was in a C4 channel type.

Road density was moderate in the watershed, but a large percentage of these roads were located in close proximity to the stream channel and crossed the stream channel frequently (almost all crossings had culverts). East Fork dam was built in 1936 to provide irrigation water in the Flint Creek drainage and acts as a fish migration barrier. The 2006 assessment determined that the operation of the dam, and associated diversion structures, resulted in direct loss of bull trout from the system (into the ditch system) and that during times of high demand for irrigation water, the natural channel was nearly absent of water flow. Reduced flows in the EFRC downstream of the dam was resulting in elevated levels of fine sediment, high water temperatures, alteration of riparian vegetation communities and simplification of instream habitats.

The 2006 assessment indicated that downstream of the dam, the majority of the watershed had been altered from natural conditions by human activities. On national forest lands, pool habitat was reduced, streambanks were less stable and instream fine sediment levels were elevated. Cursory inspection of private lands revealed a lack of riparian vegetation and unstable stream channels. An integrated assessment of species and habitat conditions rated EFRC as functioning at unacceptable risk. Private land uses were primarily for raising livestock, including grazing lands and irrigated lands used for hay production. Large-scale sub-division of ranchlands had begun and may become an increasingly important issue if the trend continues. Water temperatures were elevated above the peak growth rate for bull trout during the summer months and was most likely limiting the fishery. There was a major diversion just below the dam and additional withdrawls downstream. Land uses and altered flows downstream of the dam (a result of irrigation withdrawls) resulted in substantially warmer water entering Rock Creek. Flows near the mouth in 2004 were 17% of the total water released from the dam.

EFRC was included on the 1996 impaired water list as having the cold-water fishery beneficial use threatened due to siltation and thermal modifications from agriculture, irrigated crop production, logging road construction/maintenance, and pasture land. In 2000, the DEQ

> assessed the data quantity and quality to be insufficient to make an impairment determination. At the time of the 2006 assessment, siltation was causing impairment below the major irrigation diversion just downstream of the dam. There were also numerous signs that temperatures were elevated in the summer time; therefore thermal modifications remained a cause of impairment.

6.3.2.2 South Fork Antelope Creek

The most recent assessment performed by the DEQ's Monitoring and Assessment section for South Fork Antelope Creek (SFAC) occurred in 2006. According to the records in the assessment file:

> The macroinvertebrate fauna collected in SFAC in 2005 suggested warmer water temperatures; elevated nutrient concentrations; intact instream habitats; and year-round flows. Scrapers were rare, expressing the lack of algae growth in the channel. Overall, using DEQ mountain metrics a score of 62% was derived, demonstrating partial support of aquatic life. Little plant growth was demonstrated in the low level of detected chlorophyll-*a*, 4.7 mg/m2.
>
> Vegetation was lacking diversity and age classes, from past management abuse. The stream channel was out of balance and very unstable, with large erosional and sediment depositional areas and filled pools. The channel was incised but, starting to form meanders within the incised channel. There was little woody vegetation present to stabilize the banks. Bank vegetation was dominated by sedges, with little willows present compared to potential. The substrate was dominated by fine gravels, sand, and silt. Riffle and pool spacing had no regular frequency, and most pools were step pools partially filled with sand and sediment. Fish cover was rated as sparse to moderate, with overhanging vegetation and woody debris, but few deep pools and undercut banks. One culvert was observed and it was perched; making it difficult for small fish to migrate through. Photos showed a very simplified stream channel with thick herbaceous growth, but very little woody vegetation regeneration. There was an abundance of sand choking the channel and many of the banks were eroding. The stream channel was not in a stable state, but it still had attributes of a "B5" channel type. Wolman pebble counts indicated substrate dominated by sands and fine gravels.
>
> The only mines listed in this drainage were high in the headwaters; one of which was the Ant mine and the other was the Mountain Ram Mine. Both produced gold, but current status at the time of assessment was unknown. The Ant mine had a significant road system within 1/2 a mile of the stream. The stream showed moderate disturbance from logging and associated roads from approximately 10 years from the time of assessment. At the time of the assessment, there was a new owner on the property, and the stream was starting to recover, however much more time is needed. Based on the 2006 assessment results, SFAC remained on the 305(b) report for temperature, nutrients, sediment and other habitat alterations.

6.3.3 TMDL Data Collection

DEQ's methods for temperature TMDL development on East Fork Rock and South Fork Antelope Creeks included a combination of characterizing water temperatures throughout the summer and collecting additional vegetation, channel condition, shade, and streamflow data; which were used to model stream temperature. As described in **Appendix I and J**, the QUAL2K temperature model was calibrated to existing flow, shade, and temperature conditions, with the ability to evaluate temperature impacts from differing riparian health (shade) and streamflow conditions. Thus TMDL data collection can be grouped into three categories: (1) temperature data collection used to characterize water quality throughout the summer; (2) field data collection of flow, shade, riparian health, and channel geometry; and (3) relevant data from outside sources.

6.3.3.1 Temperature Data Collection

In 2010 continuous temperature measurements were conducted in East Fork Rock and South Fork Antelope Creeks from late July through late September. The study examined stream temperatures during the period when streamflows tend to be the lowest and water temperatures the warmest; therefore, the negative effects to the coldwater fishery and aquatic life beneficial uses are likely most pronounced. Temperature monitoring consisted of placing temperature data logging devices at 6 sites in EFRC and at 4 sites in SFAC. In addition, a temperature data logging device was placed on Meadow Creek, a tributary stream to EFRC. Temperature monitoring sites were selected to bracket stream reaches with similar hydrology, riparian vegetation type, valley type, stream aspect, and channel width (**Figures 6-1 and 6-2**).

For East Fork Rock Creek, data loggers recorded temperatures every half hour for 2 months between July 27 and 28, 2010, and September 26 and 27, 2010. Field parameters (including water temperature) were collected during data logger deployment and retrieval. The upstream-most site was below the East Fork Dam, upstream of the canal diversion (C02ROCEF05). Maximum recorded temperatures generally increased in a downstream direction ranging from 58.0 °F below the dam (C02ROCEF05) to a maximum of 64.4 °F approximately one mile below the confluence with Meadow Creek (C02ROCEF03). With one exception, the between-site variability in daily maximum temperatures was relatively constant throughout the 2010 monitoring period. The exception was that the maximum daily temperatures at the two uppermost sites (C02ROCEF05 and C02ROCEF20) were lower than those recorded at the downstream sites between the beginning of the monitoring period and mid-August. For the monitoring period, the maximum temperatures in Meadow Creek were among the highest (i.e., 63.8 °F). The most striking observation with the 2010 data was the difference in maximum daily temperatures between the upstream and downstream monitoring sites between the beginning of the monitoring period and mid-August. This suggests some kind of warming influence downstream from site C02ROCEF20. While this could be a natural phenomenon as the streamflows through the more open valley downstream, potential anthropogenic influences are irrigation withdrawals and returns, degradation of the riparian vegetation, and altered stream morphology.

For South Fork Antelope Creek, loggers recorded temperatures every half hour for 2 months between July 15 and 16, 2010, and September 23 and 24, 2010 (i.e., 70 days). Daily maximum temperatures were the coolest and varied the least (between approximately 44.0 and 55.0 °F) at the site that was most downstream (C02ANTSF10). The highest maximum temperatures were at the site that was most upstream (C02ANTSF03) and ranged from approximately 44.0 to 61.0 °F. The largest range of maximum daily temperatures was also observed at the site that is most upstream (C02ANTSF03). South Fork Antelope Creek is a small, shallow mountain stream. The coolest recorded stream temperatures were observed at the station that is most downstream, which corresponds to the lowest effective shade. The warmest recorded maximum temperatures were observed at the most upstream station where effective shade values are among the highest. This may be related to the increased influence of cooler groundwater in the lower portion of the stream or could suggest that ambient air temperature is an influencing factor affecting instream temperature. The headwaters of the creek (site C02ANSF03) are very shallow, and instream temperatures directly correspond to the ambient air temperature. Temperatures logged in the lower segments of the South Fork of Antelope Creek also typically vary with ambient air temperature, but are generally cooler than the headwaters segments during the day and warmer than the headwaters during the night.

6.3.3.2 Field Data Collection

The following section describes measurements collected by a team from WET and DEQ on East Fork Rock and South Fork Antelope Creeks in the late summer of 2011 to characterize meteorological data (e.g. air temperature, dew point, wind speed, and cloud cover), channel geometry, additional flow measurements, and/or shade variables in support of the modeling effort. Additional information was obtained from a local weather station within the Remote Automated Weather Station (RAWS) program.

Sites for streamflow, shade, and channel geometry monitoring were selected by DEQ. Shade characterization sites were identified by assessment of aerial and color infrared images and by approved access from private landowners. In total, six mainstem locations on EFRC and four mainstem sites on SFAC were monitored in the field for vegetative shade and nine of these sites were also monitored with a Solar Pathfinder ™.

6.3.3.2.1 Streamflow

Flow was measured at the sites on EFRC and SFAC by DEQ in July, August and September of 2010. Flow was also measured by DEQ in 2011 for use in model development and in the water balance inclusion of Elk Creek and Trail Creek tributaries.

A water balance was determined from the provided DEQ dataset and described in the QAPP (Water & Environmental Technologies, 2011). Additional uncharacterized surface water flow was determined to be significant on the EFRC watershed and was measured in the 2011 field effort. These flows include Elk Creek and Trail Creek. Trail Creek was measured at a location parallel with Skalkaho Road just above a driveway on private property. It appears that the flow as measured on Trail Creek is further divided toward three center pivot sprinklers and may be used for irrigation. The point of surface contact between Trail Creek and EFRC was not able to be determined without landowner approval.

6.3.3.2.2 Riparian Shading

Riparian vegetation data were assessed in the field to characterize direct solar radiation losses from topography and vegetative shade. The following measurements were collected at three transects at each site to support the modeling efforts: (1) bankfull and wetted channel width (BFW and WCW), (2) vegetation/canopy height, (3) canopy density and vegetative cover percent, (4) channel overhang, and (5) percent shade at specified transects. A fiberglass-tape, range-finder, clinometer, canopy densiometer, and Solar Pathfinder™ were used to acquire these attributes. The riparian vegetation information (BFW/WCW, height, density, overhang, and % shade) was inputted into the Shadev3.0.xls Model (Washington State Department of Ecology, 2012). The Solar Pathfinder instrument was used to determine the amount of effective shade at a specific site to gage riparian shade effectiveness for various vegetative communities and riparian conditions. The Shadev3.0.xls Model yielded shade estimates at a finer scale than the available Solar Pathfinder data (i.e., every 15 meters along the stream compared with three sites along the stream). The Shade.xls site specific results, as compared with the Solar Pathfinder results, are displayed in **Figures 6-3 and 6-4**.

DEQ collected vegetation/canopy height, canopy density, vegetative cover percent, and channel overhang at three transects at all six of its sampling locations on East Fork Rock Creek in 2011 (**Figure 6-1**). **Figure 6-3** presents shade estimates from both the Solar Pathfinder and Shadev3.0.xls Model. As estimated by the Shadev3.0.xls Model, shade varied over a large range above river mile 7 and varied over fairly constant ranges from river mile 7 to the mouth. The effective shade derived using the Shadev3.0.xls Model was compared to the field measurements from the Solar Pathfinder, aerial imagery, and site photographs. The Shadev3.0.xls output was found to be reasonably accurate (i.e., within 10 percent or less at all sites with Solar Pathfinder data; see **Figure 6-3**). Additional plots of these data sets are presented in **Appendix I**.

An analysis of aerial imagery showed that shading along South Fork Antelope Creek was highly variable because of timber harvest and changes in elevation along the stream. Therefore, riparian vegetation data for South Fork Antelope Creek was collected at three transects at four sites (C02ANTSF03, C02ANTSF02, C02ANTSF01, and C02ANTSF010) in 2011 and Solar Pathfinder data was collected at three sites (C02ANTSF10, C02ANTSF01, and C02ANTSF02). **Figure 6-4** presents shade estimates from both the Solar Pathfinder and Shade.xls Model. As estimated by the Shade Model.xls, shade varied over a large range above river mile 2.0, varied over a constant range from river mile 2.0 to river mile 0.2, and decreased considerably from river mile 0.2 to the mouth. The effective shade derived using the spreadsheet tool Shadev3.0.xls was compared to the field measurements from the Solar Pathfinder, aerial imagery, and site photographs. The Shadev3.0.xls output was found to be reasonably accurate (i.e., within 10 percent or less at all sites with Solar Pathfinder data; see **Figure 6-4**). Additional plots of these data sets are presented in **Appendix J**.

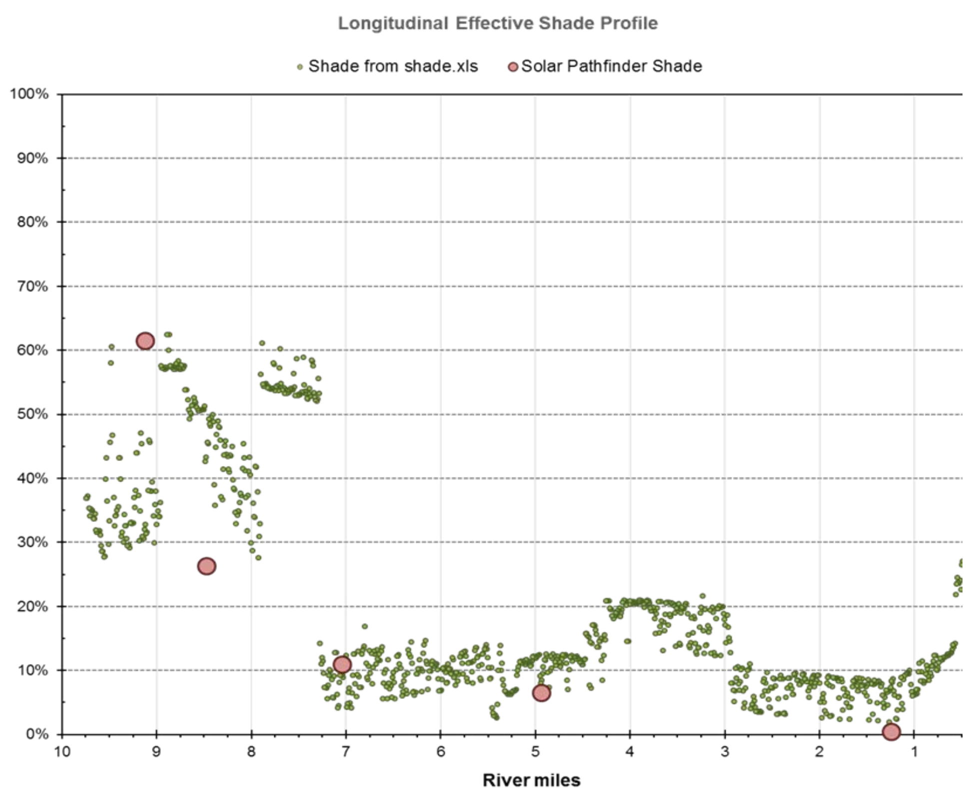

Figure 6-3. Effective shade output for EFRC from Shadev3.0.xls and Solar Pathfinder data

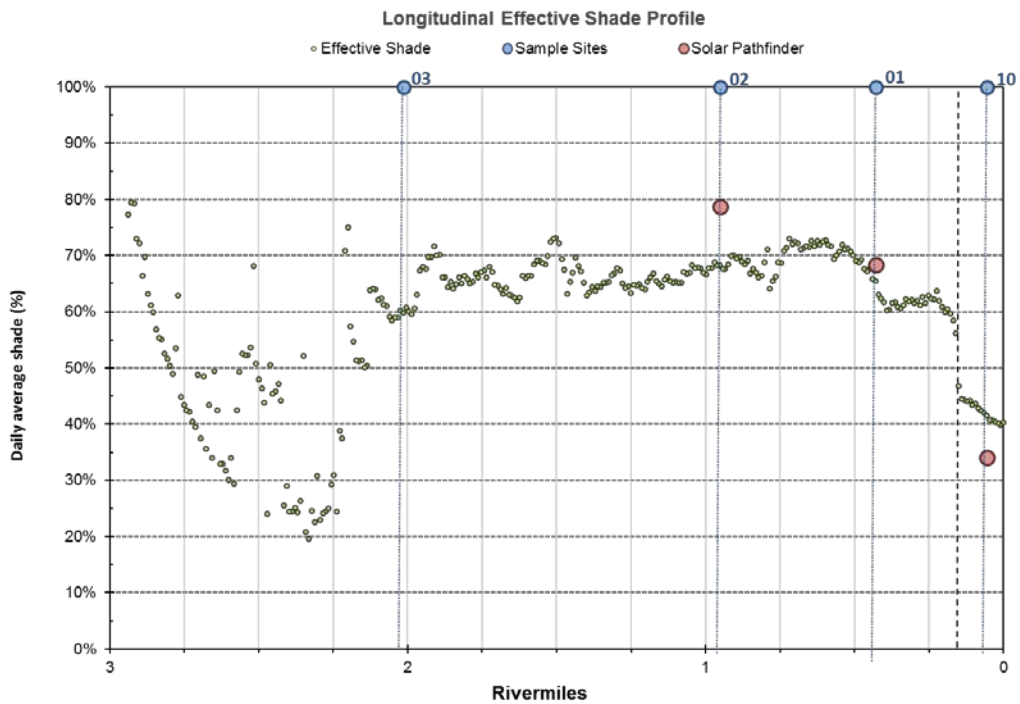

Figure 6-4. Effective shade output for SFAC from Shadev3.0.xls and Solar Pathfinder data

6.3.3.2.3 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 morphology measurements were taken at five cross-sections at two sites on East Fork Rock Creek (EFRK 01-02 and EFRK 03-03) during the DEQ sediment and habitat assessment in 2011. Representative bankfull width to depth ratios for the two sites are based on the reach average of those measurements, which averaged 22.2 at the upper site (EFRK 01-02) and 14.3 at the lower site (EFRK 03-03). Field observations were that the channel is overwidened at some discrete locations. However, both of the average reach values are within the acceptable and expected values for East Fork Rock Creek; therefore, no altered channel morphology scenario will be completed in the model to assess the influence of physical geometry on the overall heat balance of the stream.

Channel morphology measurements were taken at five cross-sections at two sites on South Fork Antelope Creek (SFAN 06-01 and SFAN 13-01) during the DEQ sediment and habitat assessment in 2011. Representative bankfull width to depth ratios for the two sites are based on the reach average of those measurements, which averaged 11.6 at the upper site (SFAN 06-01) and 12.2 at the lower site (SFAN 13-01). Field observations were that the channel was impacted by cattle and the creek channel had avulsed into hoof tracks and pockets of slower moving water. However, both of the average reach values are within the acceptable and expected values for South Fork Antelope Creek; therefore, no altered channel morphology scenario will be completed in the model to assess the influence of physical geometry on the overall heat balance of the stream.

Channel geometry inputs for QUAL2K for reaches A, B, C, and D (**Figure 6-5**) were derived using field-measured data and DEQ's cross-sections (Water & Environmental Technologies, 2011). No channel geometry data were available upstream of sample site C02ANTSF03.

Data from the 2011 DEQ sediment and habitat sites was used to derive channel geometry for the QUAL2K model. Manning's roughness coefficient (n) was estimated during a field visit (Water & Environmental Technologies, 2011). Channel slope was calculated using field-collected elevation data (Water & Environmental Technologies, 2011). Stream bottom width and the sides of the trapezoidal cross-section assumed for modeling were estimated using cross-sectional profile data collected during field work (Water & Environmental Technologies, 2011).

6.3.3.2.4 Meteorological Data

At all 2011 DEQ sites air temperature, dew point, wind speed, and cloud cover were sampled to assist in characterizing weather in the watershed. However, for the QUAL2K model, weather inputs were compiled from the closest station recording the necessary data. These data were used as model input for the July 29, 2010 critical date (the day with the warmest water temperatures within the warmest and driest week of the summer) for East Fork Rock Creek and the July 16, 2010 critical date for South Fork Antelope Creek. Air temperature, wind speed, relative humidity, and solar radiation data were obtained from the Philipsburg RAWS, which is at an elevation of 5,280 feet. Air temperature and dew point temperature data from this station were corrected to account for the elevation difference between the station and the impaired stream. Wind speed was corrected for the height differences of the sensor at Philipsburg RAWS (reported as 20 feet) and the assumed height in QUAL2K (7 meters, which is approximately 23 feet). Cloud cover was estimated on the basis of available hourly data at the Butte municipal airport (WBAN 24135) weather station that is operated by the National Weather Service, which is the closest weather station that measures cloud cover. Zero percent cloud cover was observed at the Butte municipal airport on July 16 and 29, 2010; therefore, zero percent was input for all 24 hours in the QUAL2K model.

6.3.3.2.5 Springs on SFAC

On the SFAC watershed, one spring was noted between C02ANTSF10 and C02ANTSF01 and another was noted between C02ANTSF02 and C02ANTSF03. Instantaneous water temperature was measured with the wet bulb thermometer of the sling phsychrometer in the spring and in the main SFAC channel both above and below the spring (**Table 6-1**). The temperature readout was not as accurate as a digital thermometer and should be used for comparison only. Flow of each spring was minimal.

Table 6-1. Instantaneous water temperature measurements on spring fed seeps into SFAC

Location	Date	Latitude	Longitude	Temperature of Spring (F)	Temperature of SFAC above spring (F)	Temperature of SFAC below spring (F)
Upper Spring	8/31/2011	46.2467	-113.4571	43.5	45.3	44.5
Lower Spring	8/31/2011	46.2603	-113.4606	44.1	45.5	Not recorded.

6.3.4 Other Information Sources

The following sections describe data used in the analysis of East Fork Rock and South Fork Antelope Creeks outside of the DEQ.

6.3.4.1 Additional Flow Data (DNRC)

The hydrology of East Fork Rock Creek is significantly affected by anthropogenic flow modification. In 1938, the stream was dammed and a transfer pipeline (siphon) was constructed to move the impounded water to the Flint Creek drainage. The East Fork Rock Creek Dam is owned by DNRC and operated by the Flint Creek Water Users Association. It is an earthen embankment dam, 88 feet high and 1,083 feet long. The reservoir stores 16,040 acre-feet at normal pool covering 390 acres (Montana Department of Natural Resources and Conservation, 2012).

The transfer pipeline diverts about one-quarter of a mile below the dam and follows a northwesterly direction to Trout Creek, which is used as a carrier for the diversion of water by other canals in the Flint Creek valley below (State Engineers Office, 1959). The canal has a maximum capacity of 200 cubic feet per second cfs; (Norberg, M., personal communication 2012). On the basis of flow data collected by DNRC in 2010 and 2011, water is typically diverted into the canal from late May through September with flow rates in the range of 50 to 150 cfs (Norberg, M., personal communication 2012). In 2010, the canal diverted between 34 and 98 percent (median 94 percent) of the flow discharged from East Fork Reservoir.

Montana DNRC has maintained continuously recording gages on East Fork Rock Creek for most years starting in 1994 at four locations (EF Rock above Res, EF Rock below Res, EF Rock Main Channel, and EF Rock above Elk). According to DNRC, after spring snowmelt, flow in the creek decreases considerably as much of the flow is diverted to the irrigation canal. Flows are always lowest just below the irrigation canal diversion. The stream gains between 24 and 32 cfs from just below the irrigation diversion canal to the mouth. Flow occasionally decreases or remains relatively constant in the lower half of the creek; this might be because of the cumulative effect of multiple small irrigation withdrawals, which divert to pivot and some flood irrigation (Norberg, M., personal communication 2012).

6.3.4.2 Climatic Data

In addition to the field-measured values for the East Fork Rock and South Fork Antelope Creeks, climatic data inputs for the QUAL2K model were obtained from the Western Regional Climate Center station in Philipsburg, MT, and included air temperature, dew point temperature, and wind speed.

6.4 Target Development

The following section describes 1) the framework for interpreting Montana's temperature standard; 2) the selection of indicator parameters used for target TMDL development; 3) how target values were developed; and 4) a summary of the temperature target values for East Fork Rock and South Fork Antelope Creeks.

6.4.1. Framework for Interpreting Montana's Temperature Standard

As discussed in **Section 4.1**, the TMDL targets represent attainment of applicable water quality standards. Montana's water quality standard for temperature is narrative in that it specifies a maximum allowable increase above the "naturally occurring" temperature in order to protect the existing thermal regime for fish and aquatic life. For waters classified as B-1, a 1°F maximum increase above naturally occurring water temperature is allowed within the range of 32°F to 66°F; within the naturally occurring range of 66°F to 66.5°F, no discharge is allowed which will cause the water temperature to exceed 67°F; and where the naturally occurring water temperature is 66.5°F or greater, the maximum allowable increase in water temperature is 0.5°F [ARM 17.30.623(2)(e)]. Note that under Montana water quality law, naturally occurring temperatures incorporate natural sources, yet may also include human sources with reasonable land, soil, and water conservation practices that protect current and reasonably anticipated beneficial uses.

Evaluating the extent that human activities are influencing stream temperatures is important. For the both the East Fork Rock and South Fork Antelope Creeks, a model (QUAL2K) was used to estimate the extent of human influence on temperature by evaluating the temperature deviation when existing conditions of riparian health and associated shade, channel geometry, and streamflow were compared with naturally occurring conditions for these parameters. Per the above water quality standard, human activity leading to increased temperature deviations from 0.5° F to 1.0° F (depending on the baseline naturally occurring condition) would be consistent with the existing impairment determinations for East Fork Rock and South Fork Antelope Creeks.

To help evaluate the extent and implications of impairment, it is useful to evaluate the degree to which existing temperatures affect fish populations or other aquatic life. For example, as discussed in **Section 6.3.3.1**, the existing temperatures within the East Fork Rock Creek have maximum values ranging from 58.0° F to 64.4° F for the lower portion of the stream. The maximum temperatures at several sites are just above optimum growth range for Westslope cutthroat trout (**Section 6.3.1.2**). Maximum temperatures in South Fork Antelope Creek range from 54.9° F to 61.2° F **(Section 6.3.3.1)**, which are levels within the optimal growth range for Westslope cutthroat trout (**Section 6.3.1.2**).

6.4.2 Selection of Indicator Parameters for TMDL Target Development

Naturally occurring temperatures can be estimated for a given set of conditions using QUAL2K or other modeling approaches. 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 target or indicator parameters include riparian health and associated shade, channel geometry, and improved streamflow conditions where applicable.

6.4.3 Developing Target Values

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 most of 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. Although the resulting target values are protective of fish and aquatic life use, the targets are protective of all designated uses because they are based on the reference approach, which strives for the highest achievable condition.

6.4.3.1 Riparian Canopy and Shade Target Values

Increased shading from riparian vegetation reduces sunlight hitting the stream and, thus, reduces 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 overwidened streams. Human influences affecting riparian canopy cover in the East Fork Rock Creek include current and historical agricultural activities (grazing and irrigated hay production) and some limited areas of recreational activity and residential development in the watershed. Human influences affecting riparian canopy cover in South Fork Antelope Creek include timber harvest and grazing.

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 canopy cover targets for East Fork Rock Creek and South Fork Antelope Creek are based on measurements made in the field from sites (**Section 6.3.3.2.2**) with good to moderate riparian conditions to represent a potential reference condition for each stream. The effective shade outputs derived using the Shadev3.0.xls Model were averaged from 7:00 am to 8:00 pm in order to arrive at the reach average effective shade throughout the day (based on sunrise and sunset times at the time of sampling - (National Oceanic and Atmospheric Administration, 2013)).

The target for a healthy riparian corridor for the valley section of East Fork Rock Creek (reaches A through F on **Figure 6-5**) is a minimum of 42% effective shade, which is the average riparian shade as measured from sites defined with moderate willow and shrub riparian canopy as discussed in **Section 6.3.3.2.2** and represents a potential reference condition for this section of the stream. For the upper part of East Fork Rock Creek (reaches G, H, and I on **Figure 6-6**) the target is a minimum of 63% effective shade, based on the average riparian shade as measured from sites with moderate mixed high level and coniferous riparian vegetation, representing a potential reference condition for this stream.

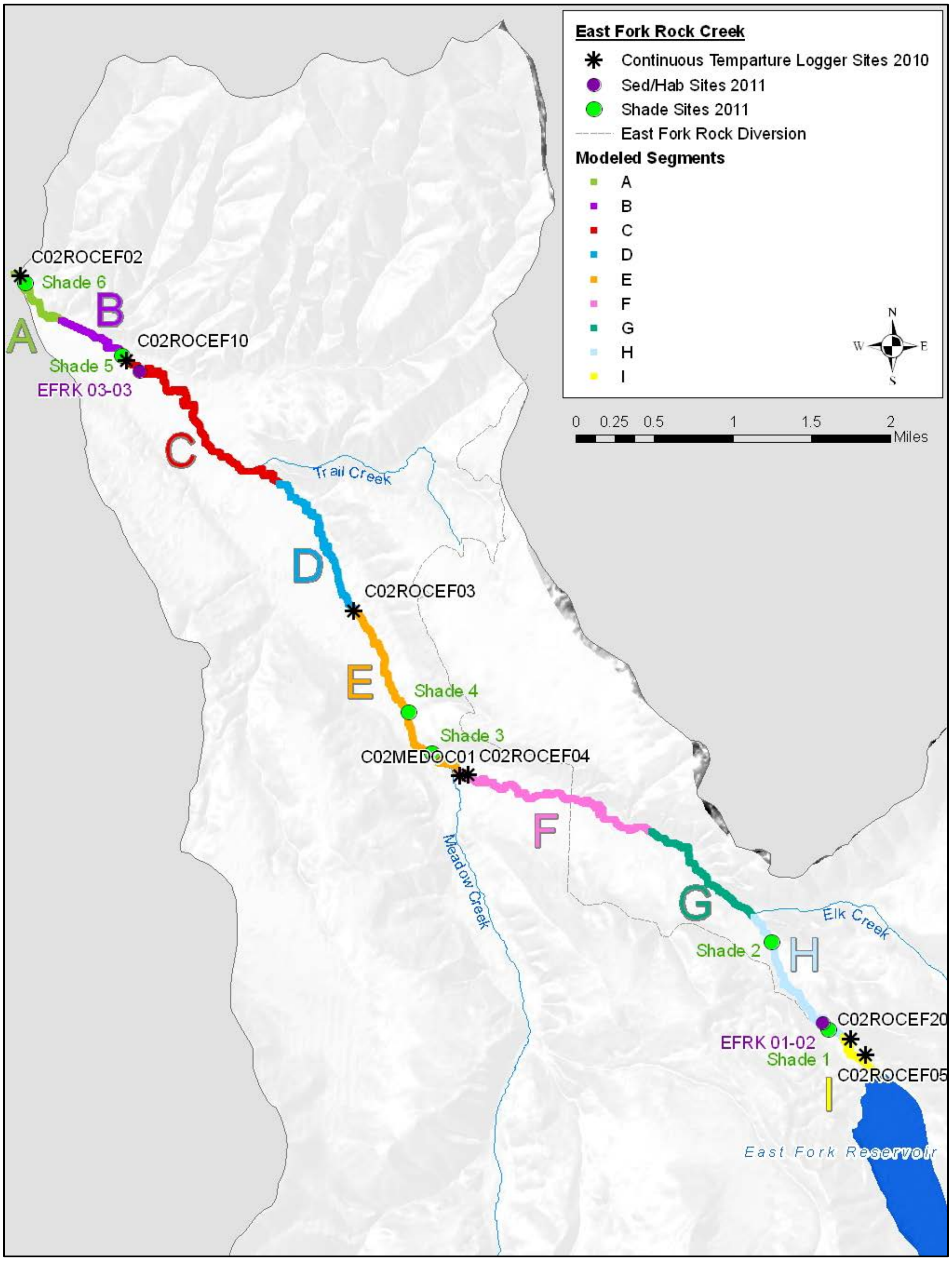

Figure 6-5. Model segmentation and sample sites along East Fork Rock Creek

The riparian canopy cover target for South Fork Antelope Creek is based on measurements made in the field from sites with good to moderate riparian conditions to represent a potential reference condition for this stream. The target for a healthy riparian corridor for all of South Fork Antelope Creek (reaches A through D) is a minimum of 76% effective shade, which is the average riparian shade as measured from sites defined with moderate riparian canopy as discussed in **Section 6.3.3.2.2.**

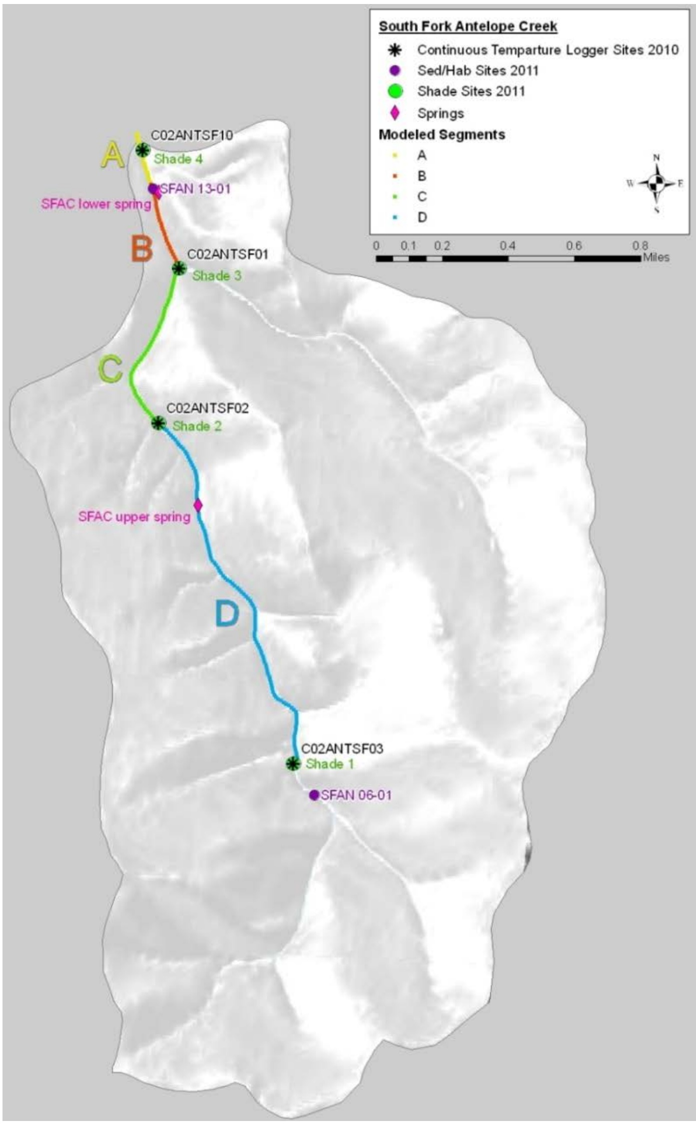

Figure 6-6. South Fork Antelope Creek Modeling Segments and Monitoring Sites

6.4.3.2 Width-to-Depth Ratio Target Values

A lower width-to-depth ratio equates to a deeper, narrower channel that has a smaller contact area with warm afternoon air and is slower to absorb heat. Also a lower width-to-depth ratio will increase the effectiveness of shading produced by the riparian canopy. Much of the stream channel widening in the East Fork Rock and South Fork Antelope Creeks is a result of destabilized streambanks from present or past agricultural activities (mostly riparian area grazing, although other human-related activities also have an impact).

Channel dimensions were not altered in the QUAL2K model scenarios; however, a channel geometry target has been developed for the dimensionless width-to-depth ratios in association with sediment TMDLs for the Rock Creek TPA (< 16 for B stream types, < 23 for C stream types, and < 12 for E stream types). East Fork Rock is a type C/E stream and South Fork Antelope is a type B stream. Width-to-depth ratio target values are used because a smaller width-to-depth ratio indicates a stream with stable channels and healthy riparian areas, directly affecting temperature. Width-to-depth target values are currently being met at the sites sampled in 2011 in East Fork Rock Creek and at the sites sampled in South Fork Antelope Creek in 2011.

The target values are not intended to be specific to every given point on the stream, the intent rather, is to achieve an average width-to-depth ratio that meets target values as a general trend throughout the East Fork Rock Creek and South Fork Antelope Creek corridors. Generally, improved riparian areas will lead to gradual improvements in width-to-depth ratio values over time. However, improvement in both riparian health and channel morphology need significant time before changes are visible. Changes in land management practices and a commitment to those practices have occurred in some locations along both creeks and should continue to be implemented throughout both creeks in order to meet goals for temperature.

6.4.3.3 Instream Discharge (Streamflow Conditions) Target Values

Larger volumes of water take longer to heat up during the day. Therefore, when flow is reduced, streams can reach higher maximum daily stream temperatures. In East Fork Rock Creek, the majority of streamflow reduction is attributed to a diversion about one quarter of a mile below the East Fork Rock Creek Dam for use in the neighboring Flint Creek watershed for irrigation purposes.

Instream discharge in East Fork Rock Creek is complicated by the inter-basin transfer of water via a significant irrigation diversion; and the relationships to groundwater and water rights both in the Flint Creek and East Fork Rock Creek watersheds. Thorough investigations into irrigation infrastructure improvements, water management (including the possibility of appropriating water for instream use), and relationships to groundwater were not conducted for this TMDL. However, for modeling purposes, a scenario was run to estimate all reasonable land, soil, and water conservation practices that included a 15% water savings from improved irrigation delivery and application efficiencies, and allowing that conserved water to flow down East Fork Rock Creek downstream from the point of the diversion of the East Fork Rock Creek canal. The focus of the 15% water savings is on the main diversion because the majority of flow released from the dam is being diverted during July and August, which is the time period of concern for instream temperatures. The 15% may be an over or under estimation of what is achievable and should be studied further, however, 15% is a reasonable value with which to start the discussion. Per Montana's water quality law, TMDL development cannot be construed to divest, impair, or diminish any water right recognized pursuant to Title 85 (MCA §75-5-705). Therefore, any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights.

The 15% water savings could be achieved through best management practices including delivery system upgrades, irrigation scheduling, and application management (Waskom, 1994). The DNRC has proposed an East Fork Rock Creek Main Canal Lining Project. The DNRC identified seepage loss in the reach of the canal from the headgate to the East Fork Siphon as high as 30 acre-feet per day, with a seasonal average of 15 to 20 acre-feet per day. According to DNRC, this water is lost through the highly pervious canal berm, and the seepage dissipates into the ground with no beneficial use. According to the DNRC, lining the canal would help to eliminate the loss of water to seepage; conserve, and put to beneficial use water captured in the East Fork reservoir; keep more water in the system, which benefits farmers and ranchers, fish and wildlife and sportsman and recreationists; and protect from excessive seepage water the recently installed 4,000 foot long East Fork siphon. In addition to improving water delivery, improvements in application efficiencies could also contribute to the 15% water savings. The U.S. Department of Agriculture (1997) has documented improvements to gravity flood systems that increase typical system efficiencies from 40%-65% up to 80%-90%. Similar efficiency improvements for gravity systems have been reported by the Montana DNRC (2008a), the Economic Research Station (1997), and Negri et al (1989). The DEQ recognizes that not all water savings from improved efficiencies are necessarily available for flow augmentation.

Water users in the East Fork Rock Creek and Flint Creek watersheds are encouraged to work with the USDA Natural Resource Conservation Service, the Montana Department of Natural Resources & Conservation, the local conservation district, and other local land management agencies to review their systems and practices.

6.4.4 Target Values Summary

The allowable temperatures defined via Montana's temperature standard represent the primary target that must be attained.

Alternatively, compliance with the temperature standard can be achieved by meeting all other targets for shade, channel width-to-depth ratio, and streamflow. In this approach, if all reasonable land, soil, and water conservation practices are installed or practiced, state standards are met. These targets, which need to be met in combination, are referred to as "temperature-influencing targets." **Table 6-2** presents a summary of the temperature influencing targets for East Fork Rock Creek and South Fork Antelope Creek. Note that an instream discharge target is not applicable to South Fork Antelope Creek because of the lack of irrigation diversions.

Table 6-2. Temperature TMDL Targets for East Fork Rock and South Fork Antelope Creeks

Target Parameter	Target Value	Existing Condition
Maximum allowable increase over naturally occurring temperature	For waters classified as B-1, a 1°F maximum increase above naturally occurring water temperature is allowed within the range of 32°F to 66°F; within the naturally occurring range of 66°F to 66.5°F, no discharge is allowed which will cause the water temperature to exceed 67°F; and where the naturally occurring water temperature is 66.5°F or greater, the maximum allowable increase in water temperature is 0.5°F [ARM 17.30.623(2)(e)].	• Calibrated QUAL2K model results are compared to restoration scenario results. • Modeling conclusions indicate Montana's temperature standard is not being met in East Fork Rock Creek (increased temperature deviation of 3.9° F), but is being met in South Fork Antelope Creek (increased temperature deviation of 0.3° F).
OR meet ALL of the temperature influencing restoration targets below		
Riparian Health - Shade	• East Fork Rock Creek: minimum 42% average effective shade for valley willow and shrub cover (Reaches A through F on **Figure 6-5**) and 63% for mixed high level and coniferous riparian areas (Reaches G through I on **Figure 6-5**) • South Fork Antelope Creek: minimum 76% average effective shade	• East Fork Rock Creek: Of the nine sites measured, effective shade was 42%, 24%, 21%, 36%, 29%, and 25% for valley willow and shrub cover and 63%, 63%, and 55% for mixed high level and coniferous riparian areas. • South Fork Antelope Creek: Of the four sites measured, effective shade was 76%, 79%, 75%, and 59%.
Width to Depth Ratio	• East Fork Rock Creek: o C stream type: < 23 o E stream type: < 12 • South Fork Antelope Creek: o B stream type: < 16	• East Fork Rock Creek: Of the two sites measured, both sites (type C) are meeting the W/D target (22.1 and 14.3) • South Fork Antelope Creek: Of the two sites measured, both sites are meeting the W/D target (11.6 and 12.2)

Instream Discharge	East Fork Rock Creek: 15% water savings from improved irrigation delivery and application efficiencies, and allowing that water savings to flow down East Fork Rock Creek downstream from the point of the diversion of the East Fork Rock Creek canal (any voluntary water savings and subsequent in stream flow augmentation must be done in a way that protects water rights). • South Fork Antelope Creek: Not applicable because of lack of irrigation withdrawals in area of concern	East Fork Rock Creek (EFRC): Instream discharge in EFRC is complicated by the inter-basin transfer of water via a significant irrigation diversion; and the relationships to groundwater and water rights both in the Flint Creek and East Fork Rock Creek watersheds. The 15% water savings could be achieved through best management practices including delivery system upgrades, irrigation scheduling, and application management (i.e. the proposed lining of the East Fork Rock Creek Main Canal). Thorough investigations into irrigation infrastructure improvements, water management, and relationships to groundwater would need to be conducted.

6.5 Source Assessment – QUAL2K Model and Modeling Scenarios

As discussed above, source assessment for East Fork Rock and South Fork Antelope Creeks involved QUAL2K temperature modeling (**Appendices I and J**). Water temperature, flow, channel dimension, and riparian shade data were incorporated in a QUAL2K water quality model to characterize existing temperature conditions and to evaluate differing land management scenarios for East Fork Rock and South Fork Antelope Creeks. This section provides a summary of the QUAL2K modeling presented in **Appendices I and J**, including a description of the model and the modeling scenarios used to evaluate human influences on both streams.

The QUAL2K model was used to determine the extent that human-caused disturbances within East Fork Rock and South Fork Antelope Creeks have increased the water temperature above the naturally occurring level. QUAL2K is a one-dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model uses steady state hydraulics that simulates non-uniform steady flow. Within the model, water temperatures are estimated based on climate data, riparian shading, and channel conditions. For this assessment, the QUAL2K model was used to evaluate maximum summer water temperatures in East Fork Rock and South Fork Antelope Creeks.

The water temperature data collected in East Fork Rock and South Fork Antelope Creeks (**Section 6.3.3**), along with climate data (**Section 6.3.4.2**), was incorporated into the model and used to calibrate to existing conditions. A number of various scenarios were then modeled to investigate the potential influences of human activities on temperatures in East Fork Rock and South Fork Antelope Creeks. The following sections describe those modeling scenarios. A more detailed report of the development and results of the QUAL2K models and scenarios are included in **Appendices I and J**.

6.5.1 QUAL2K - East Fork Rock Creek

6.5.1.1 Baseline Scenario

The baseline scenario represents the existing conditions within the East Fork Rock Creek during July 29, 2010, which was determined to be the hottest period for water temperatures on the stream in the 2010 summer. To inform the model, this scenario used the measured field data to represent temperature, flow, and shade. When field data was unavailable, reasonable assumptions and extrapolation were used. The model was then run and compared with measured conditions. Hydraulic output in the model accurately reflected measured conditions, indicating that water routing and channel morphology were adequately calibrated. To assure consistency when evaluating the potential to reduce stream temperatures, subsequent model scenarios were compared with the existing-conditions results of the baseline model and not to the field-measured values.

6.5.1.2 Low Flow Scenario

In this scenario, the flow inputs to the QUAL2K model are decreased to represent low-flow conditions, simulating the stream dynamics during an exceptionally dry season. DNRC, which manages East Fork Reservoir and the diversion to the Flint Creek watershed, maintains at least 5 cfs below the diversion. In this scenario, the water balance was altered such that 5 cfs of flow was present in the model just below the diversion. This low-flow condition scenario resulted in slightly higher temperatures along most of the stream. Daily maximum temperatures increased between 0.1 and 0.3 °F.

6.5.1.3 Full Potential Shade Scenario

The full potential shade scenario uses the existing conditions model and increases shading along the creek depending on the vegetation present in each reach. The shade in reaches A through F was set equivalent to the 24-hour shade input in reach A. The shade in reach G remained the same, and the shade in reaches H and I was set equivalent to the 24-hour shade input in reach H (see **Figure 6-5**). These full potential shade assignments are based on the review of the vegetation data and aerial photos. It appears that vegetation conditions similar to the EFRC Shade 1, which is characterized by medium conifer in the overstory with dense willows and shrubs in the understory, would be achievable in East Fork Rock Creek below East Fork Reservoir, in reaches H and I. According to site EFRC Shade 2, the potential cover is mixed high level for reach G. The potential cover for reaches A through F is based on site EFRC Shade 6, which appears to be medium willow and shrub; however, most of the stream along these reaches is below this potential condition. This scenario resulted in cooler water temperatures along most of East Fork Rock Creek. Daily maximum temperatures decreased between 0.0 and 1.8 °F.

6.5.1.4 Full Potential Shade with Low Flow Conditions Scenario

The full potential shade scenario using low-flow conditions is a combination of the scenarios presented in **Sections 6.5.1.3** and **6.5.1.4**. Flow conditions were designed to replicate a dry season, and shading was increased to approximate a mature riparian corridor. This scenario resulted in cooler water temperatures along the lower portions of East Fork Rock Creek. Daily maximum temperatures changed between –1.6 and 0.2 °F.

6.5.1.5 Increased Flow Scenario

The increased flow scenario is used to describe the potential thermal effect of water savings and flow augmentation on water temperatures in East Fork Rock Creek. This scenario assumes that improved water delivery and application efficiency could create a water savings of 15% and that the conserved water could be allowed to flow down East Fork Rock Creek past the main diversion, thereby increasing instream flow. For modeling purposes, the diversion flow rate was reduced by 15 percent, and the additional water was allowed to flow down East Fork Rock Creek. This scenario resulted in cooler water temperatures along most of East Fork Rock Creek. Daily maximum temperatures decreased between 0.6 and 2.5 °F.

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

The naturally occurring scenario represents water temperature conditions resulting from implementing all reasonable land, soil, and water conservation practices as outlined in ARM 17.30.602. This scenario identifies the naturally occurring temperature in waterbodies of interest and establishes the temperatures to which a 1° F temperature increase is allowable. In turn, this can be used to identify the impairment status of a waterbody and forms the basis for the allocations and temperature TMDLs in this document. The naturally occurring scenario used the conditions included in the full potential shade scenario (**Section 6.5.1.3**) and the increased flow scenario (**Section 6.5.1.5**). **Figure 6-7** presents the results for both the existing condition (baseline scenario) and the naturally occurring scenario. This scenario resulted in cooler water temperatures along most of East Fork Rock Creek. Daily maximum temperatures decreased between 0.6 and 3.9 °F.

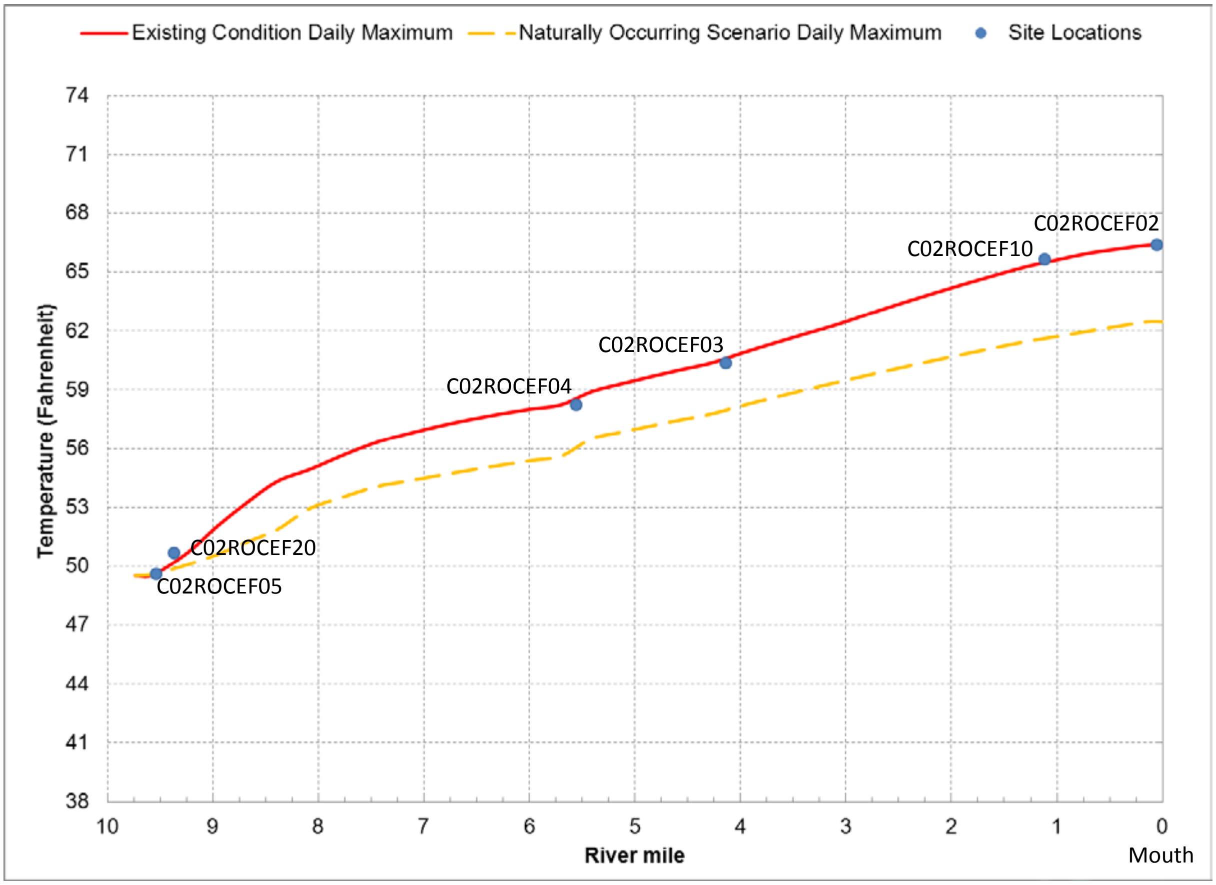

Figure 6-7. Comparison between Existing Condition Daily Maximums and Naturally Occurring Scenario Daily Maximums in East Fork Rock Creek

6.5.2 QUAL2K – South Fork Antelope Creek

6.5.2.1 Baseline Scenario

The baseline scenario represents the existing conditions within South Fork Antelope Creek on July 16, 2010, which was determined to the hottest period for water temperatures on the stream in the 2010 summer. To inform the model, this scenario used the measured field data to represent temperature, flow, and shade. When field data was unavailable, reasonable assumptions and extrapolation were used. The model was then run and compared with measured conditions. Hydraulic output in the model accurately reflected measured conditions, indicating that water routing and channel morphology were adequately calibrated. To assure consistency when evaluating the potential to reduce stream temperatures, subsequent model scenarios were compared with the existing-conditions results of the baseline model and not to the field-measured values.

6.5.2.2 Low Flow Scenario

In this scenario, the flow inputs to the QUAL2K model are decreased to represent critical low-flow conditions, simulating the stream dynamics during an exceptionally dry season. An evaluation of monthly flows at the closest USGS gaging station on the Middle Fork Rock Creek near Philipsburg, Montana (12332000) showed that low-flow conditions (represented by the monthly 25th percentile flow - Calculation Period: 1938-2011) were 37 percent smaller than the average conditions (represented by the monthly mean flow for that same calculation period) for July. An evaluation of monthly flows during the year 2010 revealed that the July through August time period was representative of the average flows for those 3 particular months (**Figure 6-8**). Therefore, the headwaters inflow, diffuse flow (i.e., groundwater) and springs' inflow were reduced by 37 percent. The low-flow condition scenario resulted in higher daily-maximum and daily-mean temperatures along the entire stream, with a greater increase in temperature corresponding to a greater decrease in flow. A uniform decrease in minimum temperatures may be related to the increased influence of cooler groundwater during low-flow conditions.

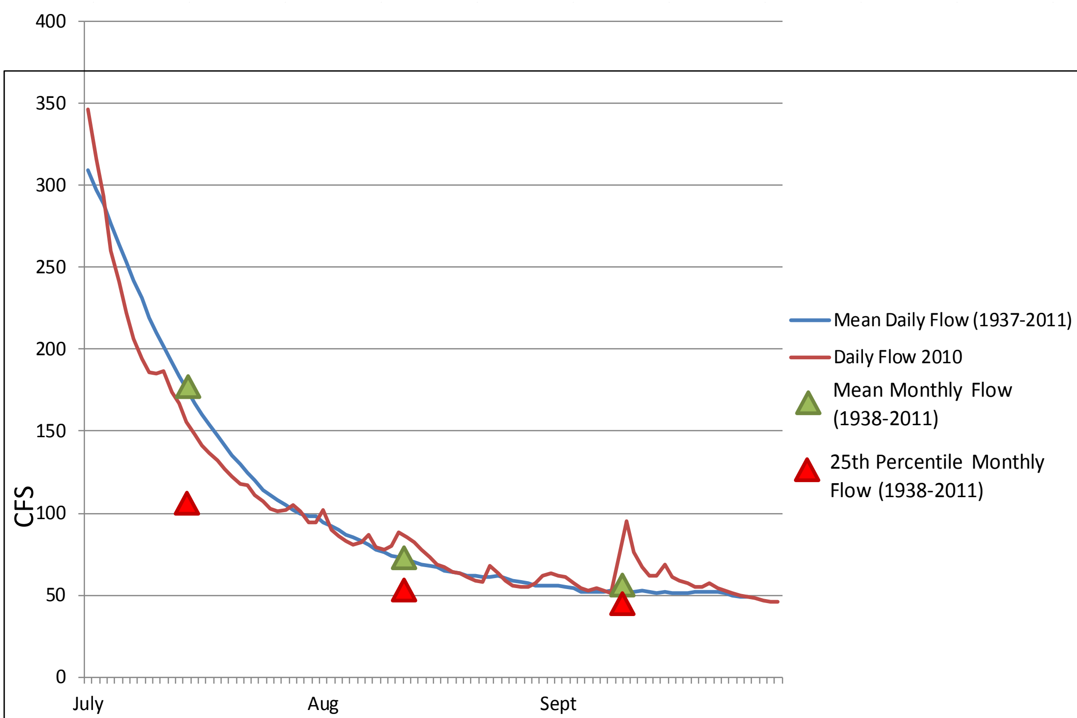

Figure 6-8. Flow comparison on the Middle Fork Rock Creek USGS gaging station

6.5.2.3 Full Potential Shade Scenario

The full potential shade scenario uses the existing conditions model and increases shading along the creek depending on the vegetation present in each reach. In this scenario, the shading of all the reaches was increased to the level of shading in the reach with the highest levels of estimated shading. The 24-hour shade input for reaches A, B, and C were set to the same as the 24-hour shade input for reach D (**Figure 6-6**). This full potential shade scenario had a minimal effect on water temperatures along South

Fork Antelope Creek, with small decreases of maximum daily water temperatures in the lower half of the watershed. Daily maximum temperatures decreased between 0°F and 0.3 °F.

6.5.2.4 Full Potential Shade with Low Flow Conditions Scenario

The full potential shade scenario using low-flow conditions is a combination of the scenarios presented in **Sections 6.5.2.2** and **6.5.2.3**. Flow conditions were designed to replicate a dry season, and shading was increased to approximate a mature riparian corridor. Daily maximum temperatures were lower, as compared to daily maximum temperatures in the low flow condition scenario, but still increased between 0.0 and 1.0 °F.

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

The naturally occurring scenario represents water temperature conditions resulting from implementing all reasonable land, soil, and water conservation practices as outlined in ARM 17.30.602. This scenario identifies the naturally occurring temperature in waterbodies of interest and establishes the temperatures to which a 1° F temperature increase is allowable. In turn, this can be used to identify the impairment status of a waterbody and forms the basis for the allocations and temperature TMDLs in this document. The naturally occurring scenario used the conditions included in the full potential shade scenario (**Section 6.5.2.3**). Daily maximum temperatures decreased, as compared to the existing condition scenario, between 0.0°F and 0.3 °F. **Figure 6-9** presents the results for both the existing condition (baseline scenario) and the naturally occurring scenario. Again, this full potential shade scenario had a minimal effect on water temperatures along South Fork Antelope Creek.

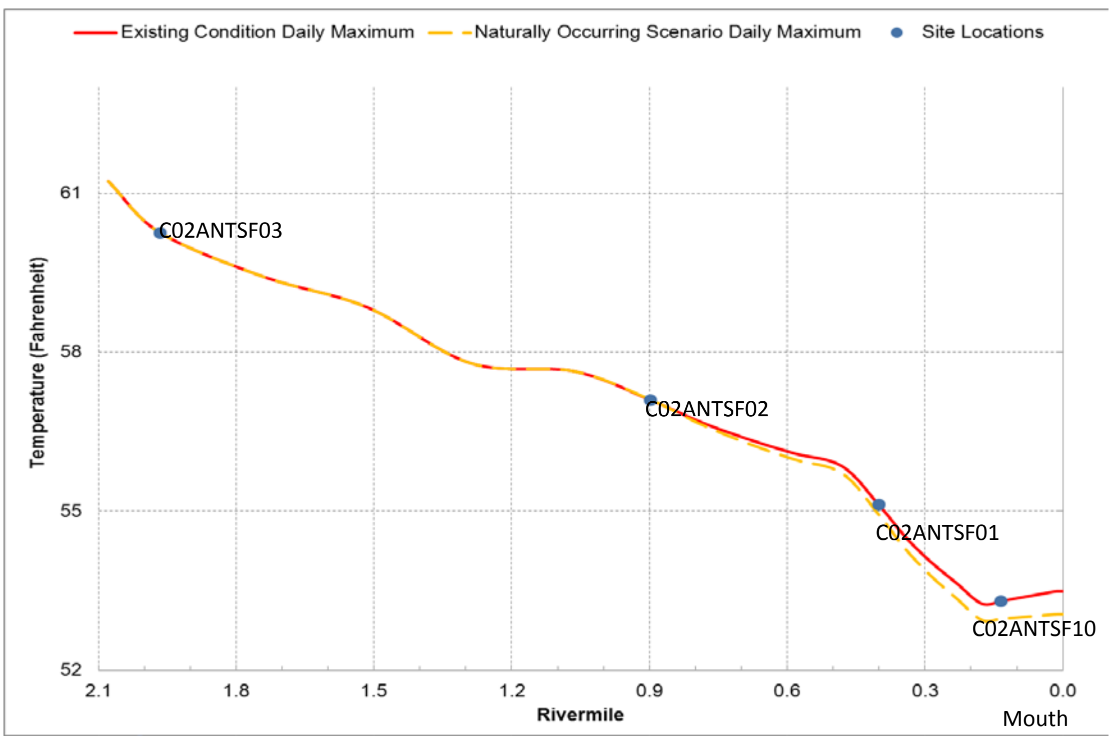

Figure 6-9. Comparison between Existing Condition Daily Maximums and Naturally Occurring Scenario Daily Maximums in South Fork Antelope Creek

6.6 TMDL Development Determination

Modeling is used to determine temperature conditions that relate to Montana's temperature standard. The model is calibrated to existing conditions and then used to simulate stream temperatures by applying temperature influencing conditions that represent a naturally occurring setting. These simulated temperatures determine the appropriate allowable increase specified by the standard (0.5°F or 1°F). The need for a TMDL is determined by comparing current conditions to a condition representing all reasonable land, soil, and water conservation practices (naturally occurring condition).

6.6.1 South Fork Antelope Creek

Based on the comparison of the existing conditions to the naturally occurring conditions (full application of BMPs with current land use) a temperature TMDL will not be written for South Fork Antelope Creek. Scenarios were developed in QUAL2K to evaluate the impacts of various factors that could affect instream water temperatures in South Fork Antelope Creek. Increasing shade to replicate the effect of re-vegetation after timber harvest resulted in a small change when compared to both the existing condition scenario (≤ 0.3°F) and the natural low-flow scenario (≤ 0.4°F) (**Figures 6-10 and 6-11**).

Because South Fork Antelope Creek is classified as B-1, and the naturally occurring temperatures for South Fork Antelope Creek are less than 66°F, the maximum allowable increase over the naturally occurring temperature is 1°F. Currently, the estimated maximum increase over the naturally occurring temperature is 0.3°F; therefore, no temperature TMDL will be written for South Fork Antelope Creek.

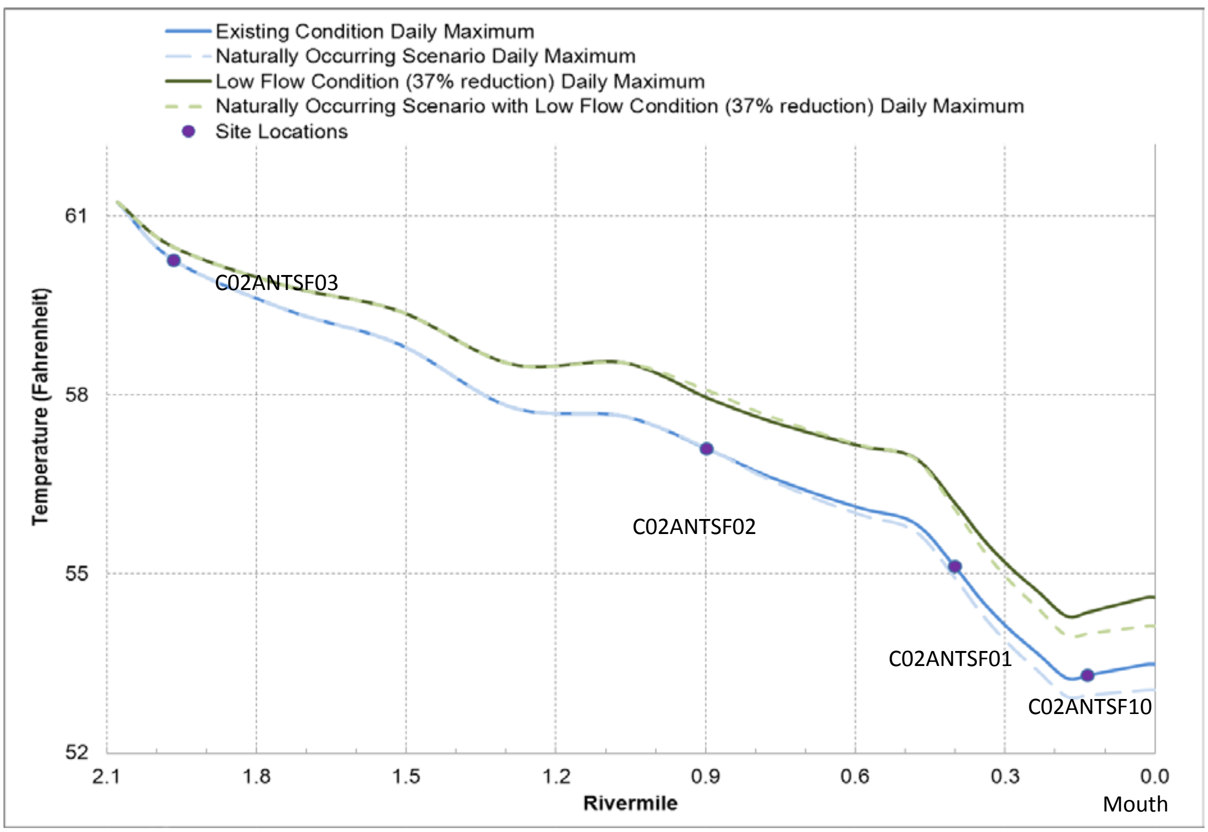

Figure 6-10. Comparison of Existing and Low Flow Conditions with Naturally Occurring Scenario

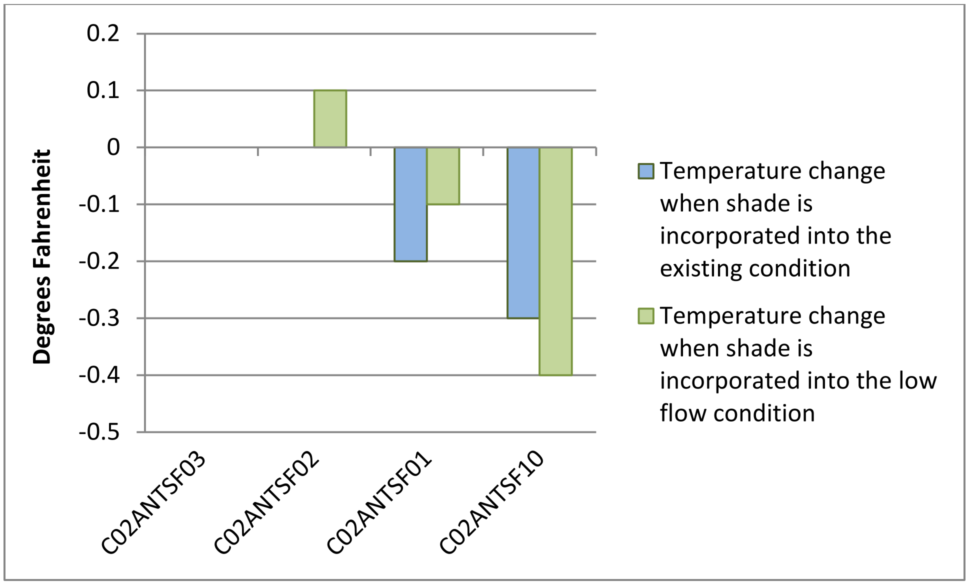

Figure 6-11. Change in Temperature when Naturally Occurring Scenario (full potential shade) is Incorporated into both the Existing and Low Flow Conditions

6.6.2 East Fork Rock Creek

Based on the comparison of existing conditions to naturally occurring conditions (full application of BMPs with current land use) and temperature influencing TMDL targets, a temperature TMDL will be developed for East Fork Rock Creek. Scenarios were developed in QUAL2K to evaluate the impacts of various factors that might affect instream water temperatures in East Fork Rock Creek. Reducing flow such that only 5 cfs was present in East Fork Rock Creek below the main diversion resulted in higher instream temperatures, which increased up to 0.3 °F. Increasing shade to replicate the effect of re-vegetation lowered stream temperatures by as much as 1.8 °F. Increasing shade with low-flow conditions resulted in higher instream temperatures in some parts of East Fork Rock Creek and cooler temperatures in other parts. Creating a water savings from improved irrigation delivery and application efficiencies, and allowing that conserved water to flow down East Fork Rock Creek downstream from the point of the diversion of the East Fork Rock Creek canal, lowered temperatures by as much as 2.5 °F. Increasing instream flow and increasing to full potential shade, which is considered to be the naturally occurring condition, lowered instream temperatures by as much as 3.9 °F.

Because East Fork Rock Creek is classified as B-1, and the naturally occurring temperatures for East Fork Rock Creek are less than 66°F, the maximum allowable increase over the naturally occurring temperature is 1°F. Currently, the estimated maximum increase over the naturally occurring temperature is 3.9°F; therefore, a temperature TMDL will be written for East Fork Rock Creek.

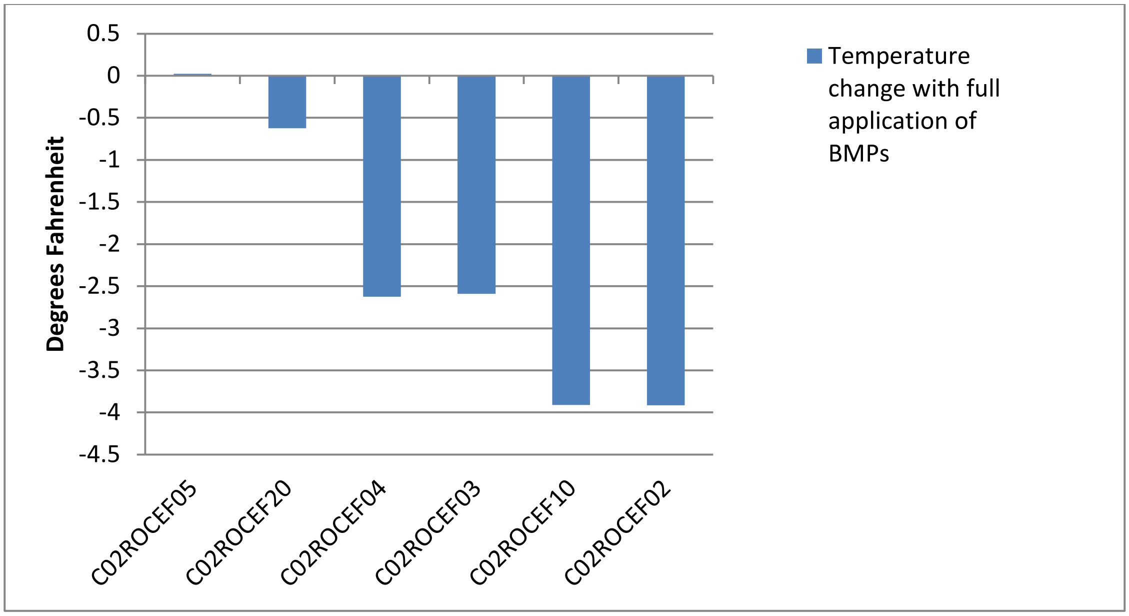

Figure 6-12. Change in Temperature when Naturally Occurring Scenario (full potential shade and instream flow augmentation) is Incorporated into the Existing Condition

6.7 East Fork Rock Creek Temperature TMDL and Allocations

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

6.7.1. Temperature TMDL East Fork Rock Creek (MT76E002_020)

Because of the dynamic temperature conditions throughout the course of a day, the temperature TMDL is the thermal load, at an instantaneous moment, associated with the stream temperature when in compliance with Montana's water quality standards. As stated earlier, the temperature standard for East Fork Rock Creek is defined as follows: For waters classified as B-1, the maximum allowable increase over the naturally occurring temperature is 1° F, if the naturally occurring temperature is less than 66° F. Within the naturally occurring temperature range of 66° F to 66.5° F, the allowable increase cannot exceed 67° F. If the naturally occurring temperature is greater than 66.5° F, the maximum allowable increase is 0.5° F. Montana's temperature standard for B1 classified waters, relative to naturally occurring temperatures, is depicted in **Figure 6-13**.

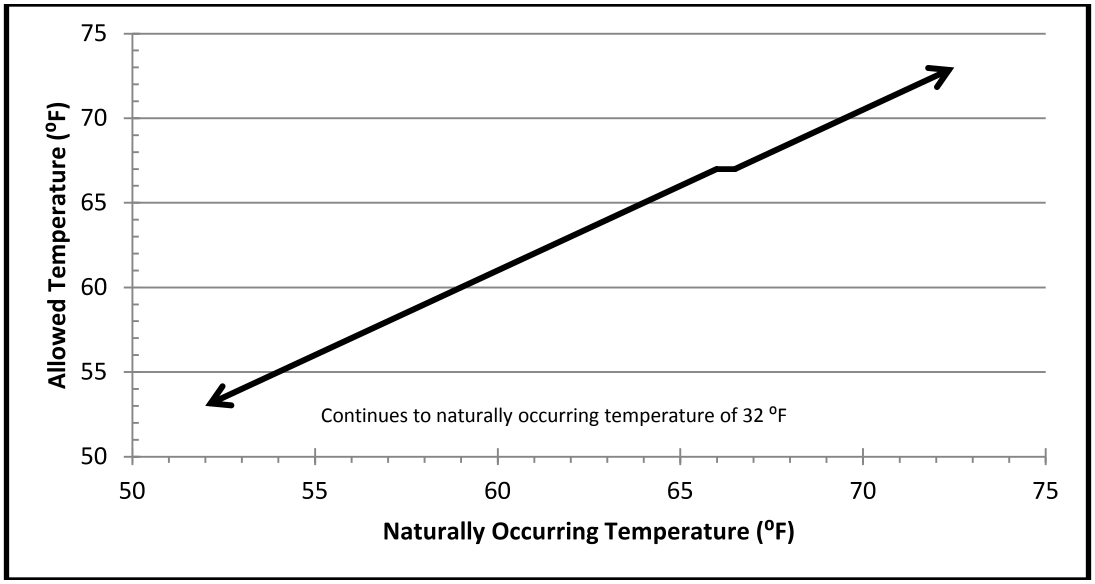

Figure 6-13. Instream Temperatures Allowed by Montana's B-1 Classification Temperature Standard

An instantaneous load is computed by the second and applied at all times. The allowed temperature can be calculated using Montana's B-1 classification standards (**Figure 6-13**) and using a modeled, measured, or estimated naturally occurring instantaneous temperature. The allowable instantaneous total maximum load (per second) at any location in the waterbody is provided by **Equation 6-1**. This equates to the kCal increase associated with the warming of the water from 32° F to the temperature that represents compliance with Montana's temperature standard, as determined from **Figure 6-13**.

Equation 6-1: $TMDL = [(T_n+A)-32]*Q*(15.6)$

Where:
T_n = naturally occurring water temperature (°F)
A = allowable increase above naturally occurring temperature (°F)
Q = streamflow (cfs)
15.6 = conversion factor (°F to kCal)
TMDL = allowable thermal load expressed as kilocalories per second above 32°F

The use of a load per second to define the temperature TMDL is appropriate to address the most sensitive summer afternoon timeframe when fish are most distressed by temperatures and when human-caused thermal loading would have the most effect. Providing thermal loads based upon an average daily temperature does not protect fish because diurnal shifts in temperature create average daily conditions. Streams with significant shade loss can be warmer than natural during the day and cooler than natural at night, resulting in circumstances that do not deviate from Montana's temperature standard when averaged over a daily timeframe. Evaluating impairment and expressing the TMDL using a short time step provides proper fishery use protection.

6.7.2 Temperature TMDL Allocations for East Fork Rock Creek (MT76E002_020)

While **Equation 6-1** provides a translation of allowable instantaneous temperature to an allowable instantaneous thermal load, the development of the TMDL allocations based on this variable thermal load does not readily translate to on-the-ground management.

Furthermore, the challenge in deriving a Total Maximum Daily Load for a parameter such as temperature is in defining the naturally occurring temperature at any given point during the day. In the case of East Fork Rock Creek, a model was used to investigate the likelihood of temperatures above the allowable limit described by the state standard. Although not a perfect representation of the complex interactions that occur in the watershed, the model has shown that human-caused activities have elevated temperatures. In addition, on-the-ground information tells us that not all reasonable land, soil, and water conservation practices (human activity under naturally occurring conditions) are currently being practiced in the watershed. Thus, in lieu of developing allocations based on quantified temperatures or thermal loads that apply under a specific set of conditions, we can express the TMDL and associated allocations through surrogate indicators of local conditions that would comply with the temperature standard. Therefore, the allocations necessary to achieve the TMDL are described using the restoration targets (**Section 6.4.4**). Linking achievement of these targets to land management activities where the application of all reasonable land, soil, and water conservation practices would achieve the state temperature standard.

Thermal conditions affecting East Fork Rock Creek are complex and influenced by many inter-related factors throughout the stream. Although all of these relationships have not been completely analyzed during the assessment of East Fork Rock Creek, field data and water quality modeling do indicate that temperatures in East Fork Rock Creek are influenced by human activity, that temperature increases are likely harmful to aquatic life during certain periods of the summer, and that improvements in vegetative canopy cover and augmenting instream flow during summer months will reduce water temperatures throughout most of the stream, from below the reservoir to the mouth.

The temperature TMDL allocations for East Fork Rock Creek are conveyed via surrogate allocations based on the temperature-related water quality targets described in **Section 6.4.4**. These surrogate TMDL allocations define conditions that will ensure compliance with Montana's temperature standard. The surrogate allocations applicable to East Fork Rock Creek are presented in **Table 6-3**. Naturally occurring conditions will be achieved via meeting the nonpoint source load allocations.

Table 6-3. Temperature TMDL Allocations for East Fork Rock Creek (MT76E002_020) from the East Fork Reservoir to the mouth (Middle Fork Rock Creek)

Source Type	Allocation
Land uses and practices that reduce riparian health and shade provided by near-stream vegetation along East Fork Rock Creek	Load Allocation: The thermal load to the stream segment when there is a minimum average effective shade of 42% along reaches A through F (**Figure 6-5**) and a minimum average effective shade of 63% for reaches G through I (**Figure 6-5**)
Land uses and practices that result in the overwidening of the stream channel such that widths are increased, depths are decreased, and thermal loading is accelerated	Load Allocation: The thermal load to the stream when there is an average width-to-depth ratio < 23 throughout East Fork Rock Creek on C channels and < 12 on E channels

Table 6-3. Temperature TMDL Allocations for East Fork Rock Creek (MT76E002_020) from the East Fork Reservoir to the mouth (Middle Fork Rock Creek)

Source Type	Allocation
Majority of streamflow in East Fork Rock Creek is diverted during summer months to provide water for irrigation.	Load Allocation: 15% water savings from improved irrigation water delivery and application efficiencies, and allowing that conserved water to flow down East Fork Rock Creek downstream from the point of the diversion of the East Fork Rock Creek canal (any voluntary water savings and subsequent in stream flow augmentation must be done in a way that protects water rights). This allocation does not imply an inherent inefficient use of water throughout the watershed, but rather calls on water users to identify their practices, determine if more efficient means are possible and practical given various economic and resource constraints, and apply those improvements wherever possible to limit the effects of practices on temperatures in the East Fork Rock Creek.

6.7.3 Achieving Temperature Allocations

Improvement in riparian health needs significant time before changes can be seen. 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 East Fork Rock Creek. In addition, the targets and allocations presented represent the desired conditions that would be expected in most areas along a stream, but DEQ acknowledges that all sites may not be able to achieve them. The targets and allocations are not intended to be specific to every given point on the stream; the intent, rather, is to achieve these goals as a typical condition throughout the East Fork Rock Creek watershed. (Note that some areas may also be able to achieve conditions greater than the target, and the best possible condition given all reasonable land, soil, and water conservation practices should be strived for in all circumstances.)

6.8 Margin of Safety and Seasonality

TMDL development must incorporate a margin of safety into the allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. In addition, all TMDL/Water Quality Restoration Planning documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream, and load allocations. This section describes, in detail, considerations of a margin of safety and seasonality in the temperature TMDL development process.

The margin of safety (MOS) is addressed in several ways as part of this section:

- MOS is implicit in each of the temperature TMDLs; they incorporate methods and assumptions that account for local conditions and assess outcomes under all reasonable land, soil, and water conservation practices, but do not ignore or prohibit current anthropogenic activity
- Montana’s water quality standards are applicable to any timeframe and any season. The temperature modeling analysis for East Fork Rock Creek investigated temperature conditions during the heat of the summer, when the temperature standards are most likely to heat the stream the most and creates the most detrimental effects on aquatic life.
- The assessment and subsequent allocation scenarios addressed streamflow influences that affect the streams dissipative and volumetric heat capacity.

- Compliance with targets and refinement of load allocations are all based on an adaptive management approach (**Section 6.8**) that relies on future monitoring and assessment for updating planning and implementation efforts.

Seasonal considerations are significant for temperature. Obviously, with high temperatures being a primary limiting factor for salmonids, summer temperatures are a paramount concern. Therefore, focusing on summer thermal regime is an appropriate approach. Seasonality addresses the need to ensure year round beneficial-use support. Seasonality is addressed in this TMDL document as follows:

- Temperature monitoring occurred during the summer season, which is the warmest time of the year. Modeling simulated heat of the summer conditions when instream temperatures are most stressful to the fishery. The fishery is the most sensitive use in regard to thermal conditions. Effective shade was collected during August, which is during the typical hottest time period of the year.
- Temperature targets, the TMDL, and load allocations apply year round, but it is likely that exceedances occur mostly during summer conditions.
- Restoration approaches will help to stabilize stream temperatures year round.

6.9 Uncertainty and Adaptive Management

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

The process of adaptive management is predicated on the premise that TMDLs, allocations and their supporting analyses are not static, but are processes which are subject to periodic modification and adjustment as new information and relationships are better understood. As further monitoring and assessment is conducted, uncertainties with present assumptions and consideration may be mitigated via periodic revision or review of the assessment which occurred for this document.

As part of the adaptive management approach, changes in land and water management that affect temperature should be tracked. As implementation of restoration projects which reduce thermal input or new sources that increase thermal loading arise, tracking should occur. Known changes in management should be the basis for building future monitoring plans to determine if the thermal conditions meet state standards.

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

Any influencing factors that increase water temperatures, including global climate change, could impact thermally sensitive fish species in Montana. The assessments and technical analysis for the temperature

TMDLs considered a worst case scenario reflective of current weather conditions, which inherently accounts for any global climate change to date. Allocations to future changes in global climate are outside the scope of this project but could be considered during the adaptive management process if necessary.

Uncertainties in environmental assessments should not paralyze, but should point to the need for flexibility in our understanding of complex systems and to adjust our current thinking and future analysis. Implementation and monitoring recommendations presented in **Section 10.2 and 10.3** provide a basic framework for reducing uncertainty and further understanding of the complex issues TMDLs undertake.

7.0 NUTRIENT TMDL COMPONENTS

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

7.1 EFFECTS OF EXCESS NUTRIENTS ON BENEFICIAL USES

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

Human activities can increase the biologically available supply of nitrogen and phosphorus. An overabundance of these nutrients in aquatic ecosystems accelerates the process known as eutrophication. Eutrophication is the enrichment of a waterbody, usually by nitrogen and phosphorus, leading to increased aquatic plant production (including algae). The increased aquatic plant or algal growth can reach nuisance levels and harm multiple beneficial uses of the waterbody. Respiration rates from nuisance algal can deplete the oxygen supply available for other aquatic organisms, potentially to levels that can kill fish and other forms of aquatic life. Nuisance algae can shift the macroinvertebrate community structure, which may affect fish that feed on macroinvertebrates (U.S. Environmental Protection Agency, 2010). Nuisance algae can also reduce water clarity, negatively affect waterbody aesthetics, and increase treatment costs of drinking water. Additionally, nuisance algae can cause changes in water clarity, fish community structure, and aesthetics. Changes in aesthetics can harm recreational uses, such as fishing, swimming, and boating (Suplee et al., 2009).

Nuisance algae can pose health risks if ingested in drinking water (World Health Organization, 2003). It can also lead to blue-green algae blooms (Priscu, 1987), which can produce toxins lethal to aquatic life, wildlife, livestock, and humans. Excess nitrogen in the form of dissolved ammonia (which is typically associated with human sources) can be toxic to aquatic life, and excess nitrogen in the form of nitrates in drinking water can inhibit normal hemoglobin function in infants.

7.2 STREAM SEGMENTS OF CONCERN

A total of 6 waterbody segments in the Rock Creek TPA appeared on the 2012 Montana 303(d) List for nutrient (phosphorus and/or nitrogen) impairments. These impairments occur on the East Fork of Rock Creek, South Fork of Antelope Creek, Scotchman's Gulch, Sluice Gulch and Flat Gulch. Brewster Creek is also included on the 2012 303(d) List as impaired for nutrients. As noted in **Section 7.4.4, Table 7-13**, DEQ has concluded that Brewster Creek not impaired for nutrients after collection and assessment of additional data. 15-16 samples were collected for total nitrogen (TN), total phosphorous (TP) and

NO_3+NO_2. All sample results were non-detect with the exception of 1 TN sample. Also assessed for nutrient impairment through the TMDL development process was Miner Gulch. Miners Gulch was not listed on the 303(d) list, and was found to not be impaired for nutrients. **Table 7-1** identifies the original 6 waterbodies with 8 nutrient impairment causes from the 2012 303(d) List. Refer to **Map A-1** for the location of these waterbodies. This table differs slightly from **Table 7-13**, which identifies those TMDLs that will be developed through this document. **Section 7.4.3** will discuss those reasons for derivation from the original listing.

Table 7-1. Nutrient Impaired Streams from the 2012 303(d) List

Stream Segment	Waterbody ID	Nutrient Pollutant Listing*
EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)	MT46E002_020	Nitrogen, Nitrate **
BREWSTER CREEK, East Fork to Mouth (Rock Creek)	MT46E002_050	Total Phosphorous
SOUTH FORK ANTELOPE CREEK, Headwater to mouth(Antelope Creek)	MT46E002_060	Total Phosphorous, Nitrate + Nitrite**
SCOTCHMAN GULCH, Headwater to mouth (Upper Willow Creek)	MT46E002_100	Total Phosphorous
SLUICE GULCH, Headwater to mouth (Rock Creek)	MT46E002_110	Nitrate + Nitrite**
FLAT GULCH, Headwaters to mouth (Rock Creek)	MT46E002_120	Total Phosphorous, Total Nitrogen

* Since creation of the 2012 303(d) List, DEQ has reassessed all six streams identified in **Table 7-1**. **Section 7.4** provides a summary of the assessment results with updated nutrient impairment determinations.
* *These two pollutant listings represent the same cause of impairment: Nitrate + Nitrite; generally referred to as NO_3+NO_2 throughout this document.

7.3 Information Sources

To assess nutrient conditions for TMDL development, DEQ compiled nutrient data and undertook additional monitoring. The following data sources represent the primary information used to characterize water quality for the six streams identified in **Table 7-1**.

1) **DEQ TMDL Sampling**. DEQ conducted water quality sampling from 2009 through 2011 to update impairment determinations and assist with the development of nutrient TMDLs. In 2009, water quality samples were collected and analyzed for nutrients on three streams through three events during the algal growing season (July–September). In 2010, all six streams were sampled through three events during the growing season. In 2011, sampling took place on three streams during two events during the growing season.

   Sample locations bracketed tributaries and changes in land-use type or management. In addition to water quality samples, algal samples were collected during growing season sampling in 2009, 2010, and 2011. Algae samples were analyzed for Chlorophyll-*a* concentration and ash free dry weight (AFDW). AFDW is a measurement that captures living and dead algal biomass and is particularly helpful for streams where some or all of the algae are dead (because chlorophyll-*a* measures only living algae). Macroinvertebrate data were collected on all streams between 2000 and 2011 to aid in nutrient impairment determinations. **Figure 7-1** shows the sample locations for the five streams that were identified as the nutrient impaired on the 2012 303(d) List and subsequently determined impaired after performing updated assessments as discussed below in **Section 7.4.3**.

2) **DEQ Assessment Files**. The files contain information used to make nutrient impairment determinations for the 2012 303(d) List. These determinations were made prior to 2006 and thus did not involve any of the recently collected data described above.

Growing-season nutrient data used for impairment assessment purposes and TMDL development are included in **Appendix K**. This and other nutrient data from the watershed is publicly available through EPA's STORET water quality database and DEQ's EQuIS water quality database.

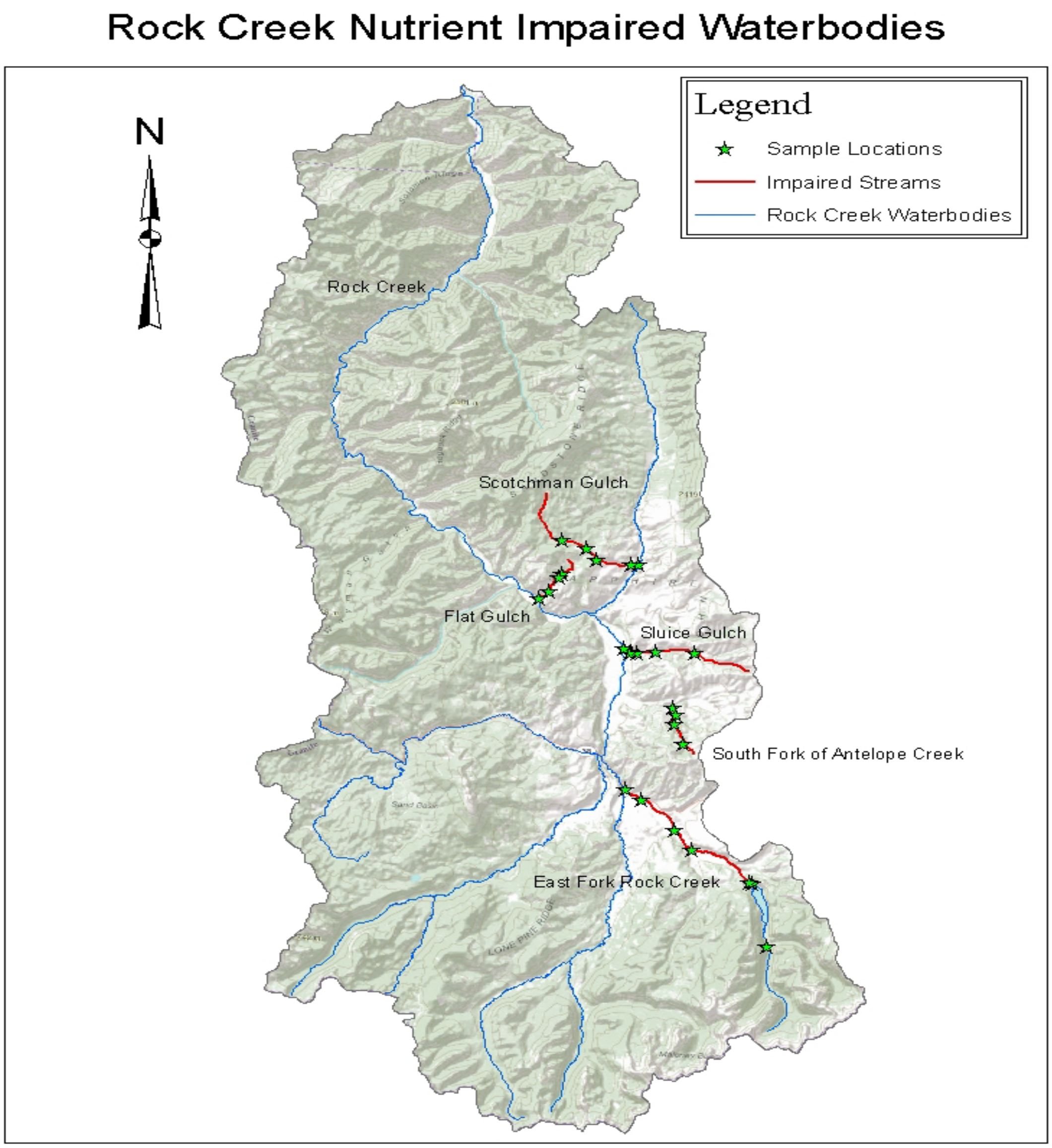

Figure 7-1. Nutrient impaired streams (based on post-2012 assessments) and associated sampling locations.

Additional sources of information used to develop TMDL components (**Section 4.0**) include the following:

- Additional chemical, physical, and biological water quality monitoring results collected during nutrient assessment work

- Streamflow data
- GIS data layers
- Outside agency and university websites and documentation
- Land-use information

The above information and water quality data are used to compare existing conditions to waterbody restoration goals (targets), to assess nutrient pollutant sources, and to help determine TMDL allocations.

7.4 Water Quality Targets

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

7.4.1 Nutrient Water Quality Standards

Montana's water quality standards for nutrients (nitrogen and phosphorous) are narrative and are addressed via narrative criteria. Narrative criteria require state surface waters to be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: 1) produce conditions that create concentrations or combinations of material toxic or harmful to aquatic life, and 2) create conditions that produce undesirable aquatic life (ARM 17.30.637 (1) (d-e)). DEQ is currently developing numeric nutrient criteria that will be established at levels consistent with narrative criteria requirements. These numeric criteria are the basis for the nutrient TMDL targets and are consistent with EPA's guidance on TMDL development and federal regulations (40 CFR Section 122.44(d)).

7.4.2 Nutrient Target Values

Nutrient water quality targets include nutrient concentrations in surface waters and measures of benthic algae (a form of aquatic life that at elevated concentrations is undesirable) chlorophyll-*a* concentrations and AFDW. The target concentrations for nitrogen and phosphorus are established at levels believed to prevent the harmful growth and proliferation of excess algae. Since 2002, DEQ has conducted studies in order to develop numeric criteria for nutrients (N and P forms). DEQ is developing draft numeric nutrient standards for total nitrogen (TN) and total phosphorus (TP) based on 1) public surveys defining what level of algae was perceived as "undesirable" and 2) the outcome of nutrient stressor-response studies that determine nutrient concentrations that will maintain algal growth below undesirable and harmful levels (Suplee et al., 2008a).

Nutrient targets for TN and TP (which are also draft numeric criteria), chlorophyll-*a*, and AFDM are based on Suplee and Watson (2013) and can be found in **Table 7-2**. The nitrate target is based on research by Suplee et al. (2008b) and can also be found in **Table 7-2**. DEQ has determined that the values for nitrate, TN, and TP provide an appropriate numeric translation of the applicable narrative nutrient water quality standards based on existing water quality data in the Rock Creek TPA and on the type of typical coldwater wadeable streams addressed by nutrient TMDL development in this document. These targets are appropriate for the Level IV Ecoregions that comprise the Rock Creek TPA (Rattlesnake-Blackfoot-South Swan-Northern Garnet- Sapphire Mountains, Deer Lodge-Philipsburg-Avon

Grassy Intermontane Hills and Valleys, Flint Creek Anaconda Mountains and Eastern Batholith). The target values are based on the most sensitive uses; therefore, the nutrient TMDLs are protective of all designated uses. When the draft criteria for TN and TP become numeric standards they will be in DEQ's DEQ-12 circular.

A macroinvertebrate biometric (Hilsenhoff's biotic index (HBI) score) is also considered in further evaluation of compliance with nutrient targets **Table 7-2**. An HBI score of greater than 4.0 is used to indicate nutrient impairment.

Because numeric nutrient chemistry is established to maintain algal levels below target chlorophyll-*a* concentrations and AFDM, target attainment applies and is evaluated during the summer growing season (July 1–September 30 for the Middle Rockies Level III Ecoregion) when algal growth will most likely affect beneficial uses. Targets listed here have been established specifically for nutrient TMDL development in the Rock Creek TPA and may or may not be applicable to streams in other TMDL project areas. The target values for nitrate, TN, and TP will be used to develop TMDLs. See **Section 7.6** for the adaptive management strategy as it relates to nutrient water quality targets.

Table 7-2. Nutrient Targets for the Rock Creek TPA

Parameter	Target Value
Nitrate	≤ 0.100 mg/L(1)
Total Nitrogen	≤ 0.300 mg/L(2)
Total Phosphorus	≤ 0.030 mg/L(2)
Chlorophyll-*a*	≤ 120 mg/m^2(2)
Ash Free Dry Mass	≤ 35 g $/m^2$(2)
Hilsenhoff's Biotic Index	< 4.0

(1) Value is from Suplee et al. (2008b).
(2) Value is from Suplee and Watson (2013).

7.4.3 Existing Conditions and Comparison with Targets

To evaluate whether nutrient targets have been met, the existing water quality conditions in each waterbody segment are compared to the water quality targets in **Table 7-2** using the methodology in the DEQ draft guidance document "2011 Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nitrogen and Phosphorus Levels" (Suplee and Sada de Suplee, 2011). This approach provides DEQ with updated impairment determinations used for TMDL development decisions. Because the original impairment listings are based on old data or were listed before developing the numeric criteria, each stream segment is evaluated for impairment from NO_3+NO_2, TN, and TP using data collected within the past 10 years. As previously noted, assessment results for Brewster Creek showed no nutrient impairments, therefore, nutrient TMDLs are not developed for this stream and assessment information is not included in this document.

The assessment methodology uses two statistical tests (Exact Binomial Test and the One-Sample Student's T-test for the Mean) to evaluate water quality data for compliance with established target values. In general, compliance with water quality targets is <u>not</u> attained when nutrient chemistry data shows a target exceedance rate of >20% (Exact Binomial Test), when mean water quality nutrient chemistry exceeds target values (Student T-test), or when a single chlorophyll-*a* exceeds benthic algal target concentrations (120 mg/m^2 or 35 g $AFDW/m^2$). Where water chemistry and algae data do not provide a clear determination of impairment, or where other limitations exist, macroinvertebrate biometrics (HBI >4.0) are considered in further evaluating compliance with nutrient targets. Lastly, inherent to any impairment determination is the existence of human sources of pollutant loading. Human-caused sources of nutrients must be present for a stream to be considered impaired. Note: to ensure a higher degree of certainty for removing an impairment determination and making any new impairment determination, the statistical tests are configured differently for an unlisted nutrient form than for a listed nutrient form. This can result in a different number of allowable exceedances for nutrients within a single stream segment. Such tests help assure that assessment reaches do not vacillate between listed and delisted status by the change in results from a single additional sample.

Simple summary statistics are provided in tables in each of the subsequent sections. These tables show the minimum, maximum , mean and 80th percentile values of the data sets for each perspective waterbody. Percentile is the value below which the percent of the observations may be found. For example , if a score is in the 80th percentile, then this score mark is higher than 80 percent of the other values. The 80th percentile is shown to give the reader an idea of where the majority of the data lies. The use of the 80^{th} percentile is also consistent with the 20% allowable exceedance rate within the Exact Binomial Test.

7.4.3.1 East Fork Rock Creek

East Fork Rock Creek appears on the 2012 303(d) List as impaired for nitrate (equivalent to NO_3+NO_2 for all practical purposes). The impaired segment of the East Fork of Rock Creek originates at the East Fork Reservoir and ends at the mouth. Tributaries to the East Fork Reservoir, including the upper portion of the East Fork Rock Creek, originate at the continental divide in the Anaconda-Pintler Wilderness. The East Fork of Rock Creek flows north-northwest from the East Fork Reservoir dam for about 10.2 miles to the confluence with the Middle Fork of Rock Creek. The confluence of the Middle Fork and the East Fork are the origins of Rock Creek.

Summary nutrient data statistics and assessment method evaluation results for the East Fork of Rock Creek are provided in **Tables 7-3 and 7-4,** respectively. Between 2004 and 2010, numerous samples were collected in the East Fork of Rock Creek. The samples are broken out as follows: 13 samples for TN, 15 samples for NO_3+NO_2 and 15 samples for TP. No NO_3+NO_2 or TN samples collected during this time exceeded target values. Only one TP sample collected during this time was above target values.

Chlorophyll-*a* data was collected from 2007 to 2010. No samples collected during this time exceeded the target criteria (>120 mg/m^2). AFDW data was collected from 2009 to 2011; 3 values exceeded target criteria (>35g/m^2). On July 26, 2010, AFDW was measured as 70.42 g/m^2, 72.59 g/m^2 and 125.5 g/m^2 at three independent sampling sites (C2ROCEF10, C2ROCEF03, C2ROCEF04 respectively). HBI data was collected in 2004. All samples collected were higher than target values, providing additional indication of impairment.

Field data sheets were reviewed to rule out irregularities in collection methods or sample QC/QC. Laboratory methods and Quality Assurance/Quality Control (QA/QC) criteria were also reviewed to ensure these values were accurate. Nothing was found to indicate the result was an anomaly. As a result of the initial listing for nitrate, elevated AFDW and elevated HBI scores DEQ will continue with TMDL development for TN. This conclusion is consistent with DEQ’s assessment method whereby elevated algal results and elevated HBI scores provide a strong indication of nutrient impairment even in the absence of elevated nutrient concentrations. The lack of elevated nutrient concentrations in the water column could be due to consumption of nitrogen and phosphorus for algal growth, and there is uncertainty as to whether the problem is mainly from elevated nitrogen or phosphorus. As such, DEQ has also made the determination to develop TN and TP TMDL. The TN TMDL will be developed because a nitrogen species was previously identified as a cause of impairment, then a nitrogen species will remain as a cause of impairment per DEQ's assessment method. In this type of situation, TN is the preferred nitrogen species for impairment determination and subsequent TMDL development.

Table 7-3. Nutrient Data Summary for East Fork Rock Creek (East Fork Reservoir to Mouth)

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2004, 2007, 2010	15	0.010	0.040	0.012	0.010
TN, mg/L	2004, 2007, 2010	13	0.010	0.110	0.062	0.086
TP, mg/L	2004, 2007, 2010	15	0.005	0.031	0.012	0.016
Chlorophyll-*a*, mg/m^2	2010	4	10.2	17.6	15.4	16.46
AFDW, g/m^2	2010	4	18.3	125.5	71.5	93.7
Macroinvertebrate HBI	2004	3	5.45	5.83	5.46	5.68

Table 7-4. Assessment Method Evaluation Results for the East fork of Rock Creek (East Fork Reservoir to Mouth)

Nutrient Parameter	Sample Size	Target Value (mg/l)	Samples Above Target	Binomial Test Result	T-test Result	AFDW Test Results	Chl-*a* Test Result	HBI Results	TMDL Required
NO_3+NO_2	15	0.100	0	PASS	PASS				NO
TN	13	0.300	0	PASS	PASS	FAIL	PASS	FAIL	Yes
TP	15	0.030	1	PASS	PASS				Yes

7.4.3.2 South Fork of Antelope Creek

The South Fork of Antelope Creek appears on the 2012 303(d) List as impaired for Nitrate + Nitrite ($N0_3$+$N0_2$) and Total Phosphorous (TP). The South Fork of Antelope Creek originates from the southwest side of the John Long Mountains. The streamflows north northwest, and its total length is about 2.8 miles from the origin to the confluence with Antelope Creek. Antelope Creek is a tributary to Rock Creek and joins Rock Creek approximately 3.8 miles downstream from the origin of Rock Creek. The likely cause of nutrient impairment in the South Fork of Antelope Creek is grazing. There are a number of federally allotted grazing units and private cattle grazing operations in this watershed.

Summary nutrient data statistics and assessment method evaluation results for the South Fork of Antelope Creek are provided in **Tables 7-5 and 7-6,** respectively. From 2004 to 2011, numerous high-flow and low-flow samples were collected in the South Fork of Antelope Creek for TP and $N0_3$+$N0_2$. TP samples exceeded target values three times out of 16 samples. From 2004 to 2011 15 growing season samples for Total Nitrogen (TN) were collected. In addition, one sample for each NO_3+NO_2, and TP were collected in 2004. All TN and NO_3+NO_2 samples collected during this time frame exceeded target values.

Chlorophyll-*a* data was collected in 2010. No samples collected during this time exceeded the target criteria (>120 mg/m^2). AFDW data was collected in 2010 as well; no values exceeded target criteria (>35g/m^2). In 2004 and 2011 4 macro invertebrate samples were collected. Two of the 4 samples collected exceeded the target criteria (>4 HBI). As a result of the initial 2012 303(d) impairment causes for TP and $N0_3$+$N0_2$ along with elevated HBI scores, DEQ will continue with TMDL development for TP, $N0_3$+$N0_2$. Also, the2004 through 2011 sampling results justify TN as an impairment cause, as such DEQ will develop a TMDL for TN for the South Fork of Antelope Creek as well.

Table 7-5. Nutrient Data Summary for South Fork of Antelope Creek

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2004,2010-2011	16	0.240	0.620	0.471	0.550
TN, mg/L	2010-2011	15	0.380	1.480	0.659	0.806
TP, mg/L	2004, 2010-2011	16	0.005	0.063	0.020	0.030
Chlorophyll-*a*, mg/m^2	2009-2011	3	7.0	30.27	17.57	25.19
AFDW, g/m^2	2009-2010	2	4.4	6.88	5.64	6.38
Macroinvertebrate HBI	2004, 2011	4	2.78	6.10	3.76	4.92

Table 7-6. Assessment Method Evaluation Results for South Fork of Antelope Creek

Nutrient Parameter	Sample Size	Target Value (mg/l)	Samples Above Target	Binomial Test Result	T-test Result	AFDW Test results	Chl-*a* Test Result	HBI Results	TMDL Required
NO_3+NO_2	16	0.100	16	FAIL	FAIL	PASS	PASS	FAIL	YES
TN	15	0.300	15	FAIL	FAIL				YES
TP	16	0.030	3	FAIL	PASS				YES

7.4.3.3 Sluice Gulch

Sluice Gulch appears on the 2012 303(d) List as impaired for NO_3+NO_2. Sluice Gulch is located in the south central portion of the Rock TPA on the southwestern-most extent of the John Long Mountains. It originates in the John Long Mountains east of Rock Creek and North of Antelope Creek. The total stream length is about 5.8 miles from its origin to the confluence with Rock Creek. The direction of flow is to the north and west. The likely cause of the elevated nutrient values in Sluice Gulch is the result of cattle grazing and historical mining practices in the area.

Summary nutrient data statistics and assessment method evaluation results for Sluice Gulch are provided in **Tables 7-7 and 7-8**. From 2004 through 2011, numerous growing season samples were collected for NO_3+NO_2, TN and TP. Between 2010 and 2011, 15 samples were collected for TN, 16 for both NO_3+NO_2, and TP. 14 out of 15 samples for TN were above target criteria; fourteen out of 16 samples for NO_3+NO_2 were above the target criteria; no TP samples were above target criteria. These results can be seen in **Table 7-8**.

Chlorophyll-*a* and AFDW data were collected in 2010, none of which exceeded the target criteria of >120 mg/m^2 and >35g/m^2, respectively. In 2011, three macroinvertebrate samples were collected, and two were above the target criteria (>4 HBI). Elevated HBI scores support the nutrient impairments identified through the water quality sampling discussed above. The initial listing of NO_3+NO_2 and its associated impairment cause will be addressed through a TMDL for NO_3+NO_2. 2004 through 2011 sampling results also justify TN as a parameter of impairment; therefore, a TMDL for TN will also be developed for Sluice Gulch.

Table 7-7. Nutrient Data Summary for Sluice Gulch

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2004-2011	16	0.06	0.5	0.365	0.45
TN, mg/L	2010-2011	15	0.27	0.67	0.42	0.53
TP, mg/L	2004-2011	16	0.010	0.19	0.0135	0.017
Chlorophyll-*a*, mg/m^2	2010	3	20.7	34.22	24.4	30.29
AFDW, g/m^2	2010	2	8.43	12.69	10.56	11.84
Macroinvertebrate HBI	2011	3	3.92	5.33	4.76	5.10

Table 7-8. Assessment Method Evaluation Results for Sluice Gulch

Nutrient Parameter	Sample Size	Target Value (mg/l)	Samples Above Target	Binomial Test Result	T-test Result	AFDW Test Result	Chl-*a* Test Result	HBI Results	TMDL Required
NO_2+NO_3	16	0.1	14	FAIL	FAIL	PASS	PASS	FAIL	YES
TN	15	0.3	14	FAIL	FAIL				YES
TP	16	0.03	0	PASS	PASS				NO

7.4.3.4 Scotchman Gulch

Scotchman Gulch appears on the 2012 303(d) List as impaired for TP. Scotchman Gulch is located in the central portion of the Rock TPA. Scotchman Gulch originates from Sandstone Ridge that separates the Beaverhead Deerlodge National Forest from the Lolo National Forest. Scotchman Gulch flows off the southeast side of Sandstone Ridge, and is located north of Flat Gulch and south of Miners Gulch. The total stream length is about 7.0 miles from the origin to the confluence with Upper Willow Creek. Willow creek is a tributary to Rock Creek, and joins Rock Creek downstream of the confluence of the East, West and Middle forks. The likely cause of the nutrient impairment is the result of cattle grazing.

Summary nutrient data statistics and assessment method evaluation results for Scotchman Gulch are provided in **Tables 7-9 and 7-10.** From 2004 through 2011, a total of 26 growing season samples were collected for NO_3+NO_2 and TP. No NO_3+NO_2 samples were above the target criteria. Eight of 24 TN samples were above target criteria, 24 of 26 TP samples were above target criteria.

Chlorophyll-*a* and AFDW data were collected from 2009 to 2011. No Chlorophyll-*a* samples exceeded the target criteria of >120 mg/m^2. No AFDW samples exceeded the criteria of >35g/m^2. In 2004 and 2009, 12 macroinvertebrate samples were collected and three were above the target criteria (>4 HBI). As a result of this assessment and the 2012 303(d) listing, DEQ will develop a TMDL for TP for Scotchman Gulch. The assessment methodology results also justify TN as a parameter of impairment; therefore, a TMDL for TN will also be developed for Scotchman gulch.

Table 7-9. Nutrient Data Summary for Scotchman Gulch

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2004-2011	26	0.005	0.095	0.0125	0.023
TN, mg/L	2007-2011	24	0.15	0.71	0.25	0.398
TP, mg/L	2004-2011	26	0.001	0.115	0.056	0.066
Chlorophyll-*a*, mg/m^2	2009,2011	11	2.29	14.29	4.16	7.15
AFDW, g/m^2	2011	3	3.98	13.82	4.16	9.96
Macroinvertebrate HBI	2004,2009	12	2.63	6.37	3.56	4.23

Table 7-10. Assessment Method Evaluation Results for Scotchman Gulch

Nutrient Parameter	Sample Size	Target Value (mg/l)	Sample Above Target	Binomial Test Result	T-test Result	AFDW Test Results	Chl-*a* Test Result	HBI Results	TMDL Required
NO_3+NO_2	26	0.1	0	PASS	PASS	PASS	PASS	FAIL	NO
TN	24	0.3	8	FAIL	FAIL				YES
TP	26	0.03	24	FAIL	PASS				YES

7.4.3.5 Flat Gulch

Flat Gulch appears on the 2012 303(d) List as impaired for TN and TP. Flat Gulch is located in the central portion of the Rock TPA. Flat Gulch originates from Sandstone Ridge that separates the Beaverhead Deerlodge National Forest from the Lolo National Forest. Flat Gulch flows off the southwest side of Sandstone Ridge, and is located south of Scotchman Gulch. The total stream length is about 3.0 miles from the origin to the confluence with Rock Creek. The likely cause of the nutrient impairment is the result of cattle grazing.

Summary nutrient data statistics and assessment method evaluation results for Flat Gulch are provided in **Tables 7-11 and 7-12.** From 2004 through 2011, numerous samples were collected for NO_3+NO_2, TN and TP. From 2009-2011 16 samples were collected for TN. Fifteen of 16 TN samples were above target criteria, 17 of 17 TP samples were above target criteria and one NO_3+NO_2 sample was above target criteria.

Chlorophyll-*a* and AFDW data were collected in 2004, 2009 to 2011. No Chlorophyll-*a* samples exceeded the target criteria of >120 mg/m^2. No AFDW samples exceeded the criteria of >35g/m^2. In 2009, 6 macroinvertebrate samples were collected and all were above the target criteria (>4 HBI). As a result of the 2012 303(d) listing and the assessment findings mentioned above, DEQ will develop a TMDL for TN and TP for Flat Gulch.

Table 7-11. Nutrient Data Summary for Flat Gulch

Nutrient Parameter	Sample Timeframe	Sample Size	Min	Max	Mean	80th percentile
Nitrate+Nitrite, mg/L	2004-2011	17	0.005	0.136	0.0375	0.052
TN, mg/L	2009-2011	16	0.229	1.23	0.464	1.04
TP, mg/L	2004-2011	17	0.078	0.402	0.211	0.31
Chlorophyll-*a*, mg/m^2	2009,2011	10	5.54	25.2	10.705	17.204
AFDW, g/m^2	2011	3	2.61	4.14	2.97	3.696
Macroinvertebrate HBI	2009	6	4.68	5.79	5.16	5.76

Table 7-12. Assessment Method Evaluation Results for Flat Gulch

Nutrient Parameter	Sample Size	Target Value (mg/l)	Samples Above Target	Binomial Test Result	T-test Result	AFDW Test Results	Chl-*a* Test Result	HBI Result	TMDL Required
NO_3+NO_2	17	0.1	1	PASS	PASS				NO
TN	16	0.3	15	FAIL	FAIL	PASS	PASS	FAIL	YES
TP	17	0.03	17	FAIL	FAIL				YES

7.4.4 Nutrient TMDL Development Summary

Table 7-13 summarizes the 2012 nutrient 303(d) listings for the Rock TPA, along with the summary of the nutrient pollutants for which TMLDs will be prepared based on DEQ's updated assessment for these stream. The changes from the 2012 303(d) List are because of limited data collection at the time the waterbody segments were initially listed (1994 through 2006) and the improved assessment method along with significant data collection since original impairment determinations. The updated impairment determinations will be reflected in the 2014 Water Quality Integrated Report. Note that as Per **Table 7-13** a total of 11 separate nutrient TMDLs will be developed for the 5 stream segments that still have nutrient impairment causes. No nutrient TMDLs will be developed for Brewster Creek since DEQ concluded that Brewster Creek in not impaired for nutrients per recent assessment results.

Table 7-13. Summary of Nutrient TMDL Development Determinations

Stream Segment	Waterbody ID	2012 303(d) Nutrient Impairment(s)	TMDLs Prepared
EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)	MT46E002_020	Nitrogen, Nitrate	Total Nitrogen, Total Phosphorous
BREWSTER CREEK, East Fork to Mouth (Rock Creek)	MT46E002_050	Total Phosphorous	NA
SOUTH FORK ANTELOPE CREEK, Headwater to mouth (Antelope Creek)	MT46E002_060	Total Phosphorous, Nitrate + Nitrite	Total Phosphorous, Nitrate + Nitrite, Total Nitrogen
SCOTCHMAN GULCH, Headwater to mouth (Upper Willow Creek)	MT46E002_100	Total Phosphorous	Total Phosphorous, Total Nitrogen
SLUICE GULCH, Headwater to mouth (Rock Creek)	MT46E002_110	Nitrate + Nitrite	Total Nitrogen, Nitrate + Nitrite
FLAT GULCH, Headwaters to mouth (Rock Creek)	MT46E002_120	Total Phosphorous, Total Nitrogen	Total Phosphorous, Total Nitrogen

7.5 Nutrient Sources, TMDLs, and Allocations

As described in **Section 7.4**, exceedances of water quality targets in the Rock TPA include Total Phosphorous (TP), nitrogen fractions; (TN), and (NO_3+NO_2). Data results show TN target exceedances on South Fork of Antelope Creek, Sluice Gulch, Scotchman Gulch and Flat Gulch are sufficient to conclude impairment and require TN TMDL development for these streams. Data results also show NO_3+NO_2 target exceedances in South Fork of Antelope Creek and Sluice Gulch. TP exceedances were documented in the South Fork of Antelope Creek, Scotchman Gulch and Flat Gulch.

Assessment of existing nutrient sources is needed to develop load allocations to specific source categories. Water quality sampling conducted from 2004 through 2011 provides the most recent data for determining existing nutrient water quality conditions in the Rock Creek watershed. DEQ collected samples from 24 sampling sites with the objective of 1) evaluating attainment of water quality targets and 2) assessing load contributions from nutrient sources within the Rock Creek watershed. These investigations form the primary dataset from which existing water quality conditions were evaluated and from which nutrient loading estimates are derived. Data used to conduct analyses and loading estimations is publicly available at http://deq.mt.gov/wqinfo/datamgmt/MTEWQX.mcpx.

This section characterizes the type, magnitude, and distribution of sources contributing to TP, TN and NO_3+NO_2 loading to impaired streams, provides loading estimates for significant source types, and establishes TMDLs and allocations to specific source categories. Source types include natural and human-caused sources and are described in further detail for each stream. Source characterization links nutrient sources loading to streams, and water quality response, and supports the formulation of the load allocation portion of the TMDL. As described in **Section 7.4.2**, TP, TN, and NO_3+NO_2 water quality targets are applicable during the summer growing season (i.e., July 1–Sept 30). Consequently, source characterizations are focused mainly on sources and mechanisms that influence nutrient contributions during this period. Similarly, loading estimates and subsequent load allocations are established for the growing season time period and are based on observed water quality data and typical flow conditions.

Source characterization and assessment was conducted primarily using extensive monitoring data collected in the watershed from 2004 through 2011 to determine temporal and spatial patterns in nutrient concentrations, loads, and biological response.

Land uses in the Rock Creek watershed are primarily agriculture, silviculture and historical mining practices. None of the nutrient impaired waterbodies in the Rock Creek watershed has contributing nutrient sources from sites with permits from the Montana Pollutant Discharge Elimination System (MPDES). Nutrient sources therefore consist primarily of 1) natural sources derived from airborne deposition, vegetation, soils, and geologic weathering; and 2) human-caused sources (agriculture, silviculture, historical mining practices). These sources may include a variety of discrete and diffuse pollutant inputs related to agricultural and mining runoff.

The below sections describe the most significant natural and human-caused sources in more detail, provide nutrient loading estimates for natural and human-caused source categories to nutrient-impaired stream segments, and establish TMDLs and load allocations to specific source categories for the following streams:

- East Fork Rock Creek
- South Fork Antelope Creek
- Sluice Gulch
- Scotchman Gulch
- Flat Gulch

7.5.1 East Fork Rock Creek (MT46E002_020)

The East Fork of Rock Creek originates at the Continental Divide in the Pintler Wilderness. The East Fork of Rock Creek flows for approximately 5.7 miles before it joins with Page Creek. After the confluence with Page Creek the streamflow for another 1.3 miles before it releases into the East Fork Reservoir. The East Fork of Rock Creek flows for another 10 miles prior to it reaching the confluence with the Middle Fork of Rock Creek, which then forms the mainstem of Rock Creek. The last 10 miles of the East Fork of Rock Creek (the lower segment) is the impaired section. For the purpose of TMDL development and this document the lower segment of the East Fork of Rock Creek will be referred to as the East Fork of Rock Creek.

Land use along the East Fork of Rock Creek consists primarily of cattle grazing in the lower segment and some limited cattle grazing and general silvicultural activities throughout the upper segments of the watershed. As determined in **Section 7.4.3.1,** the East Fork of Rock Creek did not exceeded nutrient water quality targets for NO_3+NO_2, TN, and TP. However, on one day, three AFDM samples exceeded target criteria (>35 g/m^2). On July 26, 2010, AFDW was measured as 70.42 g/m^2, 72.59 g/m^2 and 125.5 g/m^2 at sampling sites C2ROCEF10, C2ROCEF03 and C2ROCEF04 respectively. As a result of the initial listing and elevated AFDW DEQ has chosen to continue with TMDL development for TN and TP.

Complicating estimation of TN, and TP loads in the East Fork of Rock Creek is instream assimilation and retention of these nutrient loads by algae. High algal mass was observed through several reaches during the assessment process. High algal mass likely indicates that NO_3+NO_2, TN, and TP load is being taken up by algal growth and converted to biomass. This suggests that actual loads to East Fork Rock Creek may be greater than the loads measured instream.

7.5.1.1 East Fork of Rock Creek Source Assessment

The source assessment for the East fork of Rock Creek includes the evaluation of TN and TP concentrations as well as flow and loading data along the whole length of the East Fork of Rock Creek. This is followed by the quantification of natural background and the most significant human caused sources of nutrients. Human caused nutrient sources in the East Fork of Rock Creek are most likely the result of cattle grazing.

DEQ sampled water quality on the East Fork of Rock Creek during the growing season of 2010 and samples were analyzed for TN and TP. The data set for TN was limited, as the majority of the analytical results were non-detect. No values were provided for those samples that were reported as below the detection limit. For the purpose of data analysis a detection limit of 0.05 mg/L was used where data were reported as non-detect. The detection limit is well below the target value of 0.30 mg/L.

The data set for TP contained one data point that was above the target value of 0.030 mg/L. The primary reason for TMDL development for TP is the elevated AFDW and HBI scores. **Table 7-14** and **Table 7-15**, and **Figures 7-2** and **7-3** present summary statistics of TN and TP concentrations at sampling sites in the East Fork of Rock Creek. Due to the use of the detection limit in TN data analysis, the graphic representation of the data set is slightly distorted. This is exemplified in the lack of variability in the data for the sample site CO2ROCEF05 and CO2ROCEF20. This can also be seen in the closeness of some of the statistical results. For example the TN minimum and 25th percentile values for C2ROCEF05, C2ROCEF04, CO2ROCEF20 and C2ROCEF03 are almost identical. Similar lack of variability can be seen in the **Table 7-15** and **Figure 7-3**. Only one sample was collected at CO2ROCEF20, this sample exceeded the water quality target, however the lack of additional data points for this monitoring site limits the ability to conduct any relative statistics.

Table 7-14. Growing season TN Summary Statistics for sampling sites on the East Fork of Rock Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
CO2ROCEF05	3	0.050	0.050	0.050	0.050	0.050	0.050
CO2ROCEF20	1	0.050	0.050	0.050	0.050	0.050	0.050
CO2ROCEF04	3	0.050	0.090	0.0667	0.055	0.060	0.075
CO2ROCEF03	3	0.050	0.090	0.0633	0.050	0.050	0.070
CO2ROCEF10	5	0.010	0.110	0.0650	0.046	0.065	0.875

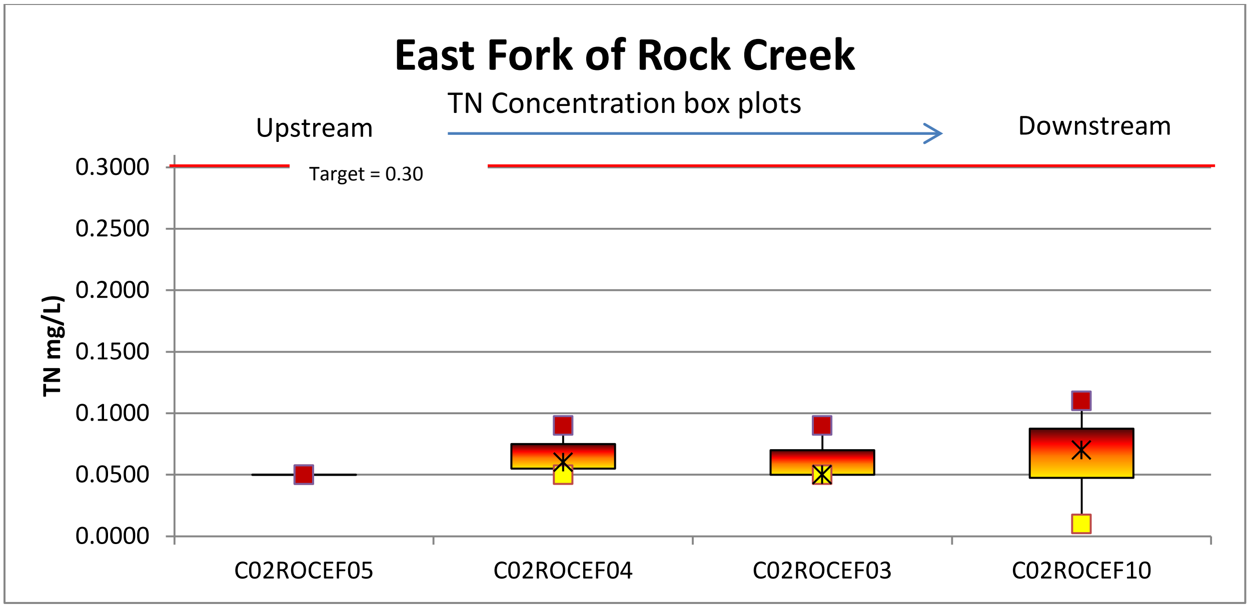

Figure 7-2. TN Concentration Box plots: East Fork of Rock Creek

Table 7-15. Growing season TP Summary Statistics for sampling sites on the East Fork of Rock Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
CO2ROCEF05	3	0.0050	0.0070	0.0060	0.0055	0.0060	0.0065
CO2ROCEF20	1	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310
CO2ROCEF04	3	0.0070	0.0090	0.0077	0.0070	0.0070	0.0080
CO2ROCEF03	3	0.0070	0.0080	0.0077	0.0075	0.0080	0.0080
CO2ROCEF10	5	0.0120	0.0240	0.0170	0.0150	0.0150	0.0210

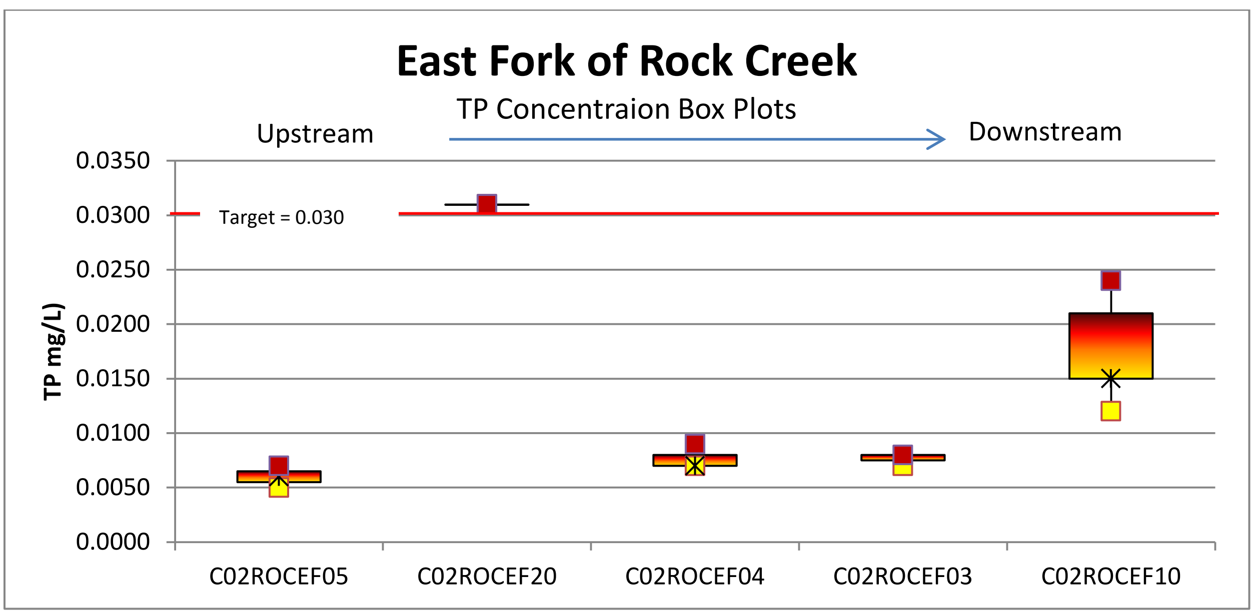

Figure 7-3. TP Concentration Box plots: East Fork of Rock Creek

Average growing season TN loads are highest in the headwater. TN load drops off significantly from monitoring location CO2ROCEF05 to CO2ROCEF20. Load gradually increases at each monitoring location from CO2ROCEF20 to that last monitoring location. There is an overall decrease from 17.7 lbs/day in the headwaters at monitoring location CO2ROCEF05 to 15.2 lbs/day at the downstream CO2ROCEF10 monitoring location. This is an average decrease of 2.5 lbs/day as is noted in **Figure 7-4**.

The initial TP loads decrease significantly between monitoring location CO2ROCEF05 and CO2ROCEF04 and then increase from CO2ROCEF04 to CO2ROCEF10 **Figure 7-5**. The total average growing season TP loads are lower at monitoring location CO2ROCEF05 (1.98 lb/day) and increase at the downstream CO2ROCEF10 monitoring location (2.66 lb/day). This is an average increase of 0.68 lbs/day.

Streamflow volume increases as you move from the headwaters to the mouth. With the exception of the upstream most monitoring location TN load increase parallels the increase in flow throughout the length of the stream. The limited tributary network in this area suggests that much of this increased flow may be via groundwater. The increased loading may be due to TN within this groundwater and/or may be linked to increased direct surface water nutrient input from cattle and other sources. TP concentrations tend to remain relatively constant along the East Fork Rock Creek as you move down stream. With the exception of one sample, all sample results are below water quality targets.

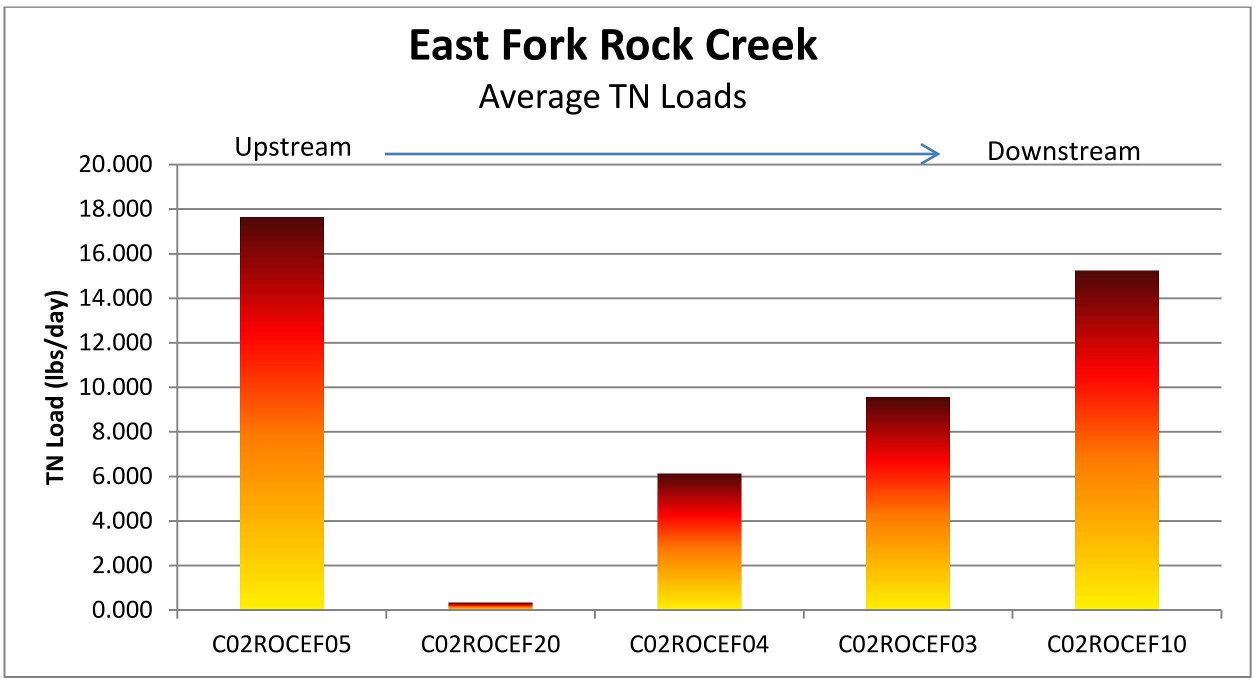

Figure 7-4 TN Load within East Fork Rock Creek

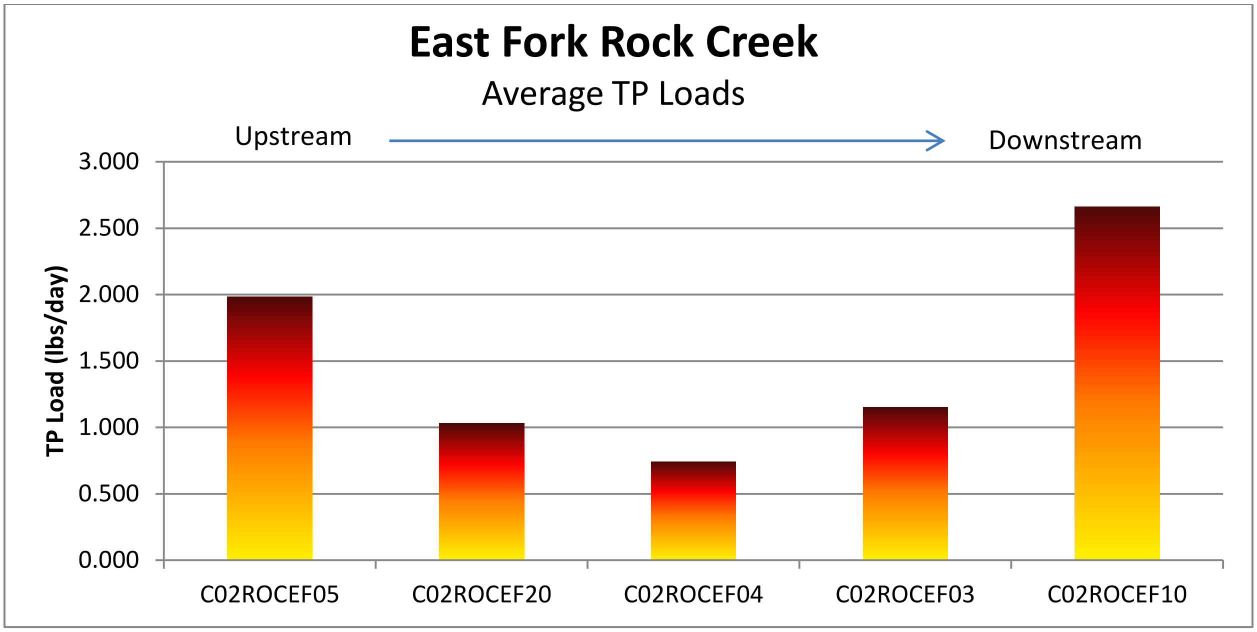

Figure 7-5. TP Load within East Fork Rock Creek

Natural background Nutrient loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. DEQ did not sample the headwaters in the East Fork of Rock Creek. Consequently, no certain background water quality data was collected for the East Fork of Rock Creek. Given the lack of data in East Fork of Rock Creek and lack of data in the Rock Creek TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion for background concentrations.

Background TN concentrations derived from (Suplee et al., 2008a) were 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L for the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.085 mg/L and a median growing season flow of 34.1 cfs, the average background TN load to the segment is calculated to be approximately 15.6 lbs/day.

Agricultural Nutrient Loading

Cattle are periodically grazed within Fork of Rock Creek watershed, during the algal growing season. The USDA Forest Service (USFS) accounts for two allotments in the East Fork of Rock Creek Watershed. These allotments are the Meadow Creek allotment and the Georgetown/Elk Creek allotment. The Meadow Creek allotment is comprised of 17,608 acres, and is grazed by 100 head of cattle from June, 21 through October, 15. The Georgetown/Elk Creek allotment spans both the East Fork of Rock Creek and the Georgetown Lake watersheds. The Elk Creek portion of this allotment is within the East Fork of Rock Creek watershed and is comprised of 5,747 acres and is capable of supporting 83 head of cattle. This allotment is currently not in use, and was last grazed in 2003. There are approximately 1,120 acres of state land within the East Fork of Rock Creek watershed. Of these 1,120 acres approximately 1,015 acres are actively grazed at a rate of 400 Animal Unit Month (AUM). AUM is a grazing descriptor which is calculated by multiplying the number of animal units by the number of months of grazing. AUM provides a useful indicator of the amount of livestock use a particular segment of land receives.

The remaining portion of the East Fork of Rock Creek is private land. There is a significant difficulty in determining the number of cattle grazed on private land in this watershed. However, the DEQ will assume that cattle are being grazed on private land within the watershed. A conservatively low methodology for determining the number of cattle being grazed is to apply an AUM of 0.1 to 0.15 per acres to the approximate 11,420 acres of private land (Phone conversation with Bret Bledso of the NRCS). This would indicate that this land was capable of supporting 1,142 to 1,713 cattle if they were grazed sustainably.

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include 1) direct loading via the breakdown of excrement 2) delivery from grazed forest and rangeland during the growing season and 3) the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas. As noted by the sediment assessment results in **Section 5.4.2.3,** vegetation, habitat, and sediment deposition in the East Fork of Rock Creek have been negatively impacted via grazing. These negative impacts contribute to a lack of riparian buffering as a significant contributor towards elevated nutrient loading along with direct loading from cattle excrement given their proximity to the stream.

7.5.1.2 East Fork Rock Creek Total Maximum Daily Loads: Total Nitrogen (TN) and Total Phosphorous (TP)

TN and TP Total Maximum Daily Loads are presented here for the East Fork Rock Creek (MT41E002_020). The TMDLs (lbs/day) for TN and TP are calculated using the water quality target values established in **Section 7.4**. The TMDL loads for TN and TP apply during the summer growing season (normally July 1–Sept. 30). The TMDL for TN is based on an instream target value of 0.30 mg/L TN and streamflow (**Figure 7-6**). The TMDL for TP is based on an instream target value of 0.03 mg/L TN and streamflow (**Figure 7-7**).

TMDL calculations for TN and TP are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L (TN =0.30 mg/L or TP =0.030 mg/L)
Y= streamflow in cubic feet per second
5.393 = conversion factor

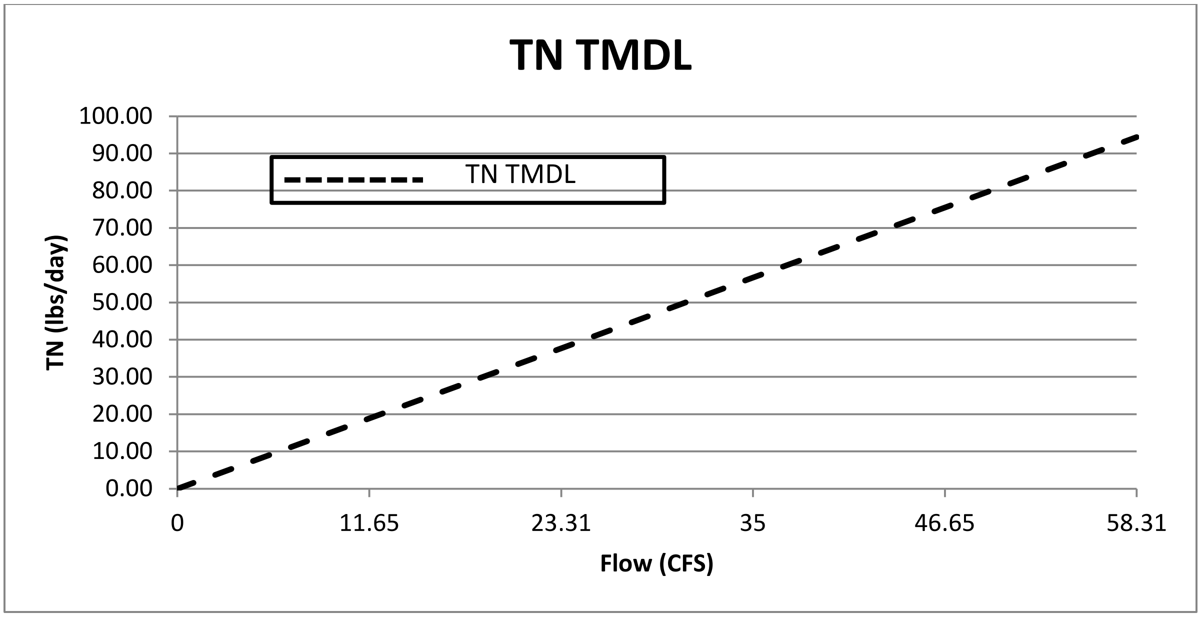

Figure 7-6. TMDL for TN as a function of flow: East Fork of Rock Creek

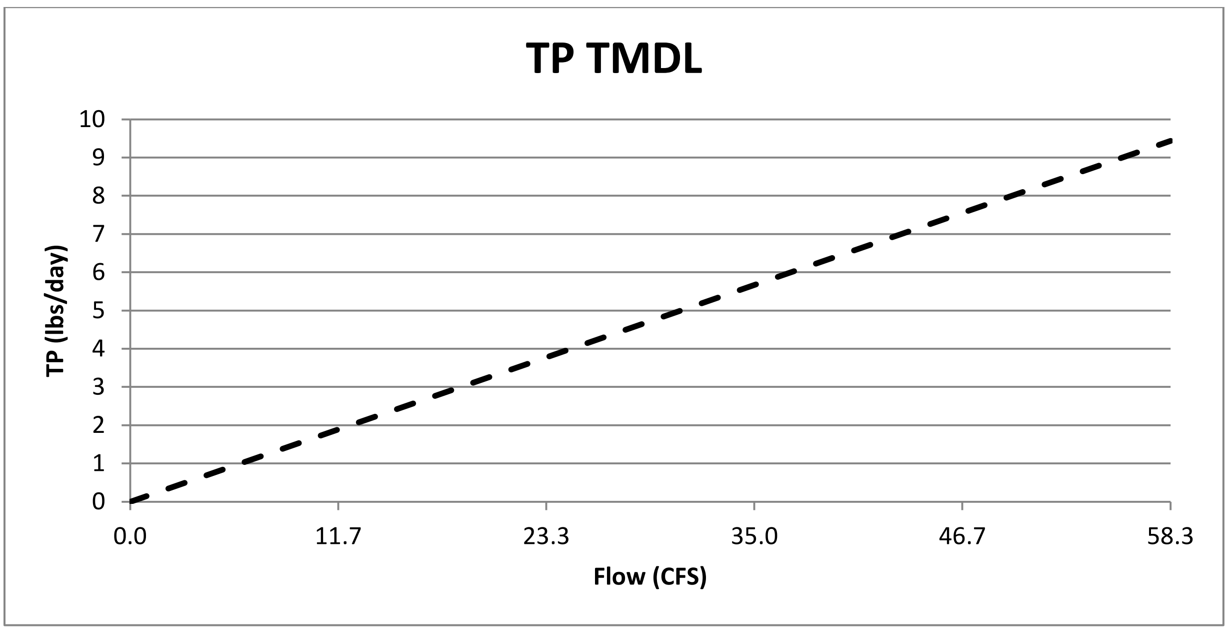

Figure 7-7 TMDL for TP as a function of flow: East Fork of Rock Creek

7.5.1.3 East Fork of Rock Creek Total Nitrogen (TN) and Total Phosphorous (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) TN and TP sources. A TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety (MOS) that accounts for uncertainties in loading and receiving water analyses. An implicit MOS is defined within **Section 4.4,** is applied toward the East Fork of Rock Creek TMDL. In addition to pollutant load allocations, a TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.1.3.1 Total Nitrogen (TN) Allocation

For The East Fork of Rock Creek the TMDL for TN comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to The East Fork of Rock Creek that would require wasteload allocations, and relevant TN nonpoint sources include natural background sources and agricultural land use. Load allocations are therefore provided for 1) natural background sources and 2) agricultural land use. In the absence of individual WLAs and an explicit MOS, the TMDL for TN in is equal to the sum of the individual load allocations as follows:

$$TMDL = LA_{NB} + LA_{ag}$$

LA_{NB} = Load Allocation to natural background sources
LA_{ag}= Load Allocation to agricultural land use

Natural Background Source

Load allocations for natural background sources are based on a natural background TN concentration of 0.085 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$$LA_{NB} = (X)(Y)(5.393)$$

LA_{NB}= TN load allocated to natural background sources
X= 0.085 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

Agricultural Source

The load allocation to the agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$$LA_{AG} = TMDL - LA_{NB}$$

TN Load Allocation

TN load allocations (**Table 7-16**) are provided for The East Fork of Rock Creek and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) agriculture (LA_{AG}). The TN TMDL is presented graphically in **Figure 7-8.**

Table 7-16. TN load allocation descriptions, East Fork of Rock Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**$LA_{NB} = (X)(Y)(5.393)$**
Agricultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks	**$LA_{AG} = TMDL - LA_{NB}$**

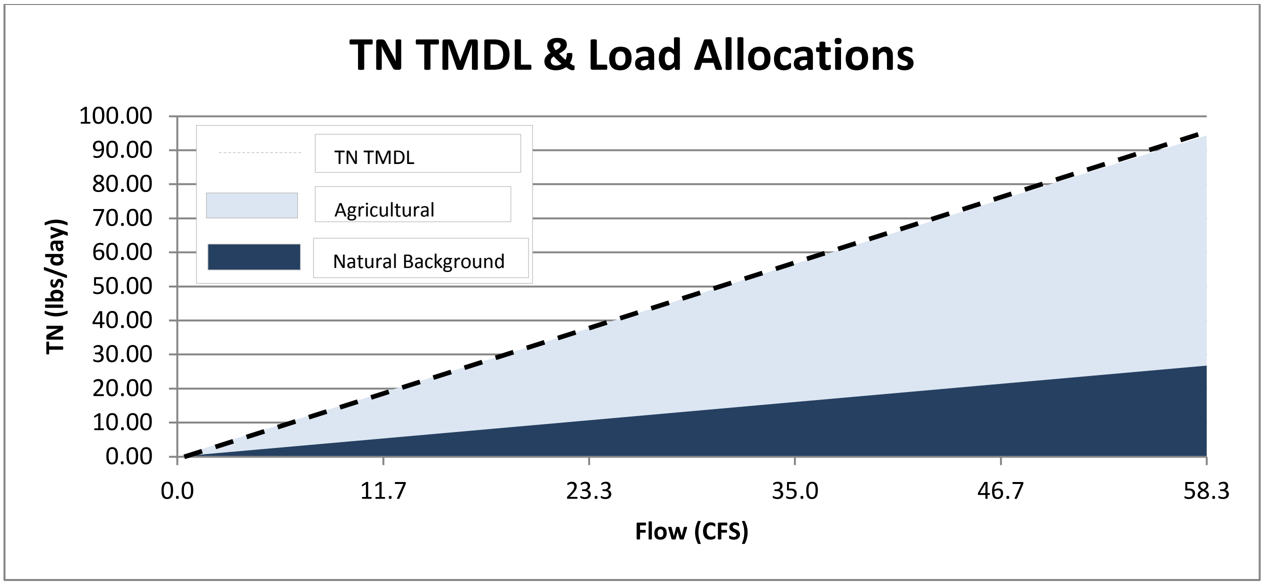

Figure 7-8. TMDL for TN and Load Allocations, the East Fork of Rock Creek

Because measured instream TN concentrations are within natural background conditions and below target concentrations, water quality data precludes calculating TN load reductions to specific source categories using empirical data. Load allocations, however, incorporate allowed loading from general source categories and establish allowable TN loads. **Table 7-17** presents example TMDLs and TN load allocations as a function of streamflow in accordance with the allocation scheme presented in **Table 7-16**; load allocations are presented at growing season flow conditions in the East Fork of Rock Creek.

Reducing nitrate loads from agricultural sources will likely mitigate the effects of nutrient impairment (algal growth, macroinvertebrate impairment) although the uncertainty regarding background conditions and nutrient contributions from agricultural sources makes it difficult to predict the extent of necessary nitrate reduction to reduce excess algal growth and increase macro invertebrate populations.

Table 7-17. The East Fork of Rock Creek Example TN load allocations and TMDL*

Source Category	Allocation & TMDL (lbs/day)*
Natural Background	15.6
Agriculture	39.6
TMDL	**55.2**

**based on a median growing season flow of 34.1 cfs*

7.5.1.3.2 Total Phosphorous (TP) Allocation

For the East Fork of Rock Creek the TMDL for TP comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the East Fork of Rock Creek that would require wasteload allocations, and relevant TP nonpoint sources include natural background sources and agricultural land use. Load allocations are therefore provided for 1) natural background sources and 2) agricultural land use. In the absence of individual WLAs and an explicit MOS, the TMDL for TP in is equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{ag}$

LA_{NB} = Load Allocation to natural background sources

LA_{ag}= Load Allocation to agricultural land use

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= TP load allocated to natural background sources
X= 0.030 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

Agricultural Source

The load allocation to the agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

LA_{AG}= TMDL - LA_{NB}

TP Load Allocation

TP load allocations (**Table 7-18**) are provided for The East Fork of Rock Creek and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) agriculture (LA_{AG}). The TP TMDL is presented graphically in **Figure 7-9.**

Table 7-18. TP load allocation descriptions, East Fork of Rock Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Agricultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks	**LA_{AG} = TMDL - LA_{NB}**

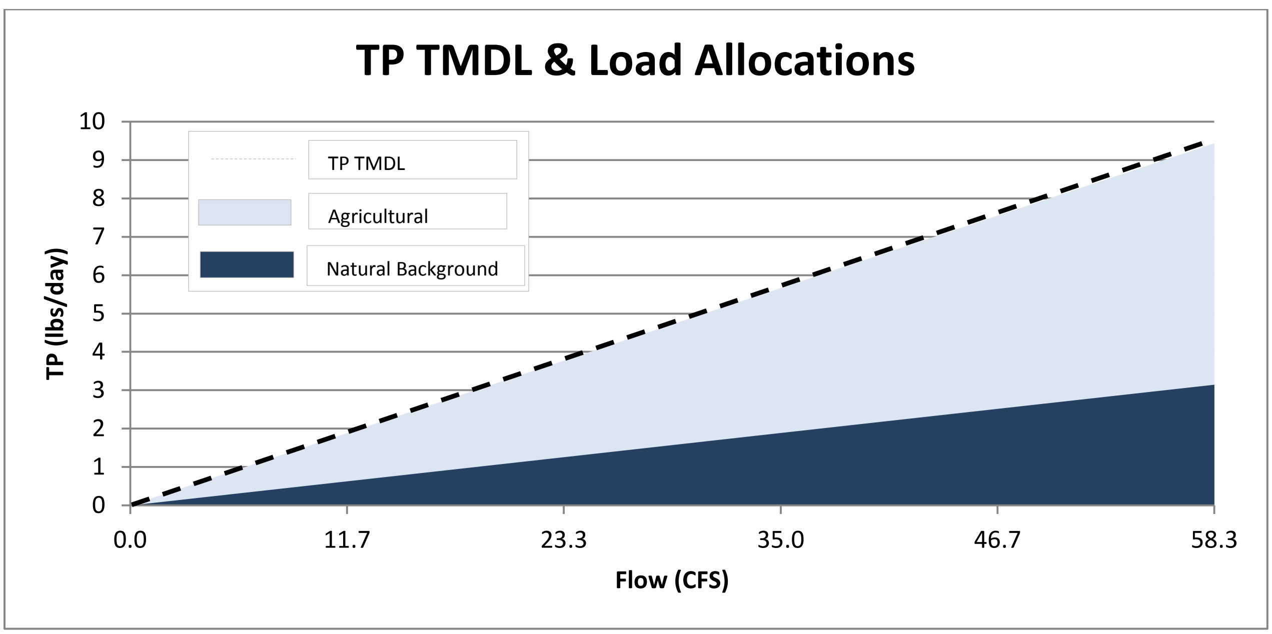

Figure 7-9. TMDL for TP and Load Allocations, the East Fork of Rock Creek

Table 7-19 provides an example TMDL and example allocations for typical summer baseflow conditions. The TP load allocations and the TP TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-19** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Typically TMDLs are developed by basing the existing load on the 80th percentile of instantaneous loads. Instantaneous loads are calculated from water quality data used in the assessment process and a corresponding streamflow volume. The 80th percentile of these loads is then used as the existing load. The existing load in this example TMDL was developed based on the one time water quality exceedance and associated flow measurement. DEQ has chosen to utilize this load because it represents the condition of the East Fork of Rock Creek at the time of the water quality target exceedance and is conservative estimate and will be protective of water quality.

Table 7-19. East Fork Rock Creek Example TP, load allocations and TMDL

Source Category	Existing Load (lbs/day)**	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	1.00	1.00	0
Agricultural and Silvicultural Land Use	9.3	4.51	51.5
	Total = 10.3	**TMDL = 5.51**	**Total = 46.5**

**based on a median growing season flow of 34.1 cfs*
***based on the one time water quality target exceedance concentration 0.31 mg/L and flow of 6.18 cfs*

The source assessment conducted for the East Fork Rock Creek has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the East Fork Rock Creek and its tributaries will result in lower TP concentrations throughout the length of East Fork Rock Creek. Reducing loads of this nature will mitigate elevated TP loads.

7.5.2 South Fork of Antelope Creek (MT46E002_060)

The South Fork of Antelope Creek flows into Antelope Creek which in turn flows into Rock Creek. Antelope Creek enters Rock Creek approximately 3.6 miles downstream from the confluence of the East Fork and West Fork. Area land use is primarily agricultural and some light historical mining in the upper reaches. There has also been limited silviculture (logging) activity within the watershed. As determined in **Section 7.4.3.2** the South Fork of Antelope Creek exceeded nutrient water quality targets for Nitrate + Nitrite ($N0_3$+$N0_2$), Total Nitrogen (TN) and Total Phosphorous (TP). TMDLs will be developed for $N0_3$+$N0_2$, TN and TP.

7.5.2.1 South Fork of Antelope Creek Source Assessment

The source assessment for the South Fork of Antelope Creek includes an evaluation of $N0_3$+$N0_2$, TN and TP concentrations, flow and loading data along the whole length of the South Fork. This is followed by quantification of natural background and the two most significant human-caused sources of nutrients. The two human-caused nutrient sources include agriculture (grazing) and historical mining practices.

Instream $N0_3$+$N0_2$, TN and TP concentrations exceeded water quality targets at a number of sampling locations during different growing season events. $N0_3$+$N0_2$, TN and TP concentrations were higher in the headwaters and decrease as you move down stream. **Table 7-20** and **Figure 7-10** present summary statistics of $N0_3$+$N0_2$ concentrations at sampling sites in the South Fork. **Table 7-21** and **Figure 7-11** present summary statistics of TN concentrations at sampling sites in the South Fork. **Table 7-22** and **Figure 7-12** present the summary statistics of TP concentrations at sampling sites in the South Fork.

Table 7-20. Growing season $N0_3$+$N0_2$ Summary Statistics for Sampling Sites on the South Fork of Antelope Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
C02ANTSF03	5	0.490	0.620	0.549	0.490	0.540	0.604
C02ANTSF02	5	0.460	0.560	0.518	0.480	0.540	0.550
C02ANTSF10	6	0.240	0.430	0.364	0.360	0.375	0.412

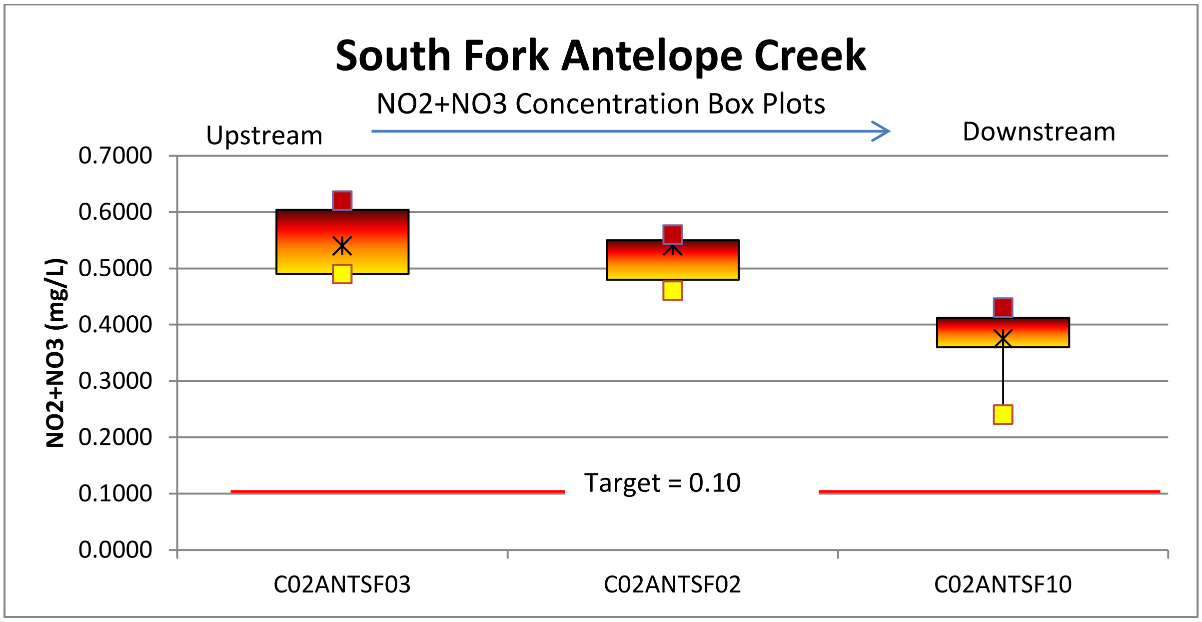

Figure 7-10. N03+N02 Concentration Box plots: South Fork of Antelope Creek

Table 7-21. Growing season TN Summary Statistics for sampling sites on the South Fork of Antelope Creek (units in mg/L)

Site	n	min	max	mean	25^{th} percentile	median	75^{th} percentile
C02ANTSF03	5	0.58	1.48	0.88	0.67	0.79	0.870
C02ANTSF02	5	0.54	1.08	0.67	0.54	0.56	0.62
C02ANTSF10	5	0.38	0.47	0.43	0.42	0.43	0.45

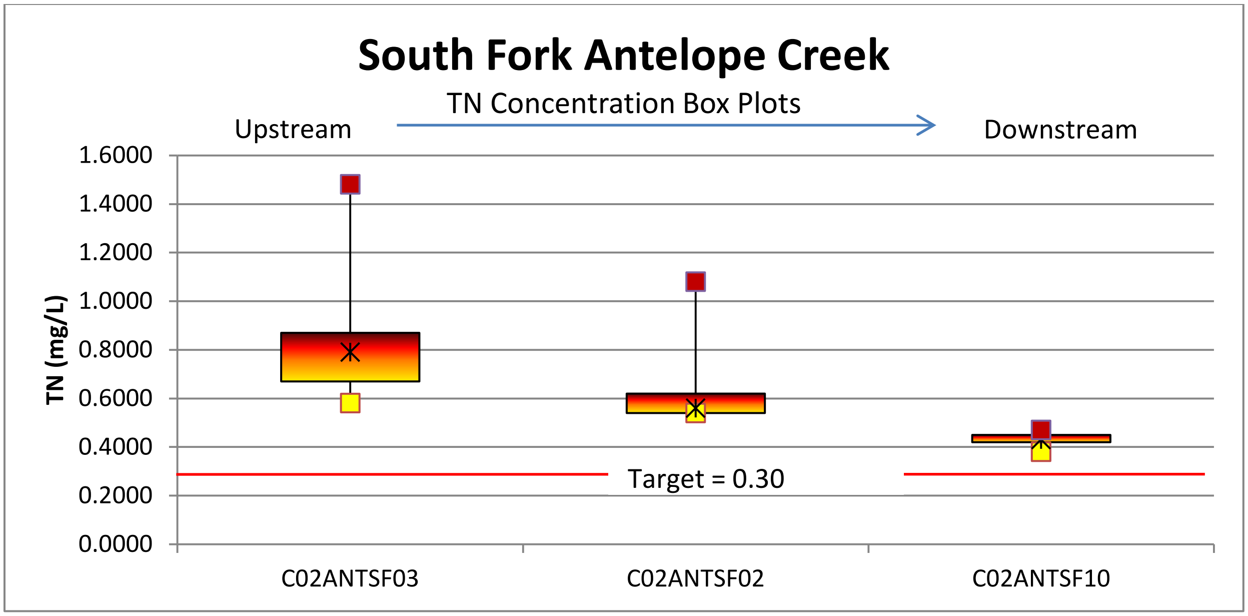

Figure 7-11. TN Concentration Box Plots: South Fork Antelope Creek

Table 7-22. Growing season TP Summary Statistics for sampling sites on the South Fork of Antelope Creek (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
C02ANTSF03	5	0.010	0.630	0.035	0.160	0.030	0.056
C02ANTSF02	5	0.007	0.016	0.012	0.013	0.013	0.013
C02ANTSF10	6	0.005	0.035	0.015	0.0103	0.0115	0.0143

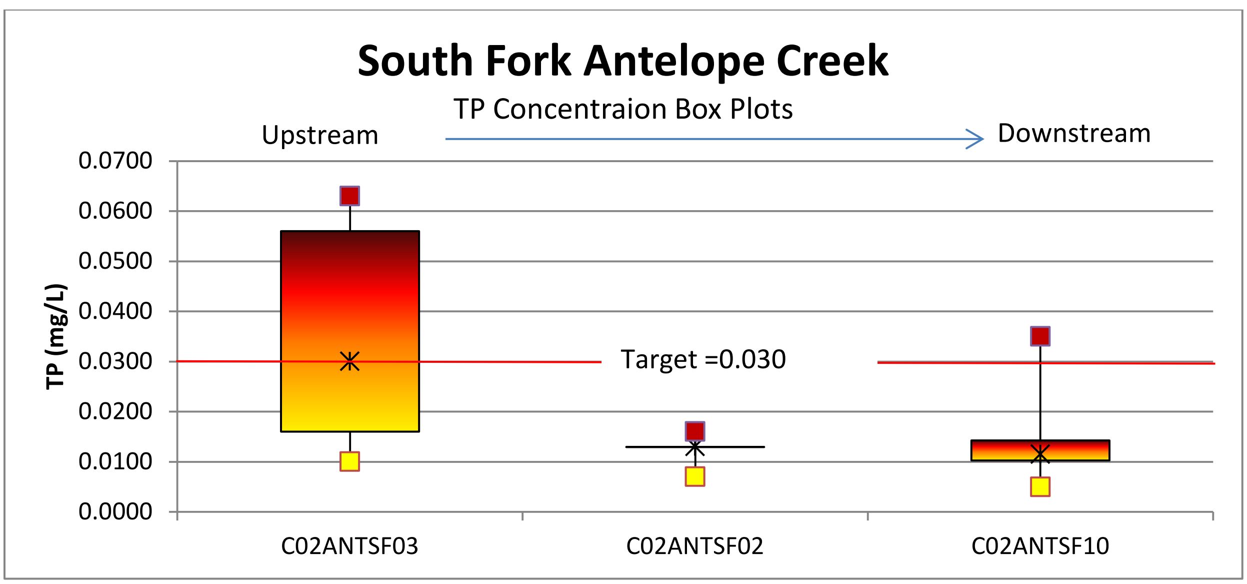

Figure 7-12. TP Concentration Box Plots: South Fork Antelope Creek

$N0_3$+$N0_2$, TN and TP loads calculated from the 2004 and 2010–2011 sampling events are depicted in **Figure 7-10, 7-11 and 7-12**, respectively. Average growing season $N0_3$+$N0_2$ loads increase from 0.68 lbs/day at monitoring location CO2ANTSF03 to 1.47 lbs/day at the downstream CO2ANTSF02 monitoring location, an average increase of 0.79 lbs/day **Figure 7-10**. From monitoring location CO2ANTSF02 to CO2ANTSF10 loads decrease slightly from 1.47 to 1.37 lbs/day.

Average growing season TN loads increase from 0.95 lbs/day at monitoring location CO2ANTSF03 to 1.97 lbs/day at the downstream CO2ANTSF02 monitoring location, an average increase of 1.02 lbs/day **Figure 7-11** From monitoring location CO2ANTSF02 to CO2ANTSF10 loads decease slightly from 1.97 to 1.5 lbs/day, an average decrease of 0.47 lbs/day.

Average growing season TP loads decrease slightly from 0.041 lb/day at monitoring location CO2ANTSF03 to 0.031 lb/day at the downstream CO2ANTSF02 monitoring location **Figure 7-12**. This is an average decrease of 0.010 lbs/day. Average low-flow TP loads remained relatively constant at approximately 0.031 lb/day between monitoring locations CO2ANTSF02 and CO2ANTSF10.

Streamflow volume increases as you move from the headwaters to the mouth. The $N0_3$+$N0_2$, and TN load increase parallels the increase in flow throughout the length of the stream. The limited tributary network in this area suggests that much of this increased flow is via groundwater. The increased loading is likely due to $N0_3$+$N0_2$ and TN within this groundwater and/or may be linked to increased direct surface water nutrient input from cattle and other sources. Additionally the $N0_3$+$N0_2$, TN and TP concentrations **(Tables 7-20, 7-21 and 7-22)** tend to decrease along the South Fork of Antelope Creek as you move down stream. This could be because the $N0_3$+$N0_2$, TN and TP concentrations in the groundwater are lower than (cleaner than) the concentrations in the South Fork. The decreased $N0_3$+$N0_2$, TN and TP concentrations could also indicate some algal nutrient uptake. The high AFDW results along the South Fork during the majority of sample events suggests that there was significant algae uptake at the time of the sampling events.

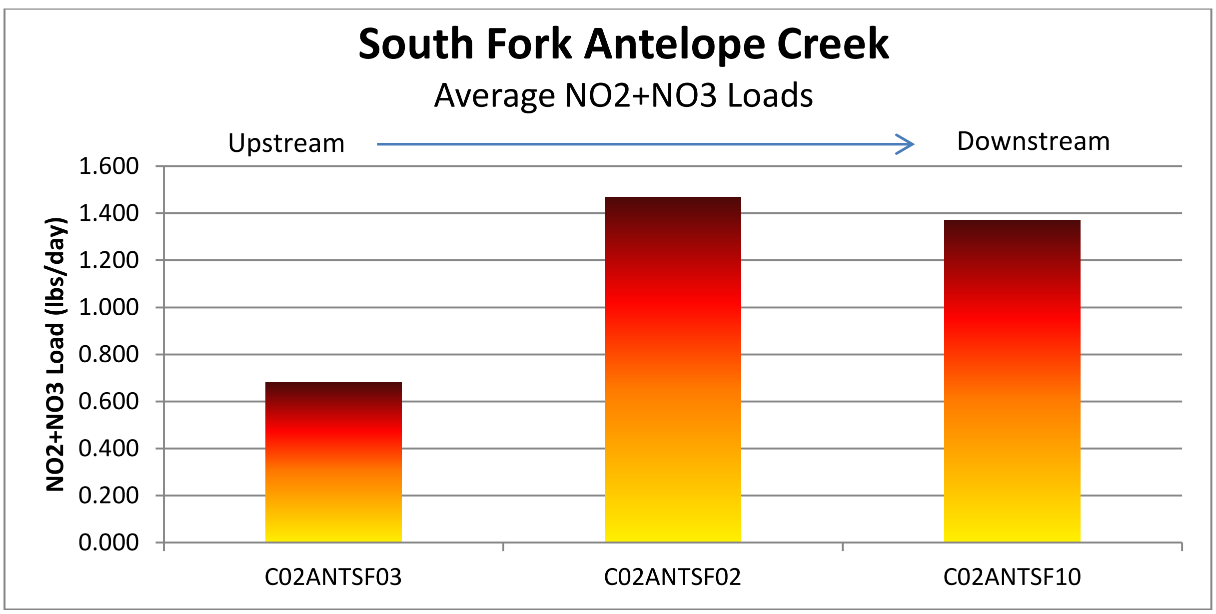

Figure 7-13. $N0_3$+$N0_2$ Load within South Fork Antelope Creek

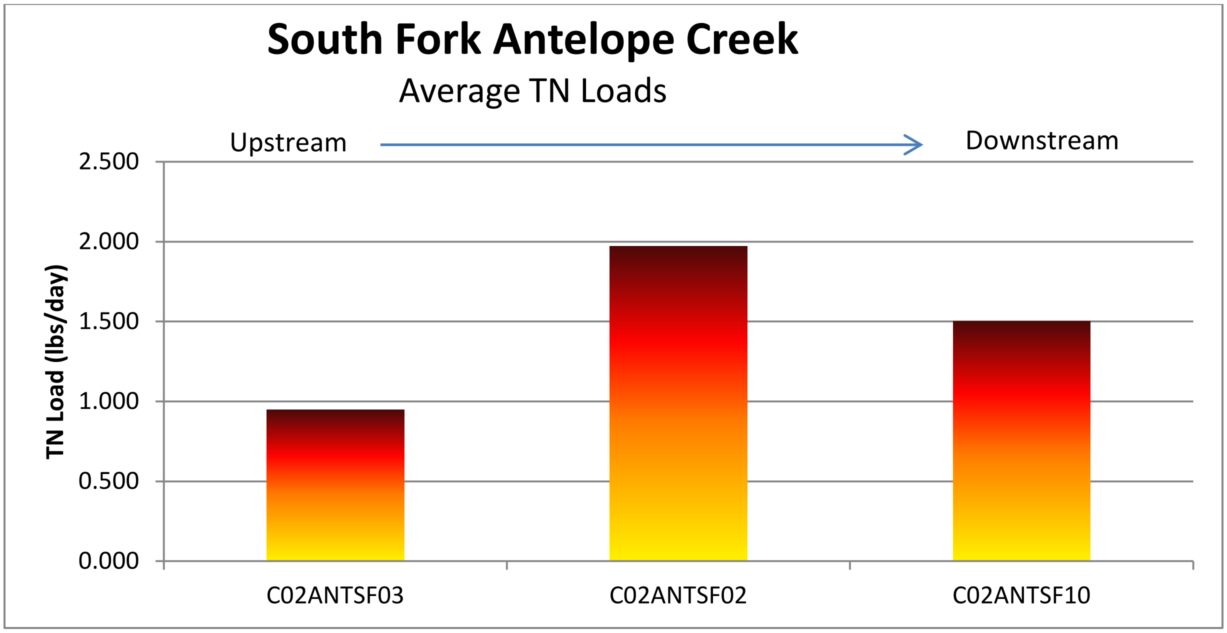

Figure 7-14. TN Load within South Fork Antelope Creek

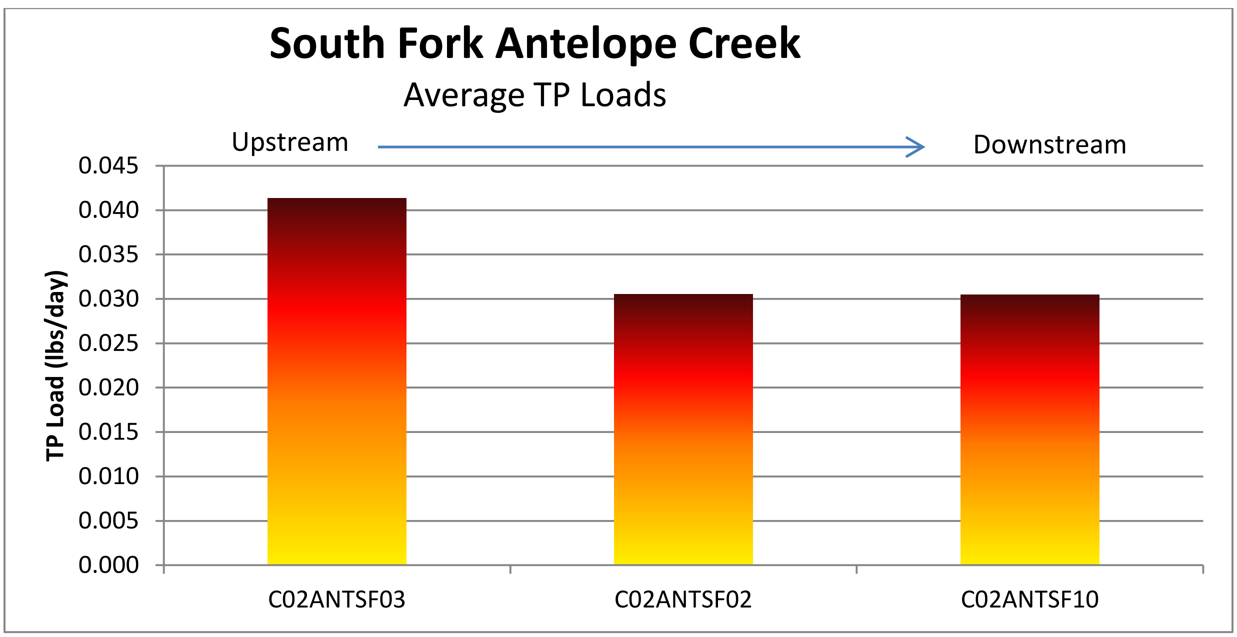

Figure 7-15. TP Load within South Fork Antelope Creek

Natural Background Nutrient Loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. No background water quality data was available for the South Fork of Antelope Creek.

Given this lack of data, and lack of data from reference streams in the Rock TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion. In a study to develop nutrient criteria for streams in Montana, (Suplee et al., 2008a) provides the 25th, 50th, and 75th percentile of the all-season reference dataset from wadeable streams to represent background conditions.

This translates to background $N0_3$+$N0_2$ values ranging from 0.005 mg/L, 0.020 mg/L, and 0.042 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.020 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.020 mg/L and a median growing season flow of 0.57 cfs, the estimated background TN load to the segment is calculated to be approximately 0.061 lbs/day.

Background TN values derived from (Suplee et al., 2008a) ranging from 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.085 mg/L and a median low-flow baseflow of 0.57 cfs, the average background TN load to the segment is calculated to be approximately 0.26 lbs/day.

Background TP values derived from (Suplee et al., 2008a) for wadeable streams ranged from 0.008 mg/L, 0.010 mg/L, and 0.020 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.010mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TP of 0.010 mg/L and a median low-flow baseflow of 0.57 cfs, the average background TP load to the segment is calculated to be approximately 0.031 lb/day.

Agricultural Nutrient Loading

Cattle are periodically grazed within the South Fork of Antelope Creek watershed, during the algal growing season. The Bureau of Land Management (BLM) accounts for three allotments in the South Fork of Antelope Creek watershed. The Antelope East, Antelope South and the Duck point allotments. These allotments are approximately 180, 386 and 58 acres respectively. Total number of livestock in these allotments is 4, 12 and 4 respectively. The South Fork of Antelope Creek watershed is approximately 1,650 acres in size, 624 acres (38 %) is in authorized BLM allotments. These allotments are used from June 15 through October 14.

The remaining portion of the South fork of Antelope Creek is private land. There is a significant difficulty in determining the number of cattle grazed on private land in this watershed. As noted by the sediment assessment results in **Section 5.6,** vegetation, habitat, and sediment deposition health in the South Fork of Antelope Creek has been negatively impacted eroding streambanks like associated with riparian grazing. These negative impacts contribute to a lack of riparian buffering as a significant contributor towards elevated nutrient loading along with direct loading from cattle excrement give their proximity to the stream. A conservative approach to determining the number of cattle being grazed is to apply an Animal Unit Month (AUM) of 0.1 to 0.15/ acre to the remaining 1,026 acres of private land (phone conversation with Bret Bledso, NRCS). This would indicate that this land was capable of providing forage for 102-154 cattle if they were grazed sustainably.

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include 1) direct loading via the breakdown of excrement and surface runoff and subsurface pathways, 2) delivery from grazed forest and rangeland during the growing season and 3) the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas. As noted by the sediment assessment results in **Section 5.4.2.1,** vegetation, habitat, and sediment deposition in Sluice Gulch have been negatively impacted via grazing. These negative impacts contribute to a lack of riparian buffering as a significant contributor towards elevated nutrient loading along with direct loading from cattle excrement given their proximity to the stream.

Silvicultural Practices

Silvicultural (timber harvest) practices inevitably cause some measure of downstream effects that may or may not be significant over time. Changes in land cover will change the rate at which water evapotranspires which will affect 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) and this will have an affect the hydrologic cycle. Changes in the biomass uptake and soil conditions will affect the nutrient cycle. Elevated nitrate concentrations result from increased leaching from the soil as mineralization is enhanced. Nutrient uptake by biomass is also greatly reduced after timber harvest, leaving more nutrients available for runoff.

There have been some historical silvicultural activities in the South Fork of Antelope Creek. Some small scale timber sales occurred in 1991, 2005 and 2006. In 1991, 189 acres were harvested for a total of 1,602,000 board feet of product. In 2005, 152 acres were harvest for a total of 794,000 board feet of product. In 2006, 12 acres were harvested for 76,000 board feet of product. Nutrient loading from harvest areas are generally linked to runoff event and lack of timber harvest best management practices. Because of grazing in the upper portions of the Rock watershed, it is difficult to use the sample results to partition grazing impacts from Silviculture impacts. DEQ data for areas with timber harvest and limited or no cattle grazing or other agricultural land management activity has routinely shown that timber harvest is typically a negligible source of elevated nutrients during the algal growing season.

Historical Mining Nutrient Loading

Surface water quality can be degraded by releases of contaminants from mine waste material or from co-mingling with acid mine drainage from mine adits. Concentration of potential contaminants depends on the timing of when mining has taken place, mechanism of chemical release, streamflow, and water chemistry.

Two known mining operations have existed in the South Fork of Antelope Creek. The Ant Mine and the Ram Mountain Mine. The Ant mine was last investigated by the DEQ in 1993. At the time of the investigation there was no visible mine tailings, however, an estimated 2,300 cubic yards of waste rock were documented. There was one mine adit that contained water. pH measured in this water was 2.9 S.U. Three other open adits were identified during this investigation. The South Fork of Antelope Creek is approximately 450 feet away from the mine remnants.

The Ram Mountain mine was originally active in the early 1900’s. This mine was opened for exploration in the mid 1980’s. During this time several underground working were opened, roads were constructed and improved and drilling took place at a number of locations. No mining occurred during this time.

Nutrient pollution is likely not a result of the mining in the South fork of Antelope Creek, considering the time that has lapsed since the mining has taken place in this watershed and remedial efforts on the existing sites.

7.5.2.2 South Fork of Antelope Creek Total Maximum Daily Loads: Nitrate plus Nitrite (NO_3 + NO_2), Total Nitrogen (TN) and Total Phosphorous (TP)

$N0_3$+$N0_2$, TN and TP Total Maximum Daily Loads are presented here for the South Fork of Antelope Creek (MT41E002_060). The TMDLs (lbs/day) for $N0_3$+$N0_2$, TN and TP are calculated using the water quality target values established in **Section 7.4**. The TMDL loads for TN and TP apply during the summer growing season (normally July 1–Sept. 30). The TMDL for $N0_3$+$N0_2$ is based on an instream target value of 0.10 mg/L TN and streamflow (**Figure 7-16**).The TMDL for TN is based on an instream target value of 0.30 mg/L TN and streamflow (**Figure 7-17**). The TMDL for TP is based on an instream target value of 0.03 mg/L TN and streamflow (**Figure 7-18**).

TMDL calculations for $N0_3$+$N0_2$, TN and TP are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L ($N0_3$+$N0_2$ = 0.10, TN =0.30 mg/L or TP =0.030 mg/L)
Y= streamflow in cubic feet per second
5.393 = conversion factor

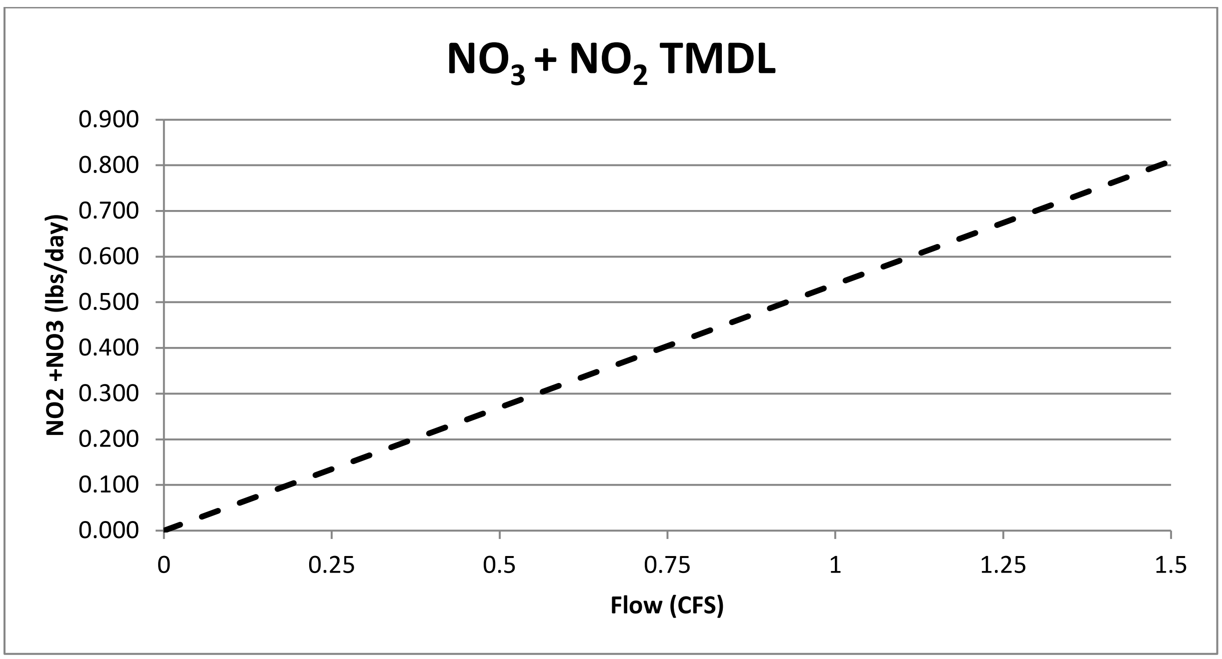

Figure 7-16. TMDL for NO_2 +NO_3 as a function of flow: South Fork of Antelope Creek

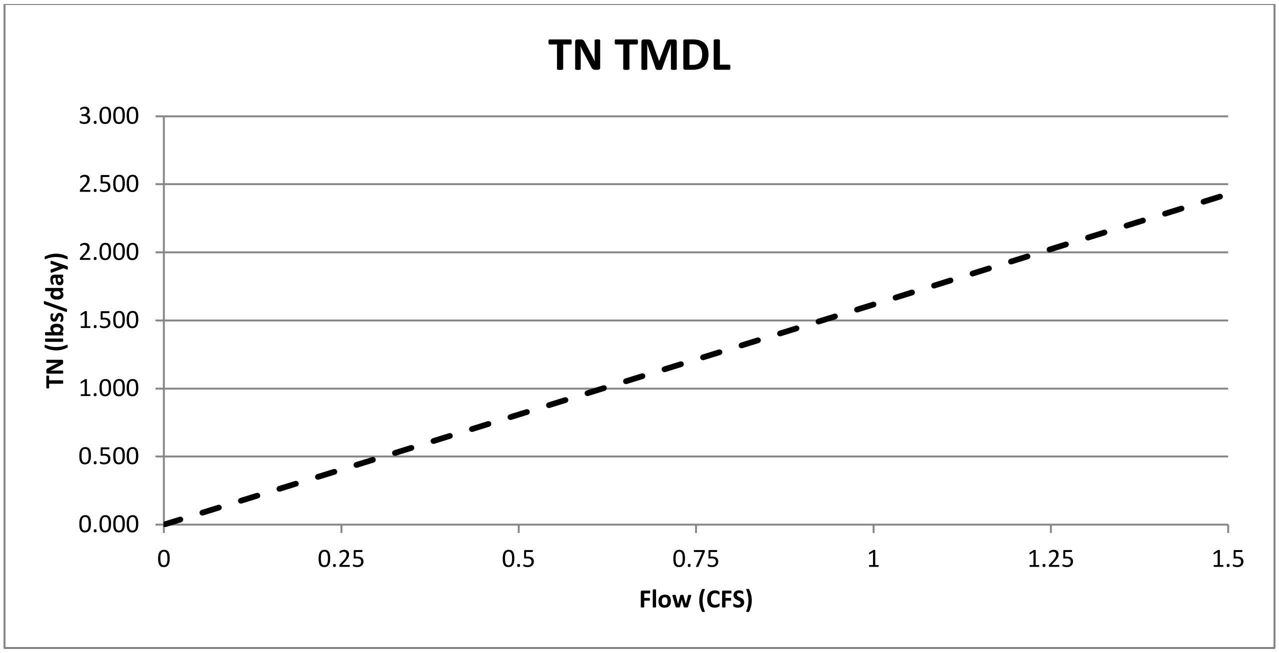

Figure 7-17. TMDL for TN as a function of flow: South Fork of Antelope Creek

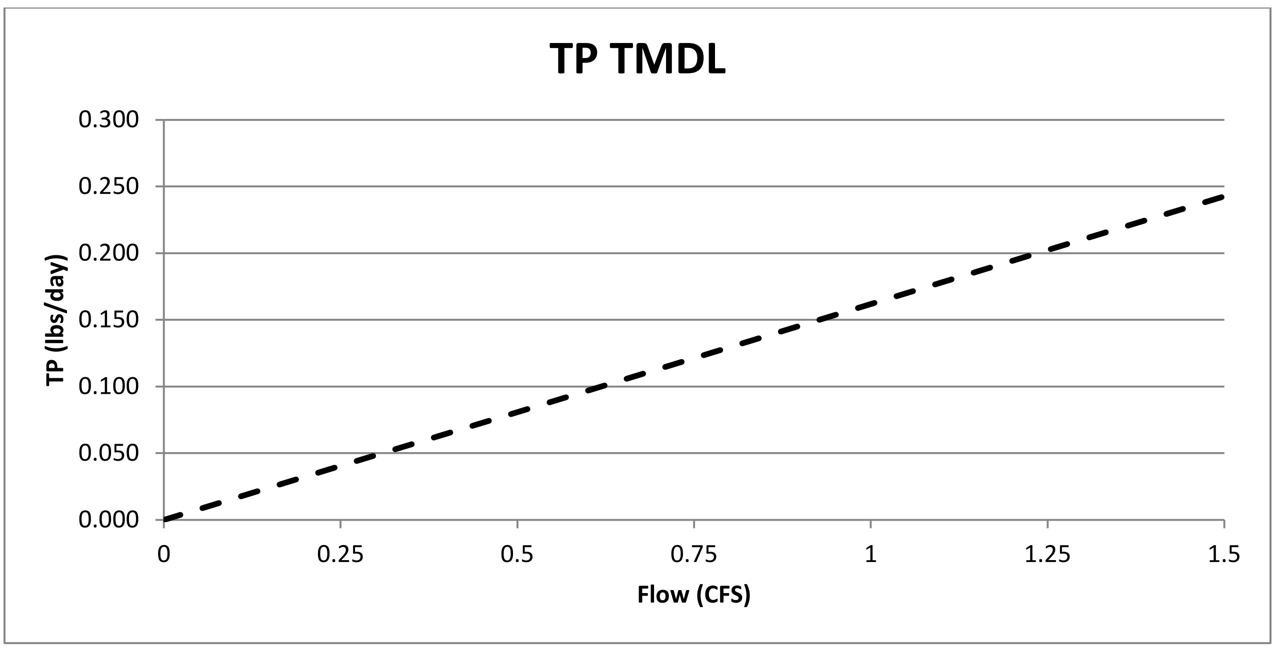

Figure 7-18. TMDL for TP as a function of flow: South Fork of Antelope Creek

7.5.2.3 South Fork of Antelope Creek Nitrate plus Nitrite (NO_2 +NO_3), Total Nitrogen (TN) and Total Phosphorus (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) $N0_3$+$N0_2$, TN and TP sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.2.3.1 Nitrate plus Nitrite (NO_3 +NO_2) Allocations

The South Fork of Antelope Creek TMDL for $N0_3$+$N0_2$, comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant $N0_3$+$N0_2$, nonpoint sources include natural background sources, agricultural, silvicultural and historical mining sources.

Due to the difficulty in determining the contribution of each potential source load allocations from each source will be composited. Load allocations are therefore provided for 1) natural background sources and 2) the combination of agricultural and silvicultural land use. In the absence of individual WLAs and an explicit MOS, TMDLs for $N0_3$+$N0_2$, in the watershed are equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + $LA_{AG+SILV}$

LA_{NB} = Load Allocation to natural background sources

$LA_{AG+SILV}$ = Load Allocation to the combination of agricultural and silvicultural land use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background $N0_3$+$N0_2$, concentration of 0.020 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= $N0_3$+$N0_2$, load allocated to natural background sources

X= 0.020 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Agriculture and Silvicultural Sources

The load allocations are to the combination of agricultural and silvicultural sources are calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG+SIlV}$= TMDL - LA_{NB}

$N0_3$+$N0_2$ Load Allocation

$N0_3$+$N0_2$ load allocations are provided for South Fork Antelope Creek and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) the combination of agricultural and silvicultural land-use sources ($LA_{AG+SILV}$). $N0_3$+$N0_2$, load allocations are summarized in **Table 7-23**. The TMDL is depicted graphically in **Figure 7-19.**

Table 7-23. $N0_3$+$N0_2$, load allocation descriptions, South Fork of Antelope Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**

Table 7-23. $N0_3$+$N0_2$, load allocation descriptions, South Fork of Antelope Creek

Source Category	Load Allocation Descriptions	LA Calculation
Combination of Agricultural and Silvicultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks • limited nutrient uptake due to loss of overstory	**LA_{AG}+SILV = TMDL - LA_{NB}**

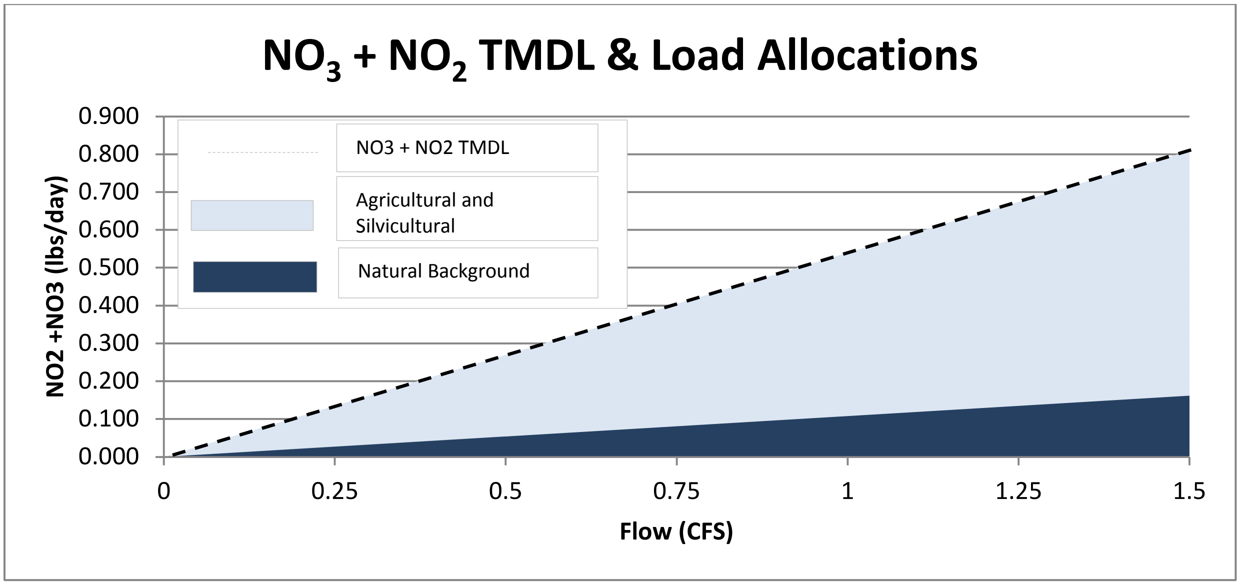

Figure 7-19. TMDL for $N0_3$+$N0_2$ and Load Allocations, South Fork Antelope Creek

Table 7-24 provides an example TMDL and example allocations for a typical summer baseflow condition. The $N0_3$+$N0_2$ load allocations and the $N0_3$+$N0_2$ TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-24** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80^{th} percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80^{th} percentile of these loads is then used as the existing load.

Table 7-24. South Fork of Antelope Creek Example $N0_3$+$N0_2$, load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.047	0.047	0%
Agricultural and Silvicultural Land Use	1.25	0.19	84.8%
	Total = 1.30	**TMDL = 0.24**	**Total =81.5%**

**based on a median growing season flow of 0.44 cfs*

The example TMDL for $N0_3$+$N0_2$ in the South Fork of Antelope Creek is calculated to be 0.24 lbs/day. Existing $N0_3$+$N0_2$ loading to the South Fork of Antelope Creek is estimated at 1.30 lbs/day, requiring a total load reduction of 81.5% in order to meet the TMDL for $N0_3$+$N0_2$ in the South Fork of Antelope Creek. Load allocations and load reductions are specifically designated to the composite load of agricultural and silvicultural land uses, along with the existing load, make up an estimated 96% of the

$N0_3$+$N0_2$ load within the South Fork of Antelope Creek. Load reductions should focus on limiting and controlling $N0_3$+$N0_2$ loads from the variety of sources associated with agricultural land use, primarily grazing impacts along the South Fork of Antelope Creek.

Because of grazing in the upper portions of the Rock watershed, it is difficult to use water quality sample results to partition the impacts from grazing impacts from impacts from Silviculture activities. The source assessment conducted for the South Fork of Antelope Creek has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the South Fork of Antelope Creek and its tributaries will result in lower $N0_3$+$N0_2$ concentrations throughout the length of Antelope Creek. Reducing loads of this nature will mitigate elevated $N0_3$+$N0_2$ loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.2.3.2 Total Nitrogen (TN) Load Allocations

The South Fork of Antelope Creek TMDL for TN comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant nonpoint source contributions include 1) natural background sources and 2) the combination of agricultural and silvicultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TP in the watershed are equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + LA_{AG}

LA_{NB} = Load Allocation to natural background sources

$LA_{AG+\,SILV}$ = Load Allocation to the combination of agricultural and silvicultural land use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TN concentration of 0.085mg/L (**see Section 7.5.1.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= TN load allocated to natural background sources

X= 0.085 mg/L natural background concentration

Y= median growing season streamflow in cubic feet per second

5.393 = conversion factor

Agriculture and silvicultural Land use Sources

The load allocation to the combination of agricultural and silvicultural land use sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG+SILV}$= TMDL - LA_{NB}

TN Load Allocation

TN load allocations are provided for South Fork Antelope Creek (**Table 7-25**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) the combination of agricultural and silvicultural land-use sources ($LA_{AG+SILV}$). The TMDL is depicted graphically in **Figure 7-20.**

Table 7-25. TN load allocation descriptions, South Fork Antelope Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	LA_{NB} = (X) (Y) (5.393)
Combination of Agricultural and Silvicultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks • limited nutrient uptake	$LA_{AG+SILV}$ = TMDL - LA_{NB}

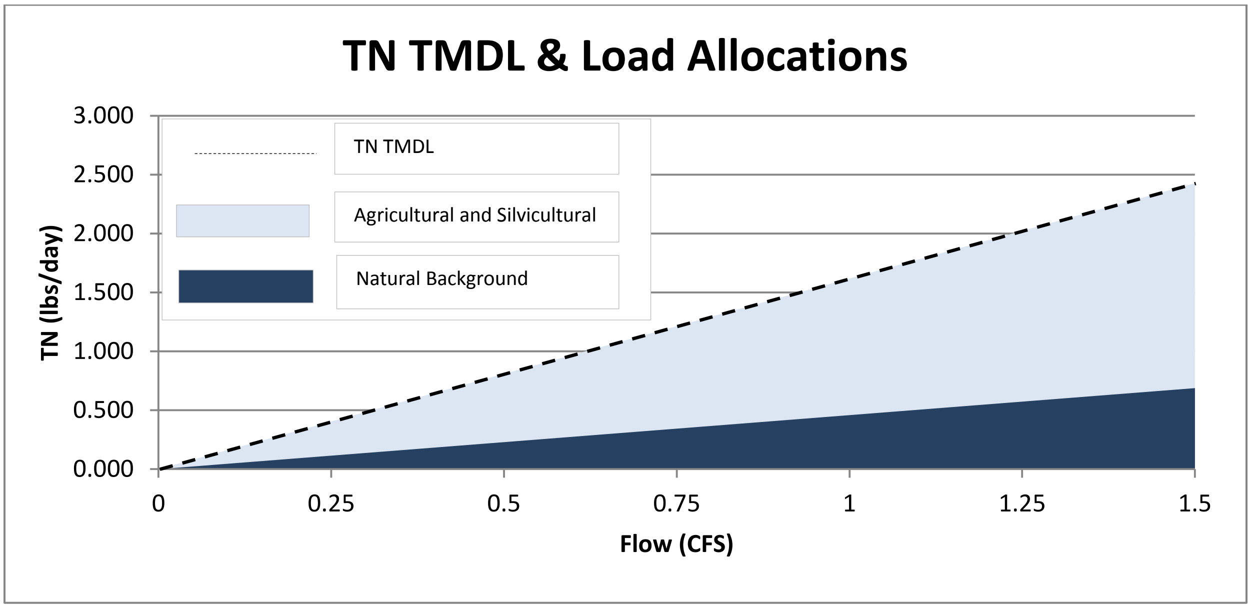

Figure 7-20. TMDL for TN and Load Allocations, South Fork Antelope Creek

Table 7-26 provides an example TMDL and example allocations for a typical summer baseflow condition. The TN load allocations and the TN TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-26** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-26. South Fork Antelope Creek Example TN load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.20	0.20	0%
Agricultural and Silvicultural Land Use Sources	2.19	0.51	76.7%
	Total = 2.39	**TMDL = 0.71**	**Total = 70.3%**

**based on a median growing season of 0.44 cfs*

The TMDL for TN in the South Fork of Antelope Creek is calculated to be 0.71 lbs/day. Existing TN loading to the South Fork of Antelope is estimated at 2.39 lbs/day, requiring a total load reduction of 70.3% in order to meet the TMDL for TN in the South Fork of Antelope Creek. Load allocations and load reductions are specifically designated to agricultural and silvicultural land uses which make up 92% of the TN load within the South Fork of Antelope Creek. Load reductions should focus on limiting and controlling TN loads from the variety of sources associated with agricultural land use, primarily grazing impacts along the South Fork of Antelope Creek.

The source assessment conducted for the South Fork of Antelope Creek has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the South Fork of Antelope Creek and its tributaries will result in lower TN concentrations throughout the length of Antelope Creek. Reducing loads of this nature will mitigate elevated TN loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.2.3.2 Total Phosphorus (TP) Load Allocations

The South Fork of Antelope Creek TMDL for TP comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant nonpoint source contributions include 1) natural background sources and 2) the combination of agricultural and silvicultural sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TP in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{AG+SILV}$

LA_{NB} = Load Allocation to natural background sources

$LA_{AG+SIIV}$ = Load Allocation to the combination of agricultural and silvicultural land use sources.

Natural Background Source

Load allocations for natural background sources are based on a natural background TP concentration of 0.010mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$LA_{NB} = (X)(Y)(5.393)$

LA_{NB}= TP load allocated to natural background sources

X= 0.010 mg/L natural background concentration

Y= median growing season streamflow in cubic feet per second

5.393 = conversion factor

Agriculture and Silvicultural Sources

The load allocations are to the combination of agricultural and silvicultural sources are calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG}= TMDL - LA_{NB}$

TP Load Allocation

TP load allocations are provided for South Fork Antelope Creek (**Table 7-27**) and include allocations to the following source categories: 1) natural background (LA_{NB}) and 2) the combination of agricultural and silvicultural land-use sources ($LA_{AG+SILV}$). The TMDL is depicted graphically in **Figure 7-21.**

Table 7-27. TP load allocation descriptions, South Fork Antelope Creek

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Combination of Agricultural and Silvicultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks • limited nutrient uptake	**$LA_{AG+SILV}$ = TMDL - LA_{NB}**

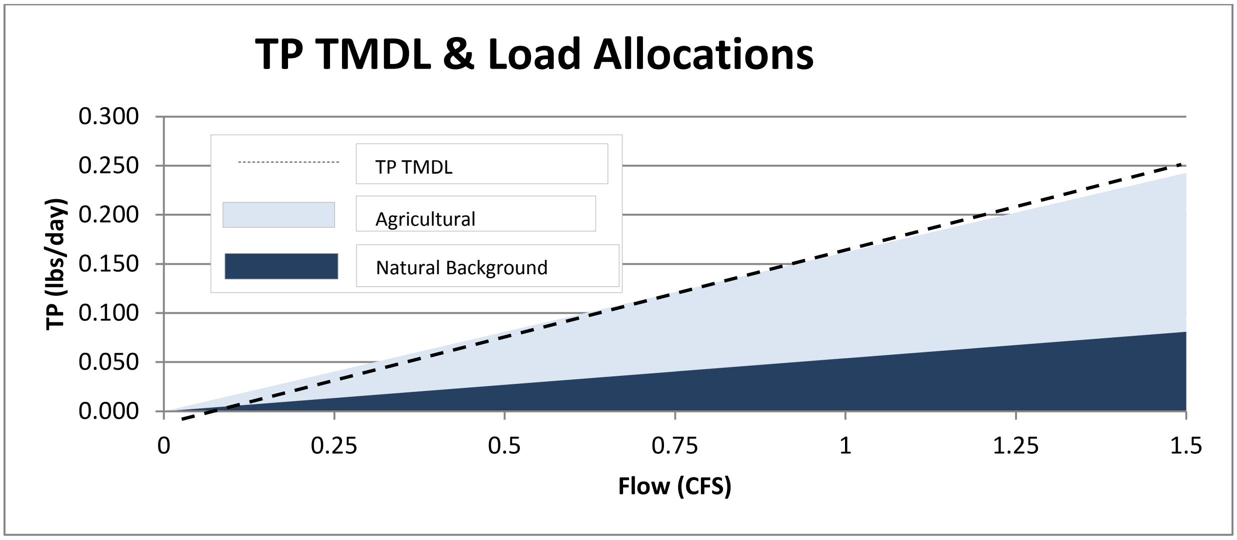

Figure 7-21. TMDL for TP and Load Allocations, South Fork Antelope Creek

Because measured instream TP concentrations are not wholly within natural background conditions and above target concentrations, water quality data warrants calculation of TP load reductions to specific source categories. Load allocations incorporate allowed loading from general source categories and establish allowable TP loads. **Tables 7-28 and 7-29** presents example TP load allocations as a function of streamflow in accordance with the allocation scheme presented in **Table 7-27**; load allocations are presented at growing season flow conditions in the South Fork of Antelope Creek. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-28. Primary calculations of the South Fork Antelope Creek example TP load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.024	0.024	0%
Agricultural and Silvicultural Land Use Sources	0.23	0.047	0%
	Total = 0.047	**TMDL = 0.071**	**Total = 0%**

**based on a median growing season flow of 0.44 cfs*

The example TMDL for TP in the South Fork of Antelope Creek is calculated to be 0.071 lbs/day. Existing TP loading to the South Fork of Antelope is estimated at 0.047 lbs/day, that TP is currently meeting the TMDL for TP. There are a number of factors that contribute to the %0 load allocation.

DEQ's assessment method utilizes a binomial test which, in order to calculate both false positive and false negative rates, includes a value referred to as effect size. The ramification of the effect size is that an exceedance rate of something less than 20% is needed for removing a nutrient impairment cause. The amount that the allowable exceedance rate is below 20% is in part a function of sample size, and as sample size increases the allowable exceedance rate approaches 20%. Because the percent reductions in **Table 7-25** are determined using the 80th percentile of the data, this can lead to zero percent reduction to meet the TMDL when in fact a reduction is necessary based on the margin of safety inherently incorporated into the binomial portion of the assessment method. This condition is exemplified in the South Fork Antelope Creek TP assessment results where 3 of 16 (18.8%) of the samples exceeded the criteria, whereas the allowable number of exceedances is 1 (6.25%). For this number of samples (16), the 94th percentile of the data would need to be equal to or less than the TP target value of 0.030 mg/l.

This exampled is compounded by the flow values used to calculate load. Load is calculated by flow measurements and corresponding TP concentrations collected during the low flow summer growing season. The 80th percentile of these loads is then used in determining the total existing load from the waterbody. Summer growing season flow measurements are typically low. Higher concentrations occur during the period of the year that experiences the lowest flows (growing season). The 80th percentile for loading will tend to miss these exceedances using the approach mentioned above.

Table 7-26 shows load reduction based on the 94th percentile of the TP concentration data and the median growing season flow of 0.44 cfs. The 94th percentile of the concentration data is 0.057 mg/L, which yields a load of 0.135 lbs/day. This suggests a 47.4% reduction in total loading would be necessary to satisfy the target conditions.

Table 7-29. Secondary Calculations of the example South Fork Antelope Creek TP load allocations and TMDL*

Source Category	Existing Load (lbs/day)*	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.024	0.024	%0
Agricultural and silvicultural Land Use Sources	0.111	0.047	57.7%
	Total = 0.135	**TMDL = 0.071**	**Total =47.4 %**

**based on a median growing season flow of 0.44 cfs*

Load allocations and load reductions are specifically designated to the combination of agricultural and silvicultural land uses which make up 82% of the TP load within the South Fork of Antelope Creek. Load reductions should focus on limiting and controlling TN loads from the variety of sources associated with agricultural land use, primarily grazing impacts along the South Fork of Antelope Creek.

The source assessment conducted for the South Fork of Antelope Creek has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the South Fork of Antelope Creek and its tributaries will result in lower TN concentrations throughout the length of Antelope Creek. Reducing loads of this nature will mitigate elevated TN loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.3 Sluice Gulch (MT46E002_110)

Sluice Gulch flows into Rock Creek. Sluice Gulch enters Rock Creek 6.2 miles downstream from the confluence of the East Fork and West Fork. Area land use is primarily agricultural and historical mining. Land use is primarily heavy grazing and past mining practices. Sluice Gulch appears on the 2012 303(d) List as impaired for NO_3+NO_2. As determined in **Section 7.4.3.3** Sluice Gulch exceeded nutrient water quality targets for Nitrate + Nitrite ($N0_3$+$N0_2$) and Total Nitrogen (TN). Source assessment was conducted for $N0_3$+$N0_2$ and TN.

7.5.3.1 Sluice Gulch Source Assessment

The source assessment for Sluice Gulch includes an evaluation of $N0_3$+$N0_2$ and TN concentrations, flow and loading data along the whole length of Sluice Gulch. This is followed by quantification of natural background and the two most significant human-caused sources of nutrients. The two human-caused nutrient sources include agriculture (grazing) and historical mining practices.

Instream concentrations exceeded water quality targets at all sampling locations during different low-flow events. Only one sample collected for $N0_3$+$N0_2$ and only one sample collected for TN were below target criteria. Both of these samples were collected at the downstream most sampling location (CO2SLUCG01).

$N0_3$+$N0_2$, and TN concentrations were higher in the head waters and decrease as you move down stream. **Table 7-30** and **Figure 7-22** present summary statistics of $N0_3$+$N0_2$ concentrations at sampling sites in Sluice Gulch. **Table 7-31** and **Figure 7-23** present summary statistics of TN concentrations at sampling sites in Sluice Gulch.

Table 7-30. Growing season $N0_3$+$N0_2$ Summary Statistics for Sampling Sites on Sluice Gulch (units in mg/L)

Site	n	min	max	mean	25^{th} percentile	median	75^{th} percentile
C02SLUCG03	5	0.360	0.500	0.46	0.410	0.490	0.490
C02SLUCG02	5	0.250	0.450	0.356	0.280	0.370	0.430
C02SLUCG01	5	0.090	0.380	0.262	0.240	0.290	0.310

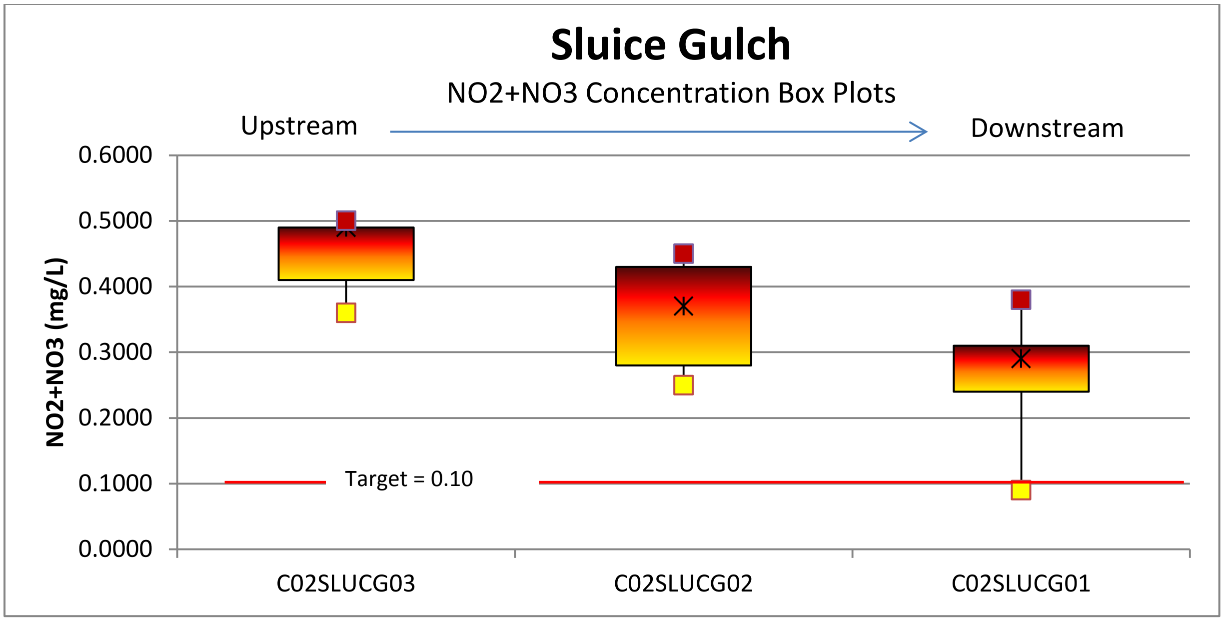

Figure 7-22. NO_3+NO_2 Concentration Box plots: Sluice Gulch

Table 7-31. Growing season TN Summary Statistics for sampling sites on Sluice Gulch (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
C02ANTSF03	5	0.420	0.670	0.550	0.520	0.550	0.560
C02ANTSF02	5	0.330	0.500	0.412	0.410	0.410	0.410
C02ANTSF10	5	0.270	0.460	0.370	0.330	0.340	0.450

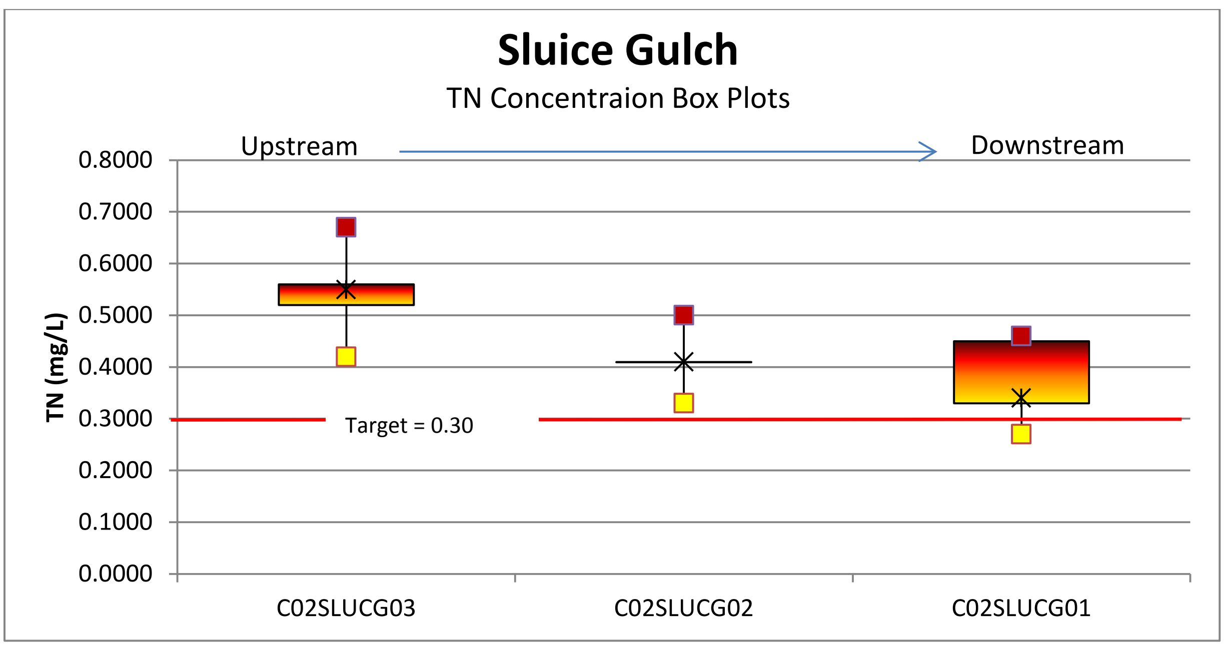

Figure 7-23. TN Concentration Box Plots: Sluice Gulch

NO_3+NO_2 and TN loads calculated from the 2004 and 2010–2011 sampling events are depicted in **Figures 7-24 and 7-25**, respectively. Average NO_3+NO_2 and TN loads decrease moving downstream from the headwaters of the Sluice Gulch to the mouth. The decrease in loading is due to the decrease in $N0_3$+$N0_2$ and TN concentrations and decrease in volume of streamflow in Sluice Gulch.

Average low-flow $N0_3$+$N0_2$ loads decrease from 3.75 lbs/day at monitoring location CO2SLUCG03 to 1.67 lbs/day at the downstream CO2SLUCG01 monitoring location, an average decrease of 2.08 lbs/day. Average low-flow TN loads decreased from 4.21 lb/day at monitoring location CO2SLUCG03 to 2.34 lb/day at the downstream CO2SLUCG01 monitoring location. This is an average decrease of 1.87 lbs/day.

The Decrease in concentration of $N0_3$+$N0_2$ and TN as you move down stream is a likely a result of the sources of $N0_3$+$N0_2$ and TN being located closer to the headwaters of Sluice Gulch. Sluice Gulch is subject to grazing approximately 2-3 months of the year, on 285 allotment acres.

Streamflow volume decreases as you move from the headwaters to the mouth. Average flow volumes decrease from 1.45 cubic feet per second (cfs) to 1.27 cfs to 1.16 cfs at the monitoring sites CO2SLUCG03, CO2SLUCG02 and CO2SLUCG01, respectively. The load decrease parallels the decrease in flow throughout the length of the stream.

The tributary network to Sluice Gulch suggests that the supply of water for this creek is adequate to maintain flow volumes. However, much of the flow volume is lost over its length, which suggests there is an overall loss of surface water to groundwater along Sluice Gulch. This idea is supported by the Belt Series Carbonate geology that is present for the length of Sluice Gulch.

The decreased $N0_3$+$N0_2$ and TN concentrations could also indicate some algal nutrient uptake, although the relatively low Chlorophyll-*a* (live algae) and AFDW results along Sluice Gulch during the majority of sample events suggests that there was not significant algae uptake at the time of the sampling events. **Figures 7-24 and 7-25** shows the decreasing $N0_3$+$N0_2$ and TN loading trends.

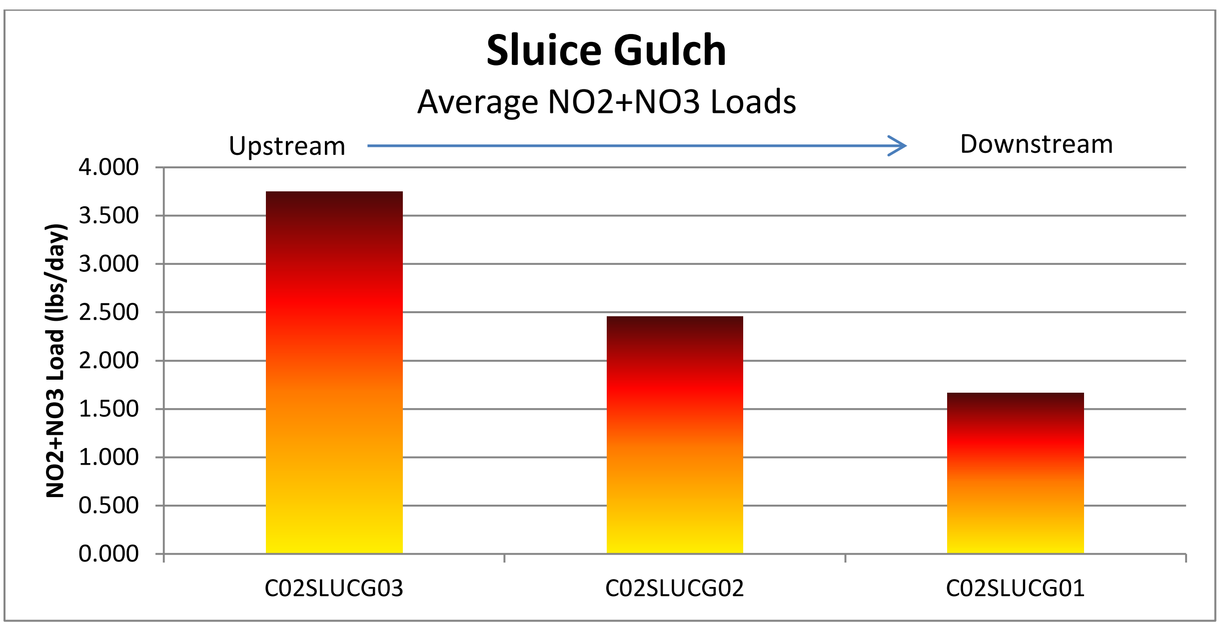

Figure 7-24. $N0_3$+$N0_2$ Load within Sluice Gulch

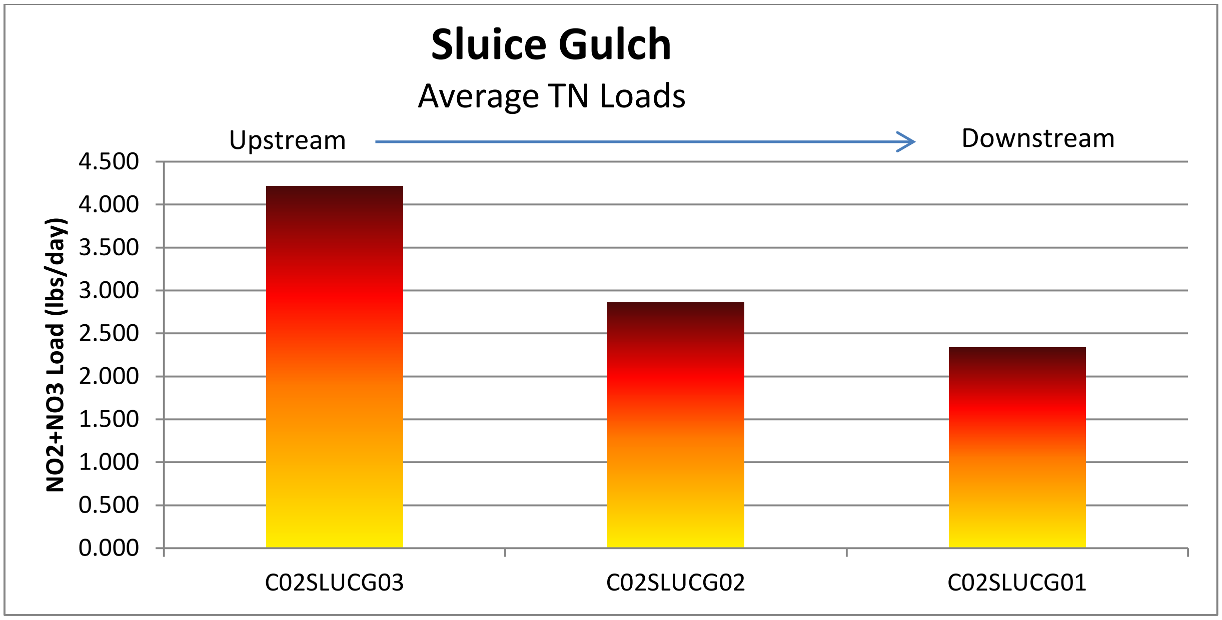

Figure 7-25. TN Load within Sluice Gulch

Natural Background Nutrient Loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. No background water quality data was available for Sluice Gulch.

Given this lack of data, and lack of data from reference streams in the Rock TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion. In a study to develop nutrient criteria for streams in Montana, (Suplee et al., 2008a) provides the 25th, 50th, and 75th percentile of the all-season reference dataset from wadeable streams to represent background conditions.

This translates to background $N0_3$+$N0_2$ values ranging from 0.005 mg/L, 0.020 mg/L, and 0.042 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.020 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for $N0_3$+$N0_2$ of 0.020 mg/L and a median low-flow baseflow of 1.27 cfs, the average background $N0_3$+$N0_2$ load to the segment is calculated to be approximately 0.14 lbs/day.

Background TN values derived from (Suplee et al., 2008a) ranging from 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.085 mg/L and a median low-flow baseflow of 1.27 cfs, the average background TN load to the segment is calculated to be approximately 0.58 lbs/day.

Agricultural Nutrient Loading

A large number of cattle are periodically grazed along and in the headwaters of Sluice Gulch, sometimes during the algal growing season. Sluice Gulch is approximately 5,532 acres, of which 240 acres are state land, and 300 acres are Bureau of Land Management (BLM) land. The BLM has a total of 285 allotted acres in the Sluice Gulch watershed. This acreage is split between two allotments. These allotments are Papoose Gulch and Sluice Gulch allotments. The BLM allows 50 cattle between the two allotments.

The remaining portion of Sluice Gulch (approximately 4992 acres) is private land. The DEQ will assume that cattle are being grazed on private land within the watershed. A conservative approach to determining the number of cattle being grazed is to apply an Animal Unit Month (AUM) of 0.1 to 0.15 to the remaining 4992 acres of private land. This would indicate that this land was capable of providing forage for 499-749 cattle if they were grazed sustainably.

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include 1) direct loading via the breakdown of excrement 2) delivery from grazed forest and rangeland during the growing season via surface water and subsurface pathways 3) the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas. As noted by the sediment assessment results in **Section XX,** vegetation, habitat, and sediment deposition in Sluice Gulch have been negatively impacted primarily via grazing. These negative impacts contribute to a lack of riparian buffering as a significant contributor towards elevated nutrient loading along with direct loading from cattle excrement given their proximity to the stream.

Historical Mining Loading

The Montana Bureau of Mines and Geology (MBMG) abandoned mines database lists two inactive mines in the Sluice Gulch drainage: the Silver King Mine and the Lori No. 13. The Silver King is a former gold and silver lode mine occupying about 18 acres on the south flank of Sluice Gulch where the drainage enters the Upper Willow Creek Valley. The mine consists of access roads, operating benches, 5 adit openings, and 30,000 cubic yards of waste rock in several dumps. A 1993 field assessment reported one of the adits discharging at about 50 gallons per minute. Approximately one mile upstream of the Silver King Mine is the Lori No. 13 that consists of a single dry adit and a revegetated waste rock dump containing about 700 cubic yards (Pioneer Technical Services, Inc., 1995). The mine disturbs about 9 acres on the north side of the gulch and is about 800 feet from Sluice Gulch surface water. Both the Silver King and Lori N. 13 are ranked as priority mine sites that have potential human health and safety hazards.

Sluice Gulch is listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012c) as being impaired due to arsenic, sediment, nitrite plus nitrate nitrogen, and alteration in streamside vegetative covers. The recent water quality dataset for Sluice Gulch contains 8 metals analysis records for samples collected in 2004 and 2010. All 8 results for arsenic exceeded the human health criterion of 10 µg/L. One in 8 results for both aluminum and copper exceeded the chronic aquatic life criterion. Other water column metals concentrations are either less than detectable concentrations, or at or below metals target values.

Surface water quality can be degraded by releases of contaminants from mine waste material or from co-mingling with acid mine drainage from mine adits. Concentration of contaminants depends on the mechanism of chemical release, streamflow, and water chemistry. Nitrates may be present in mine discharge water as a result of 1) residuals from ammonium nitrate and fuel oil (ANFO) used in blasting, 2) microbial mediates cyanide degradation, 3) leaching of ANFO contamination from waste rock or from rock with natural background nitrate, and 4) residuals from fertilizer used in reclamation (Environmental Protection Agency,1996). Some nitrate may be the result of nitric acid commonly used in the recovery process.

Nitrate pollution is likely not a result of ANFO, considering the time that has lapsed since these chemicals were used in the mining process. However, given the presence of large amounts of disturbed areas, and acid mine drainage from adits, nitrate pollution may be attributable to nitrate leaching from waste rock or to the breakdown of cyanide from leaching. Nitrate polluted groundwater in the area is another possible source of nitrates. Depending on the hydrogeologic flow regime, groundwater affected by historical mining activities may be upwelling in the area and contributing to nitrates in Sluice Gulch.

Surface water quality data collected for the purposes of assessing the current conditions of Sluice Gulch **(Section 7.7.1.1)** indicate $N0_3$+$N0_2$ and TN concentration decrease as you move downstream. Flow volumes also decrease as you move downstream, which intern causes an overall decrease in $N0_3$+$N0_2$ and TN loads. Monitoring data did not indicate a dramatic increase in concentration or load downstream of the Silver King and Lori N. 13 mines. The monitoring data did not indicate that there is a direct contribution of nutrients from the mines as such the DEQ cannot assign an individual load allocation and will assign a composite load allocation to this potential source. This composite load allocation will include both agricultural (grazing) and Mining sources throughout the watershed.

7.5.3.2 Sluice Gulch Total Maximum Daily Loads: Nitrate Plus Nitrite ($N0_3$+$N0_2$) and Total Nitrogen (TN)

$N0_3$+$N0_2$ and TN Total Maximum Daily Loads are presented here for Sluice Gulch (MT41E002_110). The TMDLs (lbs/day) for $N0_3$+$N0_2$ and TN are calculated using the water quality target values established in **Section 7.4**.X.X The TMDL loads for $N0_3$+$N0_2$ and TN apply during the summer growing season (normally July 1–Sept. 30). The TMDL for $N0_3$+$N0_2$ is based on an instream target value of 0.10 mg/L TN and streamflow (**Figure 7-26**). The TMDL for TN is based on an instream target value of 0.30 mg/L TN and streamflow (**Figure 7-27**).

TMDL calculations for $N0_3$+$N0_2$ and TN are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L ($N0_3$+$N0_2$ *=0.10 mg/L or TN =0.30 mg/L)*
Y= streamflow in cubic feet per second
5.393 = conversion factor

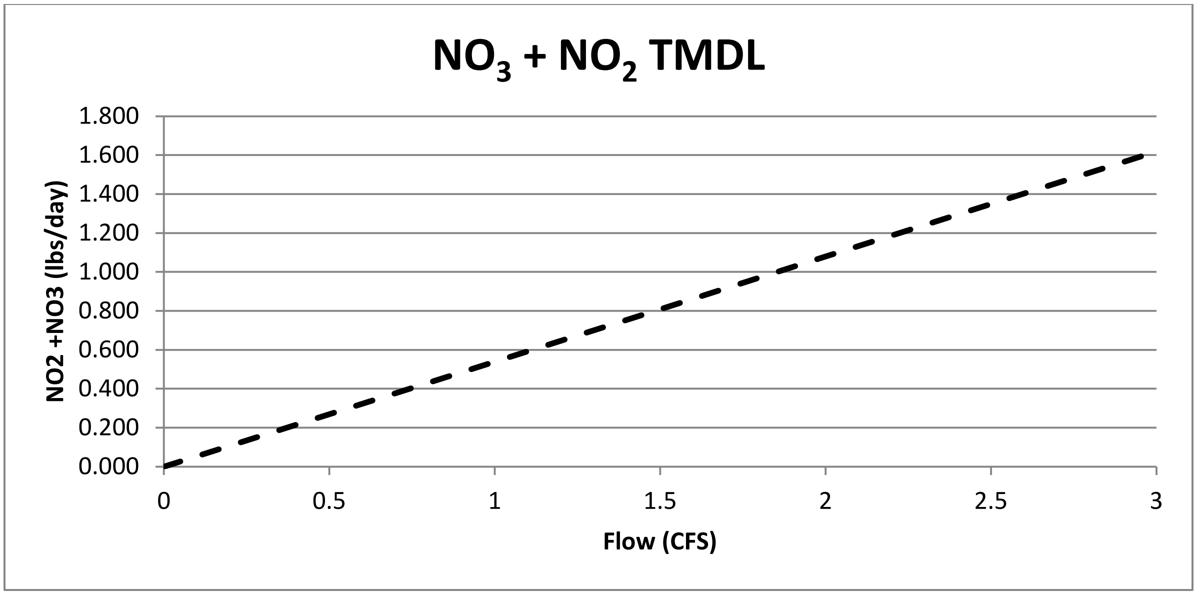

Figure 7-26. TMDL for $NO_2 + NO_3$ as a function of flow: Sluice Gulch

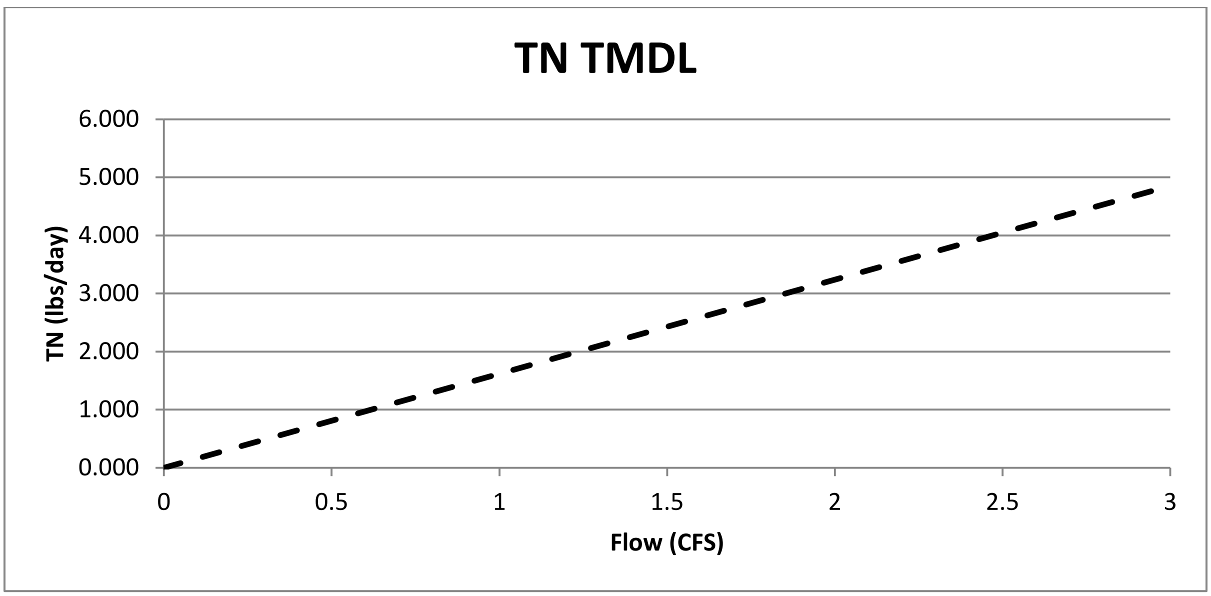

Figure 7-27. TMDL for TN as a function of flow: Sluice Gulch

7.5.3.3 Sluice Gulch Nitrate Plus Nitrite ($N0_3$+$N0_2$) and Total Nitrogen (TN) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) $N0_3$+$N0_2$ and TN sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.3.3.1 Nitrate Plus Nitrite ($N0_3$+$N0_2$) Allocations

Sluice Gulch's TMDL for $N0_3$+$N0_2$ comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant $N0_3$+$N0_2$ nonpoint sources include natural background sources and agricultural and historical mining practices. Load allocations are therefore provided for 1) natural background sources and 2) the combination of agricultural and historical mining land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for $N0_3$+$N0_2$ in the watershed are equal to the sum of the individual load allocations as follows:

TMDL = LA_{NB} + $LA_{AG+MINE}$

LA_{NB} = Load Allocation to natural background sources

$LA_{AG+MINE}$ = Load Allocation to the combination of agricultural and historical mining land-use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background $N0_3$+$N0_2$ concentration of 0.020 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= $N0_3$+$N0_2$ load allocated to natural background sources

X= 0.020 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Agriculture and Historical Mining

The load allocation of composite agricultural and mining sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG+MINE}$= TMDL - LA_{NB}

$N0_3$+$N0_2$ load allocations are summarized in **Table 7-32** and depicted graphically in **Figure 7-28.**

Table 7-32. $N0_3$+$N0_2$ load allocation descriptions, Sluice Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Combination of Agricultural Land Use and Historical Mining	• domestic animal waste • loss of riparian and wetland vegetation along streambank • Runoff from exposed rock with containing natural background nitrate • Residual chemicals left over from mining practices	**$LA_{AG+MINE}$ = TMDL - LA_{NB}**

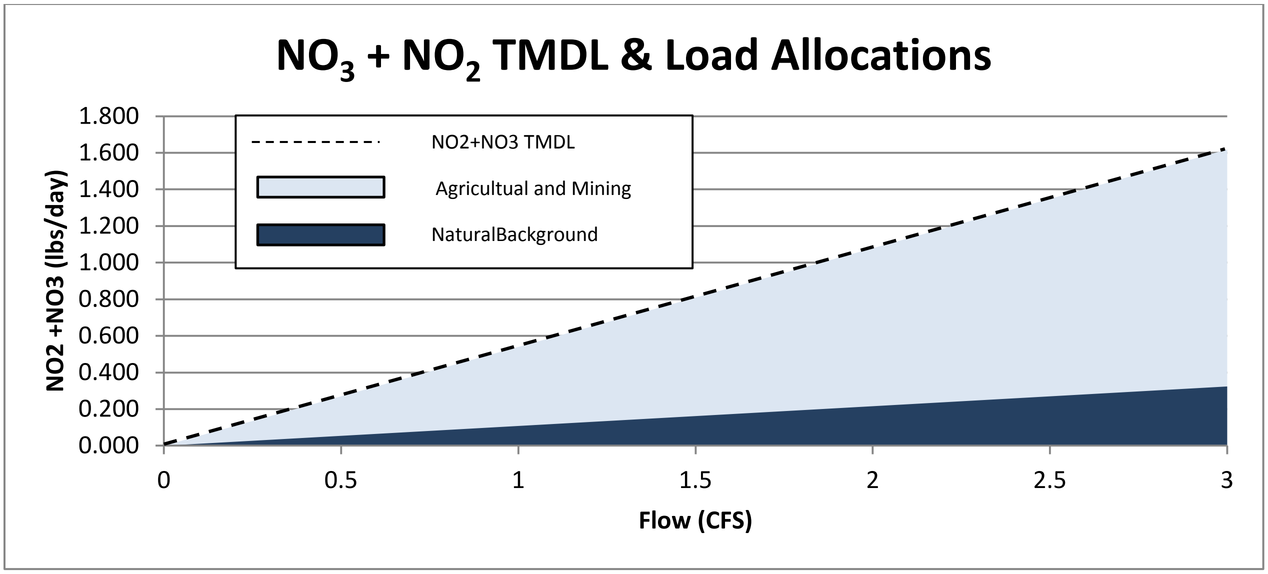

Figure 7-28. TMDL for NO_3+NO_2 and Load Allocations, Sluice Gulch

Table 7-33 provides an example TMDL and example allocations for a typical summer baseflow condition. The $N0_3$+$N0_2$ load allocations and the $N0_3$+$N0_2$ TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-33** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-33. Sluice Gulch example $N0_3$+$N0_2$ load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.14	0.14	0%
Agricultural Land-Use and Historical Mining Sources	3.06	0.54	82.4%
	Total = 3.20	**TMDL = 0.68**	**Total = 78.8%**

**based on a median growing season flow of 1.27 cfs*

The TMDL for $N0_3$+$N0_2$ in Sluice Gulch is calculated to be 0.68 lbs/day. Existing $N0_3$+$N0_2$ loading to Sluice Gulch is estimated at 2.81 lbs/day, requiring a total load reduction of 78.8% in order to meet the TMDL for $N0_3$+$N0_2$ in Sluice Gulch. Load allocations and load reductions are specifically designated to the combination of agricultural land use and historical mining which makes up an estimated 96% of the $N0_3$+$N0_2$ load measured within Sluice Gulch. Load reductions should focus on limiting and controlling $N0_3$+$N0_2$ loads from the variety of sources associated with agricultural land use and historical mining impacts along Sluice Gulch.

The source assessment conducted for the Sluice Gulch has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the Sluice Gulch and its tributaries will result in lower $N0_3$+$N0_2$ concentrations throughout the length of Sluice Gulch. Reducing loads of this nature will mitigate elevated $N0_3$+$N0_2$ loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.3.3.1 Total Nitrogen (TN) Allocations

The Sluice Gulch TMDL for TN comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant TN nonpoint sources include natural background sources and the combination of agricultural and historical mining sources. Load allocations are therefore provided for 1) natural background sources and 2) the combination of agricultural and historical mining land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TN in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{AG+MINE}$

LA_{NB} = Load Allocation to natural background sources

$LA_{AG+MINE}$ = Load Allocation to the combination of agricultural and historical mining land-use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TN concentration of 0.085 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= TN load allocated to natural background sources

X= 0.085 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Agriculture and Historical Mining

The load allocation of agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG+MINE}$= TMDL - LA_{NB}

TN load allocations are summarized in **Table 7-34** and depicted graphically in **Figure 7-29**.

Table 7-34. TN load allocation descriptions, Sluice Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Combination of Agricultural and Mining Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks • Runoff from exposed rock with containing natural background nitrate • Residual chemicals left over from mining practices	**$LA_{AG+MINE}$ = TMDL - LA_{NB}**

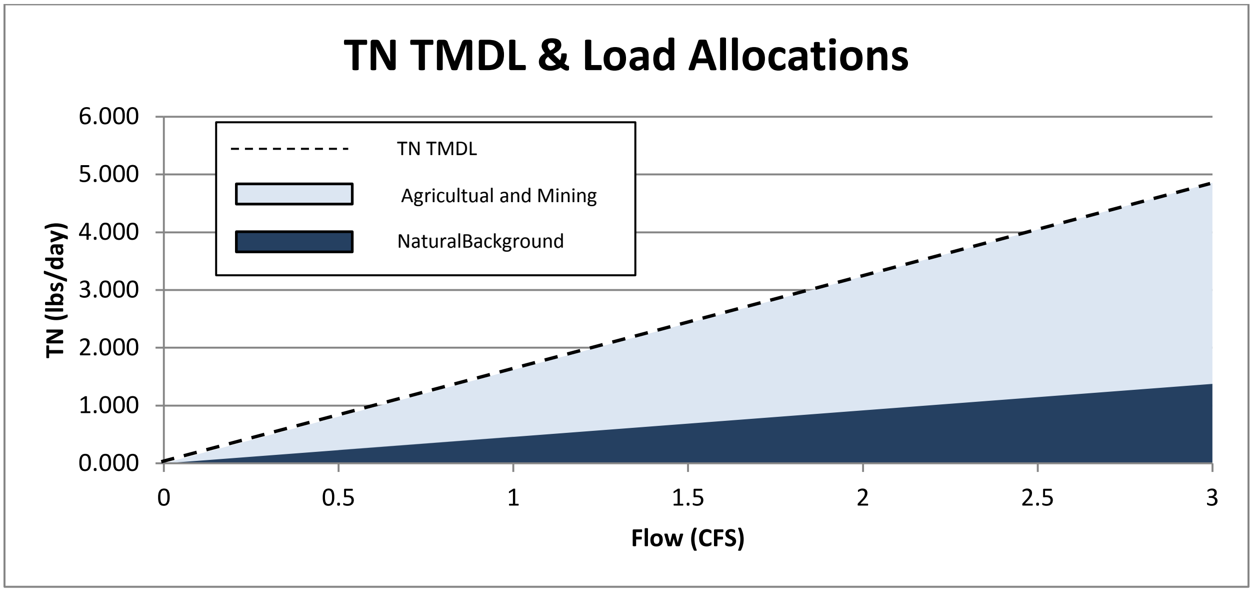

Figure 7-29. TMDL for TN and Load Allocations, Sluice Gulch

Table 7-35 provides an example TMDL and example allocations for a typical summer baseflow condition. The TN load allocations and the TN TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-35** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-35. Sluice Creek example TN load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.58	0.58	0%
Agricultural Land-Use Sources and Historical Mining	3.57	1.48	58.5%
	Total = 4.15	**TMDL =** 2.06	**Total = 50.4%**

**based on a median growing season flow of 1.27 cfs*

The TMDL for TN in Sluice Gulch is calculated to be 2.06 lbs/day. Existing TN loading to Sluice Gulch is estimated at 4.15 lbs/day, requiring a total load reduction of 50.4% in order to meet the TMDL for TN. Load allocations and load reductions are specifically designated to the combination of agricultural and mining land use which makes up an estimated 86% of the TN load within Sluice Gulch. . Load reductions should focus on limiting and controlling $N0_3$+$N0_2$ loads from the variety of sources associated with agricultural land use and historical mining impacts along Sluice Gulch.

The source assessment conducted for the Sluice Gulch has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the Sluice Gulch and its tributaries will result in lower TN concentrations throughout the length of Sluice Gulch. Reducing loads of this nature will mitigate elevated TN loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.4 Scotchman Gulch (MT46E002_100)

Scotchman Creek is a tributary of Upper Willow Creek. Scotchman Creek enters Upper Willow Creek approximately 3.7 mile up from the confluence with Rock Creek. Area land use is primarily agricultural, silviculture and some historical mining. Agriculture land use consist primarily of cattle operations, silvicultural use is comprised of timber harvesting and thinning operations. Other impacts to surface water quality in Scotchman Gulch include those from past mining practices. Scotchman Gulch appears on the 2012 303(d) List as impaired for Total Phosphorous (TP). As determined in **Section 7.4.3.4**, Scotchman Gulch exceeded nutrient water quality targets for TP and Total Nitrogen (TN). Source assessment was conducted for TP and TN.

7.5.4.1 Scotchman Gulch Source Assessment

The source assessment for Scotchman Gulch includes an evaluation of TN and TP concentrations, flow and loading data along the whole length of Scotchman Gulch. This is followed by quantification of natural background and discussion of the three most potentially significant human-caused sources of nutrients. The three human-caused nutrient sources include agriculture (grazing), silviculture and historical mining practices.

In stream concentrations exceeded water quality targets at all sampling locations during different low-flow events. Six of the 23 samples collected (26%) for TN were above the target criteria of 0.30 mg/L TN. The majority of TP samples collected were above target criteria, only 2 samples were below the target criteria of 0.030 mg/L TP. These values were observed at CO2SCTMG01 and CO2SCTMG03.
As a whole, both TN and TP concentrations were lower in the head waters and increased as you move down stream. The highest concentration observed for both parameters were seen at the downstream most sampling location. **Table 7-36** and **Figure 7-30** present summary statistics of TN concentrations at sampling sites in Scotchman Gulch. **Table 7-37** and **Figure 7-31** present summary statistics of TP concentrations at sampling sites in Scotchman Gulch.

Table 7-36. Growing season TN Summary Statistics for Sampling Sites on Scotchman Gulch (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
CO2SCTMG01	5	0.104	0.380	0.220	0.188	0.200	0.228
CO2SCTMG10	6	0.152	0.412	0.265	0.225	0.238	0.297
CO2SCTMG02	6	0.156	0.431	0.270	0.228	0.258	0.280
CO2SCTMG03	6	0.154	0.707	0.384	0.301	0.350	0.410

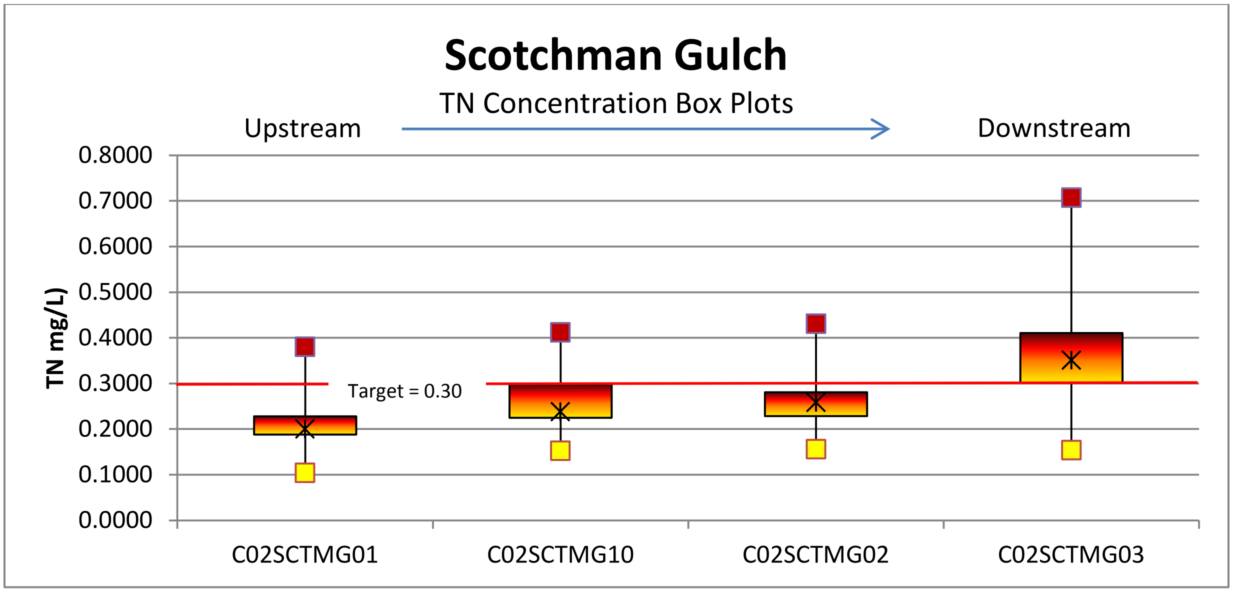

Figure 7-30. TN Concentration Box Plots: Scotchman Gulch

Table 7-37. Growing season TP Summary Statistics for sampling sites on Scotchman Gulch (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
CO2SCTMG01	5	0.028	0.046	0.035	0.031	0.032	0.036
CO2SCTMG10	7	0.036	0.064	0.051	0.043	0.047	0.062
CO2SCTMG02	6	0.045	0.074	0.056	0.047	0.054	0.063
CO2SCTMG03	6	0.001	0.115	0.063	0.048	0.056	0.091

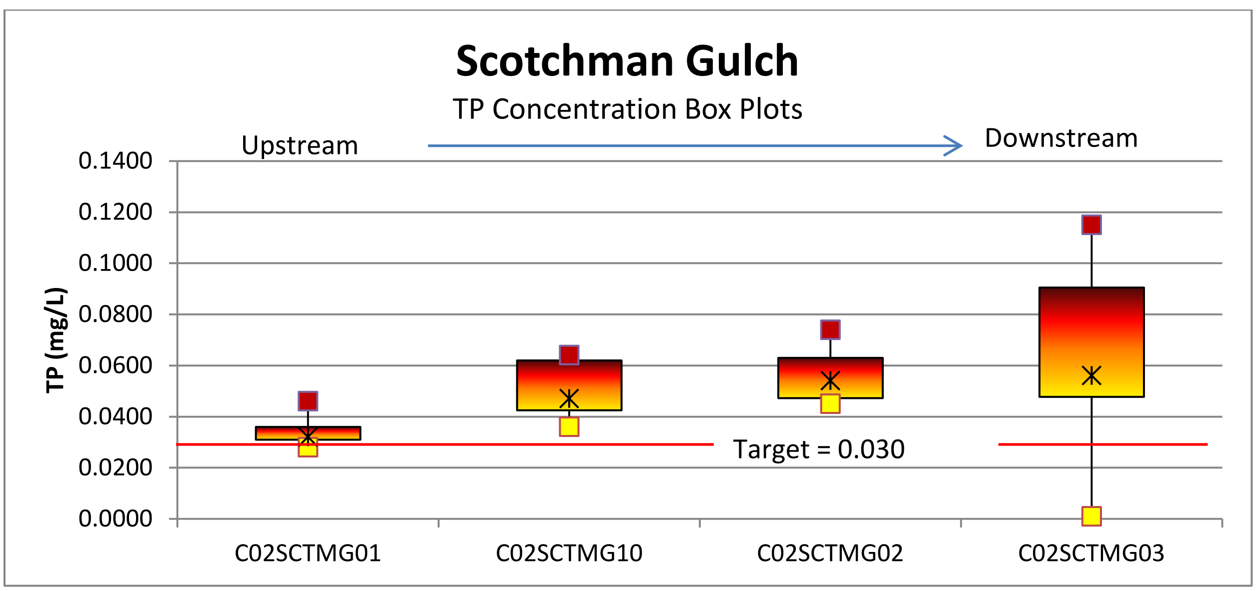

Figure 7-31. TP Concentration Box Plots: Scotchman Gulch

TN and TP loads calculated from the 2004 and 2009–2011 sampling events are depicted in **Figures 7-32 and 7-33**, respectively. As a whole, average TN and TP loads increase moving downstream from the headwaters of the Scotchman Gulch to the mouth. For example, the average low-flow TN loads increase from 0.45 lbs/day at the upstream monitoring location CO2SCTMG01 to 0.62 lbs/day at the downstream CO2SCTMG03 monitoring location, an average increase of 0.17 lbs/day. Average low-flow TP loads increase from 0.064 lb/day at monitoring location CO2SLUCG01 to 0.10 lb/day at the downstream CO2SLUCG02 monitoring location. This is an average decrease of 0.041 lbs/day. The TP load then decreases by 0.007 lbs/day from CO2SLUCG02 to CO2SLUCG03. The increase in loading is due to the increase in TN and TP concentrations and increase in volume of streamflow in Scotchman Gulch. The increase in concentration of TN and TP as you move down stream is a likely a result of the sources of TN and TP being located throughout Scotchman Gulch.

Streamflow volume increase slightly as you move from the headwater to the mouth. Average flow volumes increase from 0.33 cfs, 0.34 cfs to 0.44 cfs at the monitoring sites CO2SCTMG01, CO2SCTMG101 and CO2SCTMG02, respectively. There is a slight decrease in average flow of 0.05 cfs from CO2SCTMG02 to CO2SCTMG03.

While flow volumes in the upper segments of Scotchman Gulch are relatively constant, the extensive drainage area and land type through which Scotchman Gulch flows, suggests that the supply of water for this creek should provide increased flow volumes. A portion of the flow volume is lost between the last two sampling sites. The constant and loosing flow volumes suggest surface water may be contributing to the groundwater system in the upper segments and especially between the last two sampling locations. This idea is supported by the Belt Series Carbonate geology that is present for the length of Scotchman Gulch.

The Increased TN and TP concentrations indicate increased TN and TP contributions in the downstream segments of Scotchman Gulch. Low Chlorophyll-*a* (live algae) and AFDW results along Scotchman Gulch during the majority of sample events suggests that there was not significant uptake by algae at the time of the sampling events.

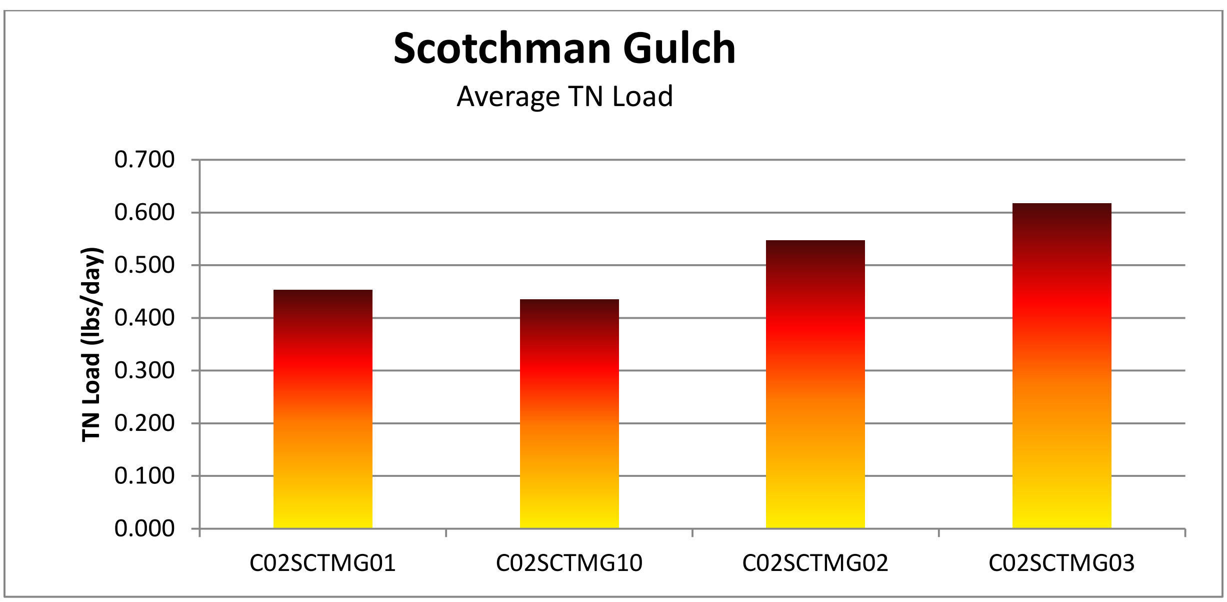

Figure 7-32. TN Load within Scotchman Gulch

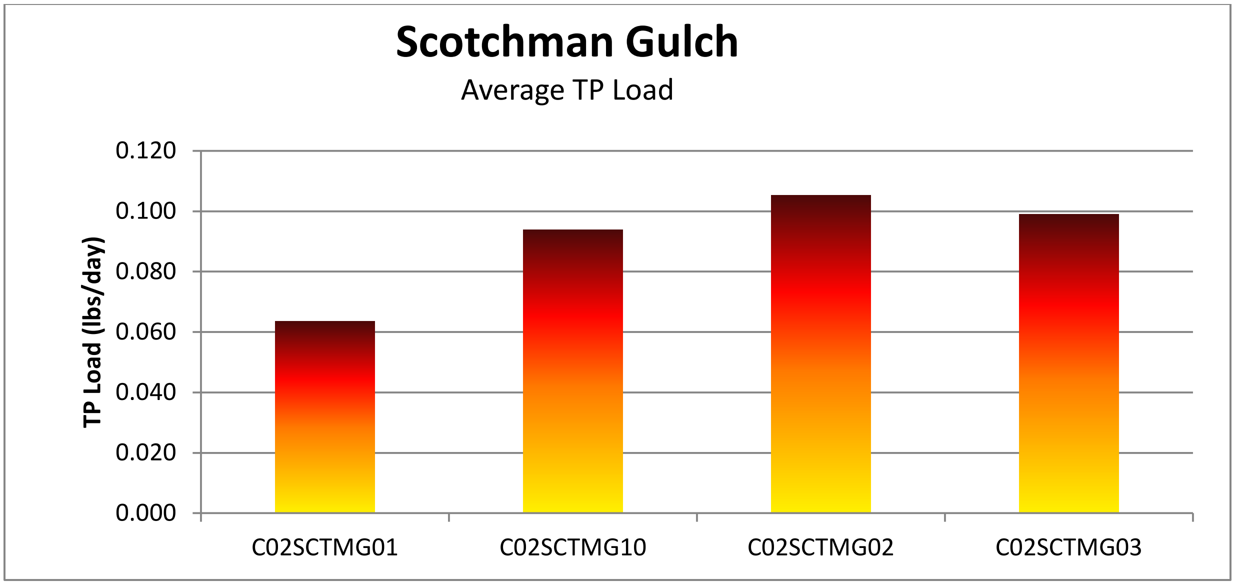

Figure 7-33. TP Load within Scotchman Gulch

Natural Background Nutrient Loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. No background water quality data was available for Scotchman Gulch.

Given this lack of data, and lack of data from reference streams in the Rock TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion. In a study to develop nutrient criteria for streams in Montana, (Suplee et al., 2008a) provides the 25th, 50th, and 75th percentile of the all-season reference dataset from wadeable streams to represent background conditions.

This translates to background TN values ranging from 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.085 mg/L and a median low-flow baseflow of 0.39 cfs,, the average background TN load to the segment is calculated to be approximately 0.18 lbs/day.

Background TP values derived from (Suplee et al., 2008a) ranging from 0.008 mg/L, 0.010 mg/L, and 0.020 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.010 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.010 mg/L and a median low-flow baseflow of 0.39 cfs, the average background TN load to the segment is calculated to be approximately 0.021 lbs/day.

Agricultural Nutrient Loading

A significant number of cattle are grazed in the Scotchman Gulch watershed, typically this takes place sometime during the algal growing season. Scotchman Gulch is approximately 4,300 acres, of which approximately 1,870 acres are Forest Service (FS) land, and 1,600 acres are Bureau of Land Management (BLM) land. The BLM has a total of 1,440 allotted acres in the Scotchman Gulch watershed. This is part of the Ram Mountain allotment. The BLM allows 160 cattle to graze this allotment from May 20 through October 15. The FS has a small allotment (approximately 845 acres) that allows 15 head of cattle from July 1 through October 15.

The remaining portion of Scotchman Gulch (approximately 830 acres) is private land. The DEQ will assume that cattle are being grazed on private land within the watershed. A conservative approach to determining the number of cattle being grazed is to apply an Animal Unit Month (AUM) of 0.1 to 0.15 to the remaining 830 acres of private land. This would indicate that this land was capable of providing forage for 83-125 cattle if they were grazed sustainably.

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include 1) direct loading via the breakdown of excrement 2) delivery from grazed forest and rangeland during the growing season via surface water and subsurface pathways 3) the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas. As noted by the sediment assessment results in **Section 5.4.2.8,** vegetation, habitat, and sediment deposition in Scotchman Gulch have been negatively impacted primarily by streambank erosion, likely associated with riparian grazing. These negative impacts contribute to a lack of riparian buffering as a significant contributor towards elevated nutrient loading along with direct loading from cattle excrement given their proximity to the stream. There have been some recent efforts recently by the Bureau of Land Management (BLM) to control cattle access to a few segments of the headwaters reaches of Scotchman Gulch. The BLM has recently installed fencing around several segments of stream channel in an attempt to alleviate grazing in these areas. Best management practices such as these are likely to contribute to reducing nutrient concentrations and loads in Scotchman Gulch.

7.5.4.2 Scotchman Gulch Total Maximum Daily Loads: Total Nitrogen (TN) and Total Phosphorous (TP)

TN and TP Total Maximum Daily Loads are presented here for Scotchman Gulch (MT41E002_100). The TMDLs (lbs/day) for TN and TP are calculated using the water quality target values established in **Section 7.X.X.X** The TMDL loads for TN and TP apply during the summer growing season (normally July 1–Sept. 30). The TMDL for TN is based on an instream target value of 0.30 mg/L TN and streamflow (**Figure 7-34**). The TMDL for TP is based on an instream target value of 0.030 mg/L TN and streamflow (**Figure 7-35**).

TMDL calculations for TN and TP are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L (TN =0.30 mg/L or TP=0.030 mg/L)
Y= streamflow in cubic feet per second
5.393 = conversion factor

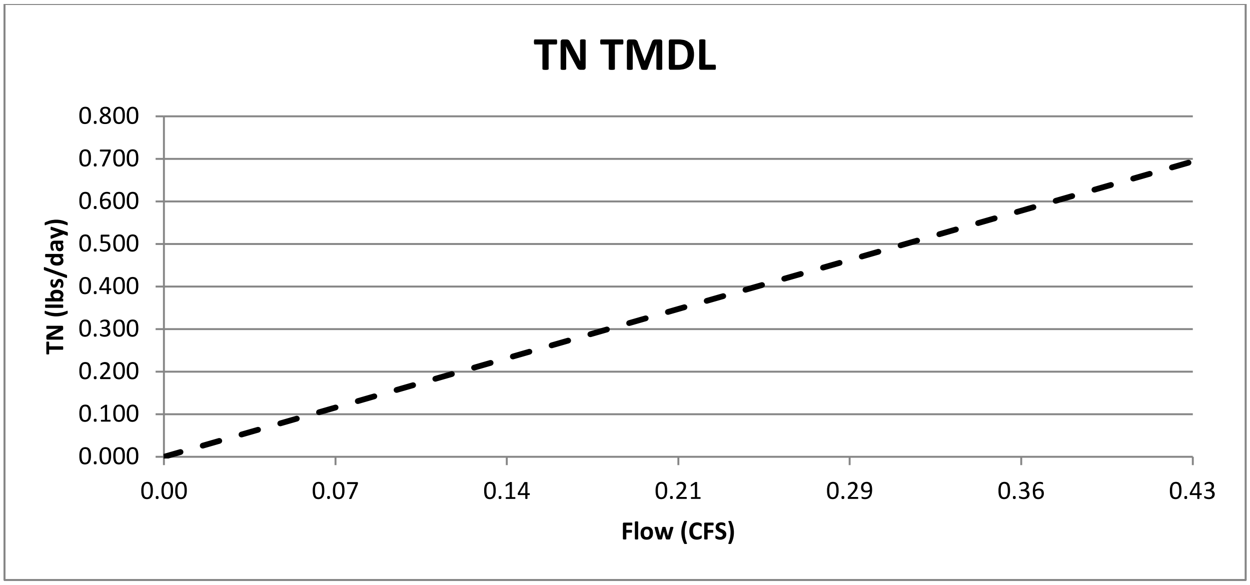

Figure 7-34. TMDL for TN as a function of flow: Scotchman Gulch

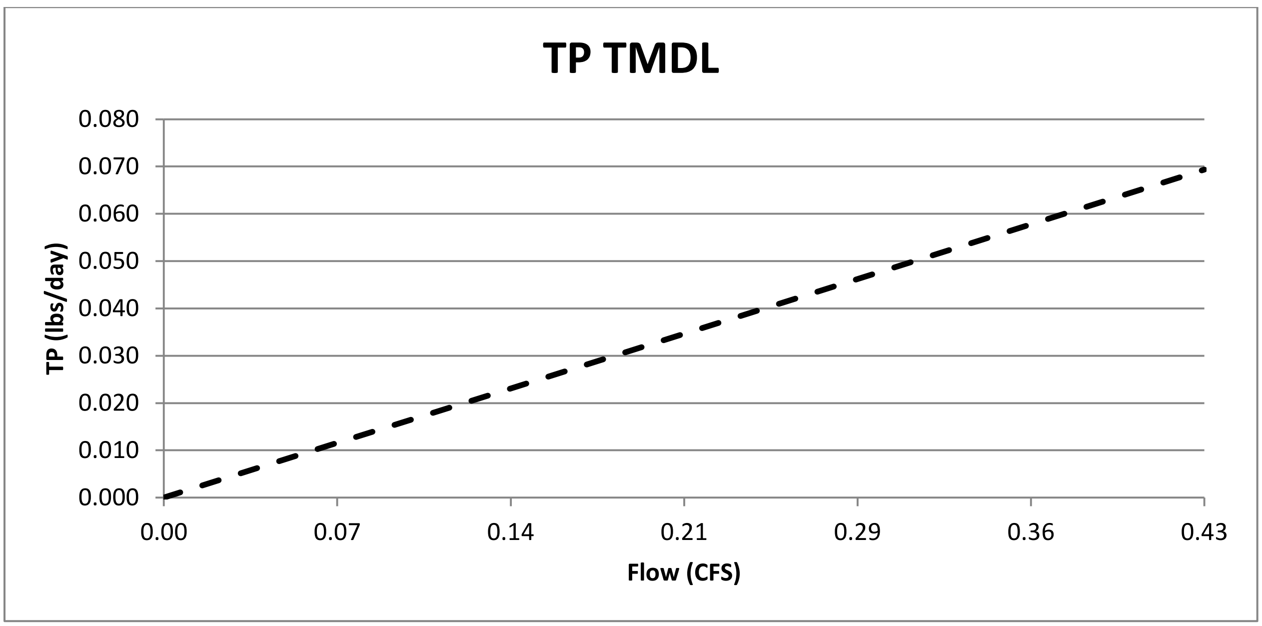

Figure 7-35. TMDL for TP as a function of flow: Scotchman Gulch

7.5.4.3 Scotchman Gulch: Total Nitrogen (TN) and Total Phosphorous (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) TN and TP sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.4.3.1 Total Nitrogen (TN) Allocations

Scotchman Gulch TMDL for TN comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant TN nonpoint sources include natural background and agricultural sources. Load allocations are therefore provided for 1) natural background sources and 2) agricultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TN in the watershed are equal to the sum of the individual load allocations as follows:

$$\mathbf{TMDL = LA_{NB} + LA_{AG}}$$

LA_{NB} = Load Allocation to natural background sources
LA_{AG} = Load Allocation to agricultural land-use sources

Natural Background Source
Load allocations for natural background sources are based on a natural background TN concentration of 0.085 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$$LA_{NB} = (X)(Y)(5.393)$$

LA_{NB}= TN load allocated to natural background sources
X= 0.085 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

Agriculture
The load allocation of agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$$\mathbf{LA_{AG} = TMDL - LA_{NB}}$$

TN load allocations are summarized in **Table-38** and depicted graphically in **Figure 7-36**.

Table 7-38. TN load allocation descriptions, Scotchman Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	$\mathbf{LA_{NB} = (X)(Y)(5.393)}$
Agricultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambank	$\mathbf{LA_{AG} = TMDL - LA_{NB}}$

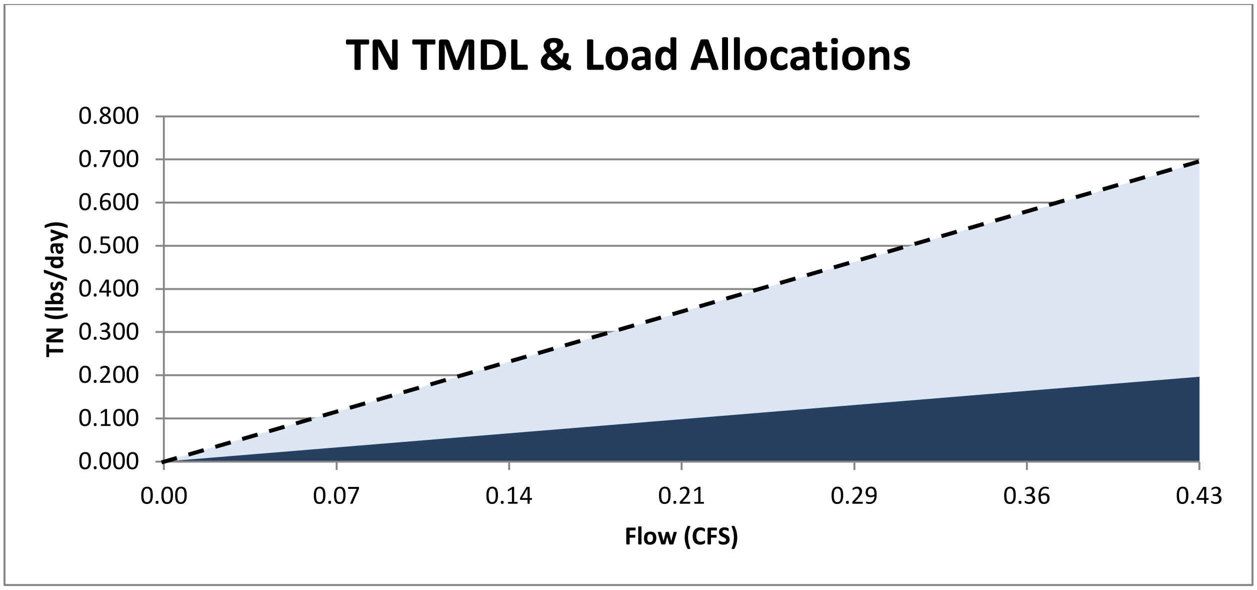

Figure 7-36. TMDL for TN and Load Allocations, Scotchman Gulch

Table 7-39 provides an example TMDL and example allocations for a typical summer baseflow condition. The TN load allocations and the TN TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-39** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-39. Scotchman Gulch example TN load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.18	0.18	0%
Agricultural Land-Use Sources	1.13	0.45	60.1%
	Total = 1.31	**TMDL = 0.63**	**Total =51.9 %**

**based on a growing season flow of 0.39 cfs*

The TMDL for TN in Scotchman Gulch is calculated to be 0.63 lbs/day. Existing TN loading to Scotchman Gulch is estimated at 1.31 lbs/day, requiring a total load reduction of 51.9% in order to meet the TMDL for TN in Scotchman Gulch. Load allocations and load reductions are specifically designated to the agricultural land use which makes up an estimated 86% of the TN load within Scotchman Gulch. Load reductions should focus on limiting and controlling TN loads from the variety of sources associated with agricultural land use impacts along Scotchman Gulch.

The source assessment conducted for the Scotchman Gulch has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the Scotchman Gulch and its tributaries will result in lower TN concentrations throughout the length of Scotchman Gulch. Reducing loads of this nature will mitigate elevated TN loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.4.3.1 Total Phosphorous (TP) Allocations

The Scotchman Gulch TMDL for TP comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant TP nonpoint sources include natural background sources and agricultural land use sources. Load allocations are therefore provided for 1) natural background sources and 2) agricultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TP in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{AG}$

LA_{NB} = Load Allocation to natural background sources
LA_{AG} = Load Allocation to agricultural land-use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TP concentration of 0.010 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$LA_{NB} = (X) (Y) (5.393)$

LA_{NB}= TP load allocated to natural background sources
X= 0.010 mg/L natural background concentration
Y= streamflow in cubic feet per second
5.393 = conversion factor

Agriculture

The load allocation of agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG}= TMDL - LA_{NB}$

TP load allocations are summarized in **Table 7-40** and depicted graphically in **Figure 7-37**.

Table 7-40. TP load allocation descriptions, Scotchman Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**$LA_{NB} = (X) (Y) (5.393)$**
Agricultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks	**$LA_{AG} = TMDL - LA_{NB}$**

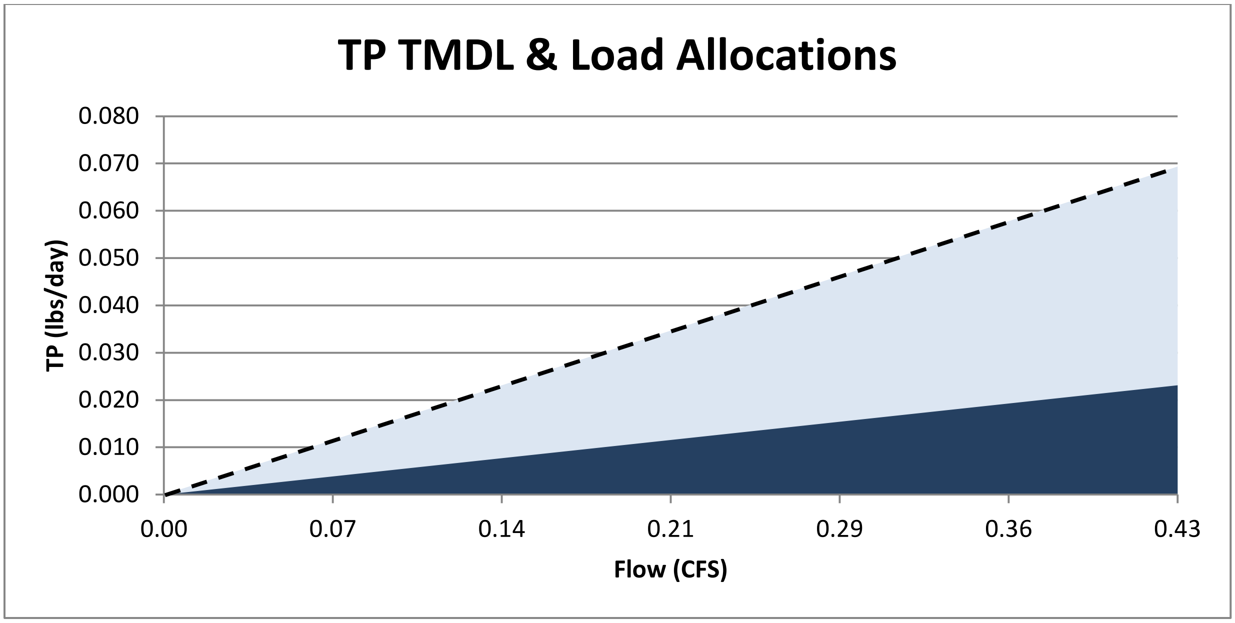

Figure 7-37. TMDL for TP and Load Allocations, Scotchman Gulch

Table 7-41 provides an example TMDL and example allocations for a typical summer baseflow condition. The TP load allocations and the TP TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-41** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-41. Scotchman Gulch example TP load allocations and TMDL*

Source Category	**Existing Load (lbs/day)**	**Allocation & TMDL (lbs/day)***	**Percent Reduction**
Natural Background	0.021	0.013	0%
Agricultural Land-Use Sources	0.129	0.050	61.2%
	Total = 0.15	**TMDL =0.063**	**Total = 58%**

**based on a median growing season flow of 0.39 cfs*

The TMDL for TP in Scotchman Gulch is calculated to be 0.063 lbs/day. Existing TP loading to Scotchman Gulch is estimated at 0.15 lbs/day, requiring a total load reduction of 58% in order to meet the TMDL for TP. Load allocations and load reductions are specifically designated to agricultural land use which makes up an estimated 86% of the TP load within Scotchman Gulch. Load reductions should focus on limiting and controlling TP loads from the variety of sources associated with agricultural land use, primarily grazing impacts along Scotchman Gulch.

The source assessment conducted for the Scotchman Gulch has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the Scotchman Gulch and its tributaries will result in lower TP concentrations throughout the length of Scotchman Gulch. Reducing loads of this nature will mitigate elevated TP loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.5 Flat Gulch (MT46E002_120)

The Flat Gulch is a direct tributary to Rock Creek. Flat Gulch enters Rock Creek approximately 35 miles upstream from the confluence of Rock Creek and the Clark Fork River. Area land use is primarily agricultural and silviculture. Agriculture land use consist primarily of cattle operations, silvicultural use is comprised of timber harvesting and thinning operations. Flat Gulch appears on the 2012 303(d) List as impaired for total nitrogen (TN) and Total Phosphorous (TP). As determined in **Section 7.4.3.5** Flat Gulch exceeded nutrient water quality targets for TN and TP. Source assessment was conducted for TN and TP.

7.5.5.1 Flat Gulch Source Assessment

The source assessment for Flat Gulch includes an evaluation of TN and TP concentrations, flow and loading data along the whole length of Flat Gulch. This is followed by quantification of natural background and the most significant human-caused sources of nutrients. The two most likely human-caused nutrient sources include agriculture (grazing) and silviculture.

In stream concentrations exceeded water quality targets at all sampling locations during different low-flow events. Fifteen of the sixteen samples collected (94%) for TN were above the target criteria of 0.30 mg/L TN. All TP (100%) samples collected were above target criteria of 0.030 mg/L TP. As a whole, both TN and TP concentrations were lower in the head waters and increased as you move down stream. Concentrations were the highest at CO2FLATG10, and decrease slightly as you move to CO2FLATG02. The highest concentration observed for both parameters were seen at the sampling location at the midpoint in the drainage (CO2FLATG10). **Table 7-42** and **Figure 7-38** present summary statistics of TN concentrations at sampling sites in Flat Gulch. **Table 7-43** and **Figure 7-39** present summary statistics of TP concentrations at sampling sites in Flat Gulch. Only one sample was collected at sampling site CO2FLATG04, as such there in no variation in statistical representation of the data.

Table 7-42. Growing season TN Summary Statistics for Sampling Sites on Flat Gulch (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
CO2FLATG04	1	0.384	0.384	0.384	0.384	0.384	0.384
CO2FLATG01	5	0.330	0.984	0.506	0.333	0.397	0.488
CO2FLATG10	6	0.429	1.230	0.793	0.456	0.774	1.077
CO2FLATG02	4	0.229	1.110	0.599	0.293	0.530	0.836

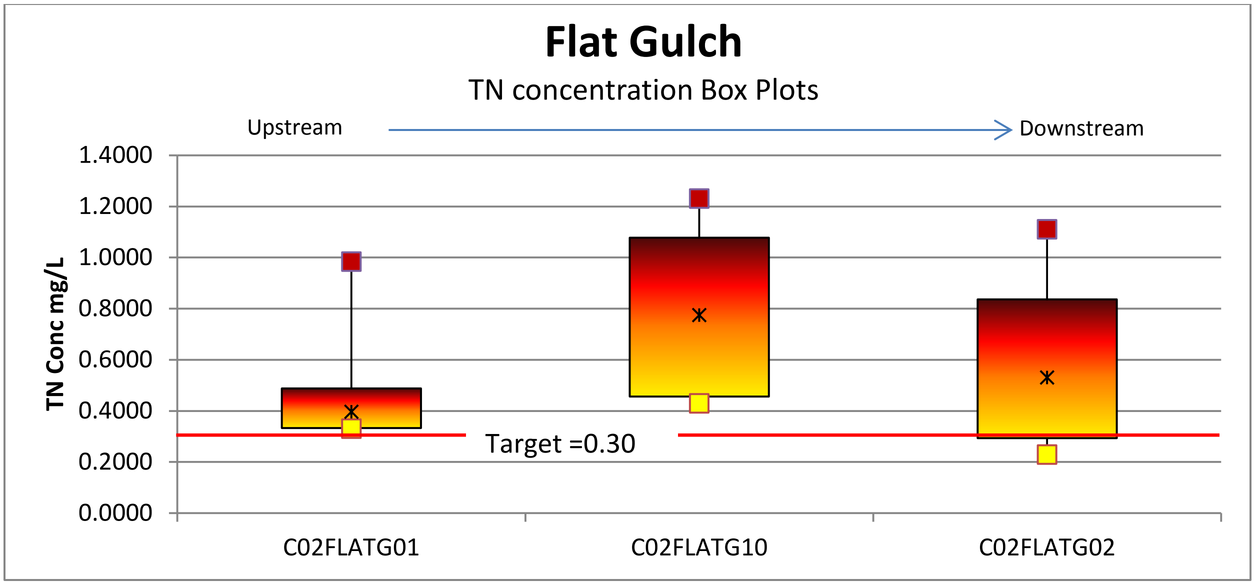

Figure 7-38. TN Concentration Box Plots: Flat Gulch

Table 7-43. Growing season TP Summary Statistics for sampling sites on Flat Gulch (units in mg/L)

Site	n	min	max	mean	25th percentile	median	75th percentile
CO2FLATG04	1	0.095	0.095	0.095	0.095	0.095	0.095
CO2FLATG01	5	0.078	0.182	0.119	0.088	0.089	0.160
CO2FLATG10	7	0.174	0.402	0.280	0.212	0.295	0.320
CO2FLATG02	4	0.115	0.324	0.240	0.189	0.261	0.312

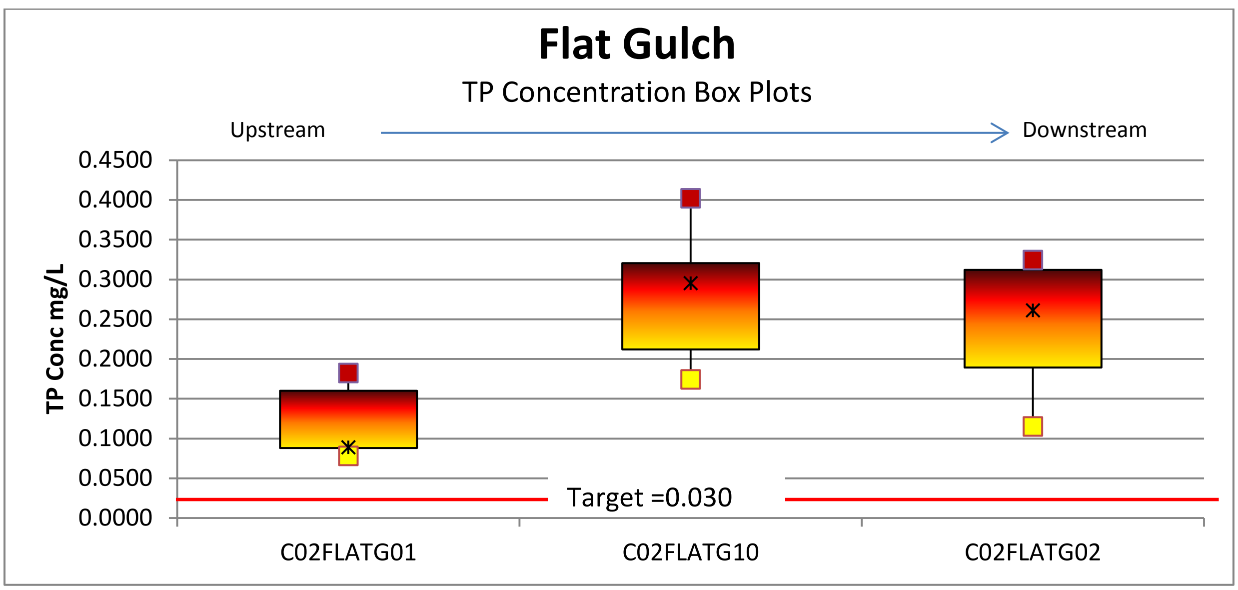

Figure 7-39. TP Concentration Box Plots: Flat Gulch

TN and TP loads calculated from the 2004 and 2010–2011 sampling events are depicted in **Figure 7-40 and 7-41**, respectively. Average low-flow TN loads increase from 0.37lbs/day at monitoring location CO2FLATG01 to 0.63 lbs/day at the downstream CO2FLATG02 monitoring location, an average decrease of 0.26 lbs/day. Average low-flow TP loads decreased from 0.08 lb/day at monitoring location

CO2FLATG01 to 0.26 lb/day at the downstream CO2FLATG10 monitoring location. This is an average decrease of 0.18 lbs/day.

Average TP and TN loads increase as you move downstream from the headwaters to the mouth. The increasing in loading is due to the increase in TN and TP concentrations and the slight increase in volume of streamflow in Flat Gulch. The increase in concentration of TN and TP as you move down stream is a likely a result of the sources of TN and TP being located closer to the midsection and mouth of Flat Gulch.

Streamflow volumes generally increase as you move from the headwater to the mouth. Average flow volumes increase from 0.11 cfs to 0.15 cfs at the monitoring sites CO2FLATG01, CO2FLATG10 2, respectively. Flows decrease slightly from CO2FLATG10 to CO2FLATG10. As a result, the load decrease parallels the decrease in flow throughout this segment of stream.

The tributary network to Flats Gulch suggests that the supply of water for this creek is adequate to maintain flow volumes. However, there is a volume of flow that is lost between CO2FLATG10 to CO2FLATG10, which suggests there is an overall loss of surface water to groundwater between these two sample locations. This idea is supported by the alluvial geology that is present at the mouth of Flat Gulch.

The TN and decreased TP concentrations could also indicate some algal nutrient uptake, although the relatively low Chlorophyll-*a* (live algae) and AFDW results along Flat Gulch during the majority of sample events suggests that there was not significant algae uptake at the time of the sampling events. **Figures 7-40 and 7-41** show this TN and decrease in TP loading.

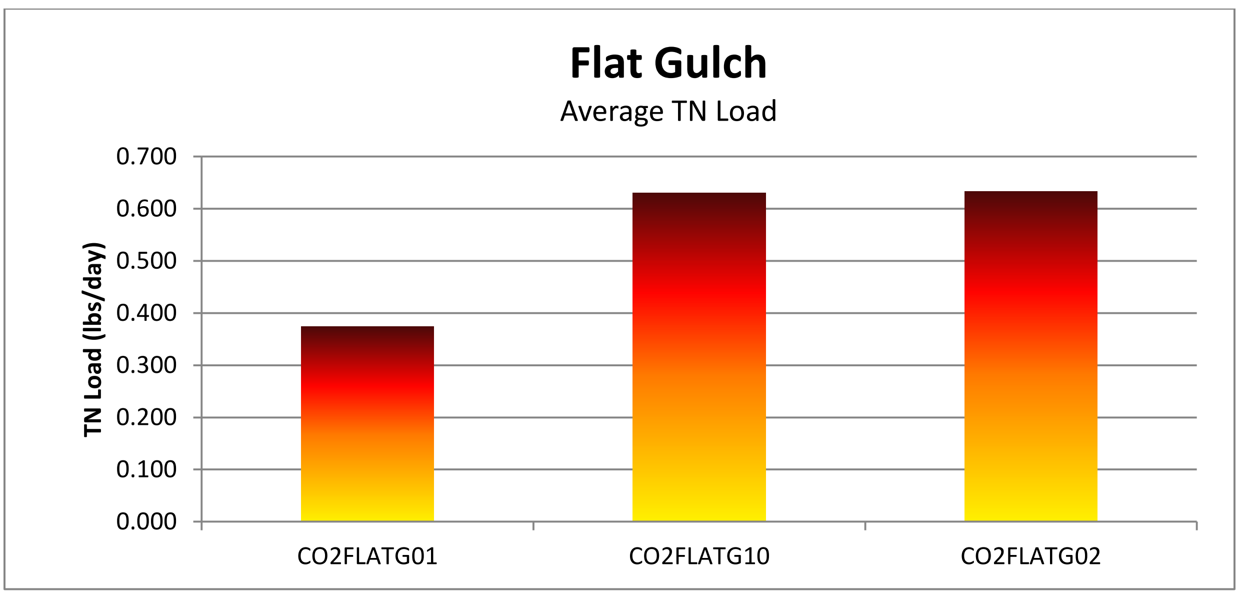

Figure 7-40. TN Load within Flat Gulch

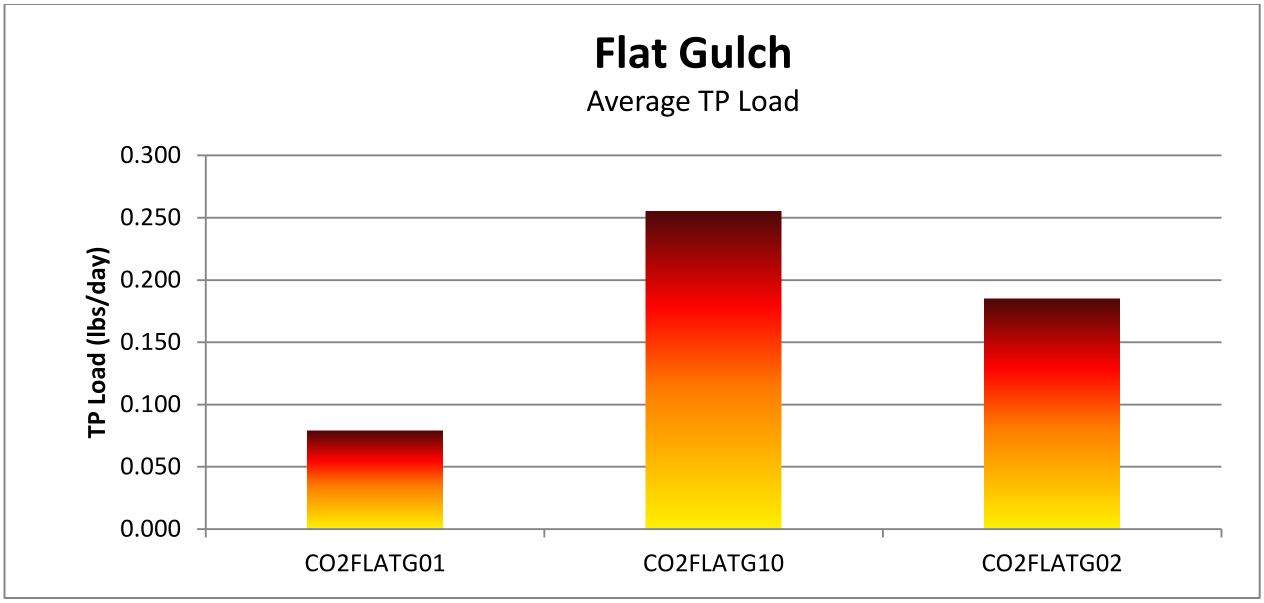

Figure 7-41. TP Load within Flat Gulch

Natural Background Nutrient Loading

Natural background sources of nitrogen include a variety of natural processes and sources and likely include: soils and local geology, natural vegetative decay, wet and dry airborne deposition, wild animal waste, and other biochemical processes that contribute nitrogen to this system. No background water quality data was available for Flat Gulch.

Given this lack of data, and lack of data from reference streams in the Rock TPA, DEQ has decided to use values from reference streams in the Level III Middle Rockies Ecoregion. In a study to develop nutrient criteria for streams in Montana, (Suplee et al., 2008a) provides the 25th, 50th, and 75th percentile of the all-season reference dataset from wadeable streams to represent background conditions.

This translates to background TN values ranging from 0.065 mg/L, 0.085 mg/L, and 0.175 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.085 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TN of 0.085 mg/L and a median low-flow baseflow of 0.12 cfs, the average background TN load to the segment is calculated to be approximately 0.06 lbs/day.

Background TP values derived from (Suplee et al., 2008a) ranging from 0.008 mg/L, 0.010 mg/L, and 0.020 mg/L at the 25th, 50th, and 75th percentiles, respectively. DEQ will use the 50th percentile value (0.010 mg/L) since it represents the central tendency for the data sets used and is a likely representation of background water quality. Assuming a natural background concentration for TP of 0.010 mg/L and a median low-flow baseflow of 0.12 cfs, the average background TN load to the segment is calculated to be approximately 0.006 lbs/day.

Agricultural Nutrient Loading

A significant number of cattle are grazed in the Flat Gulch watershed, typically this takes place sometime during the algal growing season. Flat Gulch is approximately 1,780 acres, of which approximately 205 acres are Forest Service (FS) land, and 1090 acres are Bureau of Land Management (BLM) land. The BLM has a total of 1,440 allotted acres in the Ram Mountain allotment. This allotment is split between Scotchman Gulch and Flat Gulch. 160 cattle are allowed on the Ram mountain allotment from June, 20 through October, 15. The FS has a small allotment (approximately ¾ of one section) near the mouth of Flat gulch. Approximately 160 head of cattle are allowed on this allotment From May, 5 through May, 30.

The remaining portion of Flat Gulch (approximately 485 acres) is private land. The DEQ will assume that cattle are being grazed on private land within the watershed. A conservative approach to determining the number of cattle being grazed is to apply an Animal Unit Month (AUM) of 0.1 to 0.15 to the remaining 485 acres of private land. This would indicate that this land was capable of providing forage for 49-73 cattle if they were grazed sustainably.

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include 1) direct loading via the breakdown of excrement, 2) delivery from grazed forest and rangeland during the growing season via surface runoff and subsurface pathways and 3) the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas. As noted by the sediment assessment results in **Section 5.4.2.5,** vegetation, habitat, and sediment deposition in Flat Gulch have been negatively impacted primarily by streambank erosion influenced by riparian grazing. These negative impacts contribute to a lack of riparian buffering as a significant contributor towards elevated nutrient loading along with direct loading from cattle excrement given their proximity to the stream.

Silvicultural Practices

There have been some historical silvicultural activities in Flat Gulch. One notable small scale timber sale occurred in 2010. This timber sale took place on 69 acres of land and produced a total of 296,000 board feet of product. Some more extensive timbering operations were conducted in the 1980's.

Silvicultural practices inevitably cause some measure of downstream effects that may or may not be significant over time. Changes in land cover will change the rate at which water evapotranspires which will affect 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) and this will have an affect the hydrologic cycle. Changes in the biomass uptake and soil conditions will affect the nutrient cycle. Elevated nitrate concentrations result from increased leaching from the soil as mineralization is enhanced. Nutrient uptake by biomass is also greatly reduced after timber harvest, leaving more nutrients available for runoff.

Nitrate pollution is likely not a result of timber operations, considering the limited acreage of the most recent timber operations, and the amount of time that has passed since the timber operations of the 1980's. As such this potential source will not be given an individual or composite load allocation.

7.5.5.2 Flat Gulch Total Maximum Daily Loads: Total Nitrogen (TN) and Total Phosphorous (TP)

TN and TP Total Maximum Daily Loads are presented here for Flat Gulch (MT41E002_120). The TMDLs (lbs/day) for TN and TP are calculated using the water quality target values established in **Section 7.4**. X.X.X The TMDL loads for TN and TP apply during the summer growing season (normally July 1–Sept. 30).

The TMDL for TN is based on an instream target value of 0.30 mg/L TN and streamflow (**Figure 7-42**). The TMDL for TP is based on an instream target value of 0.030 mg/L TN and streamflow (**Figure 7-43**).

TMDL calculations for TN and TP are based on the following formula:

TMDL = (X) (Y) (5.393)

TMDL= Total Maximum Daily Load in lbs/day
X= water quality target in mg/L (TN =0.30 mg/L or TP=0.030 mg/L)
Y= streamflow in cubic feet per second
5.393 = conversion factor

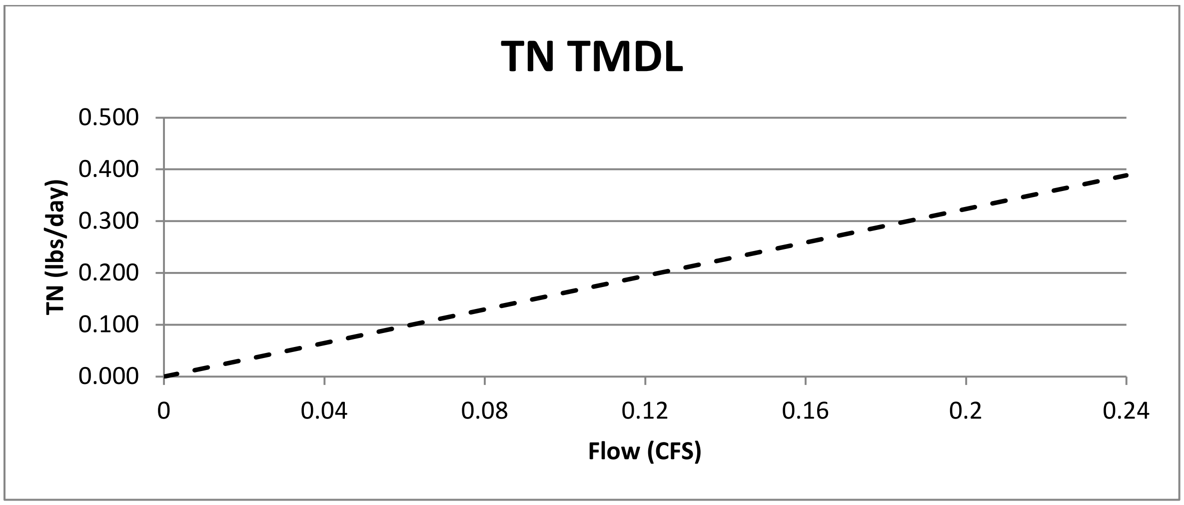

Figure 7-42. TMDL for TN as a function of flow: Flat Gulch

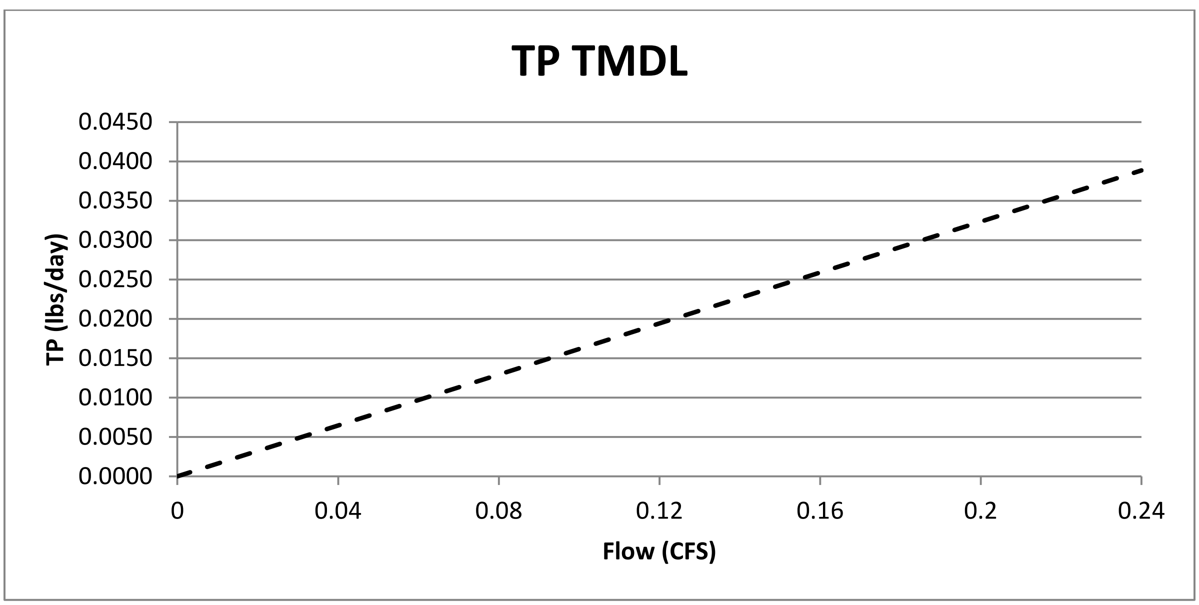

Figure 7-43. TMDL for TP as a function of flow: Flat Gulch

7.5.5.3 Flat Gulch: Total Nitrogen (TN) and Total Phosphorous (TP) Allocations

TMDLs are allocated to point (wasteload) and nonpoint (load) TN and TP sources. The TMDL comprises the sum of all point sources and nonpoint sources (natural and human-caused), plus a margin of safety that accounts for uncertainties in loading and receiving water analyses. In addition to pollutant load allocations, the TMDL must also take into account the seasonal variability of pollutant loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

7.5.5.3.1 Total Nitrogen (TN) Allocations

Flat Gulch TMDL for TN comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant TN nonpoint sources include natural background and agricultural sources. Load allocations are therefore provided for 1) natural background sources and 2) agricultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TN in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{AG}$

LA_{NB} = Load Allocation to natural background sources

LA_{AG} = Load Allocation to agricultural land-use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TN concentration of 0.085 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

LA_{NB} = (X) (Y) (5.393)

LA_{NB}= TN load allocated to natural background sources

X= 0.085 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Agriculture

The load allocation of agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG} = TMDL - LA_{NB}$

TN load allocations are summarized in **Table 7-44** and depicted graphically in **Figure 7-44**.

Table 7-44. TN load allocation descriptions, Flat Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**LA_{NB} = (X) (Y) (5.393)**
Agricultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambank	**$LA_{AG} = TMDL - LA_{NB}$**

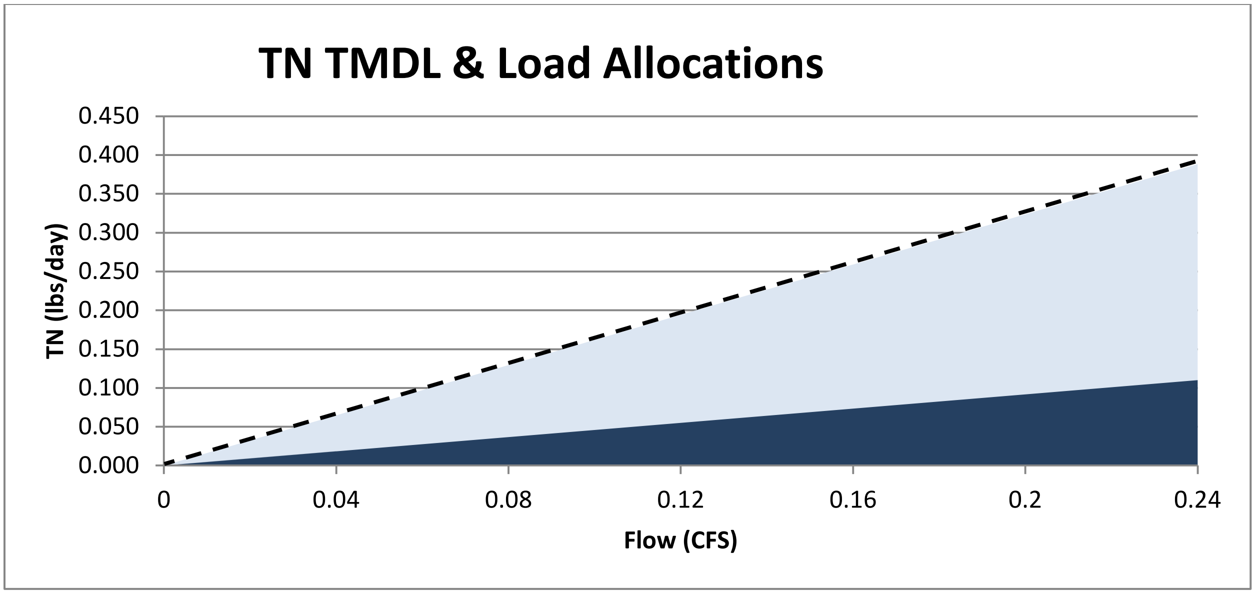

Figure 7-44. TMDL for TN and Load Allocations, Flat Gulch

Table 7-45 provides an example TMDL and example allocations for a typical summer baseflow condition. The TN load allocations and the TN TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-45** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-45. Flats Gulch example TN load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.06	0.06	0
Agricultural Land-Use Sources	0.59	0.13	77.9%
	Total = 0.65	**TMDL = 0.19**	**Total = 70.7%**

**based on a median growing season flow of 0.12 cfs*

The TMDL for TN in Flat Gulch is calculated to be 0.19 lbs/day. Existing TN loading to Flat Gulch is estimated at 0.65 lbs/day, requiring a total load reduction of 70.7% in order to meet the TMDL for TN in Flat Gulch. Load allocations and load reductions are specifically designated to agricultural land use which makes up an estimated 90% of the TN load within Flat Gulch. Load reductions should focus on limiting and controlling TN loads from the variety of sources associated with agricultural land use impacts along Flat Gulch.

The source assessment conducted for the Flat Gulch has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the Flat Gulch and its tributaries will result in lower TN concentrations throughout the length of Flat Gulch. Reducing loads of this nature will mitigate elevated TN loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.5.5.3.1 Total Phosphorous (TP) Allocations

The Flat Gulch TMDL for TP comprises the sum of the load allocations to individual source categories. There are no MPDES discharges to the reach requiring wasteload allocations. Relevant TP nonpoint sources include natural background sources and agricultural land use sources. Load allocations are therefore provided for 1) natural background sources and 2) agricultural land-use sources. In the absence of individual WLAs and an explicit MOS, TMDLs for TP in the watershed are equal to the sum of the individual load allocations as follows:

$TMDL = LA_{NB} + LA_{AG}$

LA_{NB} = Load Allocation to natural background sources

LA_{AG+} = Load Allocation to agricultural land-use sources

Natural Background Source

Load allocations for natural background sources are based on a natural background TP concentration of 0.010 mg/L (**see Section 7.5.1.1**) and are calculated as follows:

$LA_{NB} = (X) (Y) (5.393)$

LA_{NB}= TP load allocated to natural background sources

X= 0.010 mg/L natural background concentration

Y= streamflow in cubic feet per second

5.393 = conversion factor

Agriculture

The load allocation of agricultural sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

$LA_{AG}= TMDL - LA_{NB}$

TP load allocations are summarized in **Table 7-46** and depicted graphically in **Figure 7-45**.

Table 7-46. TP load allocation descriptions, Flat Gulch

Source Category	Load Allocation Descriptions	LA Calculation
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies.	**$LA_{NB} = (X) (Y) (5.393)$**
Agricultural Land Use	• domestic animal waste • loss of riparian and wetland vegetation along streambanks	**$LA_{AG} = TMDL - LA_{NB}$**

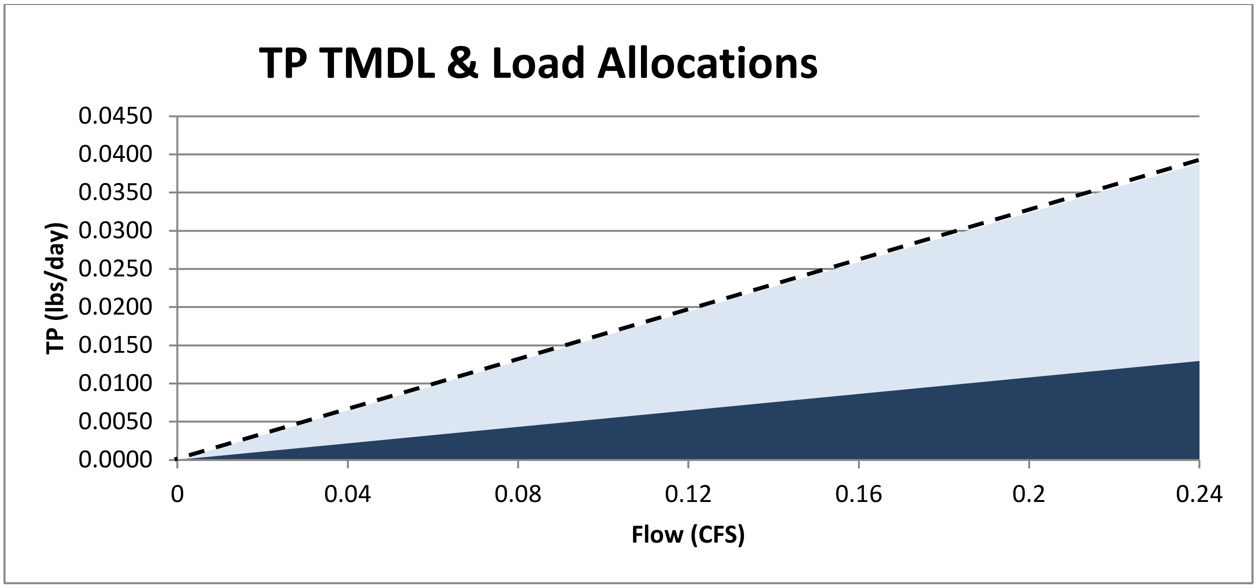

Figure 7-45. TMDL for TP and Load Allocations, Flat Gulch

Table 7-47 provides an example TMDL and example allocations for a typical summer baseflow condition. The TP load allocations and the TP TMDL are a function of streamflow and are developed in accordance with the TMDL and allocation approaches presented above. **Table 7-47** also provides existing loading values for the source categories along with the required percent reductions to satisfy the allocations and TMDL. Estimation of natural background load is explained previously in this section. The existing load is the 80th percentile of instantaneous loads calculated from water quality data used in the assessment process and discussed in **Section 7.4.3**. For each water quality sample that has a corresponding flow measurement, a load is calculated. The 80th percentile of these loads is then used as the existing load.

Table 7-47. Flat Gulch example TP load allocations and TMDL*

Source Category	Existing Load (lbs/day)	Allocation & TMDL (lbs/day)*	Percent Reduction
Natural Background	0.006	0.006	0%
Agricultural Land-Use Sources	0.31	0.013	95.8%
	Total = 0.316	**TMDL =0.019**	**Total = 94.0%**

**based on a median growing season flow of 0.12 cfs*

The TMDL for TP in Flat Gulch is calculated to be 0.019 lbs/day. Existing TP loading to Flat Gulch is estimated at 0.32 lbs/day, requiring a total load reduction of 94.0% in order to meet the TMDL for TP. Load allocations and load reductions are specifically designated to agricultural land use which makes up an estimated 98% of the TP load within Flat Gulch. Load reductions should focus on limiting and controlling TP loads from the variety of sources associated with agricultural land use, primarily grazing impacts along Flat Gulch.

The source assessment conducted for the Flat Gulch has led DEQ to determine that agricultural sources are the most current and prominent sources of nutrients in the watershed. DEQ maintains that reducing loads from agricultural sources in the Flat Gulch and its tributaries will result in lower TP concentrations throughout the length of Flat Gulch. Reducing loads of this nature will mitigate elevated TP loads. Meeting load allocations may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 8.0**.

7.6 Seasonality, Margin of Safety, and Adaptive Management

In developing TMDLs, DEQ must consider the seasonal variability, or seasonality, on water quality impairment conditions, TMDLs, and load allocations. DEQ must also incorporate a margin of safety to account for uncertainties between pollutant sources and the quality of the receiving waterbody, and to ensure (to the degree practicable) that the TMDL components and requirements sufficiently protect water quality and beneficial uses. This section describes seasonality, margin of safety, and adaptive management in developing TMDLs for nutrients in the Rock TPA.

7.6.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development; throughout this plan seasonality is an integral consideration. Water quality, and particularly nitrogen concentrations, have seasonal cycles. Specific examples of how seasonality has been addressed within this document include the following:

- Water quality targets and subsequent allocations apply to the summer growing season (July 1–Sept 30) to coincide with seasonal algal growth targets.
- Nutrient data used to determine compliance with targets and to establish allowable loads was collected during summer to coincide with applicable nutrient targets.
- Nutrient data and sources were evaluated based on an understanding of the sources and seasonal effects on the presence or absences of nutrients.

7.6.2 Margin of Safety

A margin of safety (MOS) is a required component of TMDL development. MOS accounts for the uncertainty about the pollutant loads and the quality of the receiving water; it's intended to protect beneficial uses in the face of this uncertainty. 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:

- Nutrient target values (0.100 mg/L NO_3+NO_2, 0.30 mg/L TN, and 0.030 mg/L TN) were used to calculate allowable nutrient TMDLs. Allowable exceedances of nutrient targets (see **Section 7.4.3**) were not incorporated into the calculation of allowable loads, thereby adding an MOS to established nutrient allocations.
- The 50th percentile value of summer natural background concentrations was used to establish a natural background concentration for load allocations. This acceptable approach provides an MOS for human-caused nutrient loads during most conditions.
- Seasonality and variability were considered in nutrient loading.
- An adaptive management approach was used to evaluate target attainment and allow for refinement of load allocation, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development.

7.6.3 Adaptive Management

Uncertainties in the accuracy of field data, target development, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. While uncertainties are a fact of TMDL development, mitigating uncertainties through adaptive management is a key component of ongoing TMDL implementation and evaluation. Uncertainties, assumptions, and considerations are applied throughout this document and point to the need to refine analysis, conduct further monitoring, and address unknowns in order to develop a better understanding of nutrient impairment conditions and the processes that affect impairment.

Adaptive management assumes that TMDL targets, allocations, and the analyses supporting them are not static but are processes subject to adjustment as new information and relationships are understood. For instance, numeric nutrient targets provided in **Table 7-2** are based on the best information and analyses available at the time and represent water quality concentrations believed to limit algal growth below nuisance levels within the Rock TPA. As numeric criteria for nutrients are developed and progress, water quality targets for nutrient may be adjusted.

Uncertainties associated with the assumptions and considerations may be mitigated, and loading estimates refined, to more accurately portray watershed conditions. Further monitoring and evaluation of water quality and source loading conditions should be conducted. Adaptive management land use activities, nutrient management and control should also be implemented and tracked. Changes in land use or management may change nutrient dynamics and may trigger a need for additional monitoring. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP assessments to a complete measure of target parameters above and below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration as nutrient sources are ubiquitous in the Rock TPA. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed.

Uncertainties in assessments and assumptions should not paralyze, but should point to the need to be flexible in our understanding of complex systems, and to adjust our thinking and analysis in response to this need. Implementation and monitoring recommendations presented in **Section 8.0** provide a basic framework for reducing uncertainty and furthering understanding of these issues.

8.0 METALS TMDL COMPONENTS

This section focuses on impairment of water quality caused by metals pollution. It describes: 1) the mechanisms by which metals impair beneficial uses, 2) the specific stream segments of concern, 3) the presently available data pertaining to metals impairment in the watershed, 4) the various contributing sources of metals based on recent data and studies, and 5) the metals TMDLs and allocations.

8.1 EFFECTS OF ELEVATED METALS ON BENEFICIAL USES

Elevated metals concentrations in the Rock Creek TPA are partially related to metal mining and exploration which in some cases can cause rapid and extensive exposure of waste rock, metal ores and alluvial sediments to weathering and accelerated erosion. Where mining operations expose metal sulfide minerals to oxygen (O_2) and water (H_2O), chemical reactions produce sulfuric acid and metal oxide precipitates. An example of a common metal sulfide mineral is the iron sulfide pyrite (FeS_2). Others include the lead sulfide galena (PbS), and the copper sulfide chalcocite (Cu_2S).

The following equation describes pyrite oxidation:

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{+2} + 2\ SO4^{2-} + 2\ H^+$$

Oxidizing bacteria, such as *Thiobacillus ferrooxidans*, accelerate sulfide oxidation and commonly occur in surface water and groundwater. Sulfuric acid (H_2SO_4) lowers soil and water pH and increases the dissolved concentrations of iron and other metals (e.g. copper, lead, and arsenic) to levels toxic to aquatic life. Metal oxide precipitates often cause turbidity in surface water and coat stream substrates with fine sediment that degrades aquatic habitat.

The acid generation and metal contamination caused by mining-related metal sulfide oxidation are commonly referred to as "acid rock drainage" or ARD. **Figure 8-1** shows the effects of ARD-related iron oxide precipitation on water quality in the discharge from an abandoned mine in western Montana.

Figure 8-1. The iron oxide precipitation effects of acid rock drainage (ARD)

Natural landscape erosion and, in some instances, human land uses other than mining such as timber harvesting and livestock grazing can disturb and expose surface soil to accelerated erosion and can contribute sediment-bound metals loads to surface waters. The specific metal pollutants that can exceed water quality standards as a result of accelerated soil erosion depends upon the chemical composition of the materials from which surface soil or other unconsolidated sediments have been developed. Aluminum and iron are common constituents of minerals soils and exceedances of water quality standards for these metals would be expected in areas where waters are affected by accelerated erosion. Where soils are developed from more mineralized parent materials, sediment-bound metals loads may include other parameters such as arsenic, copper, cadmium, and lead.

Waterbodies with metals concentrations exceeding the aquatic life and/or human health standards can impair several beneficial uses of surface water including aquatic life support, drinking water, and agriculture. Elevated metals concentrations can have toxic, carcinogenic, or bioconcentrating effects on aquatic organisms. Humans and wildlife can suffer acute and chronic health problems from consuming metal contaminated drinking water or fish tissue. Because elevated metals can be toxic to plants and animals, metal contamination may damage irrigation or livestock water supplies.

8.2 Stream Segments of Concern

Table 8-1 lists the 7 waterbody segments in the Rock Creek TPA that have been identified as being impaired for metals pollution. Eureka Gulch, Quartz Gulch, Sluice Gulch, and West Fork Rock Creek are included on the 2012 Montana 303(d) List of metal-impaired waters. Basin Gulch, Flat Gulch, and Scotchman Gulch are not included on the 2012 303(d) List. However they are included in **Table 8-1** because a review of recent water quality data that indicates beneficial uses for these streams are impaired by elevated metal concentrations. All 3 are first order tributary streams in the Rock Creek TPA with evidence of past placer mining. Metals-related listings include aluminum, arsenic, copper, iron, lead, and mercury.

Table 8-1. Waterbody segments in the Rock Creek TPA identified as being impaired for metals

Waterbody ID	Stream Segment
MT76E002_080	BASIN GULCH, Headwaters to mouth (Eureka Gulch)
MT76E002_090	EUREKA GULCH, Basin Gulch-Quartz Gulch confluence to mouth (un-named ditch)
MT76E002_120	FLAT GULCH, Headwaters to mouth (Rock Creek)
MT76E002_070	QUARTZ GULCH, Headwaters to mouth (Eureka Gulch)
MT76E002_100	SCOTCHMAN GULCH, Headwaters to mouth (Upper Willow Creek)
MT76E002_110	SLUICE GULCH, Headwaters to mouth (Rock Creek)
MT76E002_030	WEST FORK ROCK CREEK, Headwaters to the mouth (Rock Creek)

8.3 Information Sources and Assessment Methods

DEQ used the following information sources for describing water quality and metals loading conditions in the planning area:

- The monitoring and assessment database compiled by DEQ for the Rock Creek TPA
- United States Geological Survey (USGS), National Water Information System (NWIS) database of surface water chemistry and discharge
- United States Environmental Protection Agency (EPA) STORET database of surface water chemistry and stream discharge
- State agency databases and GIS layers of inventoried mining properties and mining and milling disturbances
- DEQ discharge permit program files for active mines and mine-related facilities
- Federal and state government agency geographical information system (GIS) data for geology, topography, land cover, and land-use layers
- United States Department of Agriculture, Forest Service Watershed Assessments
- 2011 National Agricultural Imagery Program (NAIP) Aerial photos
- DEQ historical narratives of mining and milling activities

DEQ's monitoring and assessment record (Montana Department of Environmental Quality, 2012c) is the principal basis for stream impairment listings. Most of the metals impairments are based on water column chemistry data collected by DEQ or its contractors during 2004 and from 2009 through 2012. Sediment chemistry data, collected by DEQ monitoring and assessment field crews from 2009 through 2012, is available from samples collected under both high- and low-flow conditions from streams or their tributaries with metals impairment causes. DEQ assessment data was supplemented by STORET and NWIS data collected between 2001 and 2011.

DEQ's Office of Information Technology (OIT) has compiled a host of GIS layer files representing the approximate locations of potential metals loading sources inventoried by various state and federal natural resource agencies. These include inventoried abandoned mines, mills, and ore processing sites, and priority abandoned mines. In addition, OIT maintains a GIS directory of physical and cultural land features that include topography, hydrography, land cover categories, transportation infrastructure, and land ownership, These layers, combined with interpretation of 2011 NAIP aerial imagery, are used to help identify significant sources of metals loading from mining and other sources.

DEQ's Remediation Division has compiled historical narratives of metal mine developments describing the timing, nature, and production levels of mining and milling properties in Montana's mining districts. The narratives are used to describe the level of disturbance and likely pollutant sources at specific properties.

Based on the review of water quality data, geographic information, and project reports and narratives, potential sources of metals loading in the Rock Creek TPA include:

- natural background sources from mineralized bedrock surface erosion
- abandoned mine adit discharges or precipitation seepage through mine wastes
- discharges from mining facilities operating under an Small Miners Exclusion Statement (SMES) from DEQ.
- sediment-bound metals entering surface water from human-caused surface erosion

8.3.1 Natural Background Loading

Natural background loading is assumed to be a result of local geology, with minimal influence from human-caused sources. Metal loading to surface water is strongly influenced by geology and streamflow rate. Bedrock composition commonly affects sediment mineralogy and surface water concentrations of many elements, including metals. Higher suspended sediment concentrations usually increase the water column solids concentration of metals and other constituents during seasonal high flows.
2.1.6
The sampling and analysis plans developed for stream assessments in the Rock Creek TPA from 2009 through 2011 identified three sampling sites remote from mining and other human-caused sources. The three sites occur in the upper reaches of West Fork Rock Creek (C02ROCWF01) and in the Scotchman Gulch (C02SCTMG04, C02SCTMG01) tributary of Upper Willow Creek. A fourth site, similarly remote from human-caused sources, was established in the Miners Gulch tributary of Upper Willow Creek during 2010 (C02MNRSG01). The local bedrock geology at all four sites consists of granitic batholith cells that have intruded folded and faulted Belt Series sediments (see **Section 2.1.6**). **Table 8-2** contains measured high and low-flow values and median values for metal pollutant parameters in samples from the four sites representing natural background conditions. Where measured concentrations are less than analytical method detection limit, one half of the detection limit is used to calculate loading from background sources.

The median values in the shaded rows in **Table 8-2** are used to calculate the load allocations to natural background sources of metals loading in the Rock Creek TPA.

Table 8-2. Measured and median metal concentrations for sites representing natural background conditions in the Rock Creek TPA.

Flow	Station ID	Hardness (mg/L)	Al (µg/L)	As (µg/L)	Cd (µg/L)	Cu (µg/L)	Fe (µg/L)	Pb (µg/L)	Hg (µg/L)	Zn (µg/L)
High	C02ROCWF01	7	70	<3	<0.08	<1	100	< 0.5	<0.005	<10
	C02SCTMG04	25	140	<3	<0.08	<1	310	< 0.5	--	<10
High-flow Medians		16	105	1.5	0.04	0.5	205	0.25	0.0025	5
Low	C02ROCWF01	11	--	<3	<0.08	<1	70	< 0.5	--	<10
	C02ROCWF01	12	<30	<3	<0.08	<1	60	< 0.5	<0.005	<10
	C02ROCWF01	12	<30	<3	<0.08	<1	60	< 0.5	<0.005	<10
	C02MNRSG01	16	50	1	<0.08	<1	--	<0.5	--	<10
	C02MNRSG01	18	40	<1	<0.08	<1	--	<0.5	--	< 5
	C02MNRSG01	18	50	<1	<0.08	<1	--	<0.5	--	<5
	C02SCTMG01	32	30	1	<0.08	<1	150	<0.5	--	<5
	C02SCTMG01	24	130	1	<0.08	<1	--	<0.5	--	<1
Low-flow Medians		17	40	1	0.04	0.5	60	0.25	0.0025	3.75

The data set contains 10 sampling results for most metal parameters. The high-flow data consists of water chemistry for the West Fork Rock Creek and upper Scotchman Gulch collected on June 1, 2010. The remaining 8 low flow samples were collected during low flows in 2009 and 2010. Complete water column chemistry results for the selected natural background sites are contained in **Appendix L**.

Metal concentrations in samples from natural background sites are either less than the method detection limits or within the applicable standards for all metal parameters except dissolved aluminum. The most restrictive aluminum criterion is the chronic aquatic life support value of 87 µg/L. The criterion was exceeded twice in Scotchman Gulch. Once in July, 2010, and once in June, 2012. Despite the aluminum exceedances, median aluminum concentrations values across all nine samples remain less than the aquatic life criterion. The locations of the proposed background sites are highlighted in **Figure 8-2**.

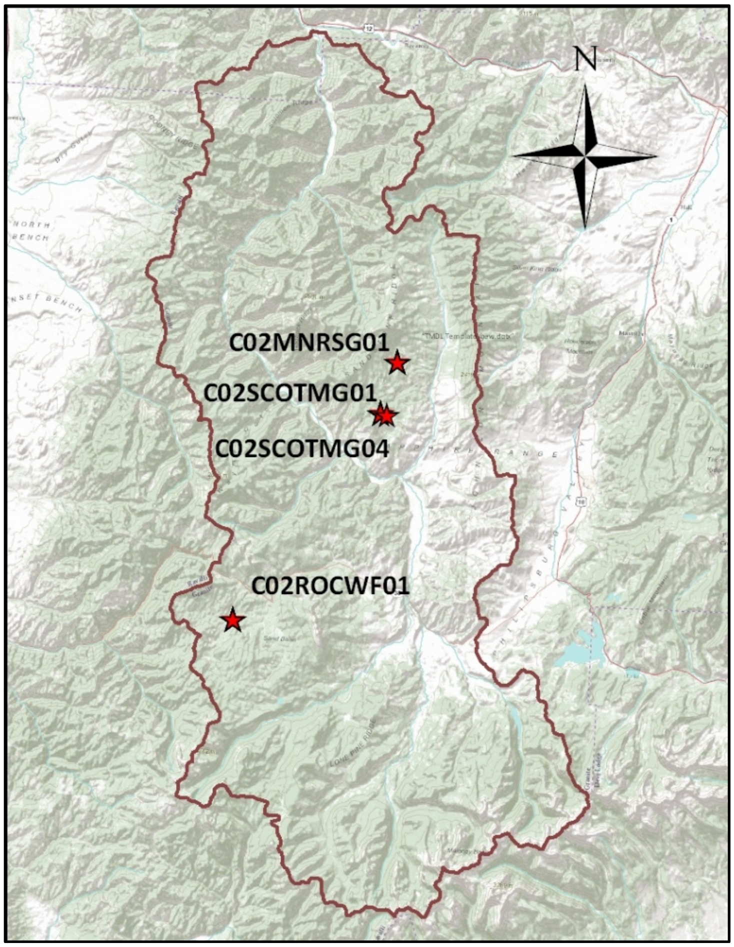

Figure 8-2. Water quality sampling sites representing natural background conditions in the Rock Creek TPA.

The sites occur in headwater reaches that are generally upstream of mining sources. The data suggest that natural background concentrations of aluminum in surface waters draining watersheds with a granitic bedrock may occasionally exceed numeric water quality standards for aluminum during high and low flows. Additional surface water monitoring is recommended to better define natural background levels of aluminum loading.

When possible, background loading is accounted for separately from human-caused sources. However, the effects of past metal mining are localized within the planning area and load allocations to natural background sources cannot always be expressed separately from human-caused sources. Regardless of the allocation scheme, the underlying assumption is that, natural background sources alone would not exceed the target metals concentrations in the water column, or the PELs in sediment. If future monitoring disproves this assumption, metals loading analyses may need revision per the adaptive management strategy described in **Section 8.9**

8.3.2 Loading from Mining Sources

Mining in the Rock Creek TPA began with the discovery of placer gold and later sapphire deposits in a number of upper Rock Creek tributaries beginning in the early 1860s and lasting as late as the 1940s (Montana Department of Environmental Quality, 2013). Placer mining still exists in the Rock TPA in limited amounts. Placer mining for sapphires is focused in several ephemeral drainages in lower West Fork Rock Creek. Placer mining of Gold deposits is taking place in the Eureka Gulch tributary of Rock Creek under three Small Mine Exclusions Statement (SMESs) issued by DEQ (SMES #s 46-126, 46-134, and 46-139). Information on these operations is on file with DEQ's Environmental Management Bureau, describes placer mining disturbances for recovery of gold, sapphires, and garnets. Alluvial deposits in Basin and Cornish gulches have been excavated by track hoe and gravity separated using a portable trommel. Information on file describes disturbances of less than 5 acres at each site. A license (#00709) was issued by DEQ on November, 30, 2009, for gold, sapphire, and garnet exploration in Basin Gulch. Exploration activities included surface trench excavation in the drainage bottom alluvium. An inspection of the exploration work by DEQ staff on September 21, 2011, reported that the excavated area had been re-graded. A portion of the reclamation bond is being withheld by DEQ pending required reseeding and weed control in the disturbed area.

DEQ and the Montana Bureau of Mines and Geology databases for abandoned and inactive mines identify 21 abandoned mine sites within the drainage areas of streams that are either listed in the 2012 Water Quality Integrated Report (Montana Department of Environmental Quality, 2012c) for metals impairment causes, or streams for which recent data indicate elevated metals concentrations. About 130 inactive mine properties are within the Rock Creek TPA boundary. However, many of these occur in the upper Ross Fork, Middle Fork, and East Fork tributaries that are either not assessed or not currently listed as being impaired by metal causes. Other concentrations of inactive mine sites occur in the Stony Creek, Williams Creek, Brewster Creek, and Welcome Creek tributaries of Rock Creek that drain the northwestern sector of the planning area. None of these streams are listed as being impaired by metals causes.

DEQ's Mine Waste Cleanup Bureau classified seven inactive mine sites in the Rock Creek TPA as "priority" mines. Priority mines, are a source of high public concern because of severe environmental degradation caused by heavy metal and mineral processing contamination of surface water and groundwater or contain mine opening hazards that pose a potential public safety issue (Pioneer Technical Services, Inc., 1995). The priority abandoned mines among the seven streams with metals impairment causes include the Silver King and Lori No. 13 properties in the Sluice Creek watershed. The potential of these two properties as metals sources to Sluice Gulch are described in **Appendix M**, **Section M 2.5.1**.

Environmental data describing individual loading contributions from abandoned mines is typically insufficient to guide allocations. Where data is adequate, wastewater discharges from abandoned mines are assigned wasteload allocations (WLA). Contributions from other abandoned mine sources are more commonly included in composite WLAs for mining sources associated with a specific property or drainage area. These allocation approaches assume that reductions in metals loading can be accomplished by treating the discharges and remediating or removing solid waste sources at abandoned mines.

8.3.3 Loading from Permitted Sources

The Integrated Compliance Information System (ICIS) is an EPA database for reporting and tracking federal environmental enforcement cases and tracking the compliance records of National Pollutant Discharge Elimination System (NPDES) permitted wastewater dischargers. Registered users of the ICIS database can retrieve information on permitted sources. A download and review of NPDES permitted facilities for Granite and Missoula Counties did identify one active permitted facility in the Rock Creek

TPA. General permit (#MTR104756) for excavation work was issued to "Scott Tucker - Elkhorn Ranch". The permit expired on 12/31/2012 but was continued on 1/1/2013.This general permit is for discharge of stormwater runoff into an unnamed wetland adjacent to Rock Creek. Discharge associated with this permit does not enter any of the streams under TMDL development in this document.

Allocations to any future permitted point sources having reasonable potential to affect surface water quality for metals would be provided a Wasteload Allocation (WLA). The wasteload allocation under a specific discharge flow is calculated using the following formula:

$\mathbf{WLA_{NPDES} = (X)\ (Y)\ (k)}$

WLA= Wasteload Allocation to NPDES permitted discharges
X= lowest applicable metals water quality target in ug/L for a specific instream hardness value
Y= discharge flow in gallons per day
k = conversion factor

Although the example WLA can guide permit development, the allocations should not be strictly applied in discharge permits when recent source-specific data is available that better describes mixing capacity, hardness, and metals concentrations in the receiving waters.

8.4 Water Quality Targets and Supplemental Indicators

Montana's established criteria for numeric water quality are adopted as the water quality targets for metal pollutants in this document. These values are published in Circular DEQ-7 (Montana Department of Environmental Quality, 2012a). Circular DEQ-7 contains acute aquatic life and chronic aquatic life criteria (designed to protect aquatic life uses). It also contains the human health criteria which are designed to protect drinking water uses. TMDLs are calculated using the most stringent target value to ensure protection of all designated beneficial uses.

DEQ has established an assessment method for determining water quality impairment caused by elevated metals concentrations (Montana Department of Environmental Quality, Water Quality Planning Bureau, Montioring and Assessment Section, 2012). The method includes guidelines for making use-support decisions based on water column metals data. Numeric metals criteria established to protect aquatic life are different from those established to protect human health. In general, an exceedance rate of 10 % or less of the chronic aquatic life criteria represents compliance with the numeric criteria and support for aquatic life. The 10 % guideline is not applied for datasets containing a result that is more than twice the acute aquatic life criteria. A single exceedance of this magnitude warrants a conclusion of aquatic life impairment. No exceedances are allowed when assessing compliance with human health criteria. Thus, the drinking water use for a waterbody can be impaired while full support remains for aquatic life uses. Compliance with *chronic* aquatic life criteria is based on an average metals concentration during a 96 hour period. The 1-hour average concentration in surface water may not exceed the a*cute* aquatic life water quality criteria more than once in any 3- year period. The presence of human-caused loading sources is critical to making impairment conclusions.

The metals assessment method recommends that impairment decisions be based on a minimum of 8 samples collected from within the same assessment reach. An impairment decision may be based on fewer samples, but caution should be taken against false conclusions that uses are supported. In general, data from the last 10 years is considered when making attainment decisions for aquatic life and drinking water uses. Older data may be useful for developing a historical reference or for loading analysis when more recent dataset is unavailable. Although samples can be taken any time of the year, 33 % of the dataset should be from samples collected during high-flow conditions, with the remaining samples collected during base-flow. At a minimum, a metals sampling suite should include analysis for total recoverable metals and dissolved aluminum. Although not required for making use-attainment decisions, dissolved concentrations for metals other than aluminum and sediment metal concentrations may be useful for identifying sources.

To summarize, the metals assessment method specifies that the maximum allowable exceedance rate for the chronic aquatic life criteria is 10 % of samples collected using a sound monitoring design that includes representative and independent samples under both high and low flow conditions. No human health exceedances or exceedances greater than twice the acute aquatic life criteria are allowed. Where the numeric criteria apply to protecting of aquatic life and human health, the most restrictive value is adopted as the water quality target. Some of the aquatic life criteria for metals are dependent on water hardness and adjust with changes in hardness. The presence of human-caused sources is required to conclude impairment.

8.4.1 Water Quality Targets: Water Column Metals Concentration

Water column metals concentration targets are the acute aquatic life (AAL), chronic aquatic life (CAL) and human health (HH) criteria. The criteria are dissolved concentrations of aluminum, and total recoverable concentrations of all other metal parameters (Montana Department of Environmental Quality, 2012a). The acute and chronic aquatic life criteria for cadmium, copper, lead, silver, and zinc increase with increasing hardness. **Table B2-5**, in **Appendix B** contains the aquatic life and human health criteria for these metals at hardness values of 25 and 100 mg/L. **Table B2-5** also contains the aquatic life and human health criteria for those metals not affected by water hardness, including aluminum, arsenic, mercury, and iron.

The human health criteria given in Circular DEQ-7 for iron (300 µg/L) and manganese (50 µg/L) are based on secondary maximum contaminant levels (MCL) established by EPA to prevent unwanted tastes, odors, or staining. These values provide a guide for determining interference with the specified uses after conventional water treatment. DEQ assumes that the concentrations of iron and manganese present in Rock Creek waterbodies, after conventional treatment, would not consistently exceed the MCLs. Therefore, the chronic aquatic life criterion of 1,000 µg/L is the water quality target for iron. Since there are no aquatic life criteria for manganese and no manganese impairment causes in the Rock Creek TPA, manganese targets are not developed in this document.

8.4.2 Supplemental Indicators

A supplemental indicator is an environmental variable linked closely to water quality, but the linkage is less certain compared with that of targets. Supplemental indicators are helpful for making TMDL decisions in cases where target departures are minimal or calculated from small or aging data sets. Although, supplemental indicators can help evaluate beneficial-use support, they are used as supporting evidence rather than direct measures of impairment. The number and magnitude of supplemental indicator exceedances are considered together with those for numeric target criteria when evaluating use support. In most cases, a combination of target departure analysis, meaningful qualitative observations, and sound professional judgment is applied in each assessment of TMDL development needs.

Sediment chemistry data are used here as supplemental indicators of water quality problems. In addition to directly affecting life that interact with stream sediments, elevated sediment values can be an indicator of elevated metals concentrations during runoff conditions. Results are available for 42 sample sites throughout the planning area. The general prohibitions in Montana's water quality standards (ARM 17.30.637) apply to additions of pollutants in sediment at harmful or toxic concentrations. The National Oceanic and Atmospheric Administration (NOAA) has developed Screening Quick Reference Tables that contain metals concentration guidelines for freshwater and marine sediments (Buchman, 2008). The screening criteria, developed from a variety of toxicity studies, are expressed as Probable Effects Levels (PELs) in **Table 8-3**.

Table 8-3. Screening criteria for sediment metals concentrations used as supplemental indicators.

Metal Parameter	PEL (µg/g dry weight)
Arsenic	17
Cadmium	3.53
Copper	197
Lead	91.3
Mercury	0.486
Zinc	315

PELs represent the concentration above which toxic effects are expected to occur frequently. PELs are used here as a screening tool to identify potential impacts to aquatic life from sediment-bound metals concentrations.

8.4.3 Targets, Supplemental Indicators, and the Need for TMDLs

The following discussion describes how a number of decision factors, together with targets, are used to determine whether current water quality conditions require TMDL development. The metals targets and supplemental indicators are summarized in **Table 8-4**.

Table 8-4. Targets and Supplemental Indicators for the Rock Creek TPA

Target Parameter	Criterion
Water Column Metal Pollutant Concentration	Montana Water Quality Standards, Circular DEQ 7 (Montana Department of Environmental Quality, 2012a)
Supplemental Indicators	**Criterion**
NOAA Quick Reference Table for Inorganics in Freshwater Sediment	Probable Effects Limits (PELs) (Buchman, 2008)

The need to develop metals TMDLs is based on the assumption that naturally occurring metals concentrations in surface water are less than the most restrictive numeric criterion under both high- and low-flow conditions. Where available background data suggests that targets may be exceeded under naturally occurring conditions, additional monitoring may be needed to better distinguish between natural background and human-caused loading. Adaptive management can be applied to newly available monitoring data to refine an initial, broadly allocated TMDL.

TMDL development decisions are guided by the following factors relating to loading sources, data quality, and pollutant listing status:

- the clear presence of human-caused metal loading sources

- the number and age of available metals data and analysis results obtained for each stream segment
- the rate and magnitude of target and supplemental indicator exceedances
- whether the pollutant in question is a 2012 impairment cause, or is a newly discovered cause.

The current method of assessing metals impairment for surface waters (Montana Department of Environmental Quality, Water Quality Planning Bureau, Montioring and Assessment Section, 2012) recommends a minimum of eight recent analytical results. Recent data are those obtained for samples collected within the past 10 years. Current pollutant impairment causes are those that appear in the Water Quality Integrated Report for 2012 (Montana Department of Environmental Quality, 2012c). New pollutant impairment causes are those that are absent from the 2012 Integrated Report (Montana Department of Environmental Quality, 2012c), but are identified after review of recent data from an adequate dataset. New pollutant causes will appear in the Water Quality Integrated Report for 2014.

The following scenarios apply to current pollutant causes for streams with known human-caused sources. Each scenario describes how the rate and magnitude of target exceedances are interpreted to determine the need for metals TMDLs:

1. Greater than 10 % of recent analytical results exceed CAL concentration targets.
2. The 10 % target exceedance threshold is not exceeded in a dataset with fewer than 8 recent results.
3. At least one analytical result in a recent dataset is greater than twice the AAL target.
4. At least one analytical result in a recent dataset exceeds the HH target.
5. Although targets are not exceeded, water column metals concentrations are elevated under both high and low flows and sediment metals concentrations greatly exceed PELs.

Despite the presence of human-caused sources, metals TMDLs are not developed for currently listed streams if targets and supplemental indicators are met by an adequate and recent dataset. Metals TMDLs are developed for streams without current metals impairment causes when known human-caused sources are present and compliance thresholds for aquatic life and human health targets are exceeded in a recent and adequately sized dataset.

Additional monitoring may be recommended in lieu of TMDL development for unlisted streams if target exceedances occur in small datasets. Additional monitoring may also be recommended in lieu of TMDLs for unlisted streams if background conditions appear to exceed water quality targets and a clear link cannot be made to known human-caused sources.

8.5 Existing Condition and Comparison with Water Quality Targets

The decision factor analysis and TMDL conclusions are summarized below for each stream segment in **Tables 8-5 - 8-11**. The water quality and sediment data on which TMDL decisions are based are compiled by stream segment in **Appendix L**. The recent water quality record for each pollutant impaired stream segment in the planning area is compared with the metal targets and supplemental indicators listed above in **Table 8-4**. The results of the comparison are stated in terms of the TMDL development decision factors described in **Section 8.4.3.** Data for currently listed metals impairment causes are evaluated first, followed by a review of the data for other metal parameters with significant target departures. The stream-by-stream review of metals loading sources and comparison of water quality data with targets and supplemental indicators is contained in **Appendix M**.

Table 8-5. Metals decision factors and TMDL conclusions for Basin Gulch.

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded(*)	2012 Listing Status	TMDL Conclusion
Aluminum	N	N	NA	Y	NA	Unlisted	No TMDL
Arsenic	N	N	Y	Y	NA	Unlisted	TMDL
Cadmium	N	N	N	Y	NA	Unlisted	No TMDL
Copper	N	N	N	Y	NA	Unlisted	No TMDL
Iron	N	NA	NA	Y	NA	Unlisted	No TMDL
Lead	N	N	N	Y	NA	Unlisted	No TMDL
Mercury	N	N	N	Y	NA	Unlisted	No TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	NA	Unlisted	No TMDL

*Sediment chemistry data are not available for basin Gulch

Table 8-6. Metals decision factors and TMDL conclusions for Quartz Gulch.

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded	2012 Listing Status	TMDL Conclusion
Aluminum	Y	N	NA	Y	NA	Unlisted	TMDL
Arsenic	N	N	N	Y	Y	Unlisted	No TMDL
Cadmium	N	N	N	Y	N	Unlisted	No TMDL
Copper	N	N	N	Y	N	Unlisted	No TMDL
Iron	N	NA	NA	Y	NA	Unlisted	No TMDL
Lead	Y	N	N	Y	N	Unlisted	TMDL
Mercury	N	N	N	Y	Y	Listed	No TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	Y	Unlisted	No TMDL

Table 8-7. Metals decision factors and TMDL conclusions for Eureka Gulch.*

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded**	2012 Listing Status	TMDL Conclusion
Aluminum	N	N	NA	Y	NA	Unlisted	No TMDL
Arsenic	N	N	Y	Y	NA	Listed	TMDL
Cadmium	N	N	N	Y	NA	Unlisted	No TMDL
Copper	N	N	N	Y	NA	Unlisted	No TMDL
Iron	N	NA	NA	Y	NA	Unlisted	No TMDL
Lead	N	N	N	Y	NA	Unlisted	No TMDL
Mercury***	NA	NA	NA	Y	NA	Listed	TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	NA	Unlisted	No TMDL

* The recent water quality dataset for Eureka Gulch consists of a single record for a sample collected at site C02EURKG10 (on July 29th, 2004). **Sediment chemistry data are not available for Eureka Gulch.
***Data show 2 exceedance from 1997. Data older than 10 years is not used in TMDL development

Table 8-8. Metals decision factors and TMDL conclusions for West Fork Rock Creek.

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded	2012 Listing Status	TMDL Conclusion
Aluminum	Y	N	NA	Y	NA	Unlisted	TMDL
Arsenic	N	N	N	Y	N	Unlisted	No TMDL
Cadmium	N	N	N	Y	N	Unlisted	No TMDL
Copper	N	N	N	Y	N	Unlisted	No TMDL
Iron	N	NA	NA	Y	NA	Unlisted	No TMDL
Lead	N	N	N	Y	N	Unlisted	No TMDL
Mercury	N	N	N	Y	N	Listed	No TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	N	Unlisted	No TMDL

Table 8-9. Metals decision factors and TMDL conclusions for Sluice Gulch.

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded	2012 Listing Status	TMDL Conclusion
Aluminum	N	N	NA	Y	NA	Unlisted	No TMDL
Arsenic	N	N	Y	Y	Y	Listed	TMDL
Cadmium	N	N	N	Y	N	Unlisted	No TMDL
Copper	Y	N	N	Y	N	Unlisted	TMDL
Iron	N	NA	NA	Y	NA	Unlisted	No TMDL
Lead	N	N	N	Y	N	Unlisted	No TMDL
Mercury	N	N	N	Y	N	Unlisted	No TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	N	Unlisted	No TMDL

Table 8-10. Metals decision factors and TMDL conclusions for Flat Gulch.

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded	2012 Listing Status	TMDL Conclusion
Aluminum	Y	N	NA	Y	NA	Unlisted	TMDL
Arsenic	N	N	N	Y	N	Unlisted	No TMDL
Cadmium	N	N	N	Y	N	Unlisted	No TMDL
Copper	N	N	N	Y	N	Unlisted	No TMDL
Iron	Y	NA	NA	Y	NA	Unlisted	TMDL
Lead	N	N	N	Y	N	Unlisted	No TMDL
Mercury*	NA	NA	NA	Y	NA	Unlisted	No TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	N	Unlisted	No TMDL

* No Mercury data was collected in Flat Gulch as part of assessment efforts

Table 8-11. Metals decision factors and TMDL conclusions for Scotchman Gulch.

Pollutant Parameter	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Human-Caused Sources Present	Sediment PELs Exceeded	2012 Listing Status	TMDL Conclusion
Aluminum	Y	N	NA	Y	NA	Unlisted	TMDL
Arsenic	N	N	N	Y	N	Unlisted	No TMDL
Cadmium	N	N	N	Y	N	Unlisted	No TMDL
Copper	N	N	N	Y	N	Unlisted	No TMDL
Iron	N	NA	NA	Y	NA	Unlisted	No TMDL
Lead	N	N	N	Y	N	Unlisted	No TMDL
Mercury	N	N	N	Y	N	Unlisted	No TMDL
Silver	NA	N	N	Y	NA	Unlisted	No TMDL
Zinc	N	N	N	Y	N	Unlisted	No TMDL

* No Mercury data was collected in Scotchman Gulch as part of assessment efforts

8.5.1 TMDL Development Summary

Seven stream segments in the Rock Creek TPA require development of 11 TMDLs for metals (**Table 8-12**). The metals of concern are aluminum, arsenic, copper, iron, lead, and mercury.

Table 8-12. Metal pollutants requiring TMDLs for streams in the Rock Creek TPA.

Waterbody Segment ID	Waterbody Segment	Metals Listings in the 2012 Integrated Report	Verified Target Exceedances and TMDL/s Developed
MT76E002_080	Basin Gulch	None	Arsenic
MT76E002_090	Eureka Gulch	Arsenic, Mercury	Arsenic, Mercury
MT76E002_120	Flat Gulch	None	Aluminum, Iron
MT76E002_070	Quartz Gulch	Mercury	Aluminum, Lead
MT76E002_100	Scotchman Gulch	None	Aluminum
MT76E002_110	Sluice Gulch	Arsenic	Arsenic, Copper
MT76E002_030	West Fork Rock Creek	Mercury	Aluminum

The recent data support three of the metal pollutant causes reported on the 2012 303(d) List:

1. Arsenic in Eureka Gulch
2. Mercury in Eureka Gulch, and
3. Arsenic in Sluice Gulch

The data also support TMDLs for 8 new pollutant-waterbody combinations and removal from the 303(d) list of 2 other metal impairment causes. All metals listings in Basin Gulch, Flat Gulch, and Scotchman Gulch are new listings. The recent data for Quartz Gulch and West Fork Rock Creek do not support the 2012 mercury listings for these streams.

8.6 TMDLs

TMDLs for metals represent the maximum amount (lbs/day) of each metal that a stream can receive without exceeding water quality standards. A stream's capacity to assimilate metal pollutants is a function of the diluting effect of stream discharge and, in some cases, water hardness. Increasing water hardness reduces the toxicity of several metals (cadmium, copper, lead, silver, and zinc) and so is a factor in determining numeric water quality criteria. Because stream discharge and water hardness vary seasonally, the TMDLs must be applied seasonally to protect beneficial uses over a range of flow and hardness conditions. All TMDLs must contain a margin of safety (MOS) to ensure beneficial-use support in light of the uncertainty in deriving load estimates. All metals TMDLs developed for the Rock TPA contain an implicit margin of safety described in **Section 8.8**. Metals TMDLs are calculated using the following equation:

TMDL = (X) (Y) (k)

Where:
TMDL = Total Maximum Daily Load in lbs/day
X = lowest applicable metals target concentration (µg/L) adjusted for hardness
Y = streamflow in cubic feet per second (cfs)
k = unit conversion factor of 0.0054

All metals TMDLs are calculated using the most restrictive target value to ensure that the TMDLs protect all designated beneficial uses. The most restrictive target is commonly the chronic aquatic life criterion. Exceptions are arsenic and mercury, where the human health criteria are the most restrictive (**Appendix B, Table B 2-5**). Circular DEQ-7 (Montana Department of Environmental Quality, 2012a) specifies that compliance with the chronic aquatic life criteria is based on an average water quality metals concentration occurring over a 96 hour (4-day) period (**Section 8.4**). Calculating an allowable daily load from the chronic criteria that are based on a 4-day exposure duration provides an implicit margin of safety in the TMDL.

Although the TMDL is often derived from the chronic standards, acute aquatic life standards are also established as water quality targets, and are applied as an instantaneous instream pollutant concentration that is not to be exceeded (when the measured concentration is twice the acute standard). The TMDL will ultimately be defined as the total allowable loading using a time period consistent with the application of the most appropriate numeric water quality criterion. Remediation required to eliminate pollutant loading that exceeds the chronic standards will often mitigate more extreme short-duration exceedances of acute criteria.

8.6.1 TMDLs for Non-Hardness Dependent Metals

The toxicity of several metal elements is independent of water hardness. The TMDLs for these substances can be illustrated graphically using the TMDL equation in **Section 8.6**, with the most restrictive water quality criterion substituted for the value of "X," and stream discharge (cfs) substituted for the value of "Y." **Figure 8-3** shows the graphs of the TMDLs for aluminum, arsenic, iron, and mercury based on the most restrictive water quality criterion for each parameter over a common range of stream discharge for the Rock TPA.

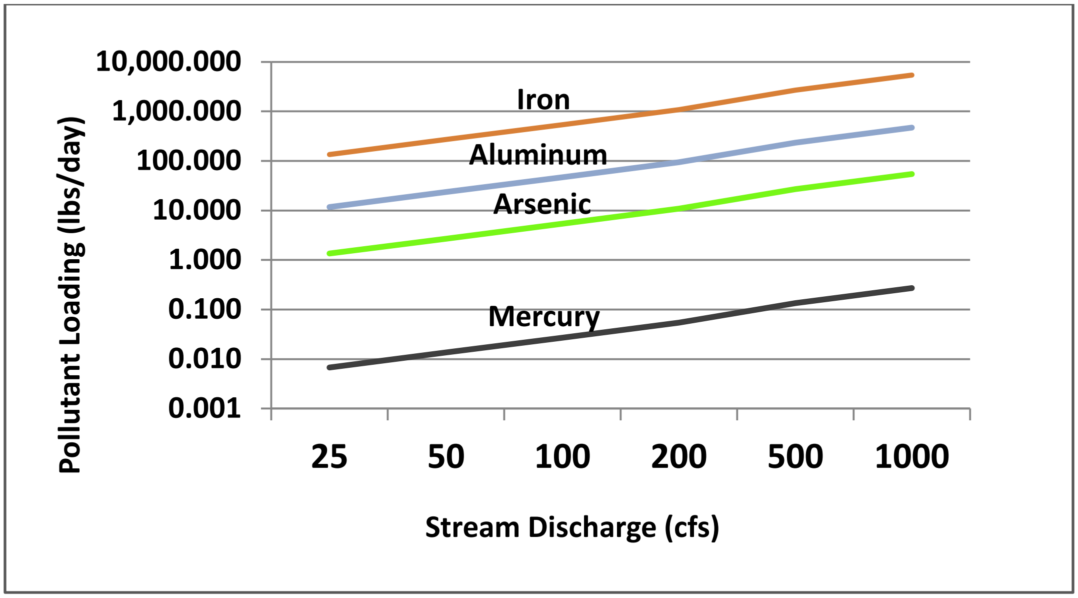

Figure 8-3. Graphs of TMDLs (lbs/day) for iron, aluminum, arsenic, and mercury with increasing stream discharge.

The **Figure 8-3** graph is based on the chronic criteria for iron (1,000 µg/L) and aluminum (87 µg/L) and the human health criteria for arsenic (10 µg/L,) and mercury (0.05 µg/L). The TMDL graph **Figure 8-3** applies to all aluminum, arsenic, iron, and mercury TMDLs in this document.

8.6.2 Example Metals TMDLs for Listed Streams

Table 8-13 gives seasonal discharge rates, hardness values, target values, example TMDLs, and load reduction needed for the seven waterbody segments in the Rock Creek TPA requiring metals TMDLs. The examples are calculated based on high- and low-flow sampling events. High flows are those occurring during the second calendar quarter (April –June); low flows are those during the remaining three quarters. Flows are medians of field measurements taken during high- and low-flow periods from 2010 through 2012. Where flow data is limited, individual high-and low-flow measurements are used. As no flow data exist for Sluice Gulch, the median of measured flows above and below the 50th percentile are used to represent high and low flows. Hardness values are calculated as the means of the field measurements classified by flow condition and stream segment.

The selection of monitoring stations is guided by the availability of flow and hardness data and the existence of significant upstream sources. **Table 8-13.** Existing loads are calculated using the largest target exceedance (i.e., highest observed concentration) multiplied by the most restrictive water quality target and a unit conversion factor. The calculated example TMDLs represent the maximum load (lbs/day) of each metal that each waterbody can receive without exceeding the most restrictive (lowest) applicable water quality standards for the specified flow and hardness. The current loads, percent reductions, and TMDL components contained in this document should not be considered rigid numbers but rather are reasonable approximations portraying the inherent loading variability. Raw data is included in **Appendix L**.

Table 8-13. Example metals TMDLs for waterbodies in the Rock Creek TPA

Stream Segment (Segment ID)	Station	Discharge (cfs)		Hardness (mg/L)		Metal	Target Concentration (µg/L)		TMDL (lbs/day)		Existing Load (lbs/day)	
		High flow	Low flow	High flow	Low flow		High flow	Low flow	High flow	Low flow	High Flow	Low Flow
Basin Gulch (MT76E002_080)	C02BASNG10	0.4	0.1	NA		Arsenic	10	10	0.0216	0.0054	0.0324	0.0081
Eureka Gulch (MT76E002_090)	C02EURKG10	0.67	0.3	NA		Arsenic	10	10	0.0361	0.0162	0.0578	0.0259
						Mercury	0.05	0.05	0.0002	0.0001	0.0018	0.00081
Flat Gulch (MT76E002_120)	C02FLATG04	0.07	0.03	NA		Aluminum	87	87	0.0329	0.0141	0.0188	0.0210
						Iron	1,000	1,000	0.3776	0.1618	0.0641	0.2217
Quartz Gulch (MT76E002_070)	C02QRTZG01	0.37	0.06	NA		Aluminum	87	87	0.1737	0.0282	0.9182	0.0049
				26	57	Lead	0.57	1.56	0.0011	0.0005	0.0012	0.0001
Scotchman Gulch (MT76E002_100)	C02SCTMG03	0.52	0.53	NA		Aluminum	87	87	0.2441	0.2487	0.5966	0.5092
Sluice Gulch (MT76E002_110)	C02SLUCG01	1.4	1.2	NA		Arsenic	10	10	0.0755	0.0647	0.0906	0.0712
				143	148	Copper	12.66	13.04	0.0956	0.0844	0.0302	0.0032
West Fork Rock Creek (MT76E002_030)	C02ROCWF05	940	33	NA		Aluminum	87	87	441	15	456	2.7

8.7 Loading Summaries and Allocations

The following sections provide a loading summary and source allocation for each pollutant-waterbody combination with a metal TMDL. It is helpful to review the loading sections on each segment with the corresponding target departure discussion in **Appendix M**. Loading summaries are based on the sample data contained in **Appendix L**. The descriptions of metals loading to Rock Creek tributaries begins with the Basin and Quartz Gulch tributaries to Eureka Gulch, followed by the adjacent West Fork of Rock Creek, then downstream to Flat Gulch, Sluice Gulch and concluding with the Upper Willow Creek tributary of Scotchman Gulch.

The purpose of the loading summaries is to identify contributing sources, and discuss seasonal pollutant fluctuations and pathways. Loads are expressed in units of pounds per day. While units of pounds per day are appropriate for expressing TMDLs, the most appropriate means of measuring compliance with metals TMDLs is a direct measurement of the contaminant concentration in surface water samples.

As discussed in **Section 4.0**, a TMDL is the sum of all the load allocations (LAs), wasteload allocations (WLAs), and an MOS. LAs are allowable pollutant loads assigned to nonpoint sources and may include the cumulative pollutant load from naturally occurring sources plus allowable human caused sources. When possible, LAs to naturally occurring sources are provided separately. WLAs are allowable pollutant loads that are assigned to permitted and non-permitted point sources. Mining-related waste sources (e.g. adit discharges, tailings accumulations, and waste rock deposits) are non-permitted point sources subject to WLAs. TMDLs are expressed by the following general equation:

TMDL = LA + WLA + MOS

The prevailing human-caused sources of metals loading in the Rock Creek TPA are inactive mines, and sediment-bound sources from road, streambank, and hillslope erosion. Where adequate data are available to evaluate loading from individual sources, these sources will be given separate WLAs. Where data from discrete sources is unavailable, loading contributions from inactive mines, streambank sources or roadways may be grouped into composite WLAs. The adaptive management process discussed in **Section 8.9** is recommended where more detail is needed for future refinement and adjustment of composite WLAs to mining and other sources.

TMDLs must incorporate an MOS. All metals TMDLs in this document apply an implicit MOS by adopting a variety of conservative assumptions in calculating TMDLs and estimating pollutant loads. These assumptions are described in more detail in **Section 8.8**. Therefore, the implicit MOS is applied in the TMDL equations above and not repeated in each of the equations to follow.

The TMDL and allocation tables in the following sections give the TMDLs for each metal pollutant parameter under both high- and low-flow conditions for each stream segment. These TMDL values are brought forward from **Table 8-13**. The **Table 8-13** column following the “TMDL” column gives values for the “Existing Metal Concentration” in units of µg/L. These are the highest values from the water quality monitoring data for each flow condition. The “Existing Loads” are calculated by multiplying these concentrations times the flow values (also brought forward from **Table 8-13**), times a unit conversion factor. For example, **Table 8-14** for Basin Gulch gives a value of 0.0324 lbs/day for existing flow arsenic loading. The high flow in Basin Creek of 0.4 cfs (**Table 8-13**) is multiplied by the highest arsenic concentration measured in Basin Creek during high flows (15 µg/L). The product of flow multiplied by concentration is, in turn, multiplied by the unit conversion factor of 0.0054 to give the existing high flow aluminum load of 0.0324 lbs/day.

Example: Basin Gulch high flow TMDL= 0.4 cfs X 15 µg/L X 0.0054 = 0.0324 lbs/day)

The "Existing Load" column in the allocation tables (eg., **Table 8-14**) is followed by "LA" and "WLA" columns containing the allowable loads from nonpoint sources (i.e. background sources) and the allowable wasteload from human-caused sources. The last column in the allocation tables contains human-caused load reduction percentages needed to meet the TMDLs. The reductions are calculated as the difference between the current and allowable human-caused pollutant loading, expressed as a percentage of the current human-caused load. In cases of high uncertainty in the degree of natural background loading, composite wasteload allocations are proposed that combine natural background and human-caused sources. In these cases, the final column in the allocation tables quantifies the reduction in the total pollutant load needed to meet the TMDL.

Example: Basin Gulch High Flow Arsenic % Reduction

1.) Total Existing Load – Natural Background (LA) = Existing human-caused load (WLA)
0.0324 lbs/day – 0.0032 lbs/day = 0.0292 lbs/day (Existing WLA)

2.) ((Existing WLA **–** TMDL WLA)/Existing WLA)* 100 = % Reduction from Human-caused Sources
((0.0292 **–** 0.0184)/0.0292)* 100 = 37% Reduction from Human-caused Sources

8.7.1 Basin Gulch (MT76E002_080)

Loading Summary

Metals target exceedances in Basin Gulch are associated with an inactive underground mine and breached tailings impoundment related to the former Blue Bell silver mine. The drainage bottom alluvium has been placer mined. Re-grading formed a series of valley bottom check dams impounding surface water. Aerial imagery shows additional surface disturbances in the upper drainage that resemble exploration trenches, drill pads, and roadways. Natural background loading is represented by the median water analysis results contained in **Table 8-2**.

TMDLs and Allocations

The metals TMDLs and allocations for high- and low-flow conditions in Basin Gulch are summarized below and in **Table 8-14**. The arsenic allocations include load allocations to natural background concentrations ($\mathbf{LA}_{BG\ NB}$) and a wasteload allocation to mining sources of arsenic ($\mathbf{WLA}_{BG\ MS}$). Natural background loading is calculated using one half of the method detection level (1.5 µg/L) for high-flow conditions and 1 µg/L for low-flow conditions. The Basin Gulch arsenic TMDL is summarized by the following equation:

$$\mathbf{TMDL_{BG} = LA_{BG\ NB} + WLA_{BG\ MS}}$$

The wasteload allocation to mining sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards. The allocations also assume that further applying best management practices (BMPs) to mining sources will reduce loading so that TMDLs and water quality targets are met.

Table 8-14. Example metal TMDLs and load- and wasteload allocation examples for Basin Gulch at site C02BASNG10.

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)	Needed Reduction (%)
Arsenic	High flow	0.0216	15	0.0324	0.0032	0.0184	37
	Low flow	0.0054	15	0.0081	0.0005	0.0049	36

The similarity between high-flow and low-flow water column concentrations of arsenic indicates a consistent year-round source of this pollutant. There are no sediment chemistry data available for Basin Gulch as a supplemental indicator of metals impairment. Such data would be helpful in learning whether sediment-bound arsenic is consistently contributing to the water quality problem in Basin Gulch.

8.7.2 Eureka Gulch (MT76E002_090)

Loading Summary

Eureka Gulch extends from the confluence of Basin and Quartz gulches to the Rock Creek floodplain where flow is intercepted by a flood irrigation lateral. The Eureka Gulch data record consists of a single water column sample collected on July 29, 2004, from site C02EURKG10. An arsenic result of 16 µg/L was detected in the sample. The mercury impairment determination in Eureka Gulch stems from samples collected from mine disturbances during 1996 and 1997. The results range from 0.2 to 0.5 µg/L.

TMDLs and Allocations

Example TMDLs and allocations for Eureka Gulch are contained in **Table 8-15**. The allocations for arsenic and mercury under both flow conditions include load allocations to natural background concentrations (**$LA_{EG\ NB}$**) and a wasteload allocation to mining sources (**$WLA_{EG\ MS}$**). Natural background loading to Eureka Gulch is represented by water analysis results from the sites listed in **Table 8-2**. This allocation scheme is reflected in the following TMDL equation:

$$\mathbf{TMDL_{EG} = LA_{EG\ NB} + WLA_{EG\ MS}}$$

Table 8-15. Example metals TMDLs and load- and wasteload allocation examples for Eureka Gulch at site C02EURKG10.

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)	Needed Reduction (%)
Arsenic	High flow	0.0361	16	0.0578	0.0054	0.0307	41
	Low flow	0.0162	16	0.0259	0.0016	0.0146	40
Mercury	High flow	0.0002	0.5	0.0018	0.000009	0.00019	89
	Low flow	0.0001	0.5	0.00081	0.000004	0.00002	88

Where background sample analysis results are less than MDLs, one half of the maximum detection limit (MDL) is the assumed background concentration. The wasteload allocation to mining sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards and that further application of BMPs to Eureka Gulch mining sources will reduce loading so that TMDLs and water quality standards are met.

The limited dataset does not contain results from high-flow sampling. Low flow sample results were used to estimate high-flows and obtain high-flow allocations for Eureka Gulch. Streambed sediment data are not available for Eureka Gulch.

8.7.3 Quartz Gulch (MT76E002_070)

Loading Summary

Quartz Gulch combines with Basin Gulch to form the Eureka Gulch tributary to Rock Creek. Aluminum and lead target exceedances in Quartz Gulch occur only during high flows, indicating a sediment-bound source of loading. The stream has been extensively placer mined. Channel stabilization after reclamation varies from stable in the upper drainage to no distinguishable channel near the mouth.

TMDLs and Allocations

Example TMDLs and allocations for Quartz Gulch are specified in **Table 8-16**. Two allocation schemes are developed for Quartz Gulch because of uncertainty in the amount of natural background aluminum loading introduced by elevated high-flow aluminum concentrations in samples from background sites. For high-flow aluminum, the TMDL is a composite wasteload allocation to natural background and mining sources. The composite allocation for high-flow aluminum is expressed by the following equation:

$$\mathbf{TMDL_{QG} = WLA_{(QG\ NB\ +\ QG\ MS)}}$$

Using a composite allocation, the sum of allowable aluminum loading from natural background, plus mining sources, is equal to the aluminum TMDL of 0.1737 lbs/day under high-flow conditions. The TMDL equation for high-flow aluminum is inserted into **Table 8-16**.

The allocations for low-flow aluminum loading and lead loading under both flow conditions include load allocations to natural background concentrations (**LA** $_{QG\ NB}$) and wasteload allocations to mining sources of these metals (**WLA** $_{QG\ MS}$). Natural background loading is calculated using the metal concentrations in **Table 8-2**. This allocation scheme is reflected in the following TMDL equation:

$$\mathbf{TMDL_{QG} = LA_{QG\ NB} + WLA_{QG\ MS}}$$

Table 8-16. Example metal TMDLs and wasteload allocation for Quartz Gulch at site C02QRTZG01.

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)	Needed Reduction (%)
Aluminum	High flow	0.1737	460	0.918	TMDL = 0.1737 lbs/day		81
	Low flow	0.0282	15	0.005	0.013	0.0152	0
Lead	High flow	0.0011	0.60	0.0012	0.0005	0.0006	14
	Low flow	0.0005	0.25	0.0001	0.0001	0.0004	0

Where background sample analysis results are less than MDLs, one half of the MDL is the assumed background concentration. The wasteload allocation to mining sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards and that further application of BMPs to mining sources in Quartz Gulch will reduce high-flow loading so that TMDLs and water quality standards are met. Additional high-flow aluminum monitoring at background sites is recommended to increase the sample size and improve our understanding of background aluminum loading in the planning area.

Sediment metals concentration data are available for one sample collected at site C02QRTZG01 in September of 2011. The arsenic concentration in the Quartz Gulch sample is 62 times the recommended PEL value. Sediment concentrations of mercury and Zinc are also elevated, but not causing water column exceedances. From the current dataset it appears that neither aluminum nor lead require load reductions during low flow, since targets are exceeded only during high flow. While elevated streambed sediment concentrations of arsenic may indicate a potential problem. None of the eight water column samples exceeded targets, thus an arsenic TMDL is not established at this time. Further arsenic sediment and water quality monitoring is recommended to better characterize arsenic in this basin.

8.7.4 West Fork Rock Creek (MT76E002_030)

Loading Summary

Metals sources in the West Fork Rock Creek consist of inactive abandoned placer mine properties in the upper portion of the drainage and quarried placer deposits in the Anaconda and Sapphire gulch drainages farther downstream. Two lode mine developments for gold recovery in the Maukey Gulch tributary of the lower West Fork consist of hillslope disturbances, access roads, and local timber harvest areas. The mercury impairment listing for West Fork Rock Creek stems from water quality data collected prior to 2000. Recent low level mercury monitoring does not confirm continuing mercury impairment.

The West Fork Rock Creek water quality dataset includes 18 records from 7 monitoring sites (**Appendix M, Figure M-1**). All sites were established by DEQ monitoring and assessment efforts. Water samples were collected during high- and low-flow periods in 2009 and 2010. Water quality records are lacking for streams in the Ross Fork tributary of the West Fork and additional assessment work is required to characterize loading from this large tributary drainage. Natural background loading is represented by the median values in **Table 8-2**.

TMDLs and Allocations

Example aluminum TMDLs and allocations for West Fork Rock Creek are contained in **Table 8-17**. The allocation scheme developed for West Fork Rock Creek is a composite allocation to natural background (NB) and mining-related sources (MS) of aluminum. Use of a composite allocation reflects the uncertainty in the background aluminum concentrations measured during high flows. The composite allocation for high-flow aluminum is expressed by the following equation:

$$\mathbf{TMDL_{WFRC} = WLA_{(WFRC\ NB\ +\ WFRC\ MS)}}$$

The composite allocation scheme states that the sum of allowable high-flow aluminum loading from natural background, plus mining sources, is equal to the TMDL of 441 lb/day under high-flow conditions. The TMDL equation for high-flow aluminum is inserted into **Table 8-17**.

The allocation for low-flow aluminum includes a load allocation to natural background concentrations ($\mathbf{LA_{WFRC\ NB}}$) and a wasteload allocation to mining sources ($\mathbf{WLA_{WFRC\ MS}}$). Natural background loading to West Fork Rock Creek is represented by water analysis results from the sites listed in **Table 8-2**. This allocation scheme is reflected in the following TMDL equation:

$$\mathbf{TMDL_{WFRC} = LA_{WFRC\ NB} + WLA_{WFRC\ MS}}$$

Table 8-17. Example TMDLs and wasteload allocation for West Fork Rock Creek at site C02ROCWF05

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)	Needed Reduction (%)
Aluminum	High flow	441	90	456	TMDLWFRC = 441 lbs/day		3
	Low flow	15	15	2.7	7.1	7.9	0

Where background sample analysis results are less than MDLs, one half of the MDL is the assumed background concentration. The wasteload allocation to mining sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards and that application of BMPs to West Fork mining sources will reduce loading so that TMDLs and water quality standards are met. The current dataset indicates that a small (3%) high-flow reduction is needed to meet the TMDL and no reduction is needed under low-flow conditions.

The sediment metals analysis record consists of 8 samples; two samples each for sites C02ROCWF01, C02ROCWF02, C02ROCWF03, and C02ROCWF04. The sediment chemistry data do not indicate a pervasive sediment-bound source of metals loading to West Fork Rock Creek.

8.7.5 Flat Gulch (MT76E002_120)

Loading Summary

There are no abandoned mines described in the Flat Gulch drainage in either the MBMG or DEQ abandoned mine databases. The aluminum impairment to Flat Gulch appears not to be directly related to mining activity but rather to aluminum-bearing minerals in local soils and streambed sediment. Natural landscape erosion and, in some instances, human land uses other than mining such as timber harvesting and livestock grazing can disturb and expose surface soil to accelerated erosion and can contribute sediment-bound metals loads to surface waters. Aluminum and iron are common constituents of minerals soils and exceedances of water quality standards for these metals would be expected in areas where waters are affected by accelerated erosion.

Flat Gulch also has a sediment impairment cause and the impairments are likely related. Sediment sources include streambank trampling by domestic livestock and timber harvesting and the associated road network in the upper portions of the drainage. Timber harvest, livestock grazing are potential sediment sources in the lower assessment reach. While no evidence of load mining was found, placer mining did occur in the low assessment reach and could be a additional source of sediment. A potential source of aluminum may be a unidentified mine adit or shaft within Flat Gulch.

Another potential source of aluminum may include metals contributions from groundwater that recharges Flat Gulch. Aluminum is present in soils and minerals and is generally present in ground and surface water at low level. Acidic conditions can dissolve aluminum in soils and geologic features and transport it to waterbodies in the dissolved state.

Flat Gulch was not listed in the 2012 303(d) List as being impaired for any metals parameter, however monitoring and assessment data has revealed that Flat Gulch is impaired for aluminum, and iron. Both iron and aluminum exceed the chronic aquatic life criteria, and therefore require TMDL development. The Flat Gulch water quality dataset includes 13 records from 4 monitoring sites (**Appendix M, Figure M-4** and **Table M-12**). All sites were established by DEQ monitoring and assessment efforts. Water samples were collected during high- and low-flow periods in 2004, 2009-2011.

TMDLs and Allocations

Example TMDLs and allocations for Flat Gulch are contained in **Table 8-18**. The allocation scheme developed for high flow aluminum in Flat Gulch is a composite load allocation to natural background (NB) and sediment sources (SS) of aluminum. Use of a composite allocation reflects the uncertainty in the background aluminum concentrations measured during high flows. The composite allocation for aluminum is expressed by the following equation

$$\mathbf{TMDL_{FG} = LA_{(FG\ NB\ +\ FG\ SS)}}$$

The allocations for low-flow aluminum and iron loading under both flow conditions include load allocations to natural background concentrations (**$LA_{FG\ NB}$**) and load allocations to unidentified human sources of these metals (**$LA_{FG\ UH}$**). Natural background loading represented by water analysis results from the sites listed in **Table 8-2**. This allocation scheme is reflected in the following TMDL equation:

$$\mathbf{TMDL_{FG} = LA_{(FG\ NB)} + LA_{(FG\ UH)}}$$

Table 8-18. Example TMDLs and wasteload allocation for Flat Gulch at site C02FLAT02

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	LA_{UH} (lbs/day)	Needed Reduction (%)
Aluminum	High flow	0.0329	50	0.0188	TMDLFG = 0.0329 lbs/day		0
	Low flow	0.0141	130	0.0210	0.0064	0.0076	47
Iron	High flow	0.3776	170	0.0641	0.0775	0.3002	0
	Low flow	0.1618	1370	0.2217	0.0097	0.1553	27

The load allocation to unidentified human influenced sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards and that application of BMPs to Flat Gulch unidentified human influenced sources will reduce loading so that TMDLs and water quality standards are met. The current dataset indicates that a 47% low-flow reduction is needed to meet the TMDL for Aluminum, and no reduction is needed under high-flow conditions. The current dataset also indicates that a 27% low-flow reduction is needed to meet the TMDL for Iron, and no reduction is needed under high-flow conditions.

The sediment metals analysis record consists of 3 samples; one samples each for sites C02FLAT01, C02FLAT02 and CO2FLAT10. All sediment samples contained less than the corresponding recommended PEL value. The sediment chemistry data do not indicate a pervasive sediment-bound source of metals loading to Flat Gulch.

8.7.6 Scotchman Gulch (MT76E002_100)

Loading Summary

Metals sources in Scotchman Gulch tend to be associated with local sources of sediment. The predominant sediment sources include past mining operations, livestock grazing and silvicultural practices. Past mining sources include two placer operations that are currently inactive. Livestock sediment sources include streambank trampling by domestic livestock. Silvicultural sources of sediment stem from timber harvesting and the associated road network in the upper portions of the drainage. Past placer mining and livestock grazing are the potential sediment sources in the upper reaches of the drainage. Some timber harvesting has occurred in the lower reaches of the forested portion of the drainage.

Scotchman Gulch was not listed in the 2012 303(d) List as being impaired for any metals parameter, however monitoring and assessment data has revealed that Scotchman Gulch is impaired for aluminum. Aluminum exceeds the chronic aquatic life criteria, and therefore requires the development of a TMDL. The Scotchman Gulch water quality dataset includes 13 records from 5 monitoring sites (**Appendix M, Figure M-5** and **Table M-15**). Scotchman Gulch exceeded the chronic aquatic life criteria four times. This provides an exceedance rate of 31% which is above the 10% threshold, requiring TMDL development. All sites were established by DEQ monitoring and assessment efforts. Water samples were collected during high- and low-flow periods in 2004, and 2009 through 2011.

TMDLs and Allocations

Example TMDLs and allocations for Scotchman Gulch are contained in **Table 8-19**. The allocation scheme developed for high flow aluminum in Scotchman Gulch is a composite allocation to natural background (NB), mining sources (MS) and sediment sources (SS) of aluminum. Use of a composite allocation reflects the uncertainty in the background aluminum concentrations measured during high flows. The composite allocation for high-flow aluminum is expressed by the following equation

$$\mathbf{TMDL_{SG} = WLA_{(SG\ NB\ +\ SG\ MS\ \&\ SS)}}$$

The composite allocation scheme states that the sum of allowable high-flow aluminum loading from natural background, plus sediment sources, is equal to the TMDL of 0.2441 lb/day under high-flow conditions. The TMDL equation for high-flow aluminum is inserted into **Table 8-19**.

The allocations for low-flow aluminum include load allocations to natural background concentrations ($\mathbf{LA_{SG\ NB}}$) and a wasteload allocation to sediment sources ($\mathbf{WLA_{SG\ SS}}$). Natural background loading is represented by water analysis results from the sites listed in **Table 8-2**.This allocation scheme is reflected in the following TMDL equation:

$$\mathbf{TMDL_{SG} = LA_{SG\ NB} + WLA_{SG\ SS}}$$

Table 8-19. Example TMDLs and wasteload allocation for Scotchman Gulch at site C02FLAT20

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	$WLA_{MS\ \&\ SS}$ (lbs/day)	Needed Reduction (%)
Aluminum	High flow	0.2441	140	0.5966	**TMDL = 0.2441 lbs/day**		59
	Low flow	0.2487	160	0.5092	0.1273	0.1213	68

The wasteload allocation to mining and sediment sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards and that application of BMPs to Scotchman Gulch sediment sources will reduce loading so that TMDLs and water quality standards are met. The current dataset for aluminum indicates that a 59% high-flow reduction and a 68% low-flow reduction is needed to meet the TMDL.

The sediment metals analysis record consists of 8 samples; two samples each for sites C02SCTMG01, C02SCTMG10, C02SCTMG02 and C02SCTMG03. All sediment samples contained less than the corresponding recommended PEL value. The sediment chemistry data do not indicate a pervasive sediment-bound source of metals loading to Scotchman Gulch.

8.7.7 Sluice Gulch (MT76E002_110)

Loading Summary

Metals sources in Sluice Gulch tend to be associated with abandoned mines and past mining activities. The predominant source of metals pollution includes two abandoned mining operations. Past mining operations include two abandoned gold and silver lode mines, the Silver king and Lori No. 13 mines. The Silver King is a former gold and silver lode mine occupying about 18 acres on the south flank of Sluice Gulch where the drainage enters the Upper Willow Creek valley. The Lori No. 13 mine disturbs about 9 acres on the north side of the gulch and is about 800 feet from Sluice Gulch surface water. Both the Silver King and Lori No. 13 are ranked as priority mine sites that have potential human health and safety hazards.

Sluice Gulch was listed in the 2012 303(d) List as being impaired for arsenic. The Sluice Gulch water quality dataset includes 8 records from 5 monitoring sites (**Appendix M, Figure M-3** and **Table M-9**). All 8 results for arsenic exceeded the human health criterion of 10 µg/L. Monitoring and assessment data has revealed that Sluice Gulch is impaired for copper as well. One in 8 results for copper exceeded the chronic aquatic life criterion. This provides an exceedance rate of 12.5% which is above the 10% threshold, requiring TMDL development. All sites were established by DEQ monitoring and assessment efforts. Water samples were collected during high- and low-flow periods in 2004, 2010 and 2011.

TMDLs and Allocations

Example TMDLs and allocations for Sluice Gulch are contained in **Table 8-20**. The allocations for arsenic and copper under both flow conditions include load allocations to natural background concentrations (**LA** $_{SLG\ NB}$) and a wasteload allocation to mining sources (**WLA** $_{SLG\ MS}$). Natural background loading to Sluice Gulch is represented by water analysis results from the sites listed in **Table 8-2**. This allocation scheme is reflected in the following TMDL equation:

$$\mathbf{TMDL = LA_{SLG\ NB} + WLA_{SLG\ MS}}$$

Table 8-20. Example TMDLs and wasteload allocation for Sluice Gulch at site C02SLUG01

Metal	Flow Conditions	TMDL (lbs/day)	Existing Metal Concentration (µg/L)	Existing Load (lbs/day)	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)	Needed Reduction (%)
Arsenic	High flow	0.0755	12	0.0906	0.0113	0.0642	17
	Low flow	0.0647	11	0.0712	0.0065	0.0582	9
Copper	High flow	0.0956	4	0.0302	0.0038	0.0918	0
	Low flow	0.0844	0.5	0.0032	0.0032	0.0812	0

The wasteload allocation to mining sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme assumes that natural background loading rates do not exceed water quality standards and that application of BMPs to Sluice Gulch mining related sources will reduce loading so that TMDLs and water quality standards are met. The current dataset for arsenic indicates that a 17% high-flow reduction and 9% low-flow reduction is needed to meet the TMDL. Even though **Table 8-20** shows copper currently meeting the TMDL with an overall reduction of 0% for both flow conditions, Sluice Gulch does require a reduction in copper loading at times not represented by **Table 8-20**. This is because the example TMDL presented in **Table 8-20** is calculated based on the highest flow and corresponding pollutant concentration. By following this selection criterion, it leads to the copper aquatic life exceedance contained in the dataset to not be represented in the example TMDL.

The sediment metals analysis record consists of 4 samples; one samples each for sites C02SLUCG01, C02SLUCG10, C02SLUCG02 and C02SLUCG03. Sediment chemistry samples from 3 of 4 sites exceeded the PEL values for arsenic in fresh water stream sediment. The magnitude of arsenic exceedance increases downstream. Measured copper sediment metals concentrations were below the PEL. The sediment chemistry data do not indicate a pervasive sediment-bound source of copper loading to Sluice Gulch.

8.8 Seasonality and Margin of Safety

All TMDL documents must consider seasonal variability on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and load allocations. TMDL development must also incorporate a margin of safety into the load allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. This section describes the considerations of seasonality and a margin of safety in the Rock Creek TPA metal TMDL development process.

8.8.1 Seasonality

Seasonality addresses the need to ensure year round designated use support. Seasonality was considered for assessing loading conditions and for developing water quality targets, TMDLs, and allocation schemes. For metals TMDLs, seasonality is important because metals loading pathways and water hardness change from high to low flow conditions. During high flows, loading associated with overland flow and erosion of metals-contaminated soils and mine wastes tend to be the major cause of elevated metals concentrations. During low flow, groundwater transport and/or adit discharges tend to be the major source of elevated metals concentrations. Hardness tends to be lower during higher flow conditions, which leads to lower water quality standards for hardness-dependent metals during the runoff season. Seasonality is addressed in this document as follows:

- Metals concentrations and loading conditions are evaluated for both high flow and low flow conditions.
- Metals TMDLs incorporate streamflow as part of the TMDL equation.
- Metals targets apply year round, with monitoring criteria for target attainment developed to address seasonal water quality extremes associated with loading and hardness variations.
- Targets, TMDLs and load reduction needs are developed for high and low flow conditions.

8.8.2 Margin of Safety

The margin of safety is to ensure that TMDLs and allocations are sufficient to sustain conditions that will support beneficial uses. All metals TMDLs incorporate an implicit MOS in several ways. The implicit margin of safety is applied by using conservative assumptions throughout the TMDL development process and is addressed by the following:

- Target attainment, refinement of load allocations, and, in some cases, impairment validations and TMDL-development decisions are all based on an adaptive management approach that relies on future monitoring and assessment for updating planning and implementation efforts.

- The monitoring results used to estimate existing water quality conditions are instantaneous measurements used to estimate daily load, whereas chronic aquatic life standards are based on average conditions over a 96 –hour period. This provides a margin of safety since a four day loading limit could potentially allow higher daily loads in practice
- The lowest or most stringent numeric water quality standard was used for TMDL target and impairment determinations for all waterbody-pollutant combinations. This ensures protection of all designated beneficial uses.
- The TMDLs are based on numeric water quality standards developed at the national level via EPA and incorporate a margin of safety necessary for the protection of human health and aquatic life.
- Sediment metals concentration criteria were used as a supplemental indicator target. This helps ensure that episodic loading events were not missed as part of the sampling and assessment activity.

8.9 Uncertainty and Adaptive Management

The environmental studies required for TMDL development include inherent uncertainties for example: accuracy of field and laboratory data, of source assessments, and of loading calculations. An adaptive management approach that revisits, confirms, or updates loading assumptions is vital to maintaining stakeholder confidence and participation in water quality improvement. Adaptive management uses updated monitoring results to refine loading analysis, to further customize monitoring strategies and to develop a better understanding of impairment conditions and the processes that affect impairment. Adaptive management recognizes the dynamic nature of pollutant loading and water quality response to remediation.

Data quality concerns are managed and mitigated by DEQ's data quality objective (DQO) process. The use of DQOs ensures that decisions are based on data of known (and acceptable) quality. The DQO process develops criteria for data performance and acceptance that:

- Clarify study intent
- Define the appropriate type of data
- Establish minimum requirements for the quality and quantity of data necessary to meet the goals of a study

Adaptive management also allows for continual feedback on the progress of restoration and the status of beneficial uses. With it we can refine targets as necessary to protect the resource or re-evaluate whether targets are achievable. Such additional monitoring and resulting refinements to loading can improve achieving and measuring success.

The water quality targets and associated metals TMDLs developed are based on future attainment of water quality standards. In order to achieve attainment, all significant sources of metal loading must be addressed via all reasonable land, soil, and water conservation practices. It is recognized however, that in spite of all reasonable efforts, attainment of water quality targets may not be possible due to natural sources or the presence of unalterable human-caused sources. For this reason, an adaptive management approach is adopted for all metals targets described within this document. Under this adaptive management approach, all metals identified in this plan as requiring TMDLs will ultimately fall into one of the categories identified below:

- Implementation of remediation and restoration activities resulting in full attainment of restoration targets for all parameters;
- Implementation of remediation and restoration activities fails to result in target attainment due to underperformance or ineffectiveness of restoration actions. Under this scenario the waterbody remains impaired and will require further restoration efforts associated with the pollutants of concern. The target may or may not be modified based on additional information, but conditions still exist that require additional pollutant load reductions to support beneficial uses and meet applicable water quality standards. This scenario would require some form of additional, refocused restoration work.
- Implementation of restoration activities fails to result in target attainment, but target attainment is deemed unachievable even though all applicable monitoring and restoration activities have been completed. Under this scenario, site-specific water quality standards and/or the reclassification of the waterbody may be necessary. This would then lead to a new target (and TMDL) for the pollutant(s) of concern, and the new target could either reflect the existing conditions at the time or the anticipated future conditions associated with the restoration work that has been performed.
- The water quality targets and TMDL are unattainable due to natural sources. Under this scenario, site-specific water quality standards and/or the reclassification of the waterbody may be necessary. This would then lead to a new target (and TMDL) for the pollutant(s) of concern, and the new target would reflect the background condition.

The Abandoned Mines Section of DEQ's Remediation Division will lead abandoned mine restoration projects funded by provisions of the Surface Mine Reclamation and Control Act of 1977. DEQ's Federal Superfund Bureau (also in the Remediation Division) will provide technical and management assistance to EPA for remedial investigations and cleanup actions at national priorities list mine sites in federal-lead status.

Monitoring and restoration conducted by other parties (USFS, BLM, the Montana Department of Natural Resources and Conservation's Trust Lands Management Division, The Nature Conservancy) should be incorporated into the target attainment and review process as well. Cooperation among agency land managers in the adaptive management process for metals TMDLs will help identify further cleanup and load reduction needs, evaluate monitoring results, and identify water quality trends. There are a number of approaches for cleanup of mining operations or other sources of metals contamination in the State of Montana. Several are mentioned above others (along with associated funding options) are discussed in depth in **Appendix N**.

DEQ acknowledges that construction or maintenance activities related to restoration, construction/maintenance, and future development may result in short term increase in surface water metals concentrations. For any activities that occur within the stream or floodplain, all appropriate permits should be obtained prior to work. Federal and State permits necessary to conduct work within a stream or stream corridor are intended to protect the resource and reduce or eliminate, pollutant loading or degradation from the permitted activity. The permit requirements typically have mechanisms that allow for some short term impacts to the resource, as long as all appropriate measures are taken to reduce impact to the least amount possible.

9.0 Other Identified Issues or Concerns

9.1 Non-Pollutant Listings

Water quality issues are not limited simply to those streams where TMDLs are developed. In some cases, streams have not yet been reviewed through the assessment process and do not appear on the 303(d) list. In other cases, streams in the Rock Creek TPA may appear on the 303(d) list but may not always require TMDL development for a pollutant, but do have non-pollutant listings such as “alteration in streamside or littoral vegetation covers” that could be linked to a pollutant. These habitat related non-pollutant causes are often associated with sediment issues, may be associated with nutrient or temperature issues, or may be having a deleterious effect on a beneficial use without a clearly defined quantitative measurement or direct linkage to a pollutant to describe that impact. Nevertheless, the issues associated with these streams are still important to consider when improving water quality conditions in individual streams, and the Rock Creek watershed as a whole. In some cases, pollutant and *non-pollutant* causes are listed for a waterbody, and the management strategies as incorporated through the TMDL development for the pollutant, inherently address some or all of the non-pollutant listings. **Table 9-1** presents only the *non-pollutant* listings in the Rock Creek TPA. Streams for which no TMDLs have been developed are presented in bold italics.

Table 9-1. Waterbody Segments in the Rock Creek TPA with Non-pollutant (Pollution) Listings on the 2012 303(d) List

Waterbody ID	Stream Segment	2012 Probable Causes of Impairment
MT76E002_080	***BASIN GULCH,*** *headwaters to mouth (Eureka Gulch)*	Alteration in streamside or littoral vegetative covers
MT76E002_050	***BREWSTER CREEK***, *East Fork to mouth (Rock Creek)*	Fish Passage Barrier
		Low Flow Alterations
MT76E002_020	EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)	Alteration in streamside or littoral vegetative covers
		Low Flow Alterations
		Chlorophyll-*a*
MT76E002_090	EUREKA GULCH, confluence of Quartz Gulch and Basin Gulch to mouth (Un-Named Ditch)	Alteration in streamside or littoral vegetative covers
MT76E002_070	QUARTZ GULCH, headwaters to mouth (Eureka Gulch)	Alteration in streamside or littoral vegetative covers
MT76E002_110	SLUICE GULCH, headwaters to mouth (Rock Creek)	Alteration in streamside or littoral vegetative covers
MT76E002_060	SOUTH FORK ANTELOPE CREEK, headwaters to mouth (Antelope Creek), T6N R15W S22	Alteration in streamside or littoral vegetative covers
MT76E002_040	***UPPER WILLOW CREEK***, *headwaters to mouth (Rock Creek)*	Alteration in streamside or littoral vegetative covers
		Low Flow Alterations
		Physical Substrate

9.2 Non-Pollutant Causes of Impairment Determination

Non-pollutant listings are often used as a probable cause of impairment when available data at the time of assessment does not necessarily 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 cause listings, however a non-pollutant category may appear independent of a pollutant listing. 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 or remediation.

Alteration in Streamside or Littoral Vegetation Covers
Alteration in streamside or littoral vegetation 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. This may include riparian vegetation removal for a road or utility corridor, effects of streamside mine tailings or placer mining remnants, 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 overwidened stream channel conditions and elevated sediment loads, in addition to elevated stream temperature from loss of canopy shade.

Physical Substrate Habitat Alterations
Physical substrate habitat alterations generally describe cases where the stream channel has been physically altered or manipulated, such as through the straightening of the channel or from 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 through placer mine operations.

Fish Passage Barrier
Impairment caused by fish passage barriers is most often related to channel obstacles such as impoundments or perched culverts at road crossings. The impairments are addressed by modification or removal of the barriers or operational changes to allow migration of fish and other aquatic life. Any fish barrier removal must be done in coordination with state and federal fishery representatives since fish passage barriers can beneficially isolate native fish populations, protecting them from non-native invasive species.

In the Rock Creek watershed toxic barriers due to mine discharge may create another form of fish barrier. Toxic barriers may isolate native fish species from non-native fish species, interrupt spawning or seasonal migrations, restrict access to preferred habitats and food resources, increase the chance of predation and disease and reduce genetic flow between populations through population fragmentation Future projects to address toxic stream conditions should incorporate necessary barrier construction or other methods to maintain appropriate fish movement. For example, mine reclamation work could be conducted in a manner to improve distribution of native fish species while maintaining isolated fisheries upstream of the toxic reach of stream.

Low Flow Alterations
Streams are typically listed for low flow alterations when local water use management leads to base flows that are too low to fully support the beneficial uses designated for that system. This could result in dry channels or extreme low flow conditions harmful to fish and aquatic life.

Other Flow Regime Alterations
Other flow regime alterations may refer to scenarios where land or water management has led to flows that would not be typical under naturally occurring flow conditions. This could be related to irrigation

practices, or dam release operations, or even groundwater use that has subsequently altered stream recharge.

It should be noted that while Montana law states that TMDLs cannot impact Montana water rights and thereby affect the allowable flows at various times of the year, the identification of low flow alterations or other flow regime alterations as a probable source of impairment does not violate any state or federal regulations or guidance related to stream assessment and beneficial use determination. Subsequent to the identification of this as a probable cause of impairment, it is up to local users, agencies, and entities to improve flows through water and land management.

Chlorophyll-*a*/Excess Algal Growth

These 2 terms are interchangeable as they identify an impairment of a beneficial use to primary contact recreation from algal growth in the stream channel. Excess algal growth refers to the often visual identification of impairment from phytoplankton/algal growth while chlorophyll-*a* is a direct measure of plant productivity. The most abundant form of chlorophyll within photosynthetic organisms, chlorophyll-*a* is used as a surrogate measure of net primary production in a stream. It is used as a measurement of the population and distribution of microscopic living plant matter (phytoplankton or algae) in a stream reach. Chlorophyll monitoring is a way to track algal growth. In surface waters high chlorophyll concentrations are often correlated with high nutrient concentrations such as nitrogen and phosphorus which can cause algal blooms. When an algal bloom dies off at the end of its life cycle or due to a change in environmental conditions, the resulting decomposition depletes dissolved oxygen (DO) levels in the water column. A loss of DO can lead to fish kills. High nutrient concentrations can be indicative of fertilizer/manure runoff, impacts from silvicultural practices, an impacts from disturbed ground surface associated with mining. Chlorophyll-*a* can therefore be used as an indirect measure of nutrient levels. For both descriptors, chlorophyll-*a* and excess algal growth indicate an oversupply of nutrients to the system.

9.3 Monitoring and BMPs for Non-Pollutant Affected Streams

Two forms of habitat alteration (alteration in streamside or littoral vegetation covers and physical substrate habitat alterations) can be linked to the sediment TMDL development, where there is overlap between the two. It is likely that meeting the sediment targets will also equate to addressing the habitat impairment conditions in each of these streams. For the streams with no developed TMDL, meeting the sediment targets applied to streams of similar size will likely equate to addressing the habitat impairment condition for each stream.

Streams listed for *non-pollutants* as opposed to a pollutant should not be overlooked when developing watershed management plans. Attempts should be made to collect sediment, nutrient, and temperature information where data is minimal and the linkage between probable cause, non-pollutant listing, and effects to the beneficial uses are not well defined. Watershed management planning should also include strategies to help increase streamflows, particularly during summer low flow periods for those streams with low flow alteration impairment causes. The monitoring and restoration strategies that follow in **Sections 10.0** and **11.0** are presented to address both pollutant and non-pollutant issues for streams in the Rock Creek TPA with TMDLs in this document, and they are equally applicable to streams listed for the above non-pollutant categories.

10.0 Water Quality Improvement Plan

10.1 Summary of Restoration Strategy

This section describes an overall strategy and specific on-the-ground measures designed to restore beneficial water uses and attain water quality standards in Rock Creek TMDL project area streams. The strategy includes general measures for reducing loading from each significant identified pollutant source.

This section should assist stakeholders in developing a more detailed adaptive Watershed Restoration Plan (WRP) in the future. The locally-developed WRP will likely provide more detailed information about restoration goals and spatial considerations within the watershed. The WRP may also encompass broader goals than the focused water quality restoration strategy outlined in this document. The intent of the WRP is to serve as a locally organized "road map" for watershed activities, sequences of projects, prioritizing types of projects, and funding sources towards achieving local watershed goals, including water quality improvements. Within this plan, the local stakeholders would identify and prioritize streams, tasks, resources, and schedules for applying Best Management Practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

10.2 Role of DEQ, Other Agencies, and Stakeholders

The DEQ does not implement TMDL pollutant reduction projects for nonpoint source activities, but can provide technical and financial assistance for stakeholders interested in improving their water quality. The 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 can 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 to meet TMDL targets and load reductions. Specific stakeholders and agencies that will likely be vital to restoration efforts for streams discussed in this document include the Granite Conservation District, USFS, USFWS, NRCS, DNRC, FWP, EPA, and DEQ. Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include the Clark Fork Coalition, Rock Creek Protective Association, Montana Trout Unlimited, Montana Water Trust, Montana Water Center, University of Montana Watershed Health Clinic, Montana Bureau of Mines and Geology, Montana Aquatic Resources Services (MARS), and MSU Extension Water Quality Program.

10.3 Water Quality Restoration Objectives

The following are general water quality goals provided in this TMDL document:

- Provide general technical guidance for full recovery of aquatic life beneficial uses to all impaired streams within the Rock Creek TPA by improving pollutant and non-pollutant related water quality conditions. This technical guidance is provided by the TMDL components in the document which include:
    - water quality targets,

- pollutant source assessments, and
- a broad restoration and TMDL implementation strategy to meet TMDL allocations

A watershed restoration plan (WRP) can provide a framework strategy for water quality restoration and monitoring in the Rock Creek TPA, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document, as well as other water quality issues of interest to local communities and stakeholders. Watershed restoration plans identify considerations that should be addressed during TMDL implementation and should assist stakeholders in developing a more detailed adaptive plan in the future. A locally developed WRP will likely provide more detailed information about restoration goals and spatial considerations but may also encompass more broad goals than this framework includes. A WRP would serve as a locally organized “road map” for watershed activities, sequences of projects, prioritizing of projects, and funding sources for achieving local watershed goals, including water quality improvements. The WRP is intended to be a living document that can be revised based on new information related to restoration effectiveness, monitoring results, and stakeholder priorities. The following are key elements suggested for the WRP:

- Support for implementing restoration projects to protect water conditions so that all streams and aquatic resources in the watershed maintain good water quality, with an emphasis on waters with TMDLs completed.
- Detailed cost/benefit analysis and spatial considerations for water quality improvement projects.
- Develop an approach for future BMP installment and efficiency results tracking.
- Provide information and education components to assist with stakeholder outreach about restoration approaches, benefits, and funding assistance.
- Other various watershed health goals, such as weed control initiatives and wetland restoration.
- Other local watershed based issues.

Water quality goals for the various pollutants are detailed in **Sections 5, 6, 7, and 8.** These goals include water quality and habitat targets as a measure for long-term effectiveness monitoring. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of waterbodies in the Rock Creek TPA. It is presumed that the meeting of all water quality and habitat targets will signal the achievement of water quality goals for a given stream. **Section 11** identifies a general monitoring strategy and recommendations to track post-implementation water quality conditions and measure restoration successes.

10.4 Overview of Management Recommendations

TMDLs were completed for ten waterbody segments for sediment, one waterbody segment for temperature, five waterbody segments for nutrients, and seven waterbody segments for metals. Other streams in the watershed may be in need of restoration or pollutant reduction, but insufficient information about them precludes TMDL formation at this time. The following sub-sections describe some generalized recommendations for implementing projects to achieve the TMDL. Details specific to each stream, and therefore which of the following strategies may be most appropriate, are found within **Section 5, 6, 7** and **8**.

10.4.1 Sediment Restoration Approach

Streamside riparian and wetland vegetation restoration and long term riparian area and wetland management are vital restoration practices that must be implemented across the watershed to achieve 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 filters pollutants from upland runoff. Therefore, improving riparian and wetland vegetation will decrease bank 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.

Riparian and wetland disturbance has occurred throughout the Rock Creek TPA as a result of many influencing factors. Riparian timber harvest and the conversion of forest and valley bottoms for agriculture, mining, livestock production, and residential development have all had varying degrees of impact, depending on the drainage. 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, restoration of streams affected by mining activity, and floodplain and streambank stabilization and revegetation efforts where necessary. In general, natural recovery of disturbed systems is preferred however it is acknowledged that existing conditions may not readily allow for unassisted recovery in some areas where disturbance has occurred. Active vegetation planting and bank or stream channel reshaping may increase costs, but may be a reasonable and relatively cost effective restoration approach, depending on the site. When stream channel restoration work is needed because of altered stream channels, cost increases and projects should be assessed on a case by case basis. The implementation of BMPs should aim to prevent the availability, transport, and delivery of a pollutant through the most natural or natural-like means possible. Appropriate BMPs will differ by location and are recommended to be included and prioritized as part of a comprehensive watershed scale plan (e.g. WRP).

Although 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 should be to divert water off of roads and 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 and upkeep of unpaved roads is a crucial component to limiting sediment production from roads. Sediment loads from culvert failure and culvert caused scour were not assessed by the TMDL source assessment, but should be considered in road sediment restoration approaches.

Assistance from resource professionals from various local, state, and federal agencies or non-profit groups should be available in the Rock Creek TPA. In particular, the Granite Conservation Districts and the NRCS are two resources that are valuable aids for assisting with investigating, developing, and implementing measures to improve conditions in the Rock Creek watershed.

10.4.2 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 mechanisms for reducing water temperature are increasing shade and increasing flow. Secondarily, recovery of overwidened stream channels to a more natural morphology 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.

Increasing instream summer flows 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 instream. 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 assessment 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 be made through increased shade and flow, 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 basin need to change their practices in order 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 continued investigations be conducted by resource managers and land owners to identify all potential areas of improvement and develop projects and practices to reduce stream temperatures in East Fork Rock Creek.

10.4.3 Nutrients Restoration Approach

The goal of the nutrient restoration strategy is to reduce nutrient input to stream channels by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, and limiting the transport of nutrients from rangeland , cropland and historically impacted areas (mining).

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

- The timing and duration of near-stream grazing
- The spacing and exposure duration of on-stream watering locations
- Provision of off-stream site watering areas to minimize near-stream damage and allow impoundment operations that minimize salt accumulations
- Active reseeding and rest rotation of locally damaged vegetation stands
- Improved management of irrigation systems and fertilizer applications
- Incorporation of streamside vegetation buffer to irrigated croplands and animal feeding areas

In addition to the agricultural related BMPs, a reduction of sediment delivery from roads and eroding streambanks is another component of the nutrient reduction restoration plan. Additional sediment related BMPs are presented in **Section 10.5.**

In general, these are sustainable grazing and cropping practices that can reduce nutrient inputs while meeting production goals. The appropriate combination of BMPs will differ according to landowner preferences and equipment but are recommended as components of comprehensive plan for farm and ranch operators. Sound planning combined with effective conservation BMPs should be sought whenever possible and applied to croplands, pastures and livestock handling facilities. Assistance from resource professionals from various local, state, and federal agencies or non-profit groups is widely available in Montana. The local USDA Service Center and county conservation district offices are geared to offer both planning and implementation assistance.

Potential nutrient loading sources associated with historical mining practices include discharging mine adits and mine waste materials on-site and in-channel. The goal of the nutrient restoration strategy is to limit the input of nutrients to stream channels from abandoned mine sites and other mining related sources. For most of the mining-related sources, additional analysis and identification will likely be required to identify site-specific delivery pathways and to develop mitigation plans.

Goals and objectives for future restoration work include the following:

- Prevent contaminants or nutrients contaminated solid materials in the waste rock and tailings materials/sediments from migrating into adjacent surface waters to the extent practicable
- Reduce or eliminate concentrated runoff and discharges that generate sediment and/or heavy contamination to adjacent surface waters and groundwater to the extent practicable
- Identify, prioritize, and select response and restoration actions based on a comprehensive source assessment and streamlined risk analysis of areas affected by historical mining.

10.4.4 Metals Restoration Approach

Metal mining is the principal human-caused source of excess metals loading in the planning area. To date, federal and state government agencies have funded and completed reclamation projects associated with past mining. Statutory mechanisms and corresponding government agency programs will continue to have the leading role for future restoration. Restoration of metals sources is typically conducted under state and federal cleanup programs. Rather than a detailed discussion of specific BMPs, general restoration programs and funding sources applicable to mining sources of metals loading are provided in **Section 10.5.6.** Past efforts have produced abandoned mine site inventories with enough descriptive detail to prioritize the properties contributing the largest metals loads. Additional monitoring needed to further describe impairment conditions and loading sources is addressed in the **Section 11.3.1**

10.4.5 Pollution Restoration Approach

Although TMDL development is not required for pollution listings, they are frequently linked to pollutants, and addressing pollution sources is an important component of TMDL implementation. Pollution listings within the Rock Creek TPA are described in **Section 9.0**. Typically, habitat impairments are addressed during implementation of associated pollutant TMDLs. Therefore, if restoration goals within the Rock Creek TPA are not also addressing pollution impairments, additional pollution-related BMP implementation should be considered.

10.5 Restoration Approaches by Source

Generalized management recommendations are outlined below for the major sources of human caused pollutant loads in the Rock Creek TPA: grazing, upland sources, riparian and wetland vegetation removal, irrigation, roads and historical mining practices. Applying BMPs are the core of the 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 an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is also an important part of the restoration process. Monitoring recommendations are outlined in **Section 11.0**.

10.5.1 Agriculture Sources

Reduction of pollutants from upland agricultural sources can be done 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 Rock Creek watershed 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 stripcropping (although currently there is very little cropping activity that occurs in the Rock Creek watershed). 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 (Montana Department of Environmental Quality, 2012d).

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 MT 590-1):

- 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 designated sensitive areas
- Guidelines for operation and maintenance

10.5.1.1 Grazing

Development of riparian grazing management plans should be a goal for any landowner in the watershed 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 necessary eliminate all grazing in riparian corridors. Nevertheless, in some areas, a more limited management strategy may be necessary for a period of time in order to accelerate re-establishment of a riparian community with the most desirable species composition and structure.

Every livestock grazing operation should have a grazing management plan. The plan should at least include the following elements:

- 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 to prevent ‘loafing’ in riparian areas
- 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

The following resources may be able to help you prevent pollution and maximize productivity from your grazing operation:

- USDA, Natural Resources Conservation Service. You can find your local USDA Agricultural Service Center listed in your phone directory or on the Internet at www.nrcs.usda.gov
- Montana State University Extension Service www.extn.msu.montana.edu
- DEQ Watershed Protection Section, Nonpoint Source Program www.deq.mt.gov/wqinfo/nonpoint/NonpointSourceProgram

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 Rock Creek watershed 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.

10.5.1.2 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 (United States Department of Agriculture, Natural Resources Conservation Service, 2005). This strategy encouraged owners of AFOs of any size or 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). CAFOs 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, 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 to 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 (United States Department of Agriculture, Natural Resources Conservation Service, 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. Studies have shown benefits in red meat and milk production of 10 to 20 percent by livestock and dairy animals when good quality drinking water is substituted for contaminated surface water.

Opportunities for financial and technical assistance (including CNMP development) in achieving voluntary AFO and CAFO compliance may be available from conservation districts, NRCS field offices, or the Montana DEQ Watershed Protection Section (among other sources). Further information on CAFO discharge permitting may be obtained from the DEQ website at:
www.deq.mt.gov/wqinfo/mpdes/cafo.mcpx

Montana's Nonpoint Source (NPS) pollution control strategies for addressing AFOs are summarized in the bullets below:

- Work with producers to prevent NPS pollution from AFOs.

- Promote use of State Revolving Fund for implementing AFO BMPs.
- Collaborate with 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 & 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.

10.5.1.3 Flow and Irrigation

Flow alteration 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 sediment 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). Restoration targets and 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 State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (MCA 75-5-705).

Irrigation management is a critical component of attaining both coldwater fishery conservation and TMDL goals. In the Rock Creek watershed, irrigation management is complicated by a diversion in East Fork Rock Creek for use in the Flint Creek watershed. Management practices for irrigation efficiency in the Rock Creek and Flint Creek watersheds should investigate reducing 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, August, and September. Understanding irrigation water, groundwater and surface water interactions is an important part of understanding how irrigation practices will affect streamflow during specific seasons.

Some irrigation practices in western Montana are based in flood irrigation methods. Occasionally, head gates and ditches leak, which can decrease the amount of water in diversion flows. The following recommended activities could 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) to increase ditch conveyance efficiency.

Future studies could investigate irrigation water return flow timeframes from specific areas in both the Rock Creek and Flint Creek watersheds. 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.

10.5.1.4 Small Acreages

Throughout Montana, the number of small acreage properties is growing rapidly, and many small acreage owners own horses or cattle. Animals grazing in 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 agricultural organizations to develop management plans for their lots. Further information may be obtained from the Montana Nonpoint Source Management Plan (Montana Department of Environmental Quality, 2012d) or the MSU extension website at: http://www.msuextension.org/ruralliving/Index.html.

10.5.1.5 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 Rock Creek TPA are vegetated filter strips (VFS) and riparian buffers. Both of these 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 percent for the filter strips and 50 percent for the buffers (Montana Department of Environmental Quality, 2012d). 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 NPS Management Plan (Montana Department of Environmental Quality, 2012d).

10.5.2 Forestry and Timber Harvest

Currently, active timber harvest is not significantly affecting sediment in the Rock Creek TPA. While no nutrient load allocations were allocated directly to timber harvests, a composite nutrient load allocation consisting of agricultural and silvicultural practices were allocated to the South Fork of Antelope Creek. Timber harvesting will likely continue in the future within the Beaverhead-Deer Lodge National Forest, and on private land. Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (Montana State University, Extension Service, 2001) and the Montana Streamside Management Zone (SMZ) Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e. within 50 feet of a waterbody), the riparian protection principles behind the law can be applied to numerous land management activities (i.e. timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. The DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

In addition to the BMPs identified above, effects that timber harvest may have on yearly streamflow levels, such as peak flow, should be considered. Water yield and peak flow increases should be modeled in areas of continued timber harvest and potential effects should be evaluated. Furthermore, noxious weed control should be actively pursued in all harvest areas and along all forest roads.

10.5.3 Riparian Areas, Wetlands, and Floodplains

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 the above named functions is dependent on the connectivity of riparian areas, wetlands and floodplains to both the stream channel and upland areas. Anthropogenic 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 Rock Creek TPA.

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 of passive BMPs that allow riparian and wetland vegetation to recover at natural rates is typically the most cost-effective approach, active restoration (i.e. 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.

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.

- Harvest and transplant locally available sod mats with an existing dense root mass which provide immediate promotion of bank stability and filtering nutrients and sediments.
- 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.
- 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.
- 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 noted 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.

10.5.4 Unpaved Roads

The road sediment reductions in this document represent a gross estimation of the sediment load that would remain once road BMPs were applied, assuming no current BMPs are in place. In general, a road with associated BMPs assumes contributing road treads, cutslopes, and fillslopes were reduced to 100 feet (from each side of a crossing). 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 100ft 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 NPS Management Plan (Montana Department of Environmental Quality, 2012d). Examples include:

- Providing adequate ditch relief up-grade of stream crossings.
- Constructing waterbars, where appropriate, and up-grade of stream crossings.
- Use rolling dips on downhill grades with an embankment on one side to direct flow to the ditch.
- Inslope roads along steep banks with the use of cross slopes and cross culverts.
- Outslope low traffic roads on gently sloping terrain with the use of a cross slope.
- Use 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.
- Prevent disturbance to vulnerable slopes.
- Use 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.

10.5.4.1 Culverts

Although there are a lot of factors associated with culvert failure and it is difficult to estimate the true at-risk load, the culvert analysis found that approximately 56% of the culverts pass the discharge of a 25-year storm event. The allocation strategy for culverts is no loading from culverts as a result of being undersized, improperly installed, or inadequately maintained. The culvert assessment included 27 culverts in the watershed, which is a small percentage of the total culverts, and it is recommended that the remaining 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. In a coarse assessment of fish passage, 96% of assessed culverts were determined to pose a significant passage risk to juvenile fish at all flows; this suggests that a large percentage of culverts in the watershed are barriers to fish passage. Each 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 FWP can aid in determining if a fish passage barrier should be mitigated, and, if so, can aid in culvert design.

10.5.4.2 Traction Sand

Severe winter weather and mountainous roads in the Rock Creek TPA 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 the extent practicable. The necessary BMPs may vary throughout the watershed and particularly between state and private roads but may include the following:

- Utilize a snow blower to directionally place snow and traction sand on cutslopes/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 MDT 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.

10.5.5 Bank Hardening/Riprap/Revetment/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 is necessary in some instances, it generally redirects channel energy and exacerbates erosion in other places. Bank armoring should be limited to areas with a demonstrated threat to infrastructure. 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 land use planning initiatives.

Bank stabilization using natural channel design techniques can provide both bank stability and 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.

10.5.6 Mining

Mining activities may have impacts that extend beyond increased metal concentrations in the water. Channel alteration, riparian degradation, and runoff and erosion associated with mining can lead to sediment, habitat, nutrient, and temperature impacts as well. The need for further characterization of impairment conditions and loading sources is addressed through the framework monitoring plan in **Section 11.3.1**.

A number of state and federal regulatory programs have been developed over the years to address water quality problems stemming from historic mines, associated disturbances, and metal refining impacts. Some regulatory programs and approaches that may be applicable to the Rock Creek watershed include:

- The State of Montana Mine Waste Cleanup Bureau's Abandoned Mine Lands (AML) Reclamation Program,
- The Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA), which incorporates additional cleanup options under the Controlled Allocation of Liability Act (CALA) and the Voluntary Cleanup and Redevelopment Act (VCRA).

10.5.6.1 The Surface Mining Control and Reclamation Act (SMCRA)

DEQ's Abandoned Mines Bureau (AMB) is responsible for reclamation of abandoned mines in Montana. The AMB reclamation program is funded through the Surface Mining Control and Reclamation Act of 1977 (SMCRA). SMCRA funding is collected as a per ton fee on coal production that is then distributed to states by the federal Office of Surface Mining Reclamation and Enforcement (OSM). Funding eligibility is based on land ownership and date of mining disturbance. Eligible abandoned coal mine sites have a priority for reclamation construction funding over eligible non-coal sites. Areas within federal Superfund sites and areas where there is a reclamation obligation under state or federal laws are not eligible for expenditures from the abandoned mine reclamation program. **Table 10-1** lists the priority abandoned mines in the Rock Creek TMDL planning area.

Table 10-1. Priority Abandoned Mine Sites in the Rock Creek TMDL Planning Area.

Site Name	Receiving Stream	Disturbance Area (acres)	Current Ranking Score
Alps	Brewster Creek	14	79
Banner Creek Tailings	Middle Fork Rock Creek	7	59
Millers Mine	Middle Fork Rock Creek	13	65
Old Dominion Mine	Middle Fork Rock Creek	14	83
Silver King	Sluice Gulch	18	34
Ant	South Fork Antelope Creek	20	82
Lori 13	Sluice Gulch	10	NA*

*Lori 13 Mine is listed on the Abandoned Hard Rock Mine Priority Sites 1995 Summary Report; however it was considered to not have significant human health or safety issues and was not given a ranking

10.5.6.2 Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA)

Reclamation of past mining-related disturbances administered by the State of Montana and not addressed under SMCRA, are typically addressed through the DEQ State Superfund program. The Comprehensive Environmental Cleanup and Responsibility Act (CECRA) passed the Montana Legislature in 1989 as a means to require cleanup of hazardous substance releases threatening human health and the environment. The CECRA program maintains a prioritized list of facilities potentially requiring response actions based on the confirmed or threatened release of a hazardous or deleterious substance.

CECRA encourages voluntary cleanup activities under the Voluntary Cleanup and Redevelopment Act (VCRA) that recommended a method of apportioning site liability and created a fund for cleanup of sites where a responsible party has not been identified. Mining-related metals loading sources identified in the future could be added to the CECRA list and addressed through CECRA, with or without the VCRA processes. A site can be added to the CECRA list at DEQ's initiative, or in response to a complete written request made to the department by any person. Currently, there is one active site on the CECRA priority list in the Rock Creek TPA:

The Neal Family Limited Partnership (Silver King Mine); located about a 1/2 mile up gradient of Rock Creek in Sluice Gulch. This site was added to the Comprehensive Environmental Response, Compensation, and Liability Act list based preliminary assessments conducted by the Bureau of Land Management in 1986 found elevated iron in the surface water of Sluice Gulch; slightly elevated copper, iron, manganese and zinc in the adit discharge water; and high arsenic and antimony and somewhat elevated copper, mercury, manganese and lead in tailings and waste rock piles. CECRA's future involvement at the site will depend upon whether or not the site is eligible for cleanup under DSL's reclamation program.

The goal of the metals restoration strategy is to limit the input of metals to streams from priority abandoned mine sites and other significant sources. Additional analysis will likely be required to describe site-specific metals delivery pathways and to develop mitigation plans. The following goals and objectives apply to future restoration of most mining-related sources:

- Prevent soluble metal contaminants or metals contaminated solid materials in waste rock and tailings from migrating into surface waters and groundwater.
- Reduce or eliminate concentrated runoff that entrains and delivers metal-laden sediment to adjacent surface waters.
- Identify, prioritize, and select reclamation and restoration options for mining sources based on a thorough source assessment and streamlined risk analysis.

10.5.6.3 Other Historical Mine Remediation Programs

Appendix N provides a summary of mining remediation programs and approaches that can be or may currently be applied within the Rock Creek watershed. The extent that these programs may be necessary will depend on the level of stakeholder involvement and initiative throughout the watersheds with metals impairment causes.

10.6 Potential Funding Sources

Funding and prioritization of restoration or water quality improvement projects is integral to maintaining restoration activities and monitoring project successes and failures. Several government agencies fund watershed or water quality improvement projects. Below is a brief summary of potential funding sources to assist with TMDL implementation. **Appendix N** of this document outlines funding sources to assist with mining related TMDL implementation.

10.6.1 Section 319 Nonpoint Source Grant Program

Section 319 grant funds are typically used to help identify, prioritize, and implement water quality protection projects with focus on TMDL development and implementation of nonpoint source projects. Individual contracts under the yearly grant typically range from $20,000 to $150,000, with a 40 percent match requirement. 319 projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county.

10.6.2 Future Fisheries Improvement Program

The Future Fisheries grant program is administered by FWP and offers funding for on-the-ground 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 Rock Creek watershed include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats.

10.6.3 Watershed Planning and Assistance Grants

The MT DNRC administers Watershed Planning and Assistance Grants to watershed groups that are sponsored by a conservation district. Funding is capped at $10,000 per project and the application cycle is quarterly. The grant focuses on locally developed watershed planning activities; eligible activities include developing a watershed plan, group coordination costs, data collection, and educational activities.

Numerous other funding opportunities exist for addressing nonpoint source pollution. Additional information regarding funding opportunities from state agencies is contained in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, 2012d) and information regarding additional funding opportunities can be found at http://www.epa.gov/nps/funding.html.

10.6.4 Environmental Quality Incentives Program

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

10.6.5 Resource Indemnity Trust/Reclamation and Development Grants Program

The Resource Indemnity Trust/Reclamation and Development Grants Program (RIT/RDG) is an annual program administered by MT DNRC that can provide up to $300,000 to address environmental related issues. This money can be applied to sites included on the AML priority list, but of low enough priority where cleanup under AML is uncertain. RIT/RDG program funds can also be used for conducting site assessment/characterization activities such as identifying specific sources of water quality impairment. RIT/RDG projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county.

11.0 Monitoring Strategy and Adaptive Management

11.1 Introduction

The monitoring strategies discussed in this section are an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis, however the scale of the watershed coupled with constraints on time and resources often result in compromises that must be made that include estimations, extrapolation, and a level of uncertainty. The margin of safety (MOS) 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 (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 and specific 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 aforementioned goals. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on stakeholder priorities for restoration and funding opportunities.

11.2 Adaptive Management and Uncertainty

An adaptive management approach is recommended to control costs and meet the water quality standards to support all beneficial uses. This approach works in cooperation with the monitoring strategy, and as new information is collected, it allows for adjustments to restoration goals or pollutant targets, TMDLs, and/or allocations, as necessary.

11.3 Future Monitoring Guidance

The objectives for future monitoring in the Rock Creek watershed include: 1) strengthen the spatial understanding of sources for future restoration work, which will also strengthen source assessment analysis for future TMDL review, 2) gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development, 3) gather consistent information among agencies and watershed groups that is comparable to targets and allows for common threads in discussion and analysis, 4) expand the understanding of streams throughout the Rock Creek Watershed beyond those where TMDL have been developed and address issues if necessary, and 5) track restoration projects as they are implemented and assess their effectiveness.

11.3.1 Strengthening Source Assessment

In the Rock Creek TPA, 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 TPA 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 source assessments for each of the pollutants may include:

Sediment

- Field surveys of road and road crossing 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 BEHI assessments. Additionally, the development of bank erosion retreat rates specific to the Rock Creek TPA 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 East Fork Rock Creek and the Flint Creek watershed to better understand irrigation efficiency and needs for the Flint Creek water users
- Field surveys to better identify riparian area conditions and potential for improvement.
- Additional temperature data logger recordings throughout the East Fork Rock Creek and at major tributary or irrigation return inputs to better discern temperature fluctuations and causes.
- Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use in the valley.
- Assessment of water use in the valley and potential for improvements in water use that would result in increased instream flows.
- Flow measurements at all temperature data locations at the time of data collection.

Nutrients

- A better understanding of nutrient concentrations in groundwater (as well as the sources) and the spatial variability of groundwater with high nutrient concentrations
- A better understanding of the cattle grazing practices and the number of animals grazed in the Rock Creek watershed
- A more detailed understanding of nutrient contributions from historical mining within the watershed
- A review of land management practices specific to sub-watersheds of concern to determine where the greatest potential for improvement can occur for the major land use categories
- Additional sampling in streams with limited data

Metals

The level of detail of the source assessment allows allocations to broad source categories and geographic areas. Additional monitoring may be helpful to better partition pollutant loading at mine sites with multiple sources. The needed refinements may require more seasonally stratified sampling or a more detailed field reconnaissance and follow-up sampling to better locate stream segments representing background loading.

In Flat Gulch, the inability to distinguish background aluminum loading from human-caused aluminum loading led to use of a broad composite allocation. Further sampling would allow better delineation of aluminum sources.

The descriptions of several of the priority abandoned mines are based on information collected during early 1990s site inventories. Additional site reconnaissance and monitoring of discrete sources is needed to better understand sources of metals loading and develop remediation strategies. The following bulleted items describe source assessment information that could improve our understanding of loading at a number of priority mine sites.

- A more detailed characterization of groundwater quality from the Old Dominion and Banner Tailings Mines as well as an assessment of groundwater interactions with surface water in the Middle Fork of Rock Creek.
- A more detailed surface water monitoring regime directed at defining sources of metals pollution from all priority mine sites.
- A more detailed mapping of source locations and past surface water monitoring sites at the Ant and Lori 13 Mines, along with more recent water quality analyses, would help clarify the loading situation these sites in the South Fork of Antelope Creek.

Additional water quality sampling in streams with minimal data such as West Fork Rock Creek, Eureka, Gulch and Scotchman Gulch would yield a better understanding of the specific metals affecting these streams (see discussion in **Section 11.3.2**).

11.3.2 Increase Available Data

While the Rock Creek watershed has been the recipient of significant remediation and restoration activities, data is still often limited depending on the stream and pollutant of interest. Infrequent sampling events at a small number of sampling sites may provide some indication of overall water quality and habitat condition, however regularly scheduled sampling at consistent locations, under a variety of seasonal conditions is the best way to assess overall stream health and monitor change.

Sediment

For sediment investigation in the Rock Creek TPA, each of the streams of interest were stratified into unique reaches based on physical characteristics and anthropogenic influence. A total of 22 sites were sampled throughout the watershed, however this equates to only a small percentage of the total number of stratified reaches, and even less on a stream by stream basis. Sampling additional monitoring locations to represent some of the various reach categories that occur would provide additional data to assess existing conditions, and provide more specific information on a per stream basis as well as the TPA as a whole, by which to assess reach by reach comparisons and the potential influencing factors and resultant outcomes that exist throughout the watershed.

Temperature

Temperature investigation for East Fork Rock Creek included 7 data loggers that were deployed throughout the stream and at a key tributary input. Increasing the number of data logger locations and the number of years of data, and collecting associated flow data, would improve our understanding of instream temperature changes in the river, and better identify influencing factors on those changes.

Nutrients
Water quality sampling locations for nutrients were distributed spatially along each assessment unit in order to best delineate nutrient sources. Over multiple sample seasons, sampling locations were refined to better quantify loading sources to the impaired waterbodies. Source refinement will continue to be necessary on streams with TMDLs and those that have not yet been assessed in the Rock Creek watershed to better assess nutrient loading.

It will be important to continually assess nutrient sources in a watershed with changing land uses and/or new MPDES permitted discharges to surface waters.

Metals
Additional monitoring may be helpful to better partition pollutant loading at mine sites with multiple sources, such as those having discrete adit discharges versus more diffuse runoff from sulfide waste accumulations. The needed refinements may require more seasonally stratified sampling or a more detailed field reconnaissance and follow-up sampling to better locate stream segments representing background loading. **Table 11-1** lists the waterbodies, pollutants, and flow conditions where additional data is needed.

Table 11-1. Waterbodies, metal pollutants, and flow conditions for which additional data is needed

Stream Segment	Pollutant/s	Flow Condition
WEST FORK ROCK CREEK	Mercury	High and Low
EUREAKA GULCH	Aluminum	High and Low
	Arsenic	High and Low
	Cadmium	High and Low
	Copper	High and Low
	Iron	High and Low
	Lead	High and Low
	Silver	High and Low
	Zinc	High and Low
	Mercury	High and Low
SCOTCHMAN GULCH	Mercury	High and Low

For the pollutant-waterbody combinations in **Table 11-1**, follow up monitoring should focus on defining the contribution from discrete sources within abandoned mine sites. As this information becomes available, TMDL allocation schemes may be modified to include load allocations to background sources, as opposed to the current composite WLAs.

11.3.3 Consistent Data Collection and Methodologies

Data has been collected throughout the Rock Creek watershed for many years and by many different agencies and entities, however the type and quality of information is often variable. Where ever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals.

The Montana Department of Environmental Quality (DEQ) is the lead agency for developing and conducting impairment status monitoring. However, other agencies or entities may work closely with DEQ to provide compatible data if interest arises. Impairment determinations are conducted by the state but can use data collected from other sources. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect beneficial uses in a manner consistent with Montana's water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, State and Federal laws. For example, reclamation of a mining related source of metals under CERCLA and CECRA typically requires source-specific sampling requirements, which cannot be defined at this time, to determine the extent of and the risk posed by contamination, and to evaluate the success of specific remedial actions.

Sediment

Sediment and habitat assessment protocols consistent with DEQ field methodologies and that serve as the basis for sediment targets and assessment within this TMDL should be conducted whenever possible. Current protocols are identified within Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (Montana Department of Environmental Quality, 2012b). 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, when collecting sediment and habitat data in the Rock Creek watershed 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
- Pool Assessment; Count and Residual Pool Depth Measurements
- Greenline Assessment; NRCS methodology

Additional information will undoubtedly be useful and assist DEQ with TMDL effectiveness monitoring in the future. Macroinvertebrate studies, McNeil core sediment samples, and fish population surveys and redd counts are examples of additional useful information used in impairment status monitoring and TMDL effectiveness monitoring which were not developed as targets but reviewed where available during the development of this TMDL.

Temperature

Consistency in temperature data collection is not as significant for what is collected as much as how and where it is collected. Data loggers should be deployed at the same locations through the years to accurately represent the site specific conditions over time, and recorded temperatures should at a minimum represent the hottest part of the summer when aquatic life is most sensitive to warmer temperatures. Data loggers should be deployed in the same manner at each location and during each sampling event, and follow a consistent process for calibration and installation. Any modeling that is used should refer to previous modeling efforts (such as the QUAL2K analysis used in this document) for consistency in model development to ensure comparability. In addition, flow measurements should also be conducted using consistent locations and method.

Nutrients

For those watershed groups and/or government agencies that monitor water quality, it is recommended that the same analytical procedures and reporting limits are used in order that water quality data may be compared to TMDL targets (**Table 11-2**). In addition, stream discharge should be measured at time of sampling.

Table 11-2. DEQ Nutrient Monitoring Parameter Requirements

Analyte	Preferred method	Alternate method	Required reporting limit (ppb)	Holding time (days)	Bottle	Preservative
Total Persulfate Nitrogen (TPN)	A4500-NC	A4500-N B	40	28	250mL HDPE	≤6°C (7d HT); Freeze (28d HT)
Total Phosphorus as P	EPA-365.1	A4500-P F	3			H2S04, ≤6°C of Freeze
Nitrate-Nitrite as N	EPA-353.2	A4500-N03 F	10			

Metals

As a result of water and sediment data collected during TMDL development, TMDLs were developed for several metals that were not on the 2012 303(d) List, and TMDLs were not developed for some listed metals because recent data did not exceed water quality targets and/or anthropogenic sources were not identified. Based on the data evaluations within this document (**Section 11.3.2**), several metals have been identified and recommended for future monitoring.

Metals monitoring should include analysis of a suite of total recoverable metals (e.g. As, Cu, Cd, Pb, Zn), sediment samples, hardness, pH, discharge and TSS for all pollutant-waterbody combinations. **Table 11-3** identifies the current DEQ metals sampling methodologies and reporting limits for the standard metals suite (water and sediment).

Table 11-3. DEQ Metals Monitoring Parameter Requirements

Parameter	Preferred Method	Alternate Method	Req. Report Limit ug/L	Holding Time Days	Bottle	Preservative
Water Sample - Common Ions and Physical Parameters						
Total Hardness as $CaCO_3$	A2340 B (Calc)		1000			
Total Suspended Solids	A2540D		4000	7	1000 ml HDPE/500 mlHDPE	≤6oC
Water Sample - Dissolved Metals (0.45 um filtered)						
Aluminum	EPA 200.7	EPA 200.8	9	180	250 ml HDPE	Filt 0.45 um, HNO_3
Water Sample - Total Recoverable Metals						
Total Recoverable Metals Digestion	EPA 200.2	APHA3030F (b)	N/A	180	500 ml HDPE/ 250 ml HDPE	HNO_3
Arsenic	EPA 200.8		1			
Cadmium	EPA 200.8		0.03			
Calcium	EPA 200.7		1000			
Chromium	EPA 200.8	EPA 200.7	1			
Copper	EPA 200.8	EPA 200.7	1			
Iron	EPA 200.7		20			
Lead	EPA 200.8		0.3			
Magnesium	EPA 200.7		1000			
Potassium	EPA 200.7		1000			
Selenium	EPA 200.8		1			

Table 11-3. DEQ Metals Monitoring Parameter Requirements

Parameter	Preferred Method	Alternate Method	Req. Report Limit ug/L	Holding Time Days	Bottle	Preservative
Silver	EPA 200.8	EPA 200.7/200.9	0.2			
Sodium	EPA 200.7		1000			
Zinc	EPA 200.7	EPA 200.8	8			
Antimony	EPA 200.8		0.5			
Barium	EPA 200.7	EPA 200.8	3			
Beryllium	EPA 200.7	EPA 200.8	0.8			
Boron	EPA 200.7	EPA 200.8	10			
Manganese	EPA 200.7	EPA 200.8	5			
Nickel	EPA 200.7	EPA 200.8	2			
Thallium	EPA 200.8		0.2			
Uranium, Natural	EPA 200.8		0.2			
Parameter	**Preferred Method**	**Alternate Method**	**Req. Report Limit mg/kg (dry weight)**	**Holding Time Days**	**Bottle**	**Preservative**
Sediment Sample - Total Recoverable Metals						
Total Recoverable Metals Digestion	EPA 200.2		N/A	180	2000 ml HDPE Widemouth	
Arsenic	EPA 200.8	EPA 200.9	1			
Cadmium	EPA 200.8	EPA 200.9	0.2			
Chromium	EPA 200.8	EPA 200.7	9			
Copper	EPA 200.8	EPA 200.7	15			
Iron	EPA 200.7	EPA 200.7	10			
Lead	EPA 200.8	EPA 200.9	5			
Zinc	EPA 200.7	EPA 200.7	20			
Sediment Sample - Total Metals						
Mercury	EPA 7471B		0.05	28	2000 ml HDPE Widemouth	

11.3.4 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 bank stability and riparian habitat, increases in instream flow, and changes in communities and distribution of fish and other bio-indicators. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints.

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

11.3.5 Watershed Wide Analyses

Recommendations for monitoring in the Rock Creek watershed 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 303(d) list 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.

12.0 STAKEHOLDER AND PUBLIC PARTICIPATION

Stakeholder and public involvement is a component of TMDL planning supported by EPA guidelines and required by Montana state law (MCA 75-5-703, 75-5-704) which directs DEQ to consult with watershed advisory groups and local conservation districts during the TMDL development process. Technical advisors, stakeholders and interested parties, state and federal agencies, interest groups, and the public were solicited to participate in differing capacities throughout the TMDL development process in the Rock Creek TPA.

12.1 PARTICIPANTS AND ROLES

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

Montana Department of Environmental Quality
Montana state law (MCA 75-5-703) directs DEQ to develop all necessary TMDLs. DEQ has provided resources toward completion of these TMDLs in terms of staff, funding, internal planning, data collection, technical assessments, document development, and stakeholder communication and coordination. DEQ has worked with other state and federal agencies to gather data and conduct technical assessments. DEQ has also partnered with watershed organizations to collect data and coordinate local outreach activities for this project.

United States Environmental Protection Agency
EPA is the federal agency responsible for administering and coordinating requirements of the Clean Water Act (CWA). Section 303(d) of the CWA directs states to develop TMDLs (see **Section 1.1**), and EPA has developed guidance and programs to assist states in that regard. EPA has provided funding and technical assistance to Montana's overall TMDL program and is responsible for final TMDL approval. Project management was primarily provided by the EPA Regional Office in Helena, MT.

Conservation Districts
The majority of the Rock Creek TPA falls within Granite County (a small portion of Missoula Conservation District falls within the TPA but does not have any streams with TMDLs). DEQ provided the Granite Conservation District with consultation opportunity during development of TMDLs. This included opportunities to provide comment during the various stages of TMDL development, and an opportunity for participation in the advisory group discussed below.

TMDL Advisory Group
The Rock Creek TMDL Advisory Group consisted of selected resource professionals who possess a familiarity with water quality issues and processes in the Rock Creek TPA, and also representatives of applicable interest groups. All members were solicited to participate in an advisory capacity per Montana state law (75-5-703 and 704). DEQ requested participation from the interest groups defined in MCA 75-5-704 and included county representatives, livestock-oriented and farming-oriented agriculture representatives, conservation groups, watershed groups, state and federal land management agencies, and representatives of recreation and tourism interests. The advisory group also included additional stakeholders and landowners with an interest in maintaining and improving water quality and riparian resources.

Advisory group involvement was voluntary and the level of involvement was at the discretion of the individual members. Members had the opportunity to provide comment and review of technical TMDL assessments and reports and to attend meetings organized by DEQ for the purpose of soliciting feedback on project planning. Typically, draft documents were released to the advisory group for review under a limited timeframe, and their comments were then compiled and evaluated. Final technical decisions regarding document modifications resided with DEQ.

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

12.2 Response To Public Comments

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

This public review period was initiated on July 26th, 2013 and ended on August 23rd, 2013. At the public meeting on August 6th in Philipsburg, MT, DEQ provided an overview of the TMDLs for the Rock Creek TMDL Planning Area, made copies of the document available to the public, and solicited public input and comment on the plan. The announcement for that meeting was distributed among the Watershed Advisory group and advertised in the following newspapers: The Missoulian and the Philipsburg Mail. This section includes DEQ's response to all public comments received during the public comment period.

One letter from the Montana Department of Natural Resources and Conservation was submitted to the DEQ during the public comment period. The comment letter is provided below. The response prepared by DEQ follows the comment. The original comment letter is held on file at the DEQ and may be viewed upon request.

Montana Department of Natural Resources and Conservation
Comment #1
Montana DNRC shares the same concerns that forest management activities should be conducted by all landowners according to Forestry BMPs for Montana (Montana State University, Extension Service, 2001) and the Montana Streamside Management Zone (SMZ) Law (77-5-301 through 307 MCA. One reference in the draft TMDL that is perplexing is that the TMDL recommends that timber harvest should not increase peak water yield be more than 10 percent of historic conditions and that natural disturbance, such as fire, increases water yield, the increase should be accounted for as part of timber harvest management. I would like additional detail on the basis for the 10% threshold specific to this area. I also don't understand what a 10% increase over historic conditions includes, especially when one considers the range of natural variability in forested conditions. The Rock Creek area has had periodic and extensive fire a Water Yield increase of 10% increase over fully forested conditions is not being very representative of the range of natural conditions that we would expect to occur in the basin.

Response to Comment #1

Thank you for reviewing the document and providing comment. The DEQ agrees that it is difficult to set a numeric threshold to this area because of natural variability. The final paragraph in **Section 10.5.2** appropriately describes the general recommendation, and therefore the entire paragraph regarding the 10% threshold recommendation was deleted.

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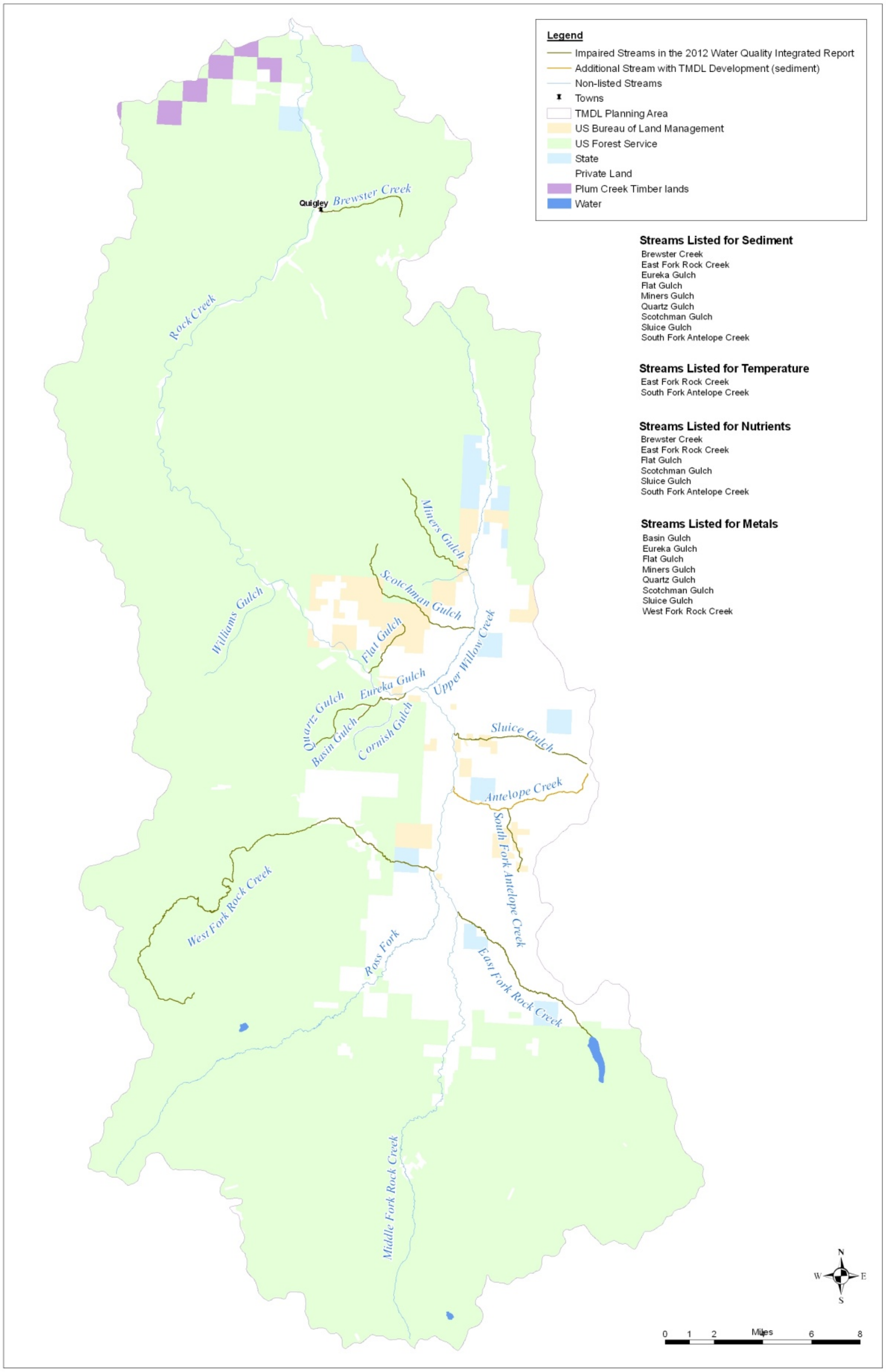
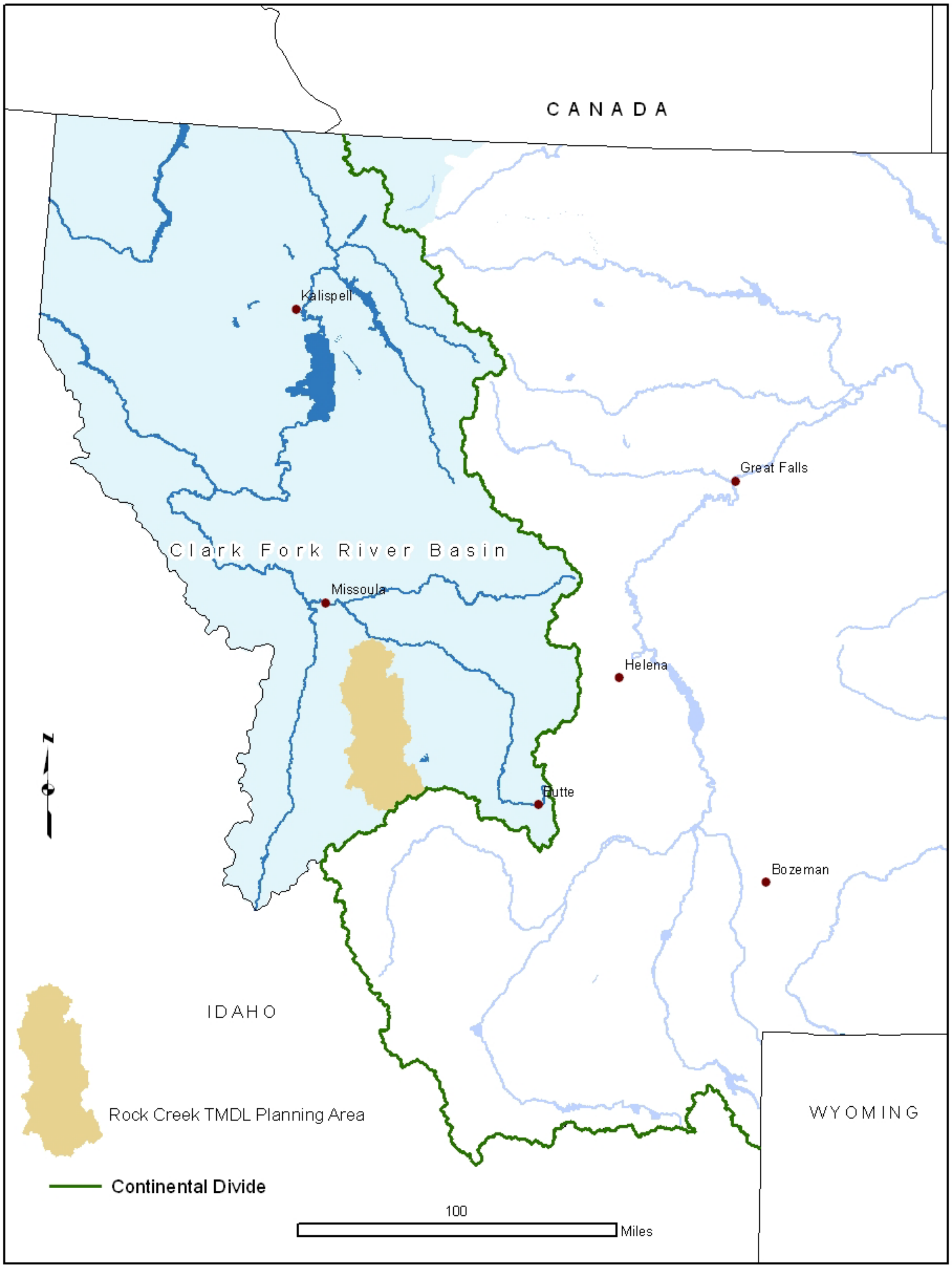
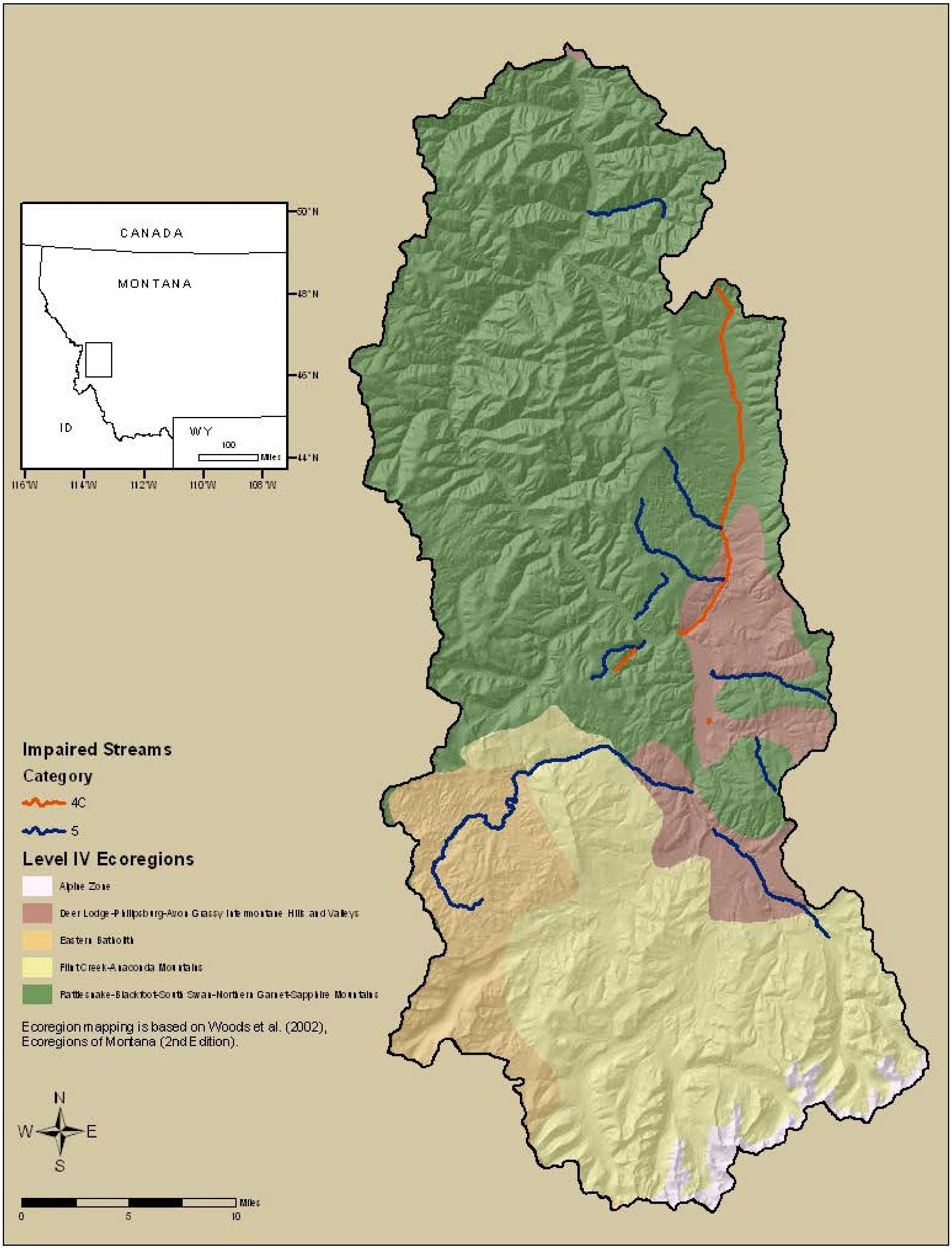
APPENDIX A – MAPS



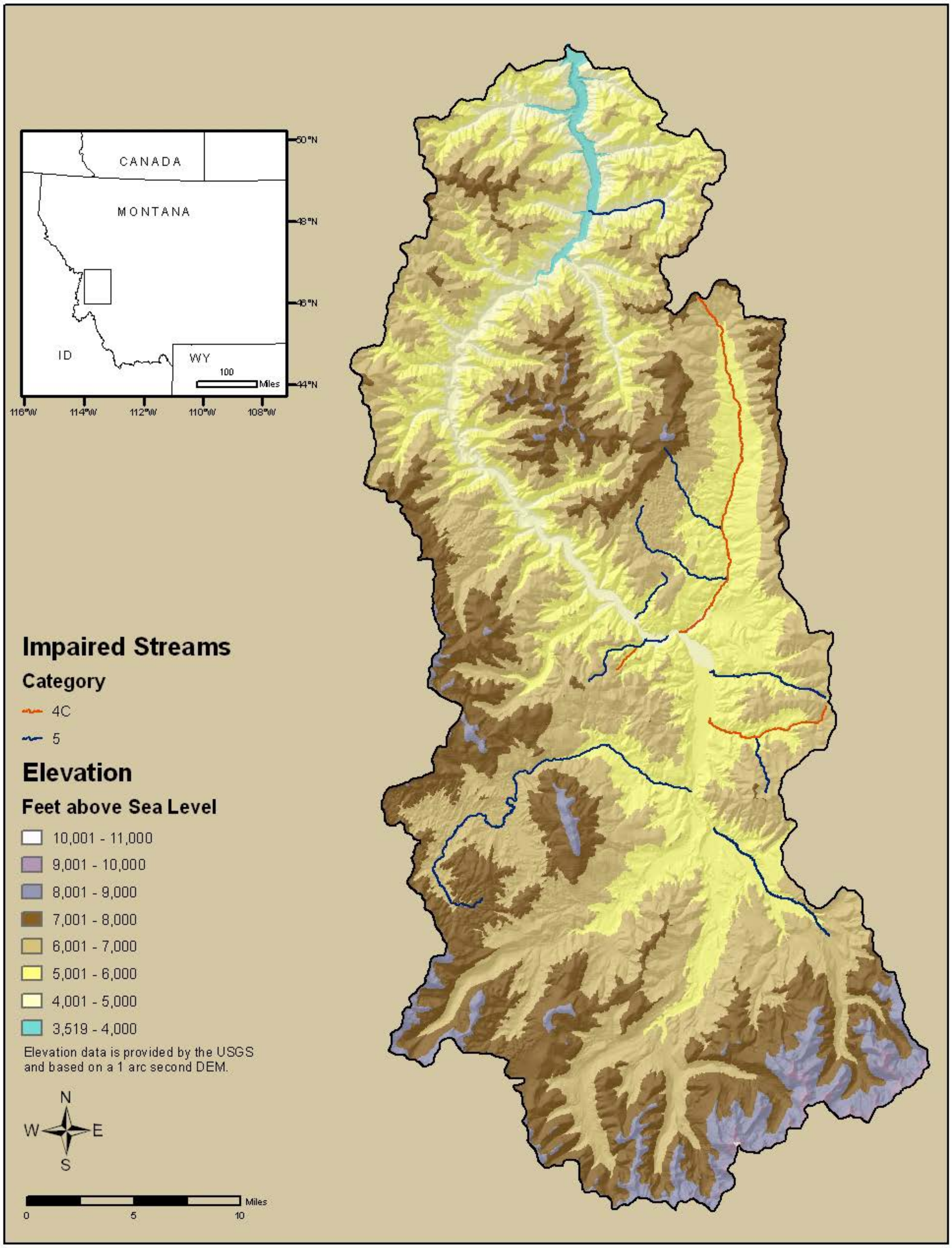
Map A-1. Waterbodies in the Rock Creek TMDL Planning Area (TPA) with sediment, temperature, nutrients, and metals pollutant listings.



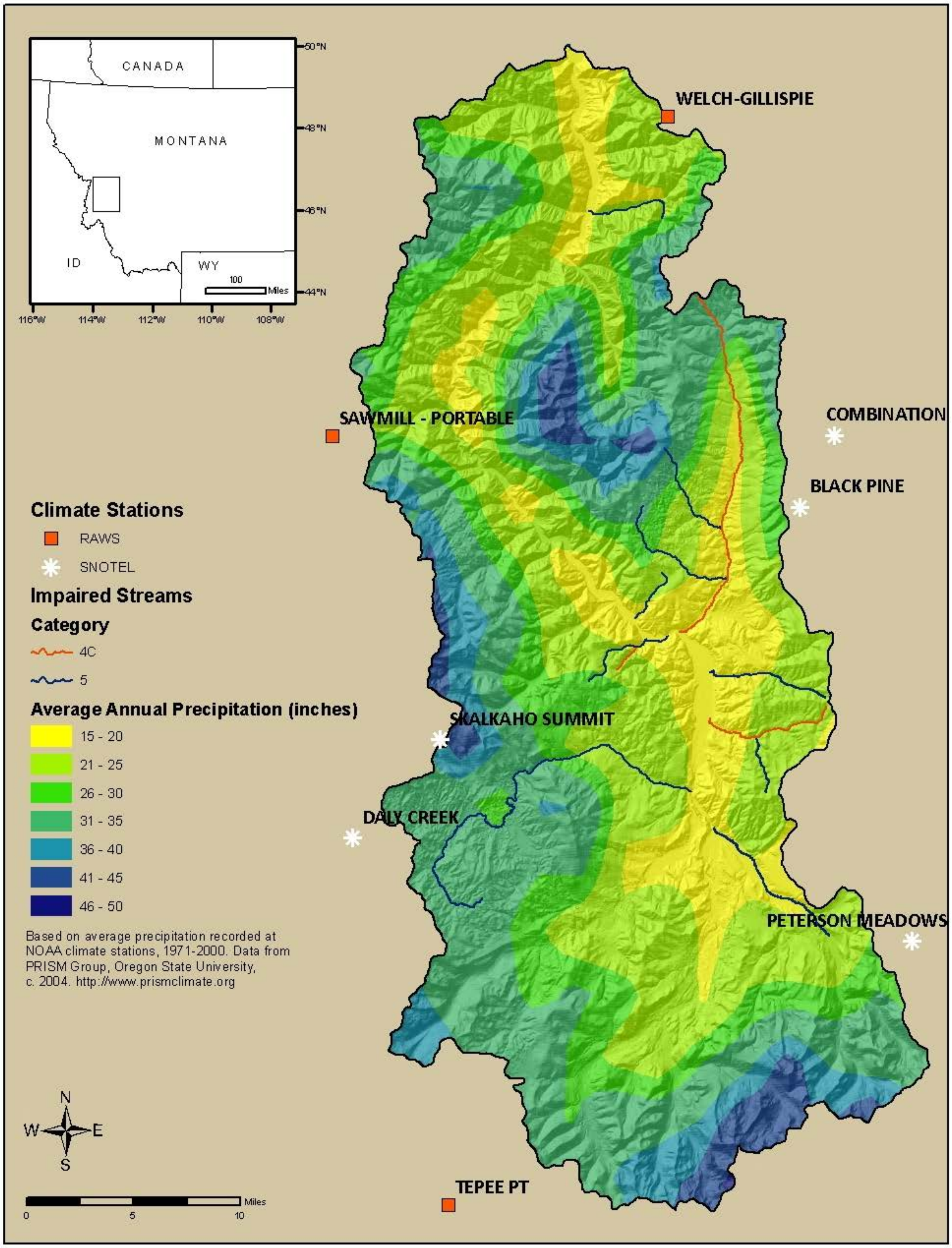
Map A-2. Location of the Rock Creek TPA



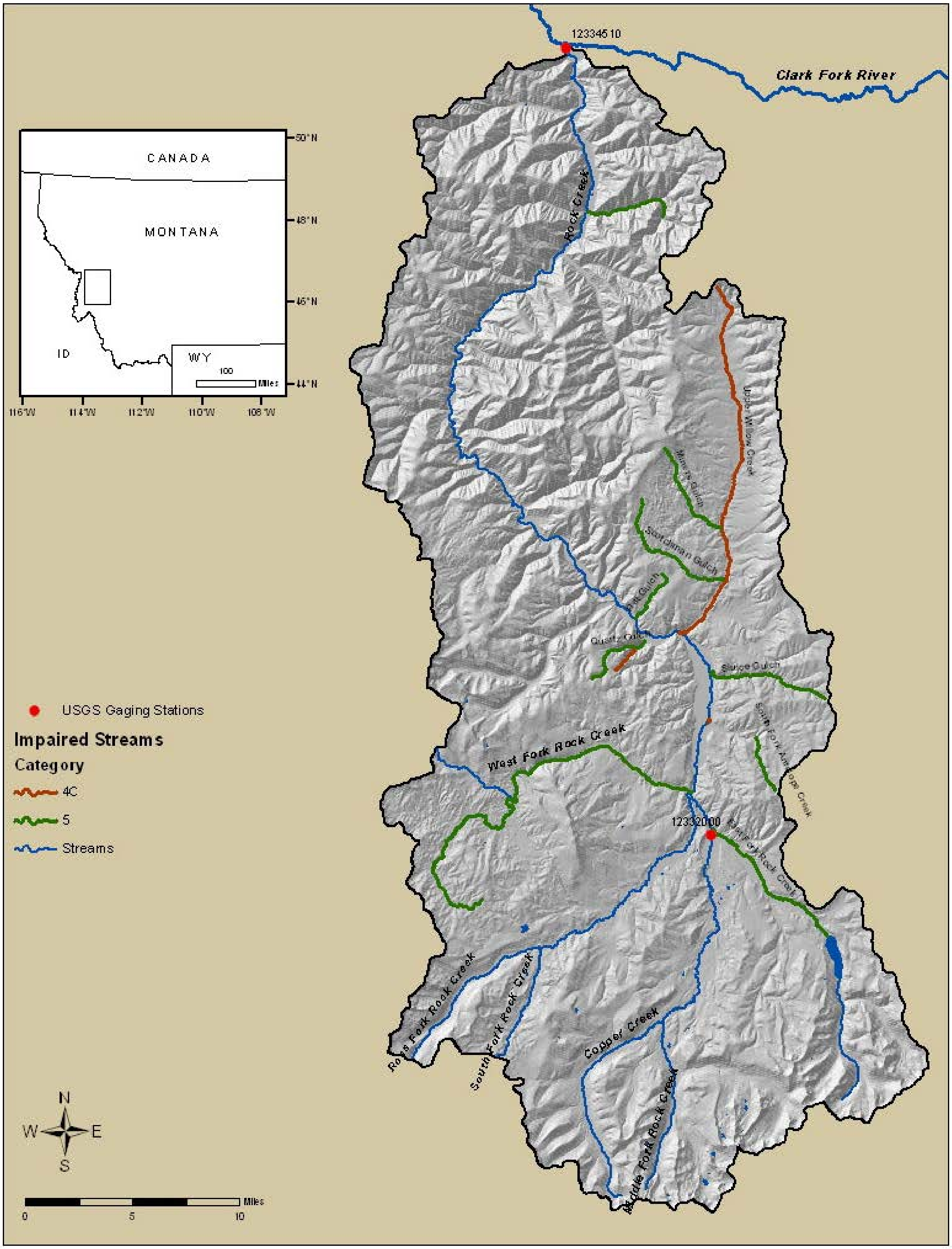
Map A-3. Level IV Ecoregions in the Rock Creek TPA



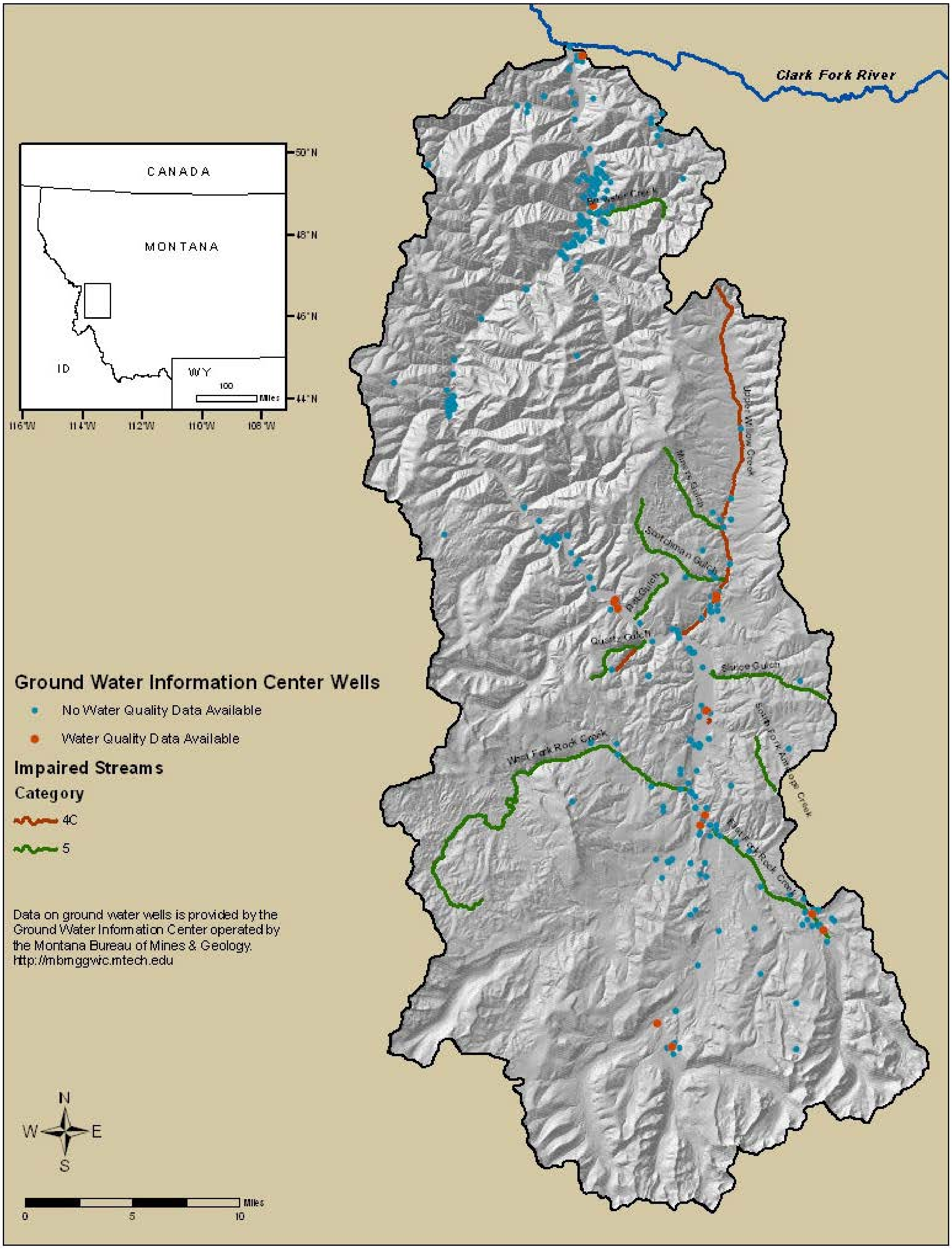
Map A-4. Topography in the Rock Creek TPA



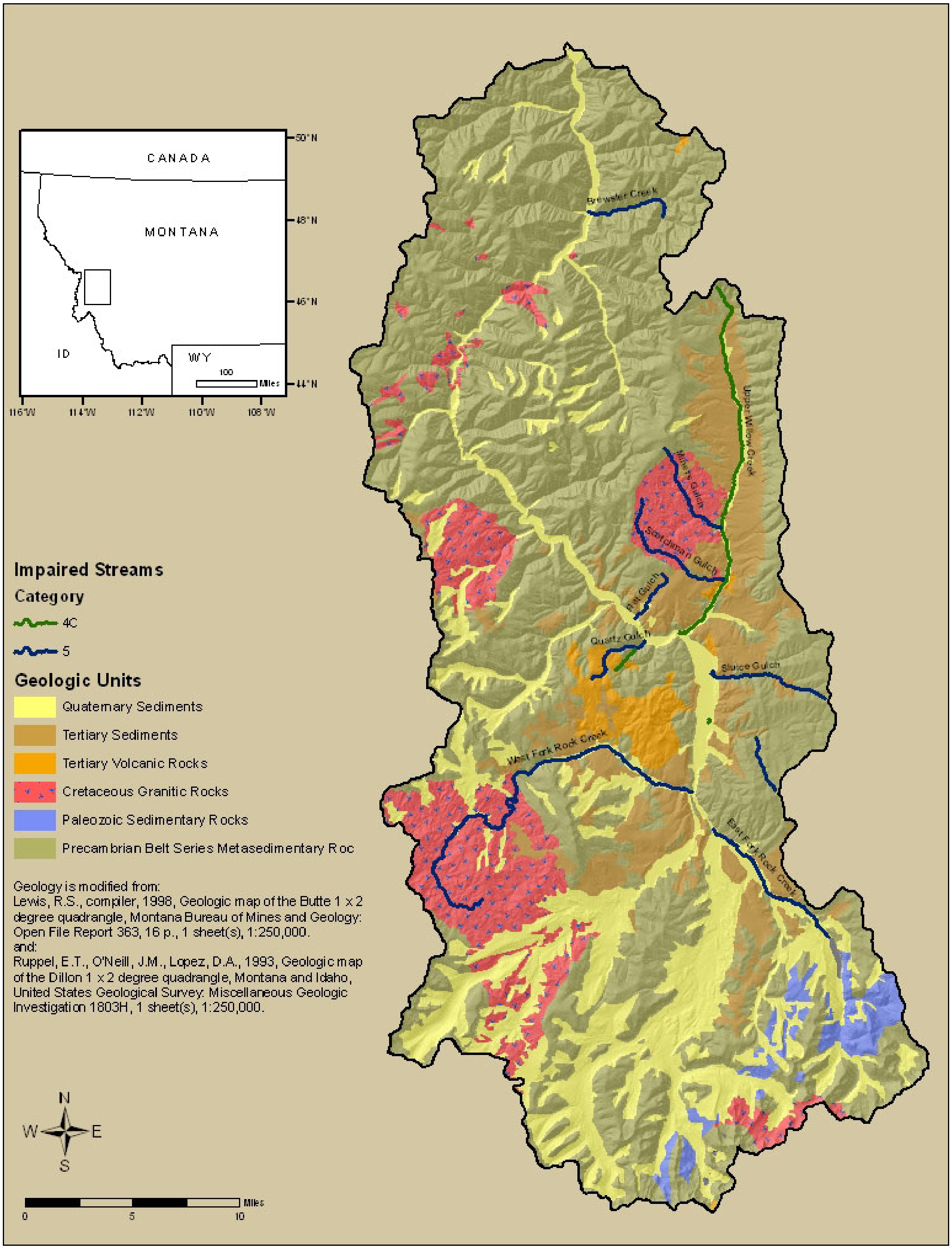
Map A-5. Precipitation in the Rock Creek TPA



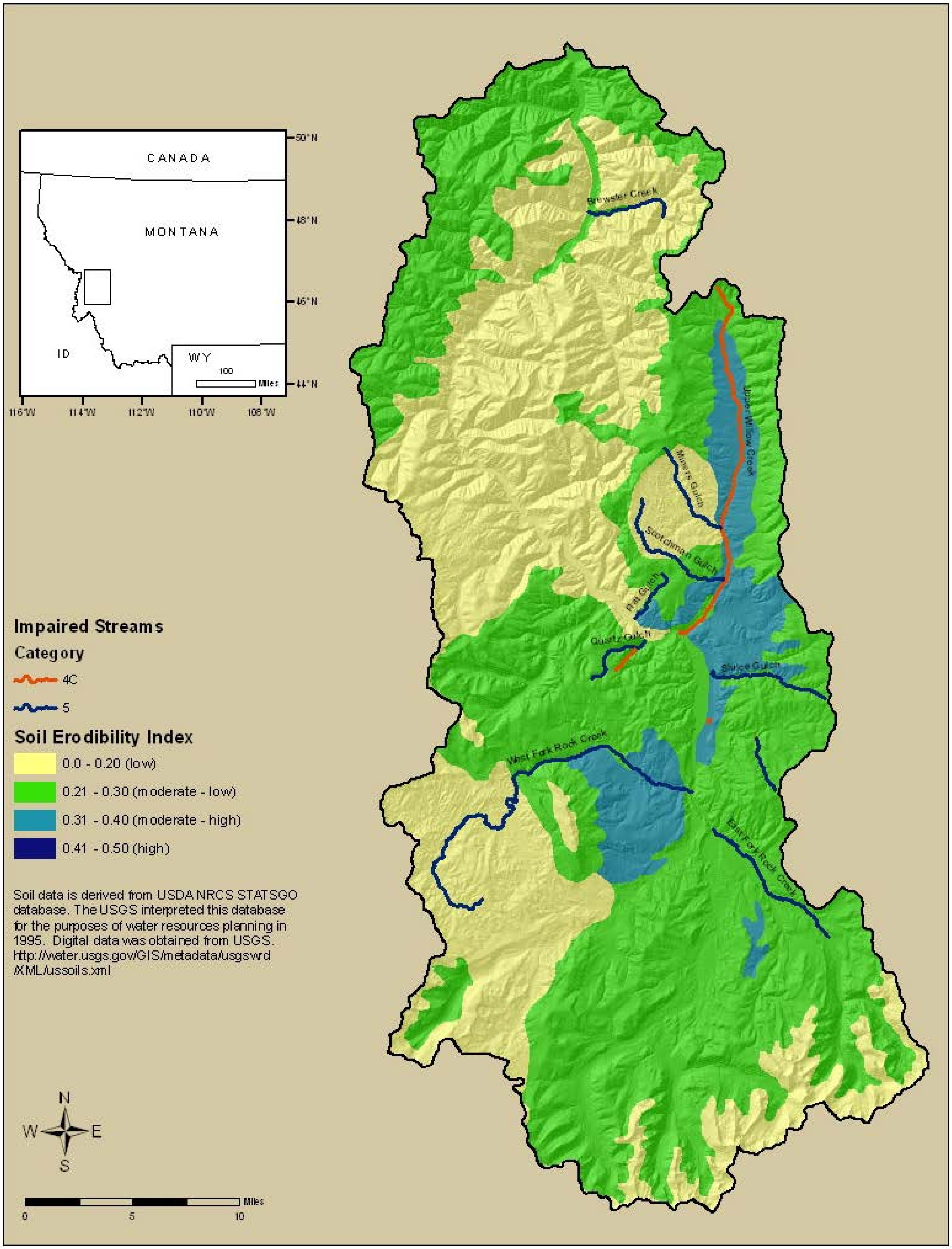
Map A-6. Hydrography in the Rock Creek TPA



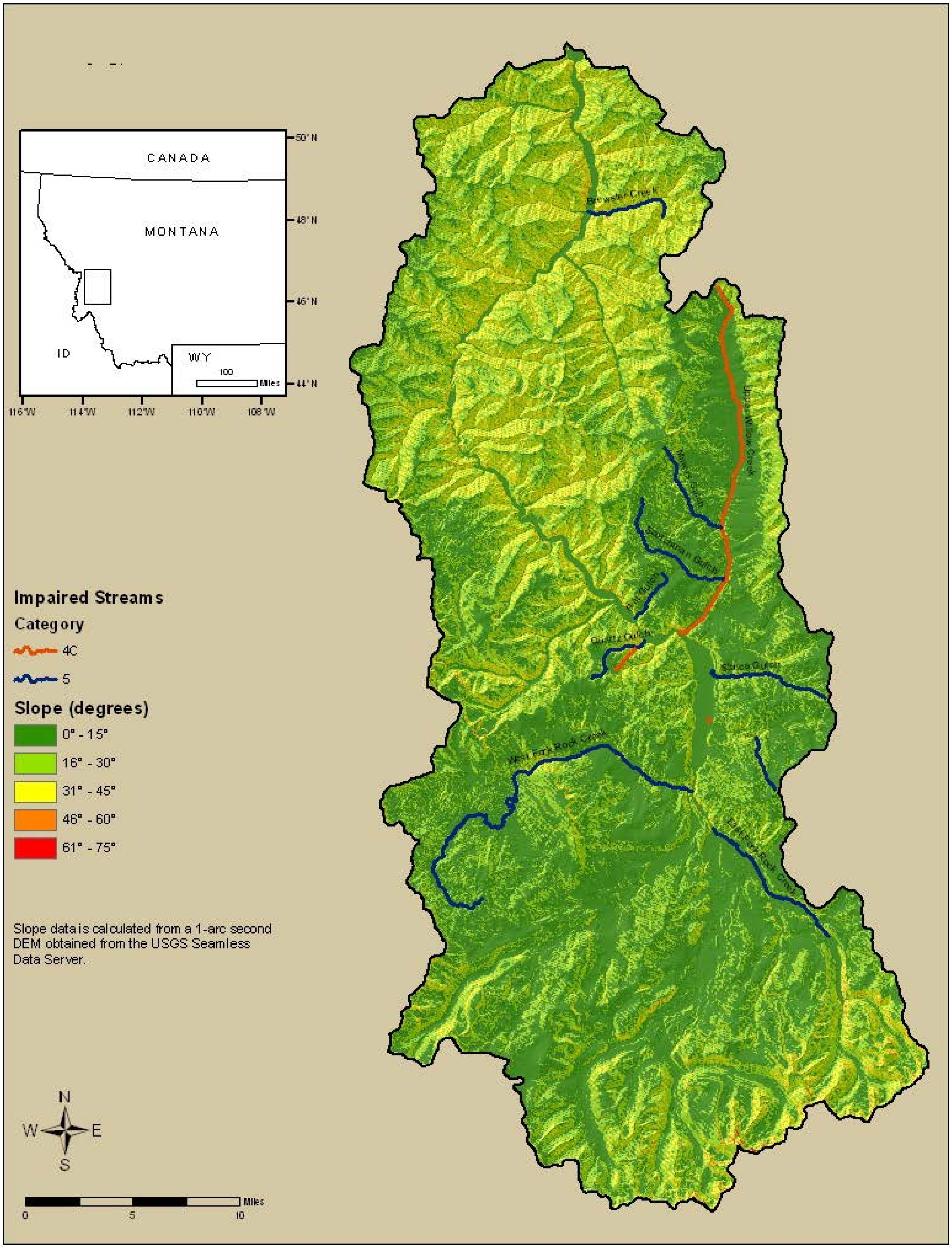
Map A-7. GWIC Well Data Points in the Rock Creek TPA



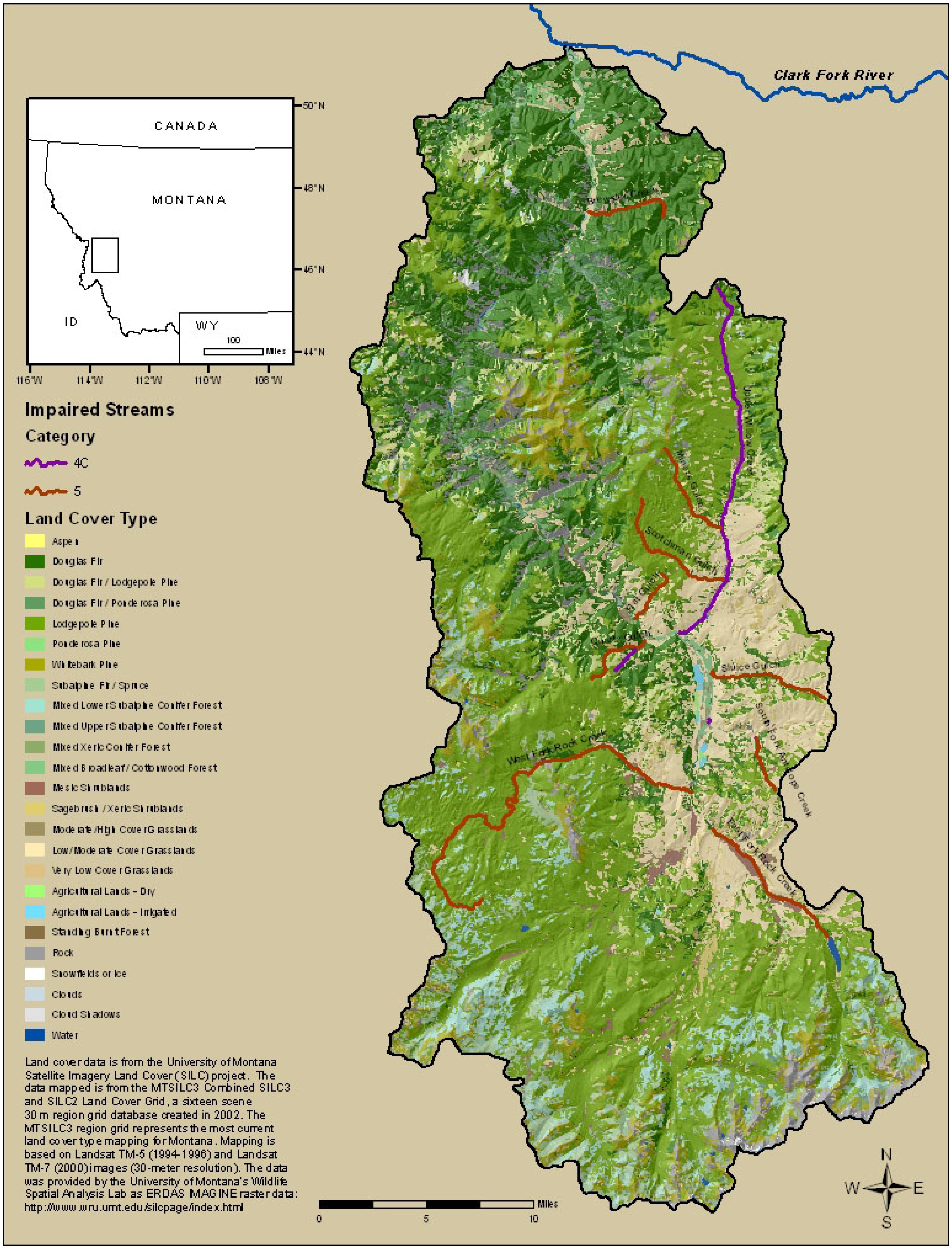
Map A-8. Geology in the Rock Creek TPA



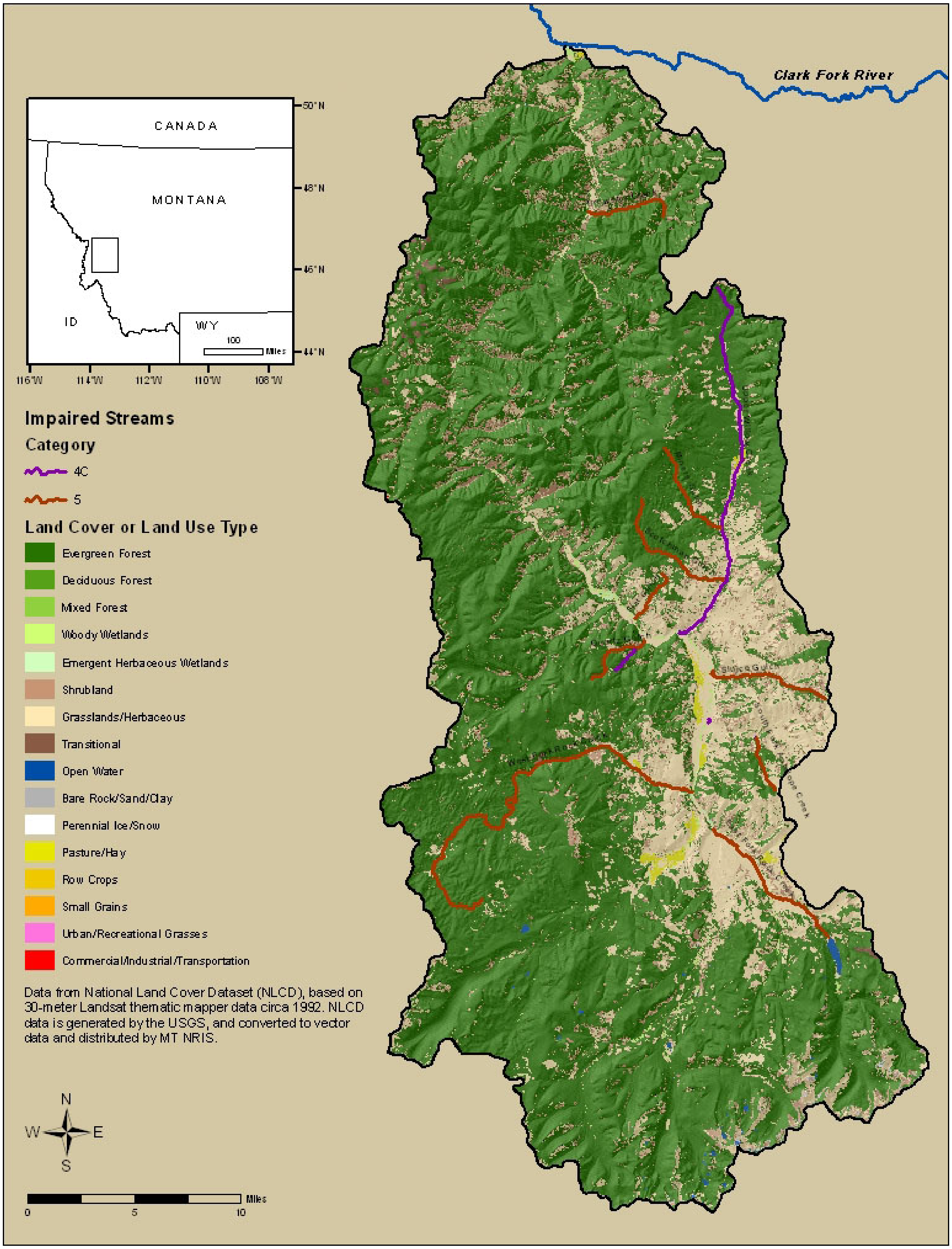
Map A-9. Susceptibility to erosion in the Rock Creek TPA



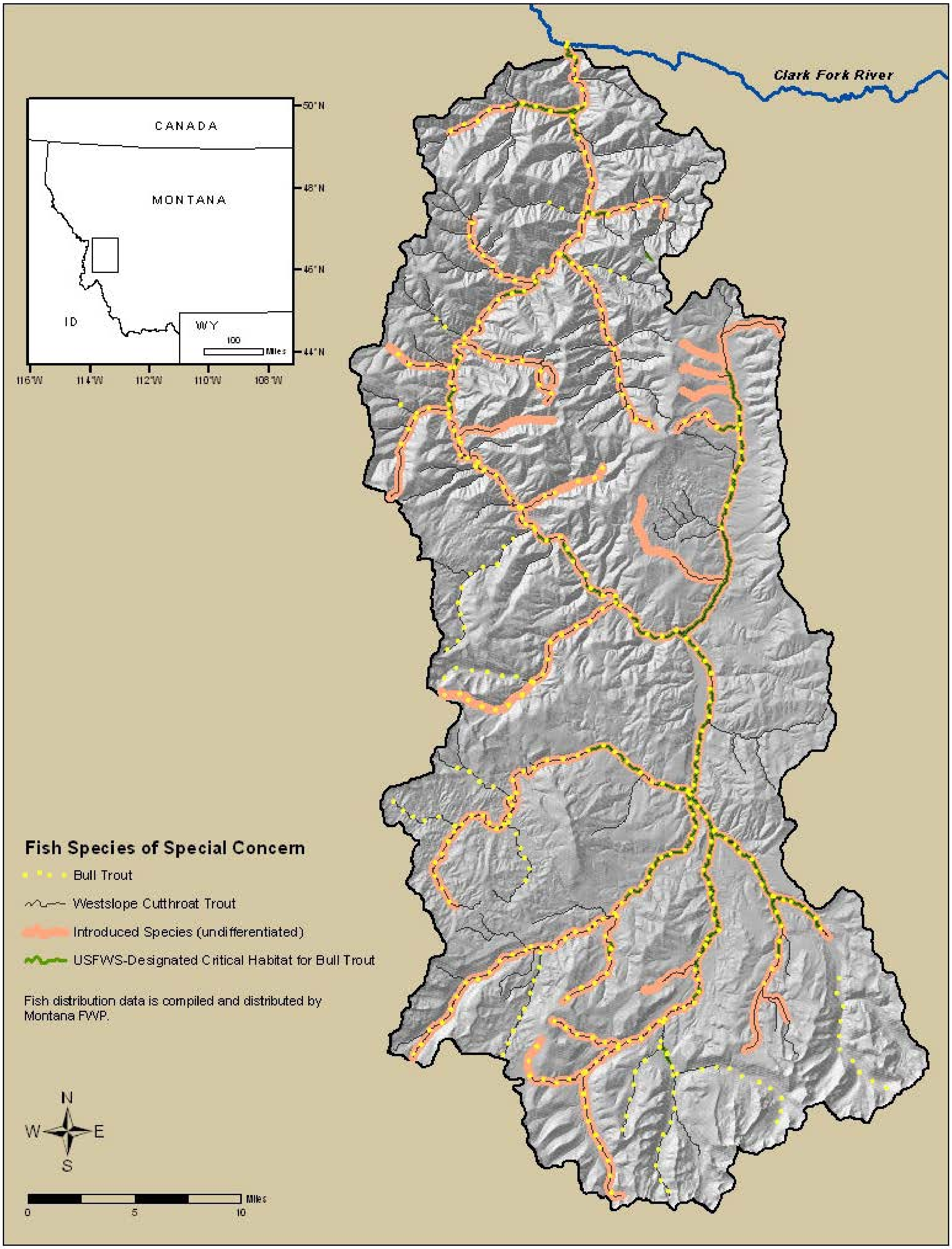
Map A-10. Slope in the Rock Creek TPA



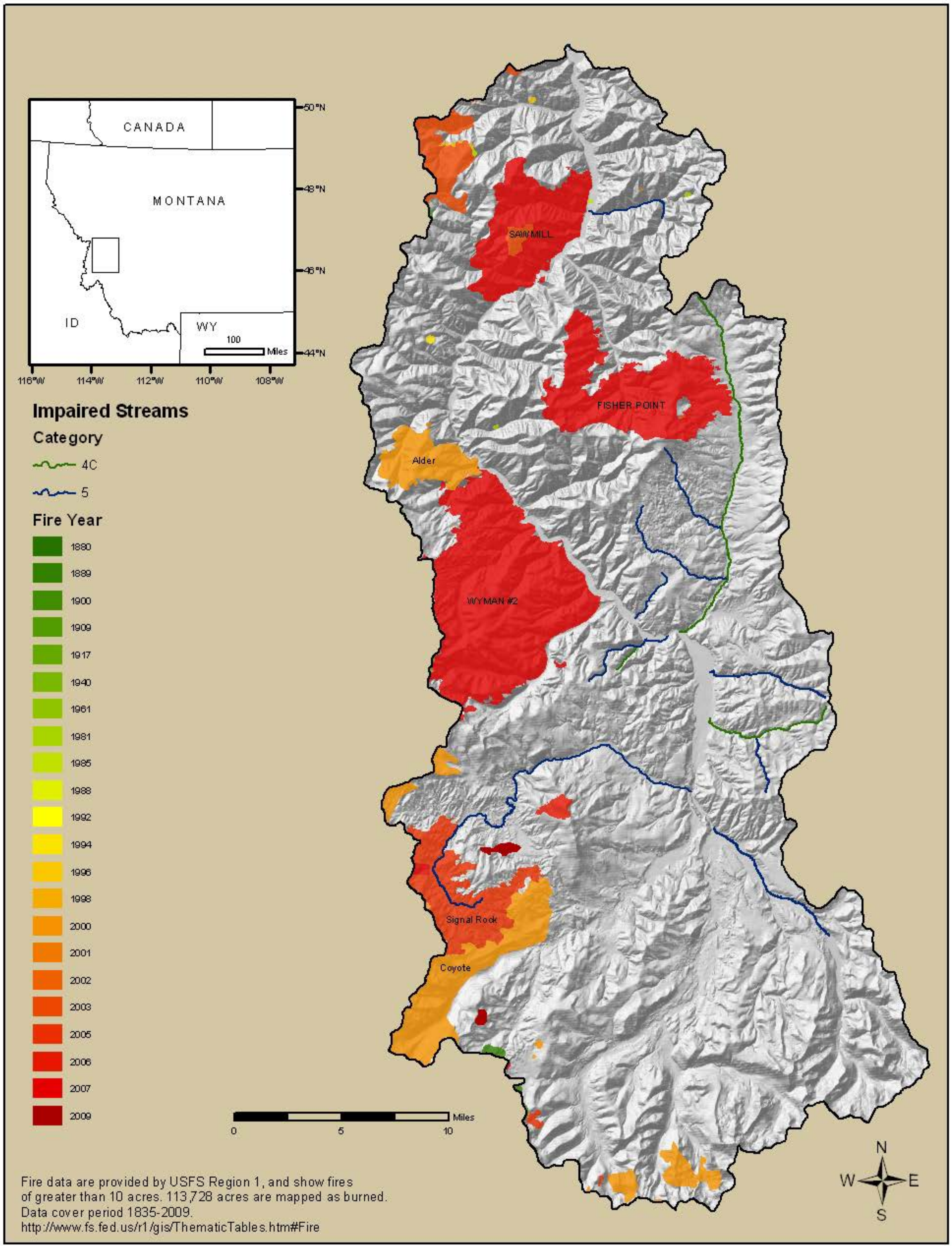
Map A-11. Landcover type in the Rock Creek TPA from the Univ. of Montana SILC Project



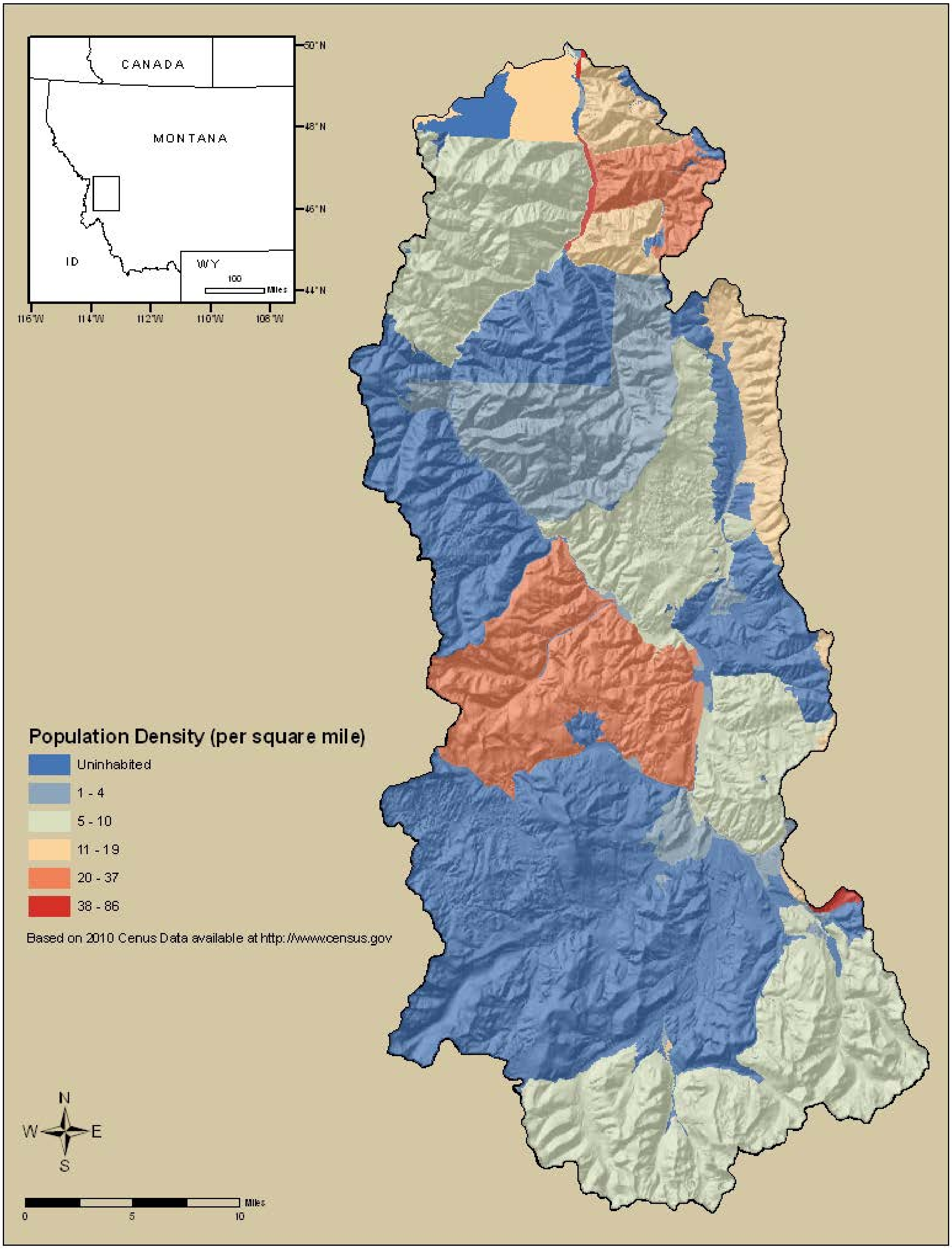
Map A-12. Landcover type in the Rock Creek TPA using the 1992 NLCD



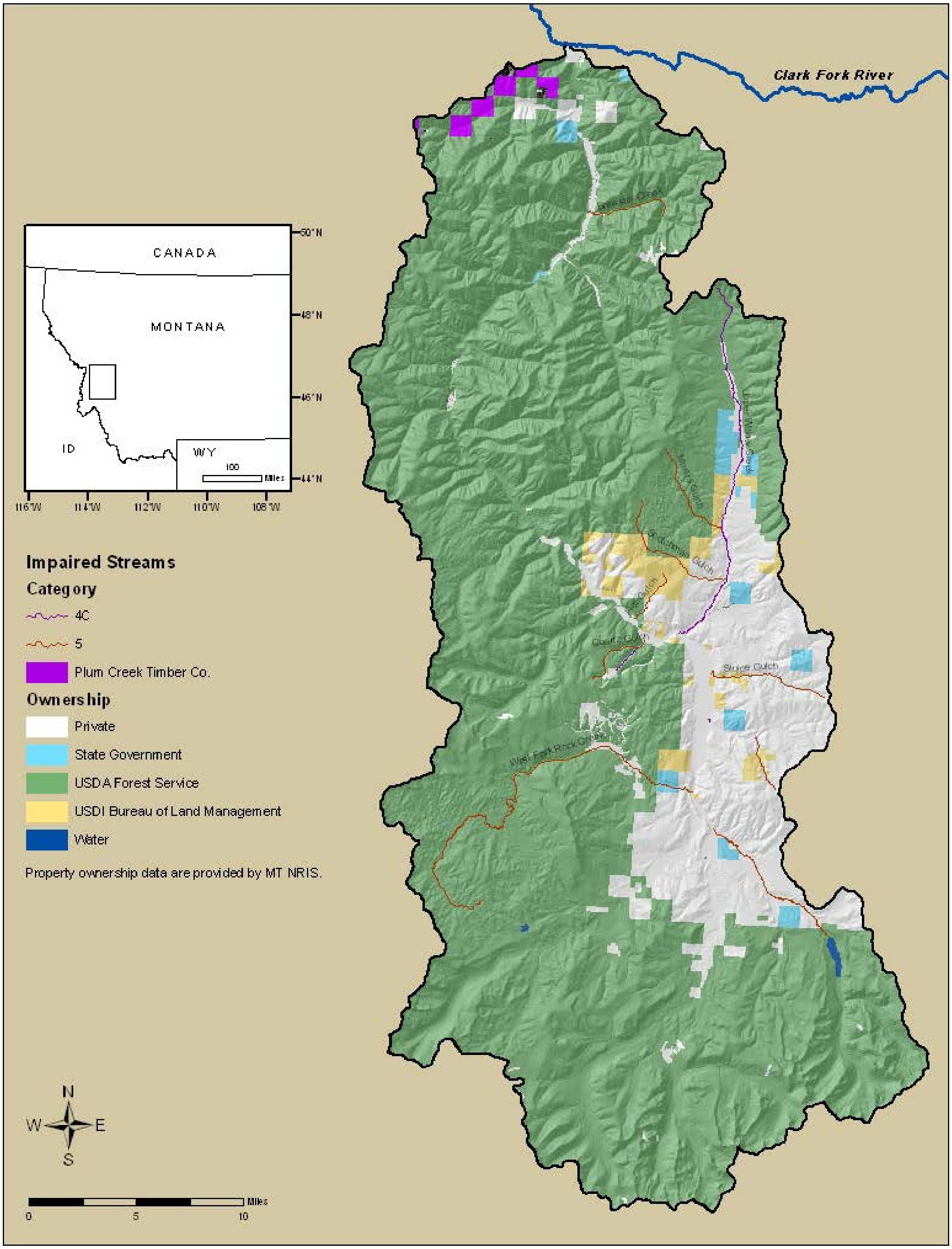
Map A-13. Fish Distribution in the Rock Creek TPA



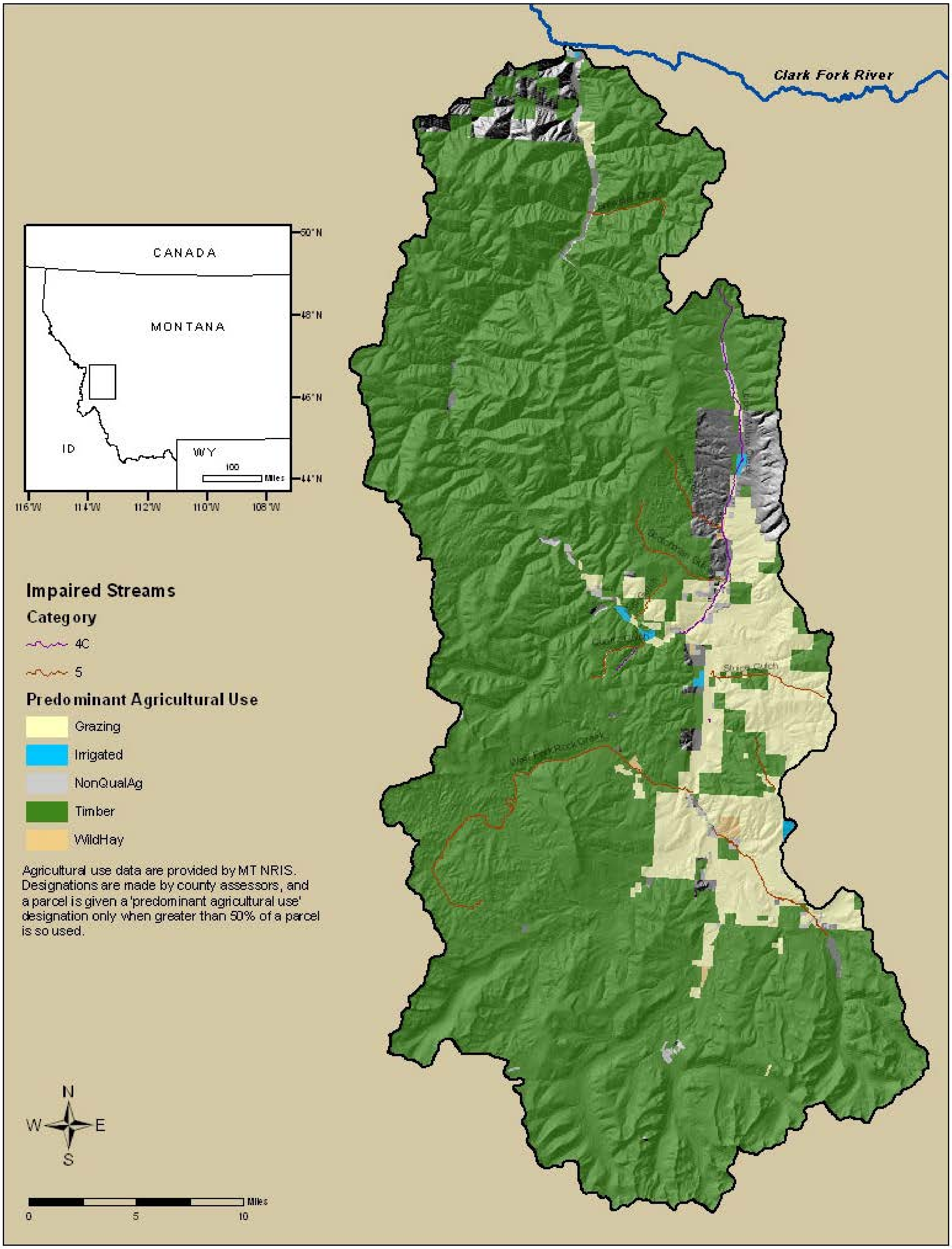
Map A-14. Recent significant fires in the Rock Creek TPA



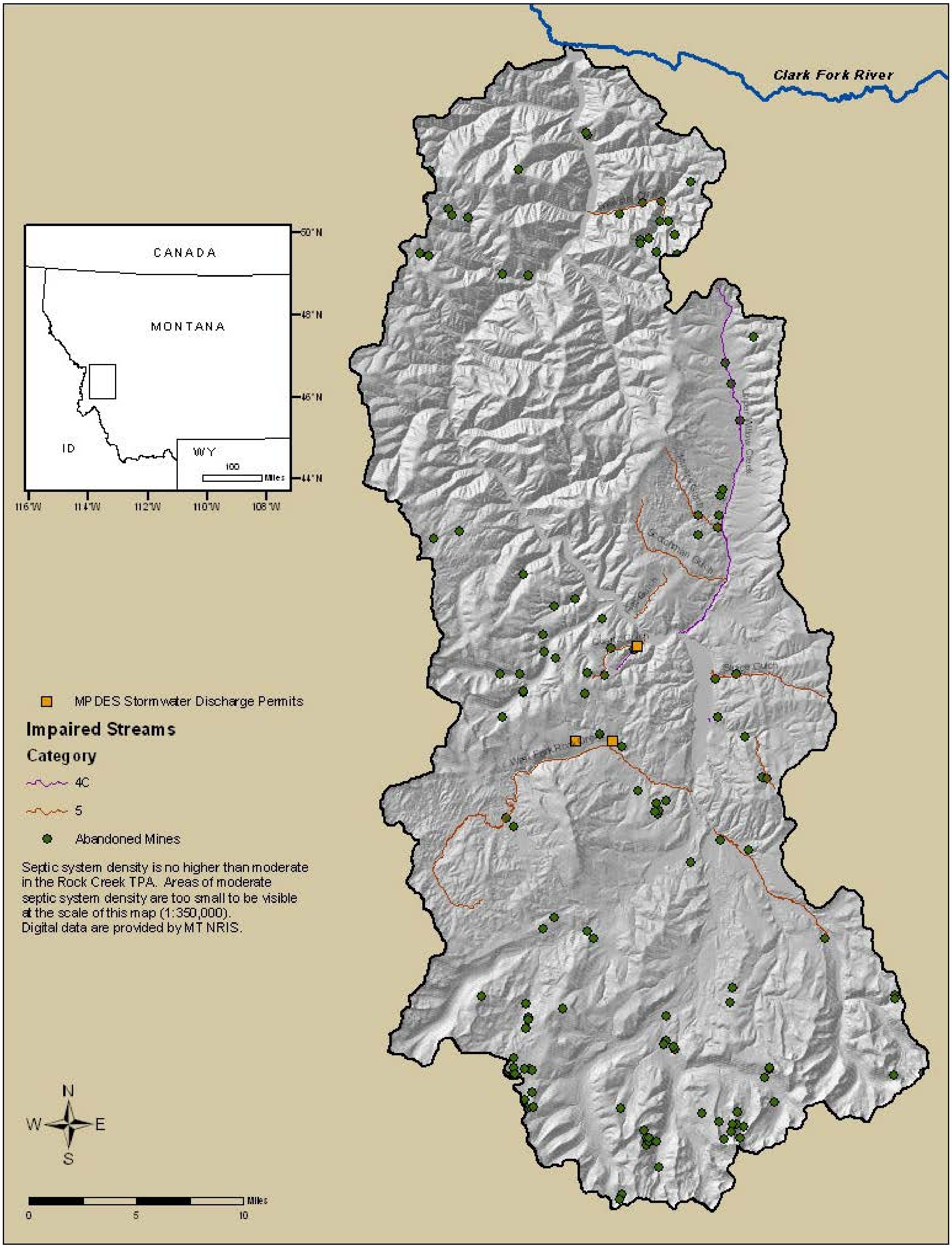
Map A-15. Population in the Rock Creek TPA



Map A-16. Land ownership in the Rock Creek TPA



Map A-17. Agricultural Land Use in the Rock Creek TPA



Map A-18. Potential Sources of Human Impacts

APPENDIX B – REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

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

B1.0 TMDL DEVELOPMENT REQUIREMENTS

Waterbodies, or individual waterbody segments where streams have been split into multiple segments, can become impaired from a variety of causes defined as either pollutants or non-pollutants. Pollutants include sediment, temperature, nutrients, and metals. Non-pollutants include flow alterations and different forms of habitat degradation. Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) require development of TMDLs for impaired waterbodies where one or more pollutants are the cause of impairment within the waterbody segment of interest.

Section 303(d) requires states to submit a list of impaired waterbodies in need of TMDL development to EPA every two years. This list is referred to the 303(d) list, and only includes waterbodies with impairment causes linked to a pollutant as defined under the CWA. The 303(d) list also includes the suspected source(s) of the pollutants of concern such as various land use activities. Prior to 2004, EPA and DEQ defined the 303(d) list as the list of all impaired waterbodies and associated impairment causes (pollutants and non-pollutants), versus just those waters with impairment causes linked to pollutants. Montana integrates the 303(d) list within the 305(b) report, which contains an assessment of Montana's water quality, information on streams impaired by non-pollutants, TMDL development status, and a description of Montana's water quality programs. This 305(b) report is also referred to as the Integrated Water Quality Report.

Under Montana state law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each waterbody is used for consistency; the actual methodology is identified in DEQ's Water Quality Assessment Process and Methods (Montana Department of Environmental Quality, 2006). This methodology was developed via a public process and was incorporated into the EPA-approved 2000 version of the 305(b) report.

A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State law and Section 303 of the CWA also require TMDL development for waterbodies threatened by a pollutant cause. There are no threatened waterbodies within the Rock Creek TPA.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable WQS to be exceeded. TMDLs are often expressed in terms of an amount, or mass, of a particular pollutant over a particular time period (e.g. pounds of total nitrogen per day). TMDLs can also be expressed in other appropriate measures such as a percent reduction in pollutant loading. TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS.

To satisfy the Federal CWA and Montana state law, TMDL development will eventually be needed for each waterbody-pollutant combination identified on Montana's 2012 303(d) List of impaired waters in the Rock Creek TPA, unless new data and associated analyses is sufficient to remove a pollutant cause of impairment from one or more waterbodies. State law (Administrative Rules of Montana 75-5-703(8)) also directs Montana DEQ to "...support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing federal, state, or local regulations.

B2.0 Applicable Water Quality Standards

Water Quality Standards (WQS's) include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. Water quality standards form the basis for the targets described in **Section 5.0** of the main document. This section provides a summary of the applicable water quality standards for sediment. The sediment TMDLs presented in this document also inherently address the additional non-pollutant causes of impairment identified in **Section 1.0** of the main document, **Table 1-1**.

B2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana Water Quality Act directs the Board of Environmental Review (BER) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (§ 75-5-301(1),MCA) and to adopt standards to protect those uses ((§ 75-5-301(1),MCA).

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

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

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table B-1**. All waterbodies within the Rock Creek TPA are classified as B-1.

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

Classification	Designated Uses
A-CLOSED CLASSIFICATION:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1 CLASSIFICATION:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.
B-1 CLASSIFICATION:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-2 CLASSIFICATION:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3 CLASSIFICATION:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1 CLASSIFICATION:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2 CLASSIFICATION:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3 CLASSIFICATION:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply. Degradation which will impact established beneficial uses will not be allowed.
I CLASSIFICATION:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

B2.2 NUMERIC AND NARRATIVE WATER QUALITY STANDARDS

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

Numeric surface WQS have been developed for many parameters to protect human health and aquatic life. Most of these standards are contained within the Department Circular WQB-7 (Montana Department of Environmental Quality, 2010). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., lifelong) exposures as well as through direct contact such as swimming.

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

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

B2.3 POLLUTANT SPECIFIC STANDARDS

The standards applicable to the TMDLs addressed in this Rock Creek TPA document are summarized below.

B2.3.1 Sediment Standards

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in **Table B-2**. The standards applicable to a B-1 classification are used in **Table B-2**. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels or from discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a condition in which any increases in sediment above naturally occurring levels are not harmful, detrimental or injurious to beneficial uses (see definitions in **Table B-2**). Naturally occurring levels are evaluated using a reference approach as defined in **Section B-3**.

Table B-2. Applicable Water Quality Standards for Sediment

Rule(s)	Standard or Definition
17.30.623(2) [B-1 classification section number; same language applies for A-1 classification]	No person may violate the following specific water quality standards for waters classified B-1:
17.30.623(2)(f) [B-1 classification section number; same language applies for A-1 classification]	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except a permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.623(2)(d) [B-1 classification]	The maximum allowable increase above naturally occurring turbidity five nephelometric turbidity units except at permitted in 75-5-318, MCA. Note: 75-5-318, MCA allows for short term variances linked to construction activities, etc.
17.30.622(3)(d) [A-1 classification]	No increase above naturally occurring turbidity or suspended sediment is allowed except at permitted in 75-5-318, MCA. Note: 75-5-318, MCA allows for short term variances linked to construction activities, etc.
17.30.637(1 a & d) [this section applies to B-1 and A-1 classifications)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: (a) settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines; ….. and (d) create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
17.30.602 (same definitions for A-1 and B-1 classifications)	DEFINITIONS
	"Sediment" means solid material settled from suspension in a liquid; mineral or organic solid material that is being transported or has been moved from its site of origin by air, water, or ice and has come to rest on the earth's surface, either above or below sea level; or inorganic or organic particles originating from weathering, chemical precipitation, or biological activity.
	"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.
	"Reasonable land, soil, and water conservation practices" means methods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include but are not limited to structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities.

B2.3.2 Temperature Standards

Montana's water quality standard for temperature specifies a maximum allowable increase above the "naturally occurring" temperature in order to protect the existing temperature regime for fish and aquatic life. For waters classified as B-1, the maximum allowable increase over the naturally occurring temperature is 1°F, if 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 [ARM

17.30.622(e), ARM 17.30.623(e)]. Note that naturally occurring temperatures incorporate natural sources along with human sources with reasonable land and water management activities.

Instream temperature monitoring and predictive modeling both indicate that naturally occurring stream temperatures in both the East Fork Rock and South Fork Antelope Creeks are likely less than 66.5°F during portions of the summer months, which is the most sensitive timeframe for supporting fishery use. Based on this analysis, the maximum allowable increase due to unmitigated human causes would be 1°F.

B2.3.3 Nutrient Standards

The narrative standards applicable to nutrients in Montana are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. Undesirable aquatic life includes bacteria, fungi, and algae. Montana has recently developed draft nutrient criteria for total nitrogen (TN) and total phosphorus (TP) based on the level III ecoregion in which a stream is located (Suplee and Watson, 2013). In addition, Suplee et al. (2013), developed a target for nitrate (also known as nitrate+nitrite nitrogen or NO_2+NO_3) for the Middle Rockies Level III Ecoregion that provides an appropriate numeric translation of the applicable narrative nutrient water quality standard. For the Middle Rockies Level III Ecoregion, draft water quality criteria for TN and TP and the target for nitrate are presented in **Table B-3**. This target and the proposed criteria are growing season, or summer, values applied from July 1st through September 30th. Additionally, numeric human health standards exist for nitrogen (**Table B-4**), but the narrative standard is most applicable to nutrients as the concentration in most waterbodies in Montana is well below the human health standard and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standard.

Table B-3. Nitrate Target and Proposed Numeric Nutrient and Criteria for the Middle Rockies Ecoregion

Parameter	Criteria/Target
Nitrate (Nitrate+Nitrite)	≤ 0.100 mg/L (1)
Total Nitrogen	≤ 0.300 mg/L (2)
Total Phosphorus	≤ 0.030 mg/L (2)

(1) From Suplee et al., 2008
(2) From Suplee and Watson, 2012

Table B-4. Human Health Standards for Nitrogen for the State of Montana.

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

[1]Maximum Allowable Concentration.

B2.3.4 Metals Standards

Water quality standards that are applicable to metals impairments include both numeric water quality criteria given in DEQ-7 (**Table B-5**) and general prohibitions (narrative criteria) given in **Table B-6.** As water quality criteria for many metals is dependent upon water hardness, **Table B-5** presents acute and chronic metals numeric water quality criteria at water harnesses of 25 mg/L and 100 mg/L for metals of concern in the Rock Creek TPA. Also presented in **Table B-5** is the Human Health Criteria (HHC): note that for mercury and arsenic, the HHC is lower than applicable chronic criteria.

For iron, the human health standard (i.e., 300ug/L) is a secondary maximum contaminant level that is based on aesthetic water properties such as taste, odor, and the tendency of these metals to cause staining. Iron is not classified as a toxin or a carcinogen. Therefore, for the purposes of this TMDL document, the secondary MCL guidance values for iron is not applied or considered in the evaluation of water quality data. The chronic aquatic life standard of 1,000 µg/L for iron is used as the metals target for iron.

It should be noted that recent studies have indicated in some streams metals concentrations may vary throughout the day because of diel pH and alkalinity changes. In some cases the variation can cross the standard threshold (both ways) for a metal. Montana water quality standards are not time of day dependent.

Table B-5. Numeric Water Quality Criteria for metal pollutants at two water hardness conditions

Metal of Concern	Aquatic Life Criteria (µg/L) at 25 mg/L Hardness		Aquatic Life Criteria (µg/L) at 100 mg/L Hardness		Human Health Criteria (µg/L)
	Acute	Chronic	Acute	Chronic	
Aluminum	750	87	750	87	NA
Arsenic, TR	340	150	340	150	10
Cadmium, TR	0.52	0.10	2.13	0.27	5
Copper, TR	3.79	2.85	14.00	9.33	1,300
Iron, TR	---	1,000	---	1,000	*300
Lead, TR	13.98	0.54	81.65	3.18	15
Mercury, total	1.70	0.91	1.70	0.91	0.05
Silver, TR	037	--	4.06	--	100
Zinc, TR	37.02	37.02	119.82	119.82	2,000

*Human Health Criteria for iron is a secondary maximum contaminant level based on aesthetic properties

In addition to numeric criteria given in **Table B-5**, narrative criteria also address water quality protection. The Administrative Rules of Montana (ARM 17.30.637 (1)(d)) prohibit additions of toxic levels of metals to stream sediment. The narrative criteria related to metals concentrations in stream sediment are given below in **Table B-6.** The criteria do not allow concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.

Table B-6. Applicable Rules for Metals Concentrations in Sediment

Rule(s)	Criteria
17.30.623 (1) 17.30.624 (1)	Waters classified B-1 (B-2) are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
17.30.623(2) 17.30.624(2)	No person may violate the following specific water quality standards for waters classified B-1 (B-2).
17.30.623 (2)(f) 17.30.624 (2)(f)	(f) No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation,

Table B-6. Applicable Rules for Metals Concentrations in Sediment

Rule(s)	Criteria
17.30.623 (2)(h) 17.30.624 (2)(h)	(h) Concentrations of carcinogenic, bioconcentrating, toxic, radioactive, nutrient, or harmful parameters may not exceed the applicable standards set forth in department Circular DEQ-7.
17.30.637	General Prohibitions
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.

C.2.3.4.1 pH Standards

Waterbodies impaired by metals are also sometimes impaired by pH as a result of acid mine drainage. For human health, changes in pH are addressed by the general narrative criteria in ARM 17.30.601 et seq. and ARM 17.30.1001 et seq. For aquatic life, which can be sensitive to small pH changes, criteria are specified for each waterbody use classification. For B-1 waters ARM 17.30.623 (2)(c) states "Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0."

B2.5 NONDEGRADATION

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant", or an authorization to degrade must be granted by the Department. However, under no circumstance may standards be exceeded. It is important to note that waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to the waterbody. Although these nondegradation rules are not integrated into TMDL development, they help limit pollutant loading in waters where designated uses are currently satisfied. Some of these waters may be healthy tributaries to waters where a TMDL is developed; thus nondegradation can help implement TMDL related pollutant controls at a watershed scale.

B3.0 REFERENCE CONDITIONS

B3.1 DEQ APPROACH FOR DEFINING A REFERENCE CONDITION

DEQ uses the reference condition to evaluate compliance with many of the narrative WQS. The term "reference condition" is defined 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, reference condition reflects a waterbody's greatest potential for water quality given historic land use activities. Although sediment water quality targets typically relate most directly to the aquatic life use, the targets are protective of all designated beneficial uses because they are based on the reference approach, which strives for the highest possible condition.

DEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as sediment) that have specific narrative standards. All classes of waters are subject to the provision that there can be no increase above naturally occurring concentrations of sediment and settleable solids, oils, or floating solids sufficient to create a nuisance or render the water harmful, detrimental, or injurious. These levels depend on site-specific factors, so the reference conditions approach is used.

Montana WQS do not contain specific provisions addressing detrimental modifications of habitat. However, detrimental modifications of habitat may often lead to or result from increases above naturally occurring concentrations of sediment, etc. and therefore the reference condition approach is used to help determine if beneficial uses are supported when habitat modifications are present. The reference approach can also be used to develop riparian and shade target parameters when evaluating temperature.

Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. It attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil, and water conservation practices. DEQ realizes that pre-settlement water quality conditions usually are not attainable.

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar season and/or hydrologic conditions for both waters. For example, the Total Suspended Solids (TSS) of a stream at base flow during the summer should not be compared to the TSS of reference condition that would occur during a runoff event in the spring. In addition, a comparison should not be made to the lowest or highest TSS values of a reference site, which represent the outer boundaries of reference conditions. The following methods may be used to determine reference conditions:

Primary Approach

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach

- Reviewing literature (e.g. a review of studies of fish populations, etc., that were conducted on similar waterbodies that are least impaired.
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential).
- Applying quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ uses the primary approach for determining reference condition if adequate regional or other primary reference data is available, and uses the secondary approach to estimate reference condition when primary approach data is limited or unavailable. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

B3.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution; whereas, water resources data tend to have a non-normal distribution (Helsel and Hirsch, 1995). For this reason, another approach is to compare stream conditions to the median value of a reference data set to see if the stream condition compares favorably to this value or falls within the range defined by the 25th and 75th percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on non-normal distributions are far less influenced by such observations.

Figure B-1 is an example boxplot type presentation of the median, 25th and 75th percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include Rosgen stream types, stream size ranges, or geology. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life, then measured values in the potentially impaired stream that fall below the 25th percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is one where high values are undesirable, then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative WQS or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (U.S. Environmental Protection Agency, 1999). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing DEQ guidance development for interpreting narrative WQS where it is determined that there is “good” confidence in the quality of the reference sites and resulting information (Suplee, 2004). If it is determined that there is only a “fair” confidence in the quality of the reference sites, then the 50th percentile or median value should be used, and if it is determined that there is “very high” confidence, then the 90th percentile of the reference data set should be used. Most reference data sets available for water quality restoration planning and related TMDL development, particularly those dealing with sediment and habitat alterations, would tend to be “fair” to “good” quality. This is primarily due to a the limited number of available reference sites/data points available after applying all potentially applicable stratifications on the data, inherent variations in monitoring results among field crews, the potential for variations in field methodologies, and natural yearly variations in stream systems often not accounted for in the data set.

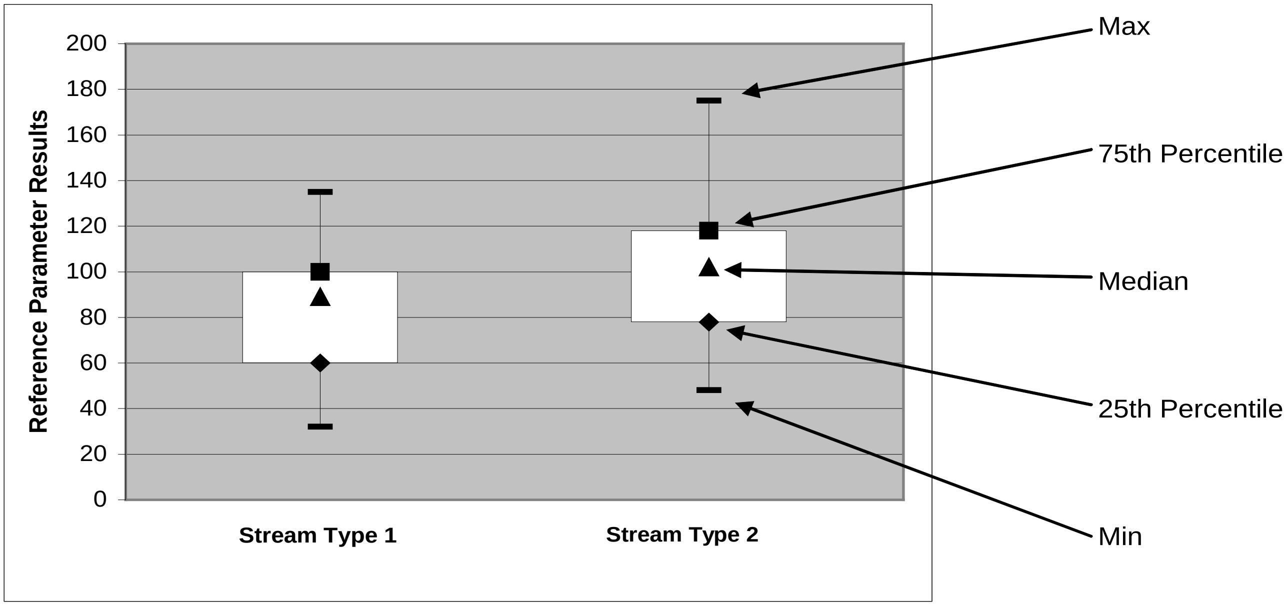


Figure B-1. Boxplot Example for Reference Data.

The above 25^{th} – 75^{th} percentile statistical approach has several considerations:

- It is a simple approach that is easy to apply and understand.
- About 25% of all streams would naturally fall into the impairment range. Thus, it should not be applied unless there is some linkage to human activities that could lead to the observed conditions. Where applied, it must be noted that the stream's potential may prevent it from achieving the reference range as part of an adaptive management plan.
- About 25% of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25^{th} to 75^{th} percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
- Obtaining reference data that represents a naturally occurring condition can be difficult, particularly for larger waterbodies with multiple land uses within the drainage. This is because all reasonable land, soil, and water conservation practices may not be in place in many larger waterbodies across the region. Even if these practices are in place, the proposed reference stream may not have fully recovered from past activities, such as riparian harvest, where reasonable land, soil, and water conservation practices were not applied.
- A stream should not be considered impaired unless there is a relationship between the parameter of concern and the beneficial use such that not meeting the reference range is likely to cause harm or other negative impacts to the beneficial use as described by the WQS. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, coldwater fish, or other beneficial uses, then an impairment determination should not be made based on the particular parameter being evaluated. Relationships that show an impact to the beneficial use can be used to justify impairment based on the above statistical approach.

As identified in (2) and (3) above, there are two types of errors that can occur due to this or similar statistical approaches where a reference range or reference value is developed: (1) A stream could be considered impaired even though the naturally occurring condition for that stream parameter does not meet the desired reference range or (2) a stream could be considered not impaired for the parameter(s) of concern because the results for a given parameter fall just within the reference range, whereas the naturally occurring condition for that stream parameter represents much higher water quality and beneficial uses could still be negatively impacted. The implications of making either of these errors can be used to modify the above approach, although the approach used will need to be protective of water quality to be consistent with DEQ guidance and WQS (Suplee, 2004). Either way, adaptive management is applied to this water quality plan and associated TMDL development to help address the above considerations.

Where the data does suggest a normal distribution, or reference data is presented in a way that precludes use of non-normal statistics, the above approach can be modified to include the mean plus or minus one standard deviation to provide a similar reference range with all of the same considerations defined above.

Options When Regional Reference Data is Limited or Does Not Exist

In some cases, there is very limited reference data and applying a statistical approach like above is not possible. Under these conditions, the limited information can be used to develop a reference value or range, with the need to note the greater level of uncertainty and perhaps a greater level of future monitoring as part of the adaptive management approach. These conditions can also lead to more reliance on secondary type approaches for reference development.

Another approach would be to develop statistics for a given parameter from all streams within a watershed or region of interest (Buck et al., 2000). The boxplot distribution of all the data for a given parameter can still be used to help determine potential target values knowing that most or all of the streams being evaluated are either impaired or otherwise have a reasonable probability of having significant water quality impacts. Under these conditions you would still use the median and the 25^{th} or 75^{th} percentiles as potential target values, but you would use the 25^{th} and 75^{th} percentiles in a way that is opposite from how you use the results from a regional reference distribution. This is because you are assuming that, for the parameter being evaluated, as many as 50% to 75% of the results from the whole data distribution represent questionable water quality. **Figure B-2** is an example statistical distribution of an entire dataset where lower values represent better water quality (and reference data are limited). In **Figure B-2**, the median and 25^{th} percentiles of all data represent potential target values versus the median and 75^{th} percentiles discussed above for regional reference distribution. Whether you use the median, the 25^{th} percentile, or both should be based on an assessment of how impacted all the measured streams are in the watershed. Additional consideration of target achievability is important when using this approach. Also, there may be a need to also rely on secondary reference development methods to modify how you apply the target and/or to modify the final target value(s). Your certainty regarding indications of impairment or non-impairment may be lower using this approach, and you may need to rely more on adaptive management as part of TMDL implementation.

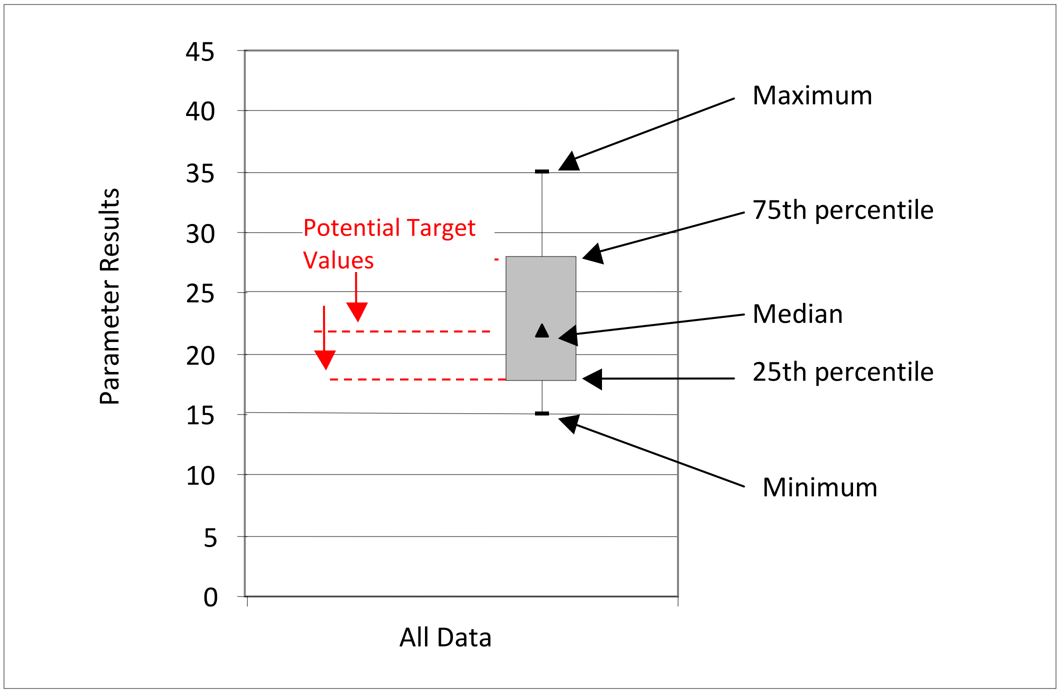


Figure B-2. Boxplot example for the use of all data to set targets.

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APPENDIX C - ANALYSIS OF BASE PARAMETER DATA AND EROSION INVENTORY DATA FOR SEDIMENT TMDL DEVELOPMENT WITHIN THE ROCK TPA

Appendix C is based on a report prepared for the DEQ by Water & Environmental Technologies, PC, June 2012, which is on file in the DEQ WQPB Library.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

C1.0 INTRODUCTION

The Rock TPA encompasses an area of approximately 569,320 acres, or approximately 890 square miles, in Granite and Missoula counties of southwestern Montana (**Attachment C1, Figure C1-1**). This TPA comprises the entire Rock Creek watershed. Waterbodies in this TPA flow through both publicly-owned (United States Forest Service, State of Montana and Bureau of Land Management) and privately-owned land. The streams in the Rock TPA are within the 4^{th} code HUC 17010202, and they have been assigned a B-1 beneficial use classification (ARM 17.30.623). Rock Creek is located in the Pend Oreille River Basin (Accounting Unit 170102) and drains from the Anaconda Range to the Clark Fork River near Clinton. The watershed is located in the Middle Rockies and Idaho Batholith Level III Ecoregions. Flow in Rock Creek is reduced by an inter-basin diversion from the East Fork Reservoir on East Fork Rock Creek into Trout Creek, a tributary of Flint Creek.

Under Montana law, an impaired waterbody is defined as a waterbody for which sufficient and credible data indicates non-compliance with applicable water quality standards (MCA 75-5-103). Section 303 of the Federal Clean Water Act requires states to submit a list of impaired water bodies or stream segments to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, this list was referred to as the “303(d) list”, but is now named the “Integrated Report”. The Montana Water Quality Act further directs states to develop TMDLs for all water bodies appearing on the 303(d) list as impaired or threatened by “pollutants” (MCA 75-5-703).

Within the Rock TPA, there are 9 waterbody segments listed on the 2012 303(d) List for sediment-related impairments: Brewster Creek, East Fork Rock Creek, Eureka Gulch, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, Sluice Gulch, and South Fork Antelope Creek. Streams identified in this sampling strategy include all of the streams listed above as well as Upper Willow Creek (which is impaired due to habitat alteration), Antelope Creek, and West Fork Rock Creek.

In 2011, Montana Department of Environmental Quality (DEQ) initiated an effort to collect data to support the development of sediment TMDLs for streams within the Rock TPA. This data collection effort involved assessing sediment and habitat conditions within the Rock Creek watershed, including stream stratification, sampling design, ground surveys, and sediment and habitat analyses. These data are intended to assist DEQ in evaluating the condition of tributary streams in the TPA and developing TMDLs where necessary.

A stream stratification process was previously completed by DEQ on stream segments in the Rock TPA. The stratification process is intended to develop similar waterbody characterizations that can be applied across watersheds, accounting for localized ecological and hydrologic variations. Stratification enables comparison between observed and expected values for various sediment and habitat parameters, and helps quantify the effects of anthropogenic influences. Stratification for streams in the Rock TPA began by dividing the water bodies into reaches and sub-reaches based on aerial photo interpretation of stream characteristics, landscape conditions, and land-use factors.

Following the initial primary reach stratification, representative reaches were chosen by DEQ for data collection. A two-day sampling reach reconnaissance was conducted in July 2011, and field personnel completed full site surveys in August 2011. Field personnel visited the selected reaches and recorded bank erosion sites, vegetation, and channel characteristic data as detailed in this report. Data were later compiled and analyzed resulting in full descriptions of sediment and habitat conditions for all of the surveyed reaches and the ability to extrapolate to non-surveyed reaches.

C2.0 Aerial Assessment Reach Stratification

C2.1 Methods

An aerial photo assessment of streams in the Rock TPA was conducted by Montana DEQ using geographic information systems (GIS) software and 2009 color aerial imagery. Relevant geographic data layers were acquired from the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA) and the Montana State National Resource Information System (NRIS) database. Layers include the following data sets.

- Ecoregion (USEPA)
- Scanned and Rectified Topographic Maps, 1:24,000 and 1:100,000 (USGS)
- National Hydrography Dataset Lakes and Streams (USGS)
- 2009 National Aerial Image Program (NAIP – NRIS)

GIS data layers were used to stratify streams into primary reaches based on stream characteristics, landscape and land-use factors. The stream reach stratification methodology applied in this study is described in *Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations* (Montana Department of Environmental Quality, 2008). The reach stratification methodology involves delineating a waterbody stream segment into stream reaches and sub-reaches. This process was completed for the following stream segments in the Rock TPA: Antelope Creek, Brewster Creek, East Fork Rock Creek, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, South Fork Antelope Creek, Sluice Gulch, Upper Willow Creek, and West Fork Rock Creek. Although Eureka Gulch was stratified, no sites were assessed on the stream during the sediment and habitat data collection in 2011 because access was not granted.

C2.2 Stream Reaches

Waterbody segments are delineated by a water use class designated by the State of Montana, e.g. A-1, B-3, C-3 (Administrative Rules of Montana Title 17 Chapter 30, Sub-Chapter 6). Although a waterbody segment is the smallest unit for which an impairment determination is made, the stratification approach described in this document initially stratifies individual waterbody segments into discrete assessment reaches that are delineated by landscape controls including Ecoregion, Strahler stream order, valley gradient, and valley confinement. The reason for this stratification is that the inherent differences in landscape controls between stream reaches often prevents a direct comparison from being made between the physical attributes of one stream reach to another. By initially stratifying waterbody segments into stream reaches having similar landscape controls, it is feasible to make broad comparisons between similar reaches with regards to observed versus expected channel morphology. Likewise, when land use is used as an additional stratification category (e.g. grazed vs. non-grazed sub-reaches), sediment and habitat parameters for impaired stream reaches can be more readily compared to reference reaches that meet the same geomorphic stratification criteria.

Once stream reaches have been stratified, reaches are further divided based on the surrounding vegetation and land-use characteristics as observed in the color aerial imagery using GIS. The result is a series of stream reaches and sub-reaches delineated by landscape and land-use factors. Stream reaches with similar landscape factors can then be compared based on the character of surrounding land-use practices.

For ease of labeling, each listed stream in the assessment was assigned an abbreviation based on the stream name. These labels were used in the individual stream reach classification. **Table C2-1** shows the abbreviations developed for each waterbody.

Table C2-1. Waterbody naming key.

Waterbody	Label Abbreviation
Antelope Creek	ANTE
Brewster Creek	BREW
East Fork Rock Creek	EFRK
Flat Gulch	FLAT
Miners Gulch	MINE
Quartz Gulch	QUTZ
Scotchman Gulch	SCOT
South Fork Antelope Creek	SFAN
Sluice Gulch	SLUI
Upper Willow Creek	UWIL
West Fork Rock Creek	WFRK

C2.3 Reach Types

Individual stream reaches were delineated by reach type based on four watershed characteristics. For the purposes of this report, a “reach type” is defined as a unique combination of Ecoregion, valley gradient, Strahler stream order, and valley confinement, and is designated using the following naming convention based on the reach type identifiers provided in **Table C2-2**:

Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement

The Rock TPA exists within the Middle Rockies (Ecoregion 17) and Idaho Batholith (Ecoregion 16) Level III Ecoregions. Only a small portion of West Fork of Rock Creek is within Ecoregion 16, including one sample site (WFRK 14-03). For the purpose of analysis within this report this site will be categorized as being in the Middle Rockies Ecoregion even though it lies partially within the Idaho Batholith Ecoregion. The Middle Rockies Ecoregion includes three Level IV Ecoregions within the Rock TPA, including the Deer Lodge-Philipsburg-Avon Grassy Intermontane Hills and Valleys (17ak), the Flint Creek-Anaconda Mountains (17am), and the Rattlesnake-Blackfoot-South Swan-Northern Garnet-Sapphire Mountains (17x). The Idaho Batholith Ecoregion includes only one Level IV Ecoregion, the Eastern Batholith (16a). Present reach type combinations for the Rock TPA are provided in **Table C2-3**, including the number of sites monitored of each reach type. Overall, 22 monitoring sites were selected for field evaluation.

Table C2-2. Reach type identifiers.

Watershed Characteristic	Stratification Category	Reach Type Identifier
Level III Ecoregion	Middle Rockies	MR
Valley Gradient	0-2%	0
	2-4%	2
	4-10%	4
	> 10%	10
Strahler Stream Order	first order	1
	second order	2
	third order	3
	fourth order	4
Confinement	confined	C
	unconfined	U

Table C2-3. Stratified reach types within the Rock TPA.

Level III Ecoregion	Valley Gradient	Strahler Stream Order	Confine-ment	Reach Type	Total Number of Reaches	Number of Monitoring Sites
Middle Rockies	<2%	1	U	MR-0-1-U	2	
		2	U	MR-0-2-U	17	
		3	C	MR-0-3-C	1	
			U	MR-0-3-U	45	6
		4	U	MR-0-4-U	9	2
	2-4%	1	C	MR-2-1-C	3	
			U	MR-2-1-U	9	1
		2	C	MR-2-2-C	8	1
			U	MR-2-2-U	18	2
		3	C	MR-2-3-C	5	
			U	MR-2-3-U	15	2
	4-10%	1	C	MR-4-1-C	25	1
			U	MR-4-1-U	40	3
		2	C	MR-4-2-C	10	1
			U	MR-4-2-U	12	2
		3	C	MR-4-3-C	1	
			U	MR-4-3-U	2	
	>10%	1	C	MR-10-1-C	21	
			U	MR-10-1-U	20	1
		2	C	MR-10-2-C	3	
Totals:					**266**	**22**

Table C2-4 shows the assessed water bodies and monitored reaches included within each reach type. A map of monitoring site locations is provided as **Attachment C1 – Figure C1-1**.

Table C2-4. Monitoring sites in assessed reach types.

Reach Type	waterbody	Monitoring Sites
MR-0-3-U	Antelope Creek, Brewster Creek, Upper Willow Creek, West Fork Rock Creek	ANTE 21-01, BREW 06-01, UWIL 11-05, WFRK 14-03, WFRK 27-03, WFRK 30-02
MR-0-4-U	East Fork Rock Creek, Upper Willow Creek	EFRK 03-03, UWIL 15-01
MR-10-1-U	Flat Gulch	FLAT 13-01

Table C2-4. Monitoring sites in assessed reach types.

Reach Type	waterbody	Monitoring Sites
MR-2-1-U	Scotchman Gulch	SCOT 08-01
MR-2-2-C	Sluice Gulch	SLUI 14-01
MR-2-2-U	Miners Gulch, Sluice Gulch	MINE 14-02, SLUI 18-02
MR-2-3-U	Brewster Creek, East Fork Rock Creek	BREW 05-01, EFRK 01-02
MR-4-1-C	Quartz Gulch	QUTZ 09-01
MR-4-1-U	Flat Gulch, Miners Gulch, Scotchman Gulch	FLAT 12-01, MINE 10-02, SCOT 16-02
MR-4-2-C	South Fork Antelope Creek	SFAN 06-01
MR-4-2-U	Antelope Creek, South Fork Antelope Creek	ANTE 07-01, SFAN 13-01

C3.0 Sediment and Habitat Dataset Review

C3.1 Field Methodology

The following sections describe the field methodologies employed during the stream assessments. The methods follow standard DEQ protocols for sediment and habitat assessment as presented in the document *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2011a). For most survey sites, a minimum of 5 team members were present, which were always divided into 3 teams, referred to as the "Greenline", "Longitudinal Profile" or "Long-Pro", and "Cross-Section" teams. The teams worked independently moving upstream through the survey site and in a pre-established order to facilitate accurate data collection and to create the least possible instream disturbance. All field data were collected on DEQ standard forms for sediment and habitat assessments, and are summarized and provided in tabular format in the original report, which is available from the DEQ WQPB library.

C3.1.1 Survey Site Delineation

Stream survey sites were delineated beginning at riffle crests at the downstream end of each surveyed reach. Survey sites were measured moving upstream at pre-determined lengths based on the bankfull width at the selected downstream riffle. Survey lengths of 500 ft were used for bankfull widths less than 10 ft, survey lengths of 1,000 ft were used for bankfull widths between 10 ft and 50 ft, and survey lengths of 1,500 ft were used for bankfull widths of 51-75 ft. Each survey site was divided into 5 equally sized study cells. For each site, the field team leader identified the appropriate downstream riffle crest to begin a reach. Where no riffles were present or the stream was dry, the field team leader identified the appropriate starting point. The GPS location of the downstream and upstream ends of the survey site was recorded on the **Sediment and Habitat Assessment Site Information Form**. Digital photographs were taken at both upstream and downstream ends of the survey site, looking both upstream and downstream. Photo numbers and a brief description were recorded in a Photo Log.

C3.1.2 Field Determination of Bankfull

All members of the field crew participated in determining the bankfull elevation prior to breaking into their respective teams. Indicators that were used to estimate the bankfull channel elevation included scour lines, changes in vegetation types, tops of point bars, changes in slope, changes in particle size and distribution, stained rocks and inundation features. Multiple locations and indicators were examined, and bankfull elevation estimates and their corresponding indicators were recorded in the **Bankfull Elevation and Slope Assessment Field Form** by the field team leader. Final determination of the appropriate bankfull elevation was determined by the team leader, and informed by the team experience and notes from the field form.

C3.1.3 Channel Cross-Sections

The "Cross-Section team" was composed of two members of the assessment crew, who also performed pebble counts, riffle grid tosses, and riffle stability index. Channel cross-section surveys were performed at the first riffle in each cell moving upstream using a line level and a measuring rod. Channel surveys were recorded in the **Channel Cross-section Field Form**. Cross-sections were surveyed in each cell containing a riffle. In the case that riffles were present in only 1 or 2 cells, but those cells contained multiple riffles, additional cross-sections were performed at the most downstream unmeasured riffle, such that a minimum of three cross-sections were surveyed. If only 1 or 2 riffles were present in the entire reach, all riffle cross-sections were surveyed.

To begin each survey, the Cross-Section team placed a bank pin at the pre-determined bankfull elevation (using bankfull indicators as guides) on the right and left banks. A measuring tape was strung perpendicular to the stream channel at the most well-defined portion of the riffle and tied to the bank pins. Where mid-channel bars or other features were present which prevented a clean line across the channel, the protocol provided in the field methodology document was followed (Montana Department of Environmental Quality, 2011a). Bankfull depth measurements were collected to the nearest tenth of a foot across the channel at regular intervals depending on channel width. The thalweg depth was recorded at the deepest point of the channel independent of the regularly spaced intervals. From the recorded data, the following information was calculated for each cross-section:

Bankfull channel width = with of the channel measured at bankfull height.

Cross-sectional area = the sum of the calculated areas from each measured cross-section cell. This value is estimated in the field and later calculated in a spreadsheet.

Mean bankfull depth = cross-section area/bankfull channel width. This value is estimated in the field and later calculated in a spreadsheet.

Width/depth ratio = bankfull width / mean bankfull depth.

Entrenchment ratio = flood prone width / bankfull width.

The flood prone depth was determined by doubling the maximum channel depth. The flood prone width was then determined by stringing a tape from the bankfull channel margin on both right and left banks until the tape (pulled tight and flat) touched ground at the flood prone elevation. The total flood prone width was calculated by adding the bankfull channel width to the distances on each end of the channel to the flood prone elevation. When dense vegetation or other features prevented a direct line of tape from being strung, best professional judgment was used to determine the flood prone width. GPS coordinates for each cross-section were recorded. Photos were taken upstream and downstream of the cross section from the middle of the channel. A photo was also taken across the channel, showing the tape across the stream.

C3.1.3.1 Riffle Pebble Count
A Wolman pebble count (Wolman, 1954) was performed by the Cross-Section team at the first riffle encountered in cells 1, 2, 3 and 5 as the team progressed upstream for a total count of at least 400 particles. These data were recorded in the **Riffle Pebble Count Field Form**. Particle sizes were measured along their intermediate length axis (*b-axis*) and results were grouped into size categories. The team progressed from bankfull edge to bankfull edge using the "heel to toe" method, measuring particle size at the tip of the boot at each step. More specific details of the pebble count methodology can be found in the field methods document (Montana Department of Environmental Quality, 2011a).

C3.1.3.2 Riffle Grid Toss
Measurements of fine sediment in riffles were recorded by the Cross-Section team using the same grid toss method as used in pools (**Section C3.1.4.3**). Grid tosses were performed approximately within the right, middle, and left third of the riffle. Grid tosses were performed in the same general location but before the pebble counts (**Section C3.1.3.1**) to avoid disturbances to fine sediments. These measurements were recorded in the **Riffle Pebble Count Field Form.**

C3.1.3.3 Riffle Stability Index
In stream reaches that had well developed point bars downstream of riffles, a riffle stability index (RSI) was performed to determine the average size of the largest recently deposited particles, and to calculate an RSI which evaluates riffle particle stability (Kappesser, 2002). For stream reaches in which well-developed gravel bars were present, a RSI was determined by first measuring the intermediate axis (*b-axis*) of 15 of the largest recently deposited particles on a depositional bar. This information was recorded in the **Riffle Pebble Count Field Form**. During post-field data processing, the arithmetic mean of the largest recently deposited particles is calculated. This value is then compared to the cumulative particle size distribution of an adjacent riffle, as determined by the Wolman pebble count. The RSI is reported as the cumulative percentile of the particle size classes that are smaller than the arithmetic mean of the largest recently deposited particles. The RSI value generally represents the percent of mobile particles within the riffle that is adjacent to the sampled bar.

C3.1.4 Channel Bed Morphology
A variety of channel bed morphology features were measured and recorded by the "Long-Pro" team, which consisted of one team member experienced in identifying these features, and who could consult with the field team leader when needed. The length of the survey site occupied by pools and riffles was identified and recorded in the **Pools, Riffles and Large Woody Debris Field Form.** Beginning from the downstream end of the survey site, the upstream and downstream stations of dominant riffle and pool features were recorded. Riffles were considered dominant when occupying over 50% of the stream width. A pool is defined as a depression in the streambed that is concave in profile, is bounded by a "head crest" at the upstream end and "tail crest" at the downstream end, and that typically has a maximum depth that is 1.5 times the pool-tail depth. Pools and riffles were measured from the downstream to upstream end of each feature. Runs and glides were not recorded in the field form. Stream features were identified using standard methods (Montana Department of Environmental Quality, 2011a).

C3.1.4.1 Residual Pool Depth
For this assessment, a pool is defined as a depression in the streambed that is concave in profile, is bounded by a "head crest" at the upstream end and a "tail crest" at the downstream end, and has a maximum depth that is 1.5 times the pool-tail depth. Backwater pools were not measured. The station

(distance in feet) of each measured pool was recorded beginning at the downstream end of the survey site. At all pools, the maximum pool depth and pool tail depth were measured, the difference of which provides the residual pool depth. In the case of dry channels, readings were taken from channel bed surface to bankfull height. No pool tail crest depth was recorded for dammed pools (see **Section C3.1.4.2**).

C3.1.4.2 Pool Habitat Quality
Qualitative assessments of each pool feature were undertaken and recorded in the **Pools, Riffles and Large Woody Debris Field Form** as follows:

Pool types were determined to be either Scour (S) or Dammed (D).
Pool size was estimated relative to bankfull channel width was recorded as Small (S) or Large (L). Small pools were defined as <1/2 of the bankfull channel width and large pools were determined to be those >1/2 of the bankfull channel width or >20 feet wide.
Pool formative features were recorded as lateral scour (LS), plunge (P), boulder (B), or woody debris (W).
The primary pool cover type was recorded using the following codes:

V = Overhanging Vegetation
D = Depth
U = Undercut
B = Boulder
W = Woody Debris
N = No apparent cover

C3.1.4.3 Fine Sediment in Depositional Spawning Areas
A measurement of the percent of fine sediment in depositional spawning areas was conducted using the grid toss method at all scour pools encountered within each cell. Grid toss readings were focused in those gravels that appeared to be suitable or potentially suitable for trout spawning. Measurements were taken within the "arc" just upstream of the pool tail crest or other pool locations suitable for spawning, following the methodology in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2011a). Three measurements were taken across the channel with specific attention given to measurements in gravels determined to be of appropriate size for salmonid spawning. The presence of spawning gravels was recorded as Yes (Y), No (N) or Unknown (?) at each pool location.

C3.1.4.4 Woody Debris Quantification
The amount of large woody debris (LWD) was recorded by the Long-Pro team along the entire assessment reach in the **Pools, Riffles and Large Woody Debris Field Form**. Large pieces of woody debris within the bankfull channel and which were relatively stable as to influence the channel form were counted as either single, aggregate or willow bunch. For this assessment, a piece of large woody debris is defined as being greater than 9 feet long or two-thirds of the wetted stream width, and at least 4 inches in diameter at the small end. An aggregate is comprised of two or more single pieces of large woody debris. Further description of these categories is provided in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2011a).

C3.1.5 Riparian Greenline Assessment

After the entire survey station length was measured by the “Greenline” team member, an assessment of riparian vegetation cover was performed. The reach was walked by the “Greenline” team member who noted the general vegetation community type of the groundcover, understory and overstory on both banks. Vegetation types were recorded in the **Riparian Greenline Field Form** at intervals of 10’, 15’ or 20’ depending on the length of the reach.

The *ground cover* vegetation (<1.5 feet tall) was described using the following categories:

W = Wetland vegetation, such as sedges and rushes
G = Grasses or forbs, rose, snowberry (vegetation lacking binding root structure)
B = Bare/disturbed ground
R = Rock, when a large cobble or bolder is encountered
RR = Riprap

The *understory* (1.5 to 15 feet tall) and *overstory* (>15 feet tall) vegetation was described using the following categories:

C = Coniferous
D = Deciduous, riparian shrubs and trees with sufficient rooting mass and depth to provide protection to the streambanks
M = mixed coniferous and deciduous

At 50-foot intervals, riparian buffer width was estimated for both banks by evaluating the belt of riparian vegetation buffering the stream from adjacent land uses. Upon conclusion of the Greenline measurements, the total numbers of each type of vegetation were tallied.

C3.1.6 Streambank Erosion Assessment

An assessment of all actively/visually eroding and slowly eroding/undercut/vegetated streambanks was conducted along each survey site. This assessment consisted of the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) estimation which are used to quantify sediment loads from bank erosion. All streambank measurements were recorded in the **Streambank Erosion Field Form** and **Additional Streambank Erosion Measurements Form.** Further information related to the streambank erosion assessment methodology and results is included in **Sections C4.2** and **C4.3**.

C3.1.7 Water Surface Slope

The water surface slope was measured using a transit level and stadia rod using methods described in the field methods document (Montana Department of Environmental Quality, 2011a) and recorded on the **Slope Worksheet Field Form**. In areas where line of sight is not possible due to interference of vegetation or topography, slope was estimated between similar stream features using a clinometer.

C3.1.8 Field Notes

At the completion of data collection at each survey site, field notes were collected by the field team leader with inputs from the entire field team. The following four categories contributed to field notes, which served to provide an overall context for the condition of the stream channel relative to surrounding and historical uses:

- Description of human impacts and their severity;
- Description of stream channel conditions;
- Description of streambank erosion conditions; and

- Description of riparian vegetation conditions.

C3.1.9 Quality Assurance/Quality Control

Quality assurance and quality control (QA/QC) was achieved through strict adherence to the project's Sampling and Analysis Plan (SAP) (Montana Department of Environmental Quality, 2011b). During each stream assessment, the field team leader and most experienced crew members led the separate teams. Equipment checks were done each morning and field maps were reviewed with drivers before approaching field sites. Field forms were distributed and double-checked before teams left the vehicles to the survey sites. At the conclusion of each stream assessment, all field forms were reviewed for completeness and accuracy. Any questions that arose from field teams were brought to the attention of the field team leader until resolved to the leader's satisfaction.

Despite the best efforts to adhere to the project's SAP, some deviations did occur while in the field. Any deviations from the SAP are described in the Quality Assurance/Quality Control Review in the original report (Water & Environmental Technologies, 2012).

C3.2 Sampling Parameter Descriptions and Summaries by Reach Type

The following sections provide definitions of sampling parameters that were measured at each reach, and basic statistical summaries of data for each parameter organized by reach type. Parameters described in this section include bankfull channel width, width/depth ratio, entrenchment ratio, percent understory shrub cover, percent bare/disturbed ground, riffle pebble count data (% <2 mm and <6 mm, D50), riffle grid toss data (% <6 mm), riffle stability index (RSI), mean pool depth, pool frequency, pool grid toss data (% <6 mm), and large woody debris (LWD) frequency. Data for each individual measurement site were used in the statistical analysis (i.e. data from each of the individual cross sections in one assessment reach were used), and then sample reaches and water bodies were grouped into reach types as shown in **Table C2-3**.

Data provided for each parameter include statistical box plots and data tables organized by each reach type and a total that includes data from all monitored sites. The box plots and data tables provide the minimum and maximum observed values, and the 25th (Q1), 50th (median), and 75th (Q3) percentile values. The statistics tables also provide the number of reaches sampled and the number of data cases available for each parameter. Parameters with a limited number of cases (N<4) or with little variability may appear as a single line on the box plots.

C3.2.1 Bankfull Channel Width

Bankfull is a concept used by hydrologists to define a regularly occurring, channel-forming high flow. One of the first generally accepted definitions of bankfull was provided by Dunne and Leopold (1978):

> *"The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels."*

Bankfull channel width is measured at each surveyed cross-section as the width of the channel at bankfull height. In general, bankfull channel width will increase with stream order, although overwidened streams may have an artificially high channel width.

The measured bankfull channel widths are presented in **Figure C3-1** by reach type, and summary statistics are provided in **Table C3-1**. All surveyed cross sections are included in the data generated for each reach type**.**

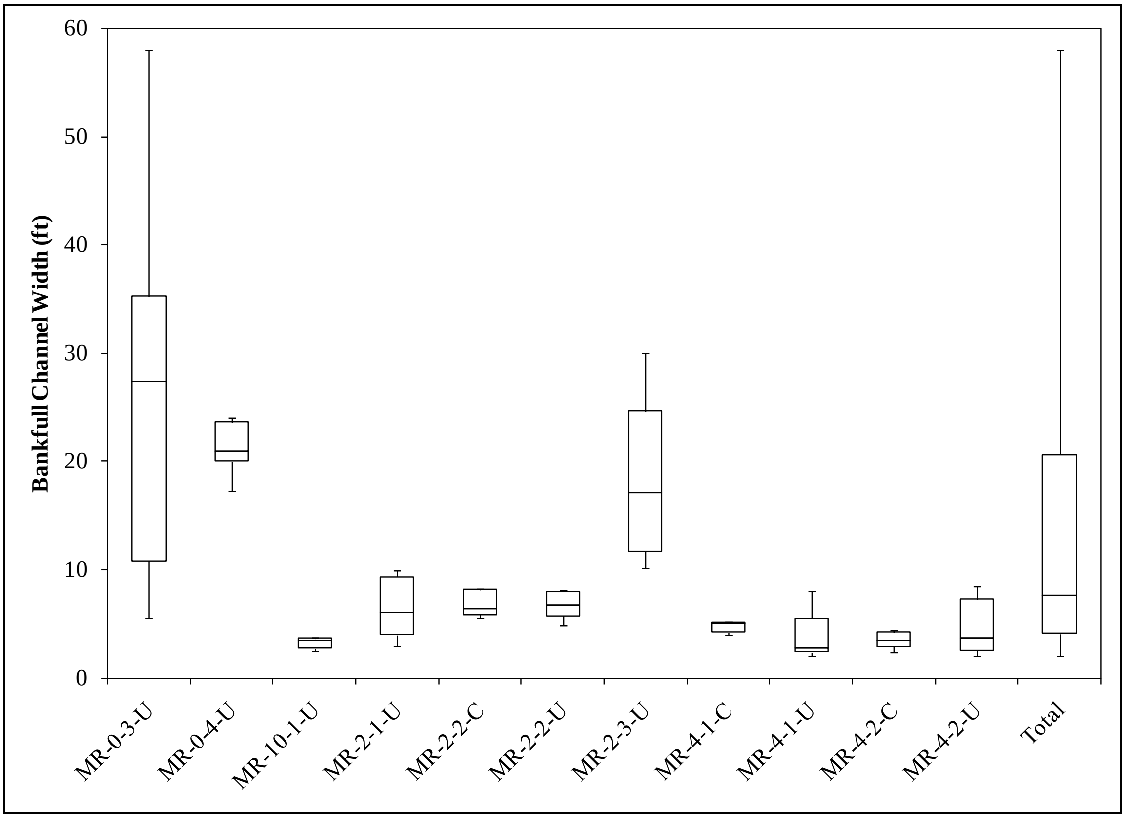

Figure C3-1. Bankfull channel width by reach type.

Table C3-1. Summary statistics of bankfull channel width by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	28	5.5	10.8	27.4	35.3	58.0
MR-0-4-U	2	10	17.3	20.1	21.0	23.6	24.0
MR-10-1-U	1	5	2.5	2.8	3.5	3.7	3.8
MR-2-1-U	1	5	3.0	4.0	6.1	9.4	10.0
MR-2-2-C	1	5	5.5	5.9	6.4	8.2	8.3
MR-2-2-U	2	10	4.9	5.8	6.8	8.0	8.2
MR-2-3-U	2	10	10.2	11.8	17.2	24.6	30.0
MR-4-1-C	1	5	4.0	4.3	5.0	5.1	5.2
MR-4-1-U	3	15	2.0	2.4	2.8	5.5	8.0
MR-4-2-C	1	5	2.4	3.0	3.5	4.2	4.4
MR-4-2-U	2	10	2.0	2.6	3.7	7.3	8.5
Total	**22**	**108**	**2.0**	**4.1**	**7.7**	**20.7**	**58.0**

C3.2.2 Width/Depth Ratio

The stream channel width/depth ratio is defined as the channel width at bankfull height divided by the mean bankfull depth (Rosgen, 1996). The width/depth ratio is one of several measurements used to classify stream channels, making it useful for comparing conditions on reaches within the same stream type. A comparison of observed and expected width/depth ratio is an indicator of channel overwidening and aggradation, which are often linked to excess streambank erosion or acute or chronic erosion from sources upstream. Channels that are overwidened often are associated with excess deposition and erosion, contain shallow warm water, and provide fewer deepwater refugia for fish. Width to depth ratios were calculated using mean segment depths instead of field measured depths, meaning that for each segment (the distance between any two adjacent field measured points on the cross section), the two field measured depths that make up the boundaries of that segment were averaged together (thereby estimating the midpoint for that segment of the cross- section's depth).

The measured width/depth ratios are presented in **Figure C3-2** by reach type, and summary statistics are provided in **Table 3-2**. All surveyed cross sections are included for each reach type**.**

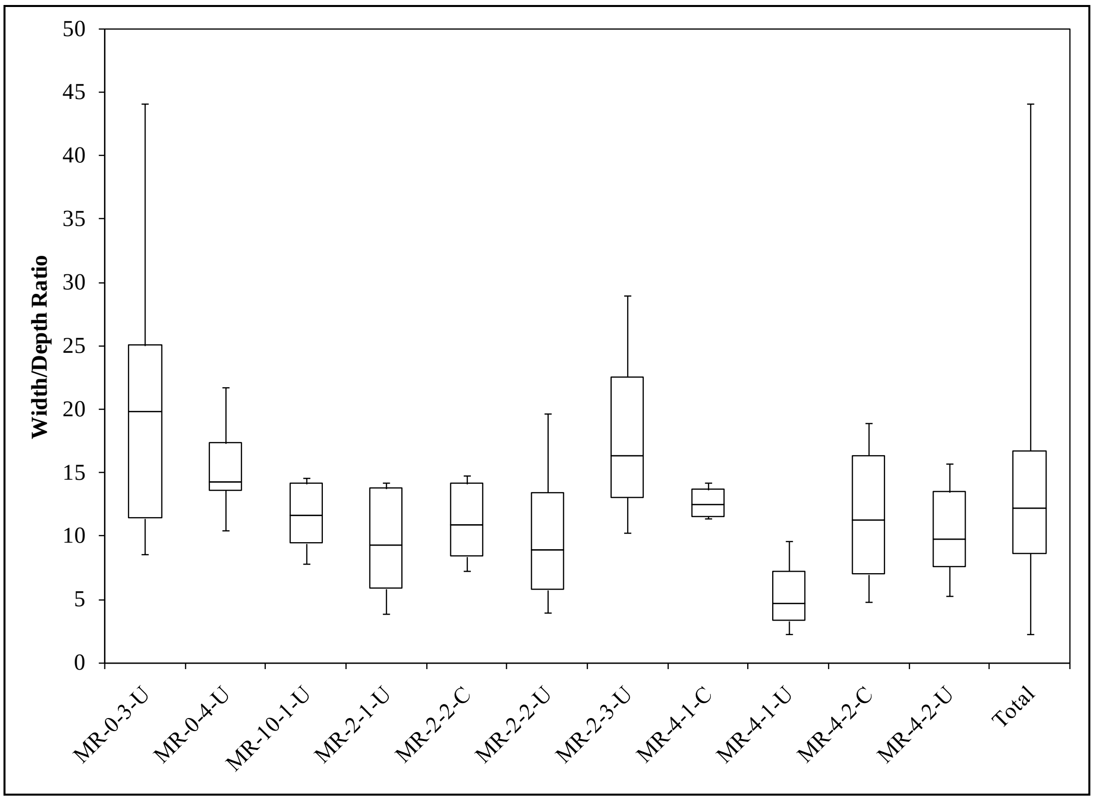

Figure C3-2. Width/depth ratio by reach type.

Table C3-2. Summary statistics of width/depth ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	28	8.6	11.4	19.8	25.0	44.1
MR-0-4-U	2	10	10.5	13.6	14.2	17.3	21.7
MR-10-1-U	1	5	7.8	9.5	11.7	14.2	14.6
MR-2-1-U	1	5	3.9	5.9	9.3	13.8	14.2
MR-2-2-C	1	5	7.2	8.4	10.9	14.2	14.8
MR-2-2-U	2	10	4.0	5.8	8.9	13.5	19.7
MR-2-3-U	2	10	10.3	13.1	16.3	22.6	29.0
MR-4-1-C	1	5	11.4	11.6	12.5	13.7	14.2
MR-4-1-U	3	15	2.2	3.3	4.7	7.2	9.6

Table C3-2. Summary statistics of width/depth ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-4-2-C	1	5	4.8	7.0	11.3	16.4	18.9
MR-4-2-U	2	10	5.3	7.6	9.8	13.5	15.7
Total	**22**	**108**	**2.2**	**8.6**	**12.2**	**16.7**	**44.1**

C3.2.3Entrenchment Ratio

Stream entrenchment ratio is equal to the flood prone width divided by the bankfull width (Rosgen, 1996). Entrenchment ratio is used to help determine if a stream shows departure from its natural stream type. It is an indicator of stream incision, and therefore indicates how easily a stream can access its floodplain. Streams are often incised due to detrimental land management or may be naturally incised due to landscape characteristics. A stream that is overly entrenched generally is more prone to streambank erosion due to greater energy exerted on the banks during flood events. Greater scouring energy in incised channels results in higher sediment loads derived from eroding banks. If the stream is not actively degrading (downcutting), the sources of human caused incision may be historical in nature and may not currently be present, although sediment loading may continue to occur. The entrenchment ratio is an important measure of channel condition as it relates to sediment loading and habitat condition, due to the long-lasting impacts of incision and the large potential for sediment loading in incised channels.

The entrenchment ratios by reach type are presented in **Figure C3-3**, and summary statistics are provided in **Table C3-3**. All surveyed cross sections are included in the statistics generated within each reach type**.**

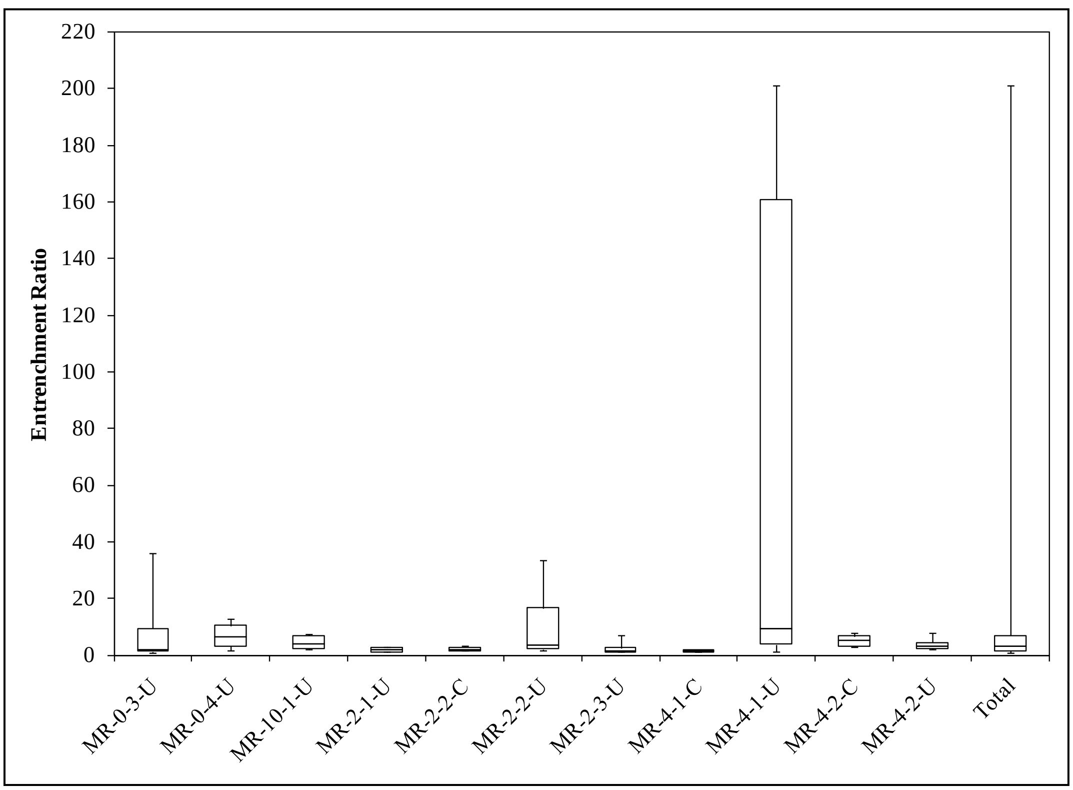

Figure C3-3. Entrenchment ratio by reach type.

Table C3-3. Summary statistics of entrenchment ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	28	1.1	1.4	2.0	9.4	36.0
MR-0-4-U	2	10	1.6	3.2	6.7	10.6	12.7
MR-10-1-U	1	5	2.3	2.3	4.2	7.0	7.7
MR-2-1-U	1	5	1.2	1.3	1.9	2.9	3.0
MR-2-2-C	1	5	1.6	1.7	1.9	2.9	3.4
MR-2-2-U	2	10	1.9	2.2	3.7	16.8	33.5
MR-2-3-U	2	10	1.2	1.2	1.6	2.6	7.0
MR-4-1-C	1	5	1.2	1.2	1.4	1.5	1.5
MR-4-1-U	3	15	1.5	4.0	9.2	161.0	201.0
MR-4-2-C	1	5	3.0	3.1	5.3	6.8	8.1
MR-4-2-U	2	10	2.0	2.4	3.3	4.6	7.9
Total	**22**	**108**	**1.1**	**1.6**	**3.0**	**7.0**	**201.0**

C3.2.4 Riffle Pebble Count: Substrate Fines (% <2 mm)

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The most obvious forms of degradation occur when critical habitat components such as spawning gravels (Chapman and McLeod, 1987) and cobble surfaces are physically covered by fines, thereby decreasing inter-gravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macroinvertebrates and algae (Lisle, 1989; Waters, 1995). Chapman and McLeod found that size of bed material is inversely related to habitat suitability for fish and macroinvertebrates and that excess sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-invertebrate relationships may be described as follows: 1) invertebrate abundance is correlated with substrate particle size; 2) fine sediment reduces the abundance of original populations by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles); and 3) species type, species richness, and diversity all change as particle size of substrate changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters, 1995).

The percent of fine sediment in a stream channel provides a measure of the siltation occurring in a river system and is an indicator of stream channel condition. Although it is difficult to correlate percent surface fines with sediment loading directly, the Clean Water Act allows "other applicable measures" for the development of TMDL water quality restoration plans. Percent surface fines have been used successfully in other TMDLs in western Montana addressing sediment related to stream bottom deposits, siltation, and aquatic life uses. Surface fine sediment measured in the Wolman pebble count is one indicator of aquatic habitat condition and can indicate excessive sediment loading. The Wolman pebble count method provides a survey of the particle distribution of the entire channel width, allowing investigators to calculate a percentage of the surface substrate (as frequency of occurrence) composed of fine sediment.

In addition to being a direct measure of impairment to the aquatic macroinvertebrate community, riffle percent surface fines can be used as an indicator of possible impairment condition to coldwater fish since the elevated riffle surface fines are likely an indicator of elevated subsurface fines within spawning gravels.

The pebble count measurements for particles <2 mm by reach type are presented in **Figure C3-4**, and summary statistics are provided in **Table C3-4**.

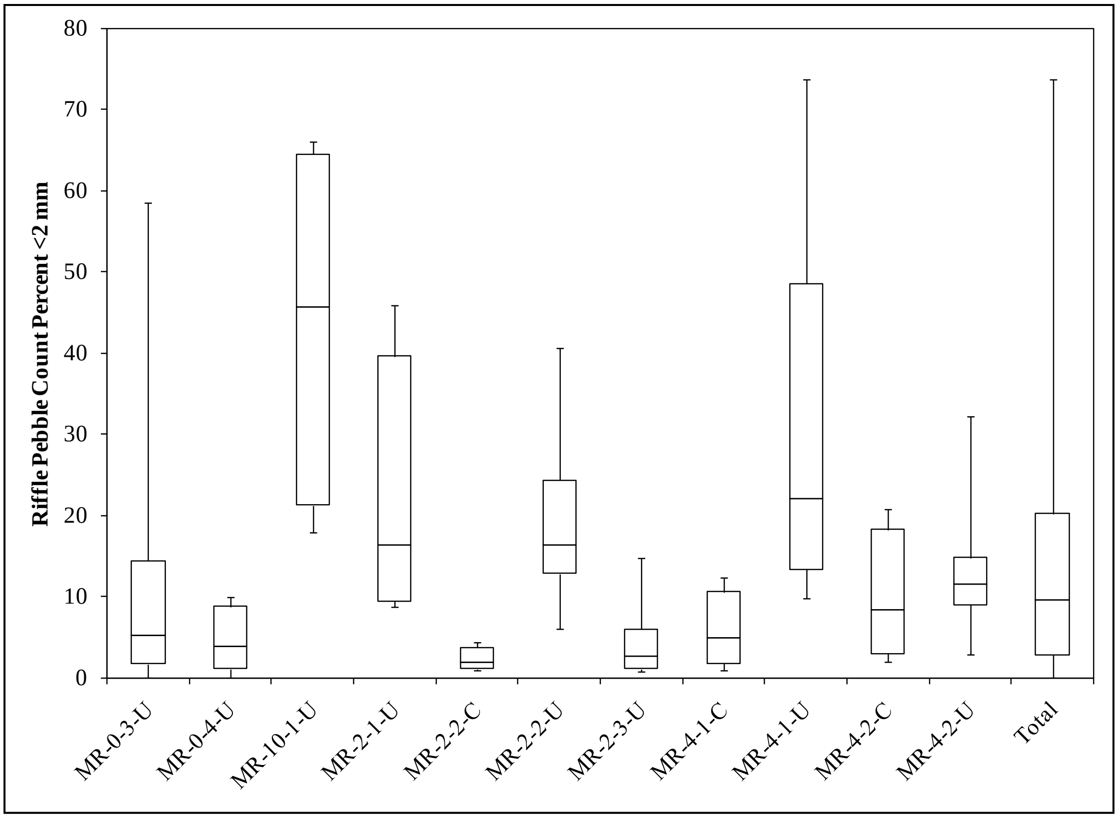

Figure C3-4. Riffle pebble count (% <2 mm) by reach type.

Table C3-4. Summary statistics of riffle pebble count (% <2 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	0.0	1.7	5.3	14.5	58.5
MR-0-4-U	2	8	0.0	1.2	3.8	8.8	9.9
MR-10-1-U	1	4	17.9	21.3	45.7	64.5	66.0
MR-2-1-U	1	4	8.7	9.5	16.3	39.6	45.9
MR-2-2-C	1	4	0.9	1.1	1.9	3.8	4.4
MR-2-2-U	2	8	6.0	12.8	16.3	24.4	40.6
MR-2-3-U	2	8	0.8	1.1	2.7	6.0	14.7
MR-4-1-C	1	4	0.9	1.8	4.9	10.6	12.4
MR-4-1-U	3	12	9.8	13.4	22.0	48.6	73.8
MR-4-2-C	1	4	2.0	3.0	8.4	18.3	20.8
MR-4-2-U	2	8	2.9	9.0	11.5	14.8	32.2
Total	**22**	**88**	**0.0**	**2.8**	**9.5**	**20.3**	**73.8**

C3.2.5 Riffle Pebble Count: Substrate Fines (% <6 mm)

As with surface fine sediment smaller than 2 mm diameter, an accumulation of surface fine sediment less than 6 mm diameter may also indicate excess sedimentation and has the potential to negatively impact the spawning success of coldwater fish. The size distribution of substrate material in the streambed is also indicative of habitat quality for salmonid spawning and incubation. Excess surface fine substrate may have detrimental impacts on aquatic habitat by cementing spawning gravels, thus reducing their accessibility, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan, 1991).

Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material less than 6.35 mm and the emergence success of westslope cutthroat trout and bull trout. Weaver (1996) noted that bull trout spawning is threatened in streams when the percent of riffle substrate <6.35mm exceeds 35% (Weaver, 1996).

The pebble count measurements for sediment fines (% <6 mm) by reach type are presented below in **Figure C3-5** and summary statistics are provided in **Table C3-5**.

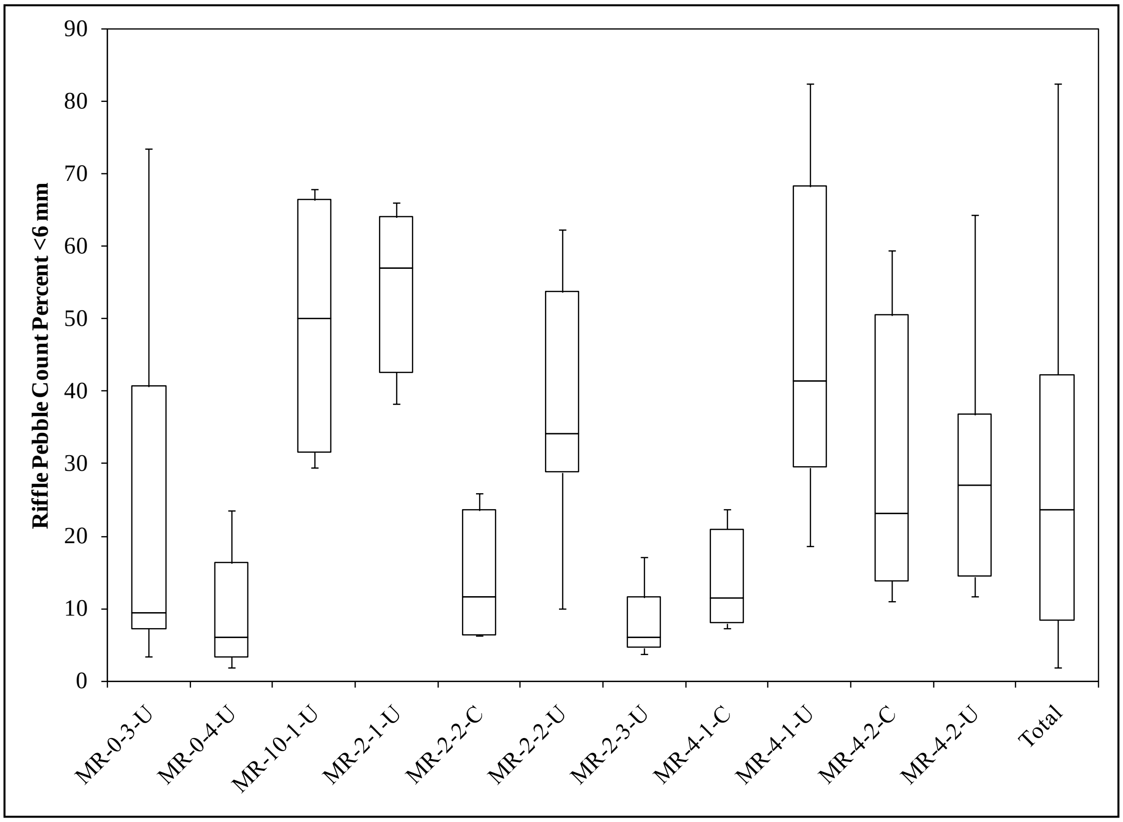

Figure C3-5. Riffle pebble count (% <6 mm) by reach type.

Table C3-5. Summary statistics of riffle pebble count (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	3.5	7.3	9.5	40.7	73.5
MR-0-4-U	2	8	1.8	3.4	6.0	16.3	23.6
MR-10-1-U	1	4	29.5	31.6	50.0	66.5	68.0
MR-2-1-U	1	4	38.3	42.7	57.1	64.1	66.1
MR-2-2-C	1	4	6.4	6.4	11.6	23.6	26.0
MR-2-2-U	2	8	10.0	28.9	34.1	53.8	62.4
MR-2-3-U	2	8	3.8	4.7	6.1	11.6	17.1
MR-4-1-C	1	4	7.3	8.1	11.5	21.0	23.8
MR-4-1-U	3	12	18.7	29.5	41.5	68.3	82.5
MR-4-2-C	1	4	11.0	13.9	23.2	50.5	59.4
MR-4-2-U	2	8	11.8	14.5	27.1	36.8	64.4
Total	**22**	**88**	**1.8**	**8.4**	**23.7**	**42.3**	**82.5**

C3.2.6 Riffle Pebble Count: D50

The D50 represents the median (50th percentile) particle size of a riffle as determined by the Wolman pebble count. This value can be used to evaluate the suitability of a riffle as spawning gravel for salmonids. Kondolf and Wolman (1993) state that the appropriate size of spawning gravels varies based on stream size and fish species, since larger fish are capable of moving larger particles. In general, fish can spawn in gravels with a median diameter up to about 10% of their body length (Kondolf, 2000). Appropriate sized spawning gravels should be less than approximately 40 mm for salmonids.

Results of the riffle pebble count D50 are presented below by reach type in **Figure C3-6** and summary statistics are provided in **Table C3-6**.

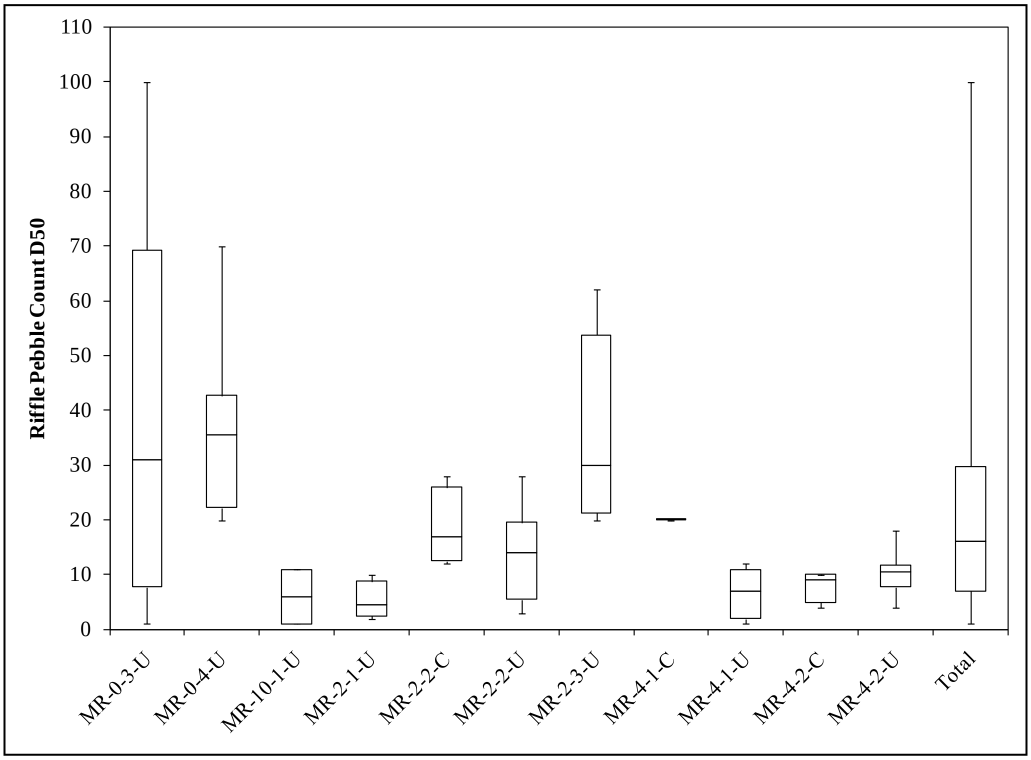

Figure C3-6. Riffle pebble count D50 (mm) by reach type.

Table C3-6. Summary statistics of riffle pebble count D50 (mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	1	8	31	69	100
MR-0-4-U	2	8	20	22	36	43	70
MR-10-1-U	1	4	1	1	6	11	11
MR-2-1-U	1	4	2	3	5	9	10
MR-2-2-C	1	4	12	13	17	26	28
MR-2-2-U	2	8	3	6	14	20	28
MR-2-3-U	2	8	20	21	30	54	62
MR-4-1-C	1	4	20	20	20	20	20
MR-4-1-U	3	12	1	2	7	11	12
MR-4-2-C	1	4	4	5	9	10	10
MR-4-2-U	2	8	4	8	11	12	18
Total	**22**	**88**	**1**	**7**	**16**	**30**	**100**

C3.2.7 Riffle Stability Index

The riffle stability index (RSI) is used to evaluate riffle particle mobility in an area receiving excessive sediment input (Kappesser, 2002). The mobile fraction in a riffle is estimated by comparing the particle sizes in the riffle to the arithmetic mean of the largest mobile particles on an adjacent depositional bar. Riffle particles of the size class smaller than the largest particles on a depositional bar are interpreted as mobile, and the RSI value represents the percent of mobile particles within a riffle. Riffles that have received excessive sediment from upstream eroding banks have a higher percent of mobile particles than riffles in equilibrium. The following breaks are provided as general guidelines for interpreting RSI values:

RSI Value	Description
< 40	High bedrock component to riffle (very stable system) or channel has been scoured
40 – 70	Stream is in dynamic equilibrium – good channel and watershed stability
70 – 85	Riffle is somewhat loaded with excessive sediment
> 85	Riffle is loaded with excessive sediment

Limited RSI data were collected during this field effort due to the frequency of poorly developed point bars downstream of riffles and actively eroding banks. The riffle stability index results for all reaches are provided below in **Table C3-7**.

Table C3-7. Riffle stability index results for all reaches.

Reach ID	Cell	Reach Type	Arithmetic Mean (mm)	Riffle Stability Index
QUTZ 09-01	2	MR-4-1-C	35	71
UWIL 15-01	1	MR-0-4-U	61	73
UWIL 15-01	5	MR-0-4-U	74	87
WFRK 30-02	1	MR-0-3-U	95	66

C3.2.8 Riffle Grid Toss: Substrate Fines (% <6 mm)

The wire grid toss is a standard procedure frequently used in aquatic habitat assessment to approximate the percent fine material in a stream. The grid toss measurement does not cover the entire channel width as in the Wolman pebble count, but rather provides a more focused measurement of surface fines in a subsample of the cross-section.

The riffle grid toss results for sediment fines (% <6 mm) are presented below in **Figure C3-7** and summary statistics are provided in **Table C3-8**. A great degree of variability exists for some reach types due to the high percent of fines in some individual reaches. Riffle grid toss data for individual reaches is shown in a latter section of this report (see **Figure C3-18**).

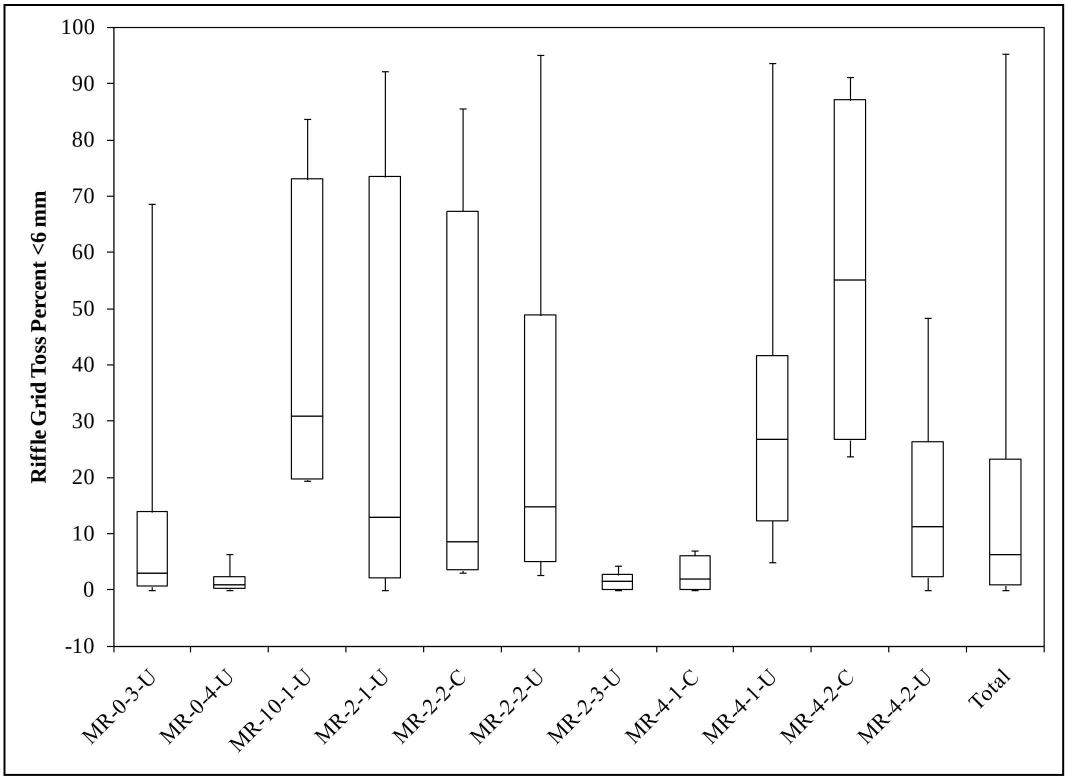

Figure C3-7. Riffle grid toss (% <6 mm) by reach type.

Table C3-8. Summary statistics of riffle grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	0.0	0.7	3.1	13.9	68.7
MR-0-4-U	2	8	0.0	0.2	0.8	2.4	6.3
MR-10-1-U	1	4	19.4	19.7	30.9	73.0	83.7
MR-2-1-U	1	4	0.0	2.2	12.9	73.5	92.3
MR-2-2-C	1	4	3.0	3.5	8.6	67.3	85.7
MR-2-2-U	2	8	2.7	5.1	14.7	48.8	95.2
MR-2-3-U	2	8	0.0	0.2	1.5	2.7	4.3
MR-4-1-C	1	4	0.0	0.2	2.0	6.1	7.0
MR-4-1-U	3	12	4.9	12.3	26.8	41.7	93.7
MR-4-2-C	1	4	23.8	26.7	55.1	87.1	91.2
MR-4-2-U	2	8	0.0	2.3	11.2	26.4	48.3
Total	**22**	**88**	**0.0**	**0.9**	**6.2**	**23.3**	**95.2**

C3.2.9 Pool Grid Toss within Depositional Spawning Areas: Sediment Fines (% <6 mm)

Grid toss measurements in depositional spawning areas provide a measure of fine sediment accumulation in potential spawning sites. Excess surface fines may have detrimental impacts on aquatic habitat by cementing spawning gravels, thus reducing their accessibility, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan, 1991). Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material < 6.35mm and the emergence success of cutthroat and bull trout.

Grid toss results for sediment fines (% <6 mm) found within depositional spawning areas are provided below in **Figure C3-8** and summary statistics are provided in **Table C3-9**. The data presented here represents only pool tails that were identified as having the appropriate sized gravels to support spawning. There were four assessed reaches (FLAT 12-01, FLAT 13-01, UWIL 11-05, and WFRK 27-02) where spawning gravels did not exist in pool tails.

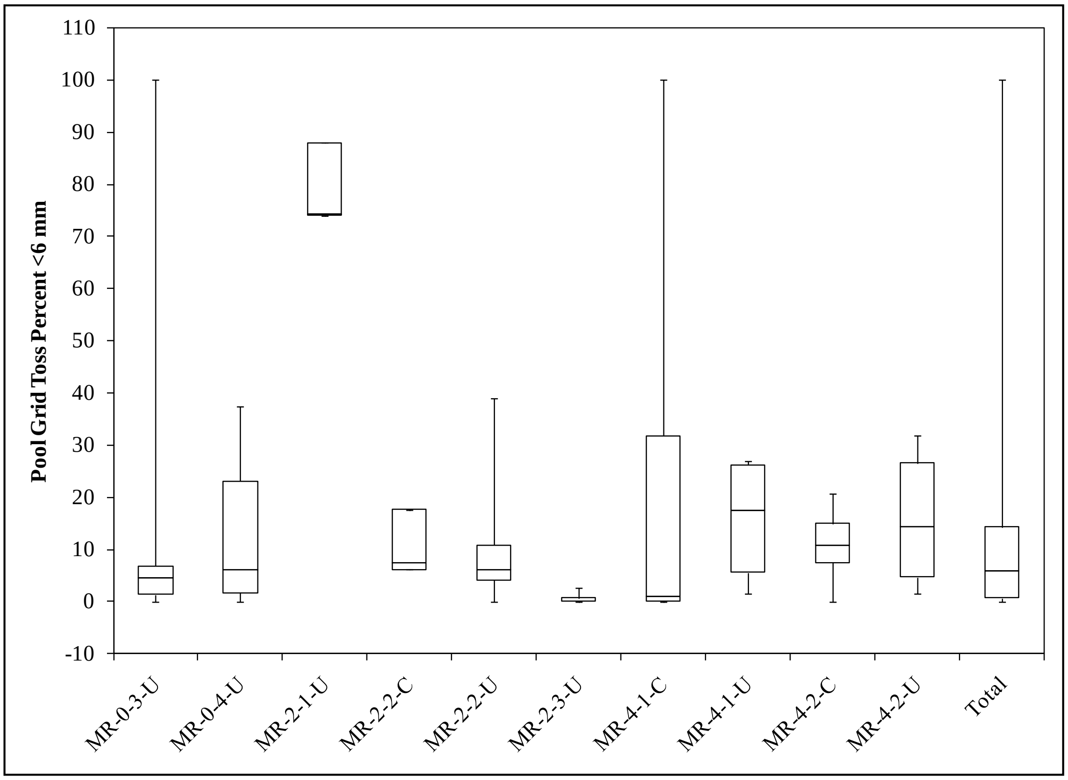

Figure C3-8. Pool grid toss (% <6 mm) by reach type.

Table C3-9. Summary statistics of pool grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	4	15	0	1	4	7	100
MR-0-4-U	2	18	0	2	6	23	38
MR-2-1-U	1	3	74	74	74	88	88
MR-2-2-C	1	3	6	6	7	18	18
MR-2-2-U	2	19	0	4	6	11	39
MR-2-3-U	2	19	0	0	0	1	3
MR-4-1-C	1	14	0	0	1	32	100
MR-4-1-U	2	6	1	6	18	26	27
MR-4-2-C	1	7	0	8	11	15	21
MR-4-2-U	2	11	1	5	14	27	32
Total	**18**	**115**	**0**	**1**	**6**	**14**	**100**

C3.2.10 Pool Residual Depth

Residual pool depth, defined as the difference between pool maximum depth and crest depth, is a discharge-independent measure of pool depth and an indicator of the quality of pool habitat. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods. Pool residual depth is also an indirect measurement of sediment inputs to listed streams. An increase in sediment loading would be expected to cause pools to fill, thus decreasing residual pool depth over time.

Data are presented below in **Figure C3-9** and **Table C3-10**. Note that the data presented represents the mean residual pool depth for each reach, so some reach types have only one data point. Residual pool depths were not calculated for dammed pools.

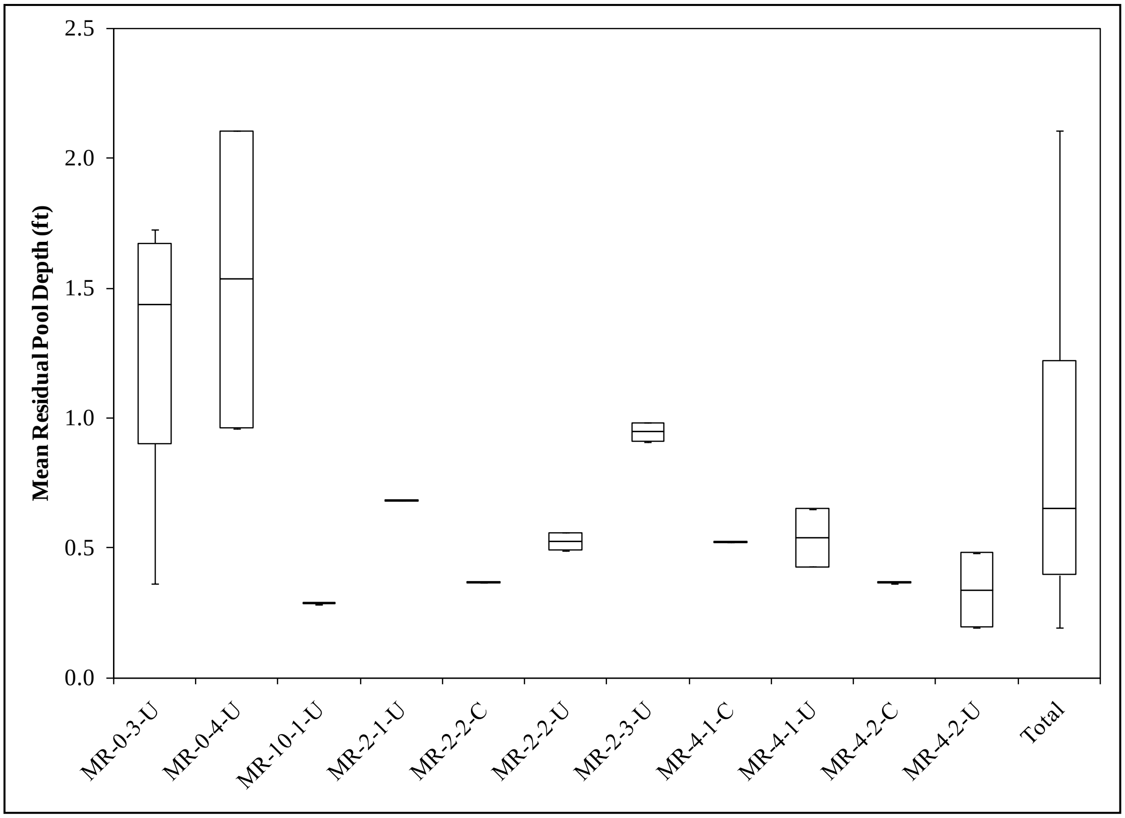

Figure C3-9. Residual pool depth (ft) by reach type.

Table C3-10. Summary statistics of residual pool depth (ft) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	6	0.4	0.9	1.4	1.7	1.7
MR-0-4-U	2	2	1.0	1.0	1.5	2.1	2.1
MR-10-1-U	1	1	0.3	0.3	0.3	0.3	0.3
MR-2-1-U	1	1	0.7	0.7	0.7	0.7	0.7
MR-2-2-C	1	1	0.4	0.4	0.4	0.4	0.4
MR-2-2-U	2	2	0.5	0.5	0.5	0.6	0.6
MR-2-3-U	2	2	0.9	0.9	0.9	1.0	1.0
MR-4-1-C	1	1	0.5	0.5	0.5	0.5	0.5
MR-4-1-U	3	3	0.4	0.4	0.5	0.7	0.7
MR-4-2-C	1	1	0.4	0.4	0.4	0.4	0.4
MR-4-2-U	2	2	0.2	0.2	0.3	0.5	0.5
Total	**22**	**22**	**0.2**	**0.4**	**0.7**	**1.2**	**2.1**

C3.2.11 Pool Frequency

Pool frequency is a measure of the availability of pools within a reach to provide rearing habitat, cover, and refugia for salmonids. Pool frequency is related to channel complexity, availability of stable obstacles, and sediment supply. Excessive erosion and sediment deposition can reduce pool frequency by filling in smaller pools. Pool frequency can also be affected adversely by riparian habitat degradation resulting in a reduced supply of large woody debris or scouring from stable root masses in streambanks.

The pool frequencies per 1,000 ft for each reach type are presented in below **Figure C3-10** and summary statistics are provided in **Table C3-11**. As with residual pool depth, some reach types are represented by only a single value.

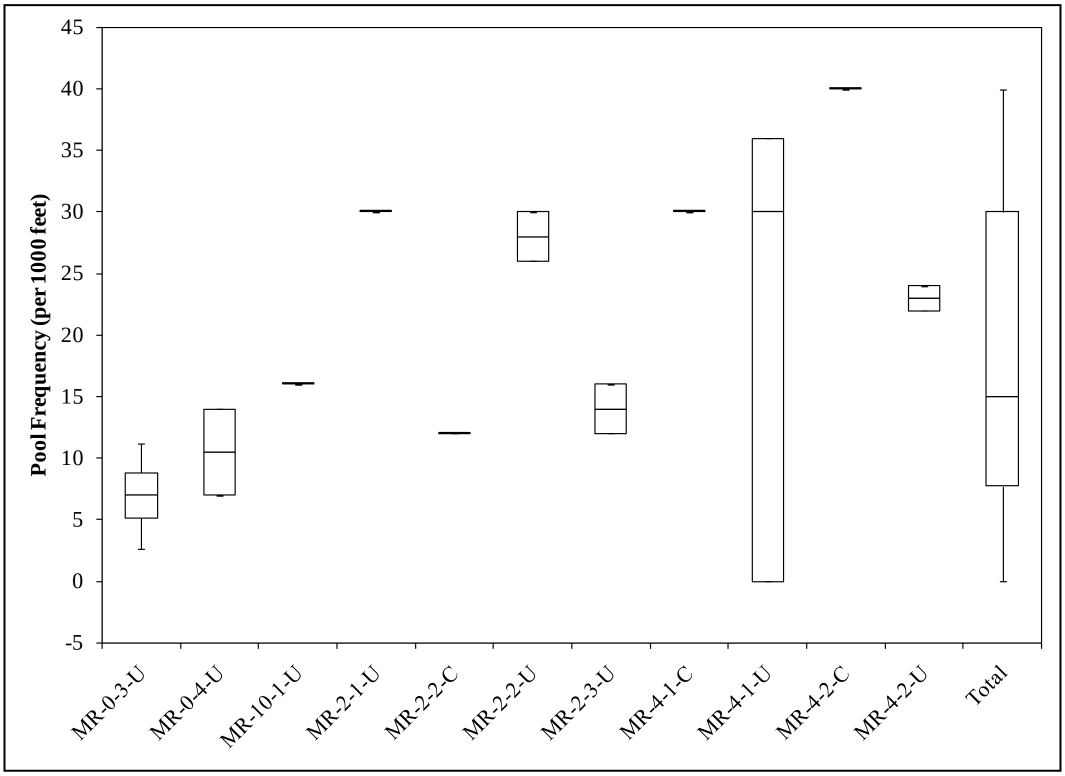

Figure C3-10. Pool frequency (per 1,000 ft) by reach type.

Table C3-11. Summary statistics of pool frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	6	3	5	7	9	11
MR-0-4-U	2	2	7		11		14
MR-10-1-U	1	1	16		16		16
MR-2-1-U	1	1	30		30		30
MR-2-2-C	1	1	12		12		12
MR-2-2-U	2	2	26		28		30
MR-2-3-U	2	2	12		14		16
MR-4-1-C	1	1	30		30		30
MR-4-1-U	3	3	0	0	30	36	36
MR-4-2-C	1	1	40		40		40
MR-4-2-U	2	2	22		23		24
Total	**22**	**22**	**0**	**8**	**15**	**30**	**40**

C3.2.12 Large Woody Debris Frequency

Large woody debris (LWD) is a critical component of salmonid habitat, providing stream complexity, pool habitat, cover, and long-term nutrient inputs. LWD also constitutes a primary influence on stream function, including sediment and organic material transport, channel form, bar formation and stabilization, and flow dynamics (Bilby and Ward, 1989). LWD frequency can be measured and compared to reference reaches or literature values to determine if more or less LWD is present than would be expected under reference conditions. Too little or too much LWD may indicate riparian habitat impairment or upstream influences on habitat quality. Target values for LWD span a broad range of values, even for streams of similar size. Results for LWD should be interpreted with caution, as the guideline value for this parameter is tied to a high degree of variability due to land use, vegetative community and soils, among other factors.

The LWD frequencies for each reach type are provided below in **Figure C3-11** and summary statistics are provided in **Table C3-12**.

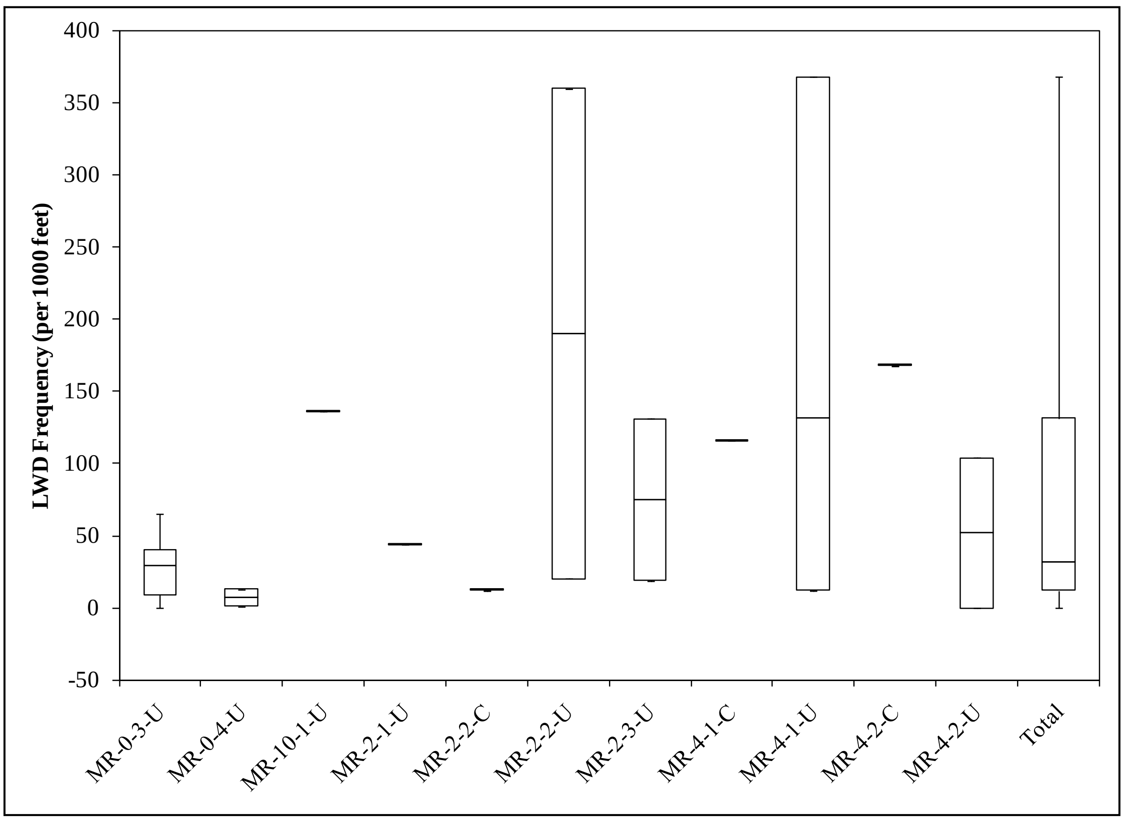

Figure C3-11. LWD frequency (per 1,000 ft) by reach type.

Table C3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	6	0	9	29	41	65
MR-0-4-U	2	2	1		7		13
MR-10-1-U	1	1	136		136		136
MR-2-1-U	1	1	44		44		44
MR-2-2-C	1	1	12		12		12

Table C3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-2-2-U	2	2	20		190		360
MR-2-3-U	2	2	19		75		131
MR-4-1-C	1	1	116		116		116
MR-4-1-U	3	3	12	12	132	368	368
MR-4-2-C	1	1	168		168		168
MR-4-2-U	2	2	0		52		104
Total	**22**	**22**	**0**	**12**	**32**	**131**	**368**

C3.2.13 Greenline Inventory: Percent Understory Shrub Cover

Riparian shrub cover is an important factor on streambank stability. Removal of riparian shrub cover can dramatically increase streambank erosion and increase channel width/depth ratios. Shrubs stabilize streambanks by holding soil and armoring lower banks with their roots, and reduce scouring energy of water by slowing flows with their branches. Good riparian shrub cover is also important for fish habitat. Riparian shrubs provide shade which reduce solar inputs and help maintain cooler water temperatures. The dense network of fibrous roots of riparian shrubs allows streambanks to remain intact while water scours the lowest portion of streambanks, creating important fish habitat in the form of overhanging banks and lateral scour pools. Overhanging branches of riparian shrubs provide important cover for aquatic species. In addition, riparian shrubs provide critical inputs of food for fish and other aquatic life. Terrestrial insects falling from riparian shrubs provide one main food source for fish. Organic inputs from shrubs, such as leaves and small twigs, provide food for aquatic macroinvertebrates, which are also an important food source for fish.

Summary statistics and boxplots from original report were removed because the data collected in the field was not correctly reported in the report.

C3.2.14 Greenline Inventory: Percent Bare/Disturbed Ground

Percent bare ground is an important indicator of erosion potential, as well as an indicator of land management influences on riparian habitat. Bare ground was noted in the Greenline inventory in cases where recent ground disturbance was observed, leaving bare soil exposed. Bare ground is often caused by trampling from livestock or wildlife, fallen trees, recent bank failure, new sediment deposits from overland or overbank flow, or severe disturbance in the riparian area, such as past mining, road-building, or fire. Ground cover on streambanks is important to prevent sediment recruitment to stream channels. Sediment can wash in from unprotected areas due to snowmelt, storm runoff, or flooding. Bare areas are also much more susceptible to erosion from hoof shear. Most stream reaches have a small amount of naturally-occurring bare ground. As conditions are highly variable, this measurement is most useful when compared to reference values from best available conditions within the study area or literature values.

Summary statistics and boxplots from original report were removed because the data collected in the field was not correctly reported in the report.

C3.3 Sampling Parameter Summaries by Individual Reach

The following **Figures C3-12** to **C3-18** display statistical boxplots of stream channel parameters that were measured in each of the monitored sites. Individual reaches are also grouped by reach type and displayed below the reach names on each boxplot.

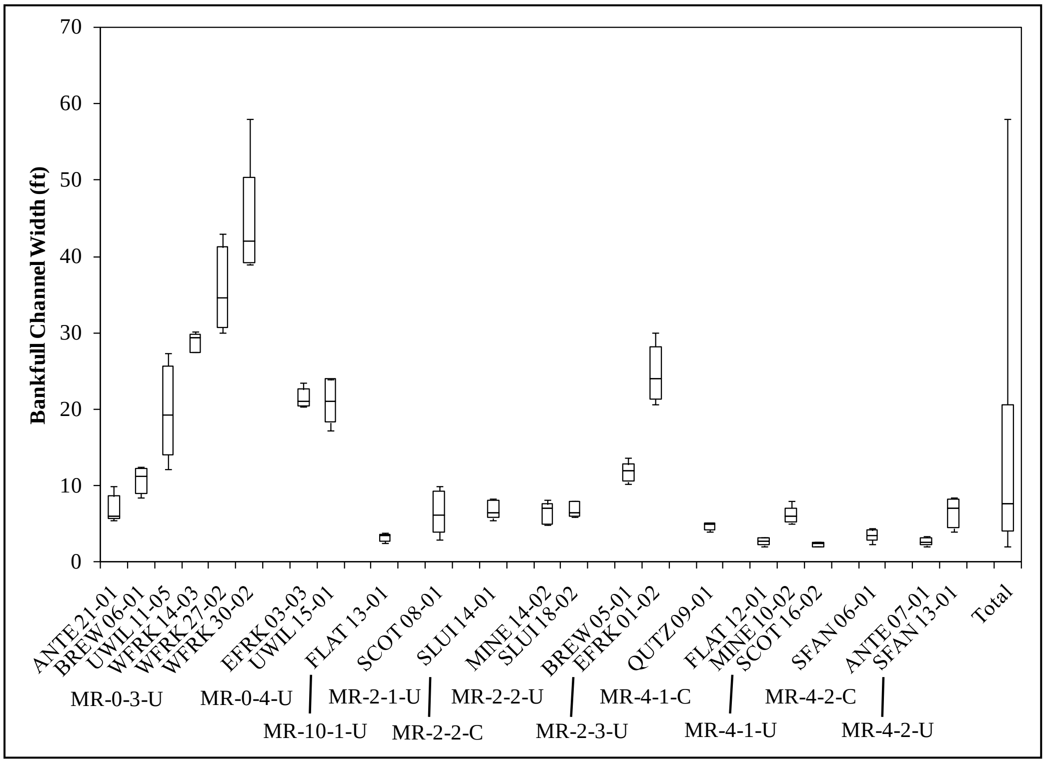

Figure C3-12. Bankfull channel width by reach.

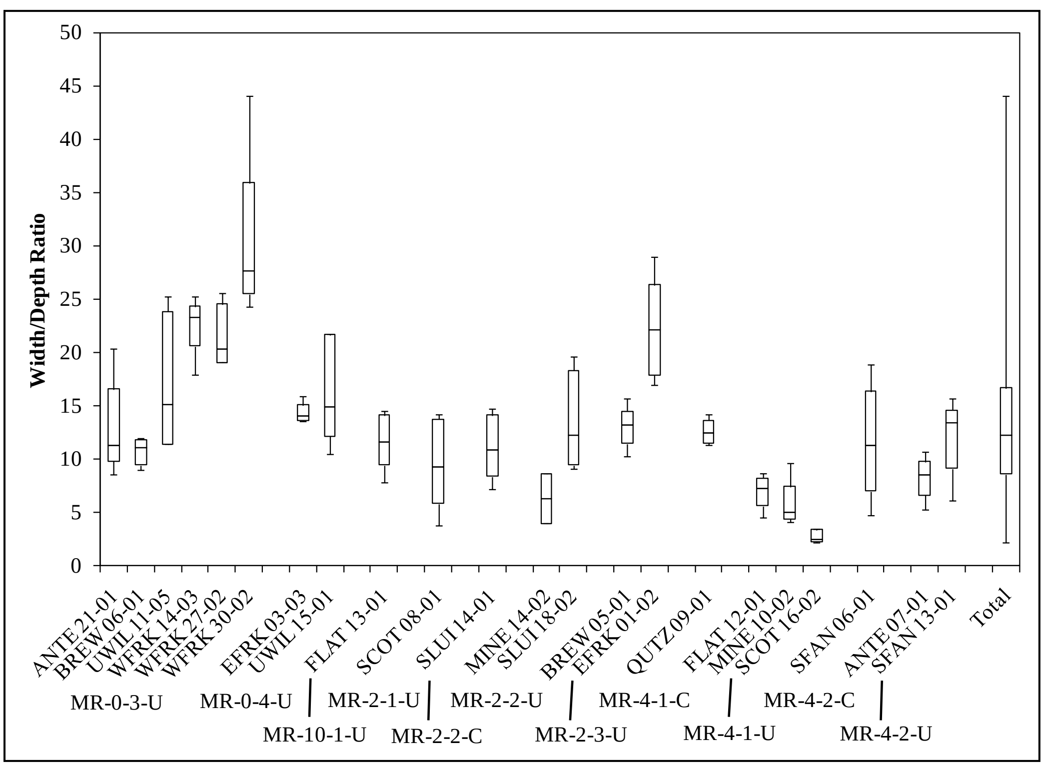

Figure C3-13. Width/depth ratio by reach.

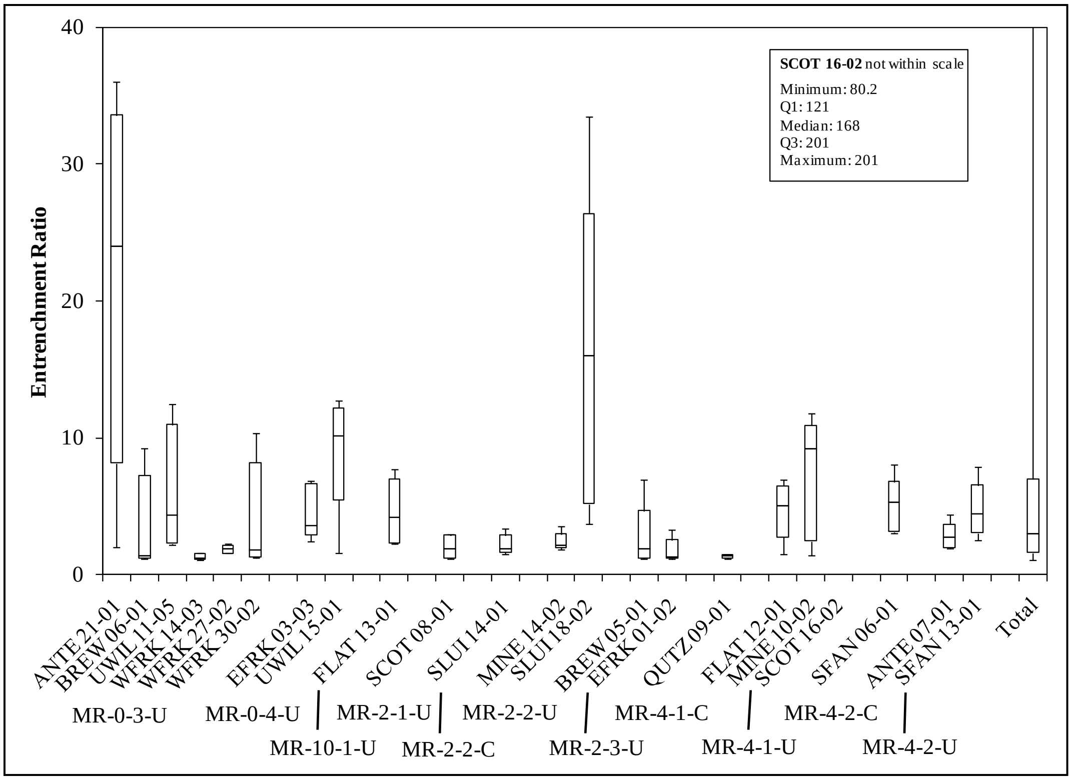

Figure C3-14. Entrenchment ratio by reach.

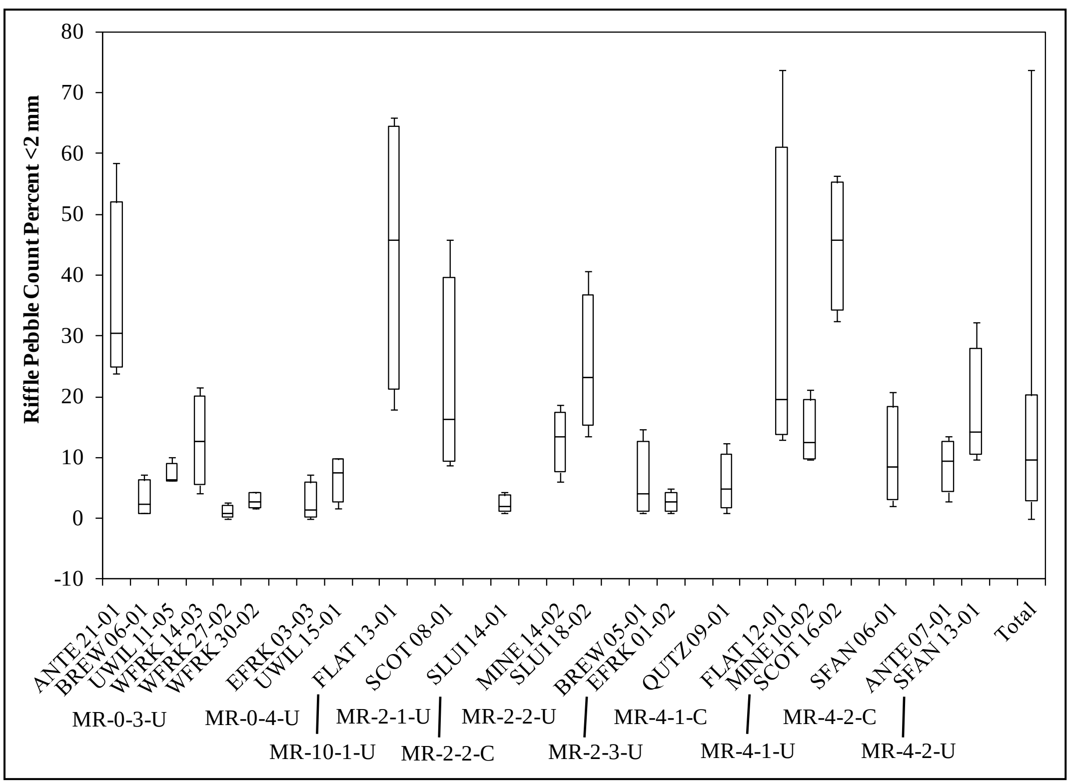

Figure C3-15. Riffle pebble count (% <2 mm) by reach.

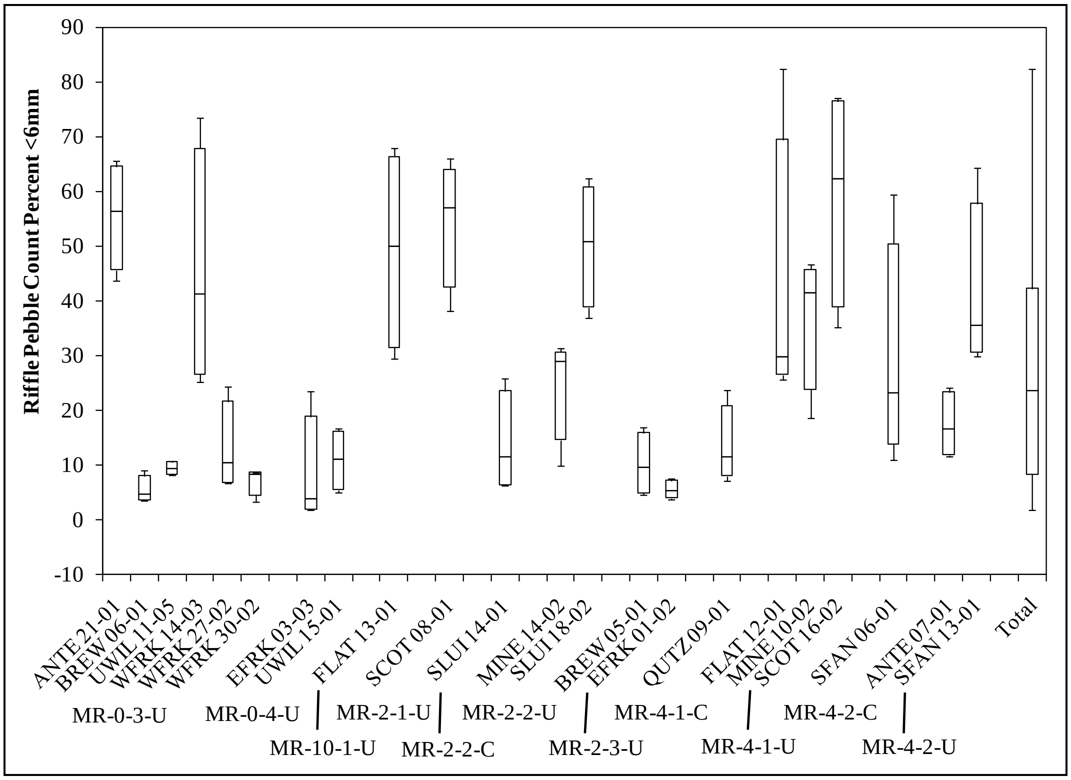

Figure C3-16. Riffle pebble count (% <6 mm) by reach.

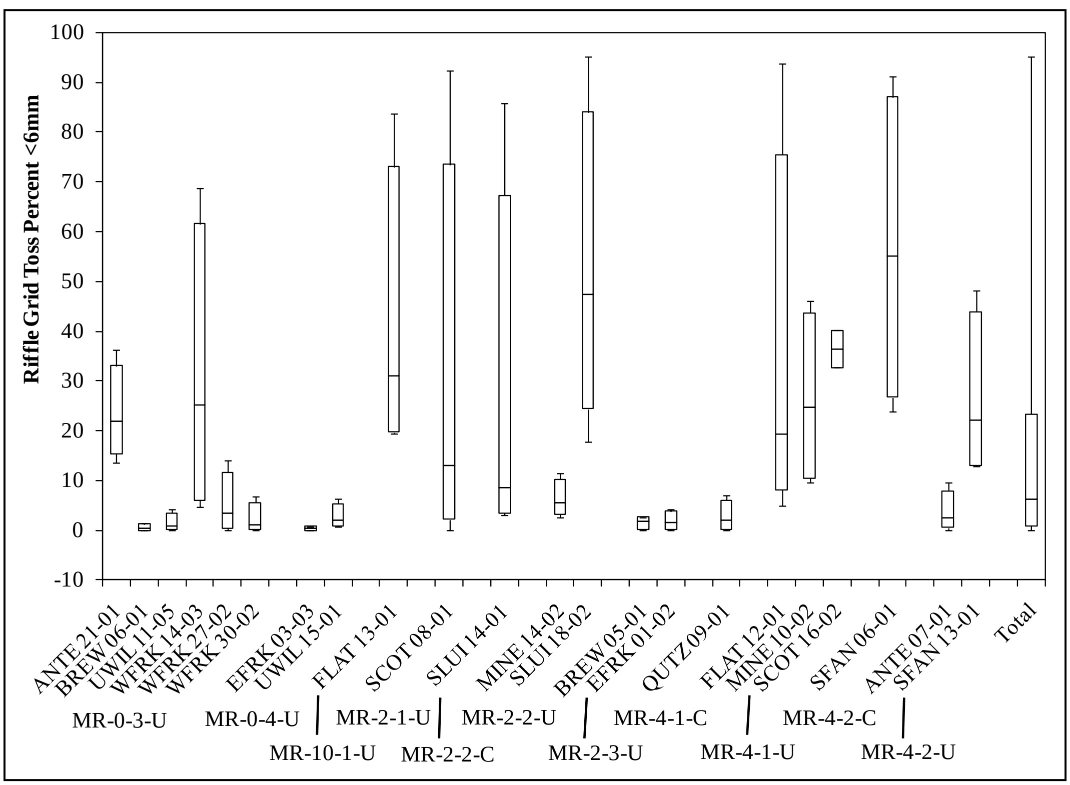

Figure C3-17. Riffle grid toss (% <6 mm) by reach.

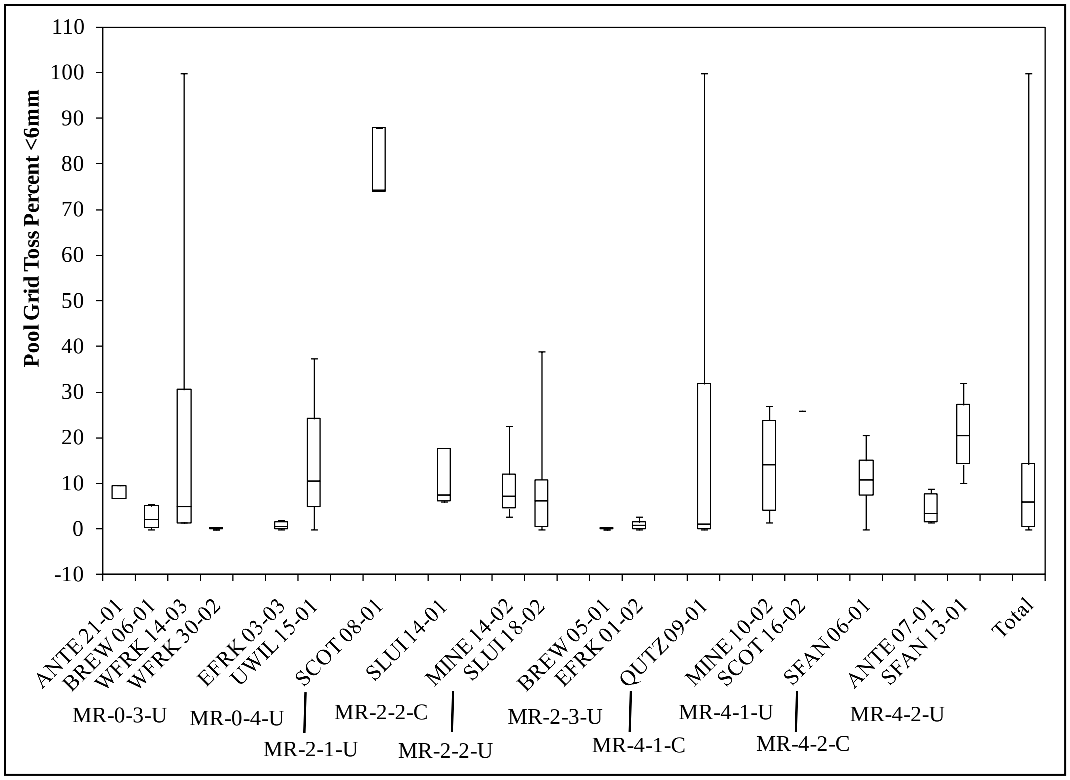

Figure C3-18. Pool grid toss (% <6 mm) by reach.

C4.0 Streambank Erosion Source Assessment

For each monitoring reach assessed during the study, measurements were collected to calculate the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) in accordance with guidelines provided in *Watershed Assessment of River Stability and Sediment Supply* (Rosgen, 2006). These measurements were used in conjunction with streambank length and erosion source notes to determine sediment loads per 1,000 feet within each surveyed reach.

For sites within the Rock TPA, eroding banks were identified as "actively eroding" or "slowly eroding" based on conditions observed in the field. Actively eroding banks typically show evidence of recent erosion, such as slumping banks, exposed soil, or trampling by animals. Slowly eroding banks show evidence of chronic erosion, but often have some form of surface protection, such as cobble or vegetation. The designation of "active" versus "slow" is independent of the BEHI or NBS determinations, so sediment loads from actively eroding banks may not necessarily be higher than loads from slowly eroding banks. The banks selected for evaluation provide a representative sample of conditions throughout the reach, and banks which are similar to the evaluated banks are measured and recorded as "additional banks". At each eroding bank, photos were taken from locations perpendicular and upstream/downstream of the streambank. Photos were labeled according to the streambank site and position of the photo.

C.4.1 FIELD MEASUREMENTS AND LOADING CALCULATIONS

C4.1.1 Field Measurements

Within each sampled reach, eroding streambanks were identified by the field team and supporting measurements were recorded for the following metrics:

- Bank condition (includes actively eroding or slowly eroding/undercut/vegetated banks)
- Bank height
- Bankfull height
- Root depth
- Root density
- Bank angle
- Surface protection
- Material adjustments
- Bankfull mean depth
- Near bank maximum depth
- Stationing
- Mean height
- Bank composition (size classes)
- Hoof shear presence
- Sources of streambank instability (%)

C4.1.2 Determination of BEHI Scores

To determine the BEHI score for each eroding bank, the following parameters are used:

- Bank height/bankfull height
- Root depth/bank height
- Weighted root density (root density * root depth/bank height)
- Bank angle
- Surface protection

These bank erosion parameters are used to determine a numerical BEHI index score that ranks erosion potential from very low to extreme based on relationships provided by Rosgen (2006) (**Table C4-1**).

Table C4-1. BEHI score and rating system for individual parameters.

Parameter		Very Low	Low	Moderate	High	Very High	Extreme
Bank Height Ratio	Value	1.0 – 1.1	1.11 – 1.19	1.2 – 1.5	1.6 – 2.0	2.1 – 2.8	> 2.8
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Root Depth Ratio	Value	1.0 – 0.9	0.89 – 0.5	0.49 – 0.3	0.29 – 0.15	0.14 – 0.05	<0.05
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Weighted Root Density	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 5	<5
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Bank Angle	Value	0 – 20	21 – 60	61 – 80	81 – 90	91 – 119	>119
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Surface Protection	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 10	<10
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10

After obtaining the BEHI index score for each individual parameter, the index scores are summed to produce a total BEHI score. Bank material factors are then considered, and total BEHI scores may be adjusted up or down. Banks comprised of bedrock, boulders, or cobble have very low erosion potential, and total BEHI scores for banks composed of these materials may be adjusted down by up to 10 points. Banks composed of cobble and/or gravel with a high fraction of sand have increased erosion potential, and total BEHI scores may be adjusted up by 5 to 10 points depending on the amount of sand present and whether the sandy material is exposed to erosion. Stratified banks containing layers of unstable material also have greater erosion potential, and total BEHI scores may be adjusted up by 5 to 10 points if stratified banks are present. After all material adjustments are made to the total BEHI score, the erosion potential is ranked from very low to extreme based on the scale provided below (**Table C4-2**).

Table C4-2. Total BEHI score and rating system.

Rating	Very Low	Low	Moderate	High	Very High	Extreme
Score	<10	10 - 19.9	20 - 29.9	30 - 39.9	40 - 45	>45

C4.1.3 Near Bank Stress (NBS) Determination

To calculate Near Bank Stress (NBS) for each eroding bank, the following relationship is used:

NBS = Near Bank Maximum Bankfull Depth (ft) / Bankfull Mean Depth (ft)

As with the BEHI scores, the resulting NBS values correspond to a categorical rating that ranks the erosion potential from very low to extreme (**Table C4-3)**. The NBS rating is calculated in the field by collecting the near bank maximum bankfull depth at the eroding bank location and dividing this value by the average of five measurements across the bankfull channel. NBS can also be estimated in the field based on channel form or by using best professional judgment.

Table C4-3. Near bank stress (NBS) rating system.

NBS Value	Rating
< 1.0	very low
1.0 - 1.5	low
1.51 - 1.8	moderate
1.81 - 2.5	high
2.51 - 3.0	very high
> 3.0	extreme

C4.1.4 Retreat Rate

Once respective BEHI and NBS ratings are found for each eroding bank, the ratings are used to derive the average retreat rate of each streambank based on empirical relationships derived from Colorado by Rosgen (2006), which are applicable to areas with sedimentary and/or metamorphic geology like the Rock Creek TPA. The average retreat rates (ft/yr) based on BEHI and NBS ratings are provided below in **Table C4-4**.

Table C4-4. Streambank retreat rate (ft/yr) based on BEHI and NBS rating.

	Near Bank Stress					
BEHI	**Very Low**	**Low**	**Moderate**	**High**	**Very High**	**Extreme**
Low	0.02	0.04	0.07	0.16	0.32	0.67
Moderate	0.09	0.15	0.25	0.42	0.70	1.16
High-Very High	0.17	0.25	0.38	0.58	0.87	1.32

C4.1.5 Sediment Loading Calculation

Once retreat rate is determined from the BEHI and NBS ratings, the dimensions of the eroding streambank are used to find the total mass eroding from each bank per year. The total mass eroded from each streambank is calculated using the following equation:

*mass eroded (tons/yr) = bank length (ft) * bank height (ft) * retreat rate (ft/yr) * material density (tons/ft^3)*

The sediment load from each streambank is filtered into two bank erosion type categories including actively eroding banks or slowly eroding/undercut/vegetated banks. The total loads for each bank erosion type and for the entire reach are then calculated in tons of sediment per year per 1000 feet of reach.

C4.2 Sediment Loading Results by Assessment Reach

The following sections provide sediment loading results for each sampled stream. One data table is included for each stream which includes data from each reach summarizing bank erosion and sediment loading for each bank erosion type (active or slowly eroding) and for the total reach. Information provided includes the number of eroding banks, the mean BEHI rating for each erosion type, the percent of reach that has eroding banks, the sediment load per 1000 feet, and the percent contribution from each erosion source present. The percentage of reach with eroding streambanks was calculated by summing the total footage of eroding banks (active and slow) and dividing the total by the total bank footage in the reach, including both right and left banks. Identified sources of streambank erosion within the Rock TPA included transportation, riparian grazing, cropland, irrigation (or changes in stream energy), natural sources, or those classified as “other” (historical grazing and mining, rural residential, and recreation); however, each erosion source may not be present at all sample sites.

C4.2.1 Sediment Loading Results for Antelope Creek

C4.2.1.1 ANTE 07-01

Five eroding banks were identified in this reach, including one actively eroding bank and four slowly eroding banks. Banks are typically low, grass-covered and hummocky from cattle, although the actively eroding bank is taller. Typical eroding streambank conditions are depicted for this reach in **Figure C4-1** and sediment loading results are provided in **Table C4-5**.

Figure C4-1. Typical eroding streambank conditions in Antelope Creek Reach 07-01.

C4.2.1.2 ANTE 21-01

This reach had two slowly eroding banks. Eroding banks were low grass-covered banks which were heavily grazed this year, likely in spring. Hummocking occurs along the entire length of the reach. Typical eroding streambank conditions are depicted in **Figure C4-2** and sediment loading results are provided in **Table C4-5**.

Figure C4-2. Typical eroding streambank conditions in Antelope Creek Reach 21-01.

Table C4-5. Sediment loading results for Antelope Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Source (%)
						Riparian Grazing
ANTE 07-01	Active	1	high	3.6	1.8	100.0
	Slow	4	moderate	81.6	10.0	100.0
	Total	5	high	85.2	11.8	100.0
ANTE 21-01	Active	0				
	Slow	2	high	98.4	16.6	100.0
	Total	2	high	98.4	16.6	100.0

C4.2.2 Sediment Loading Results for Brewster Creek

C4.2.2.1 BREW 05-01

This reach has eleven slowly eroding banks. Eroding banks were typically well vegetated overhanging banks with cobble. Typical eroding streambank conditions are depicted for this reach in **Figure C4-3** and sediment loading results are provided in **Table C4-6**.

Figure C4-3. Typical eroding streambank conditions in Brewster Creek Reach 05-01.

C4.2.2.2 BREW 06-01

This reach had eleven slowly eroding banks with two bank types. Eroding banks are typically well vegetated with a high root density. Some banks are associated with the small bridges that cross the stream within the surveyed reach. Typical eroding streambank conditions are depicted for this reach in **Figure C4-4** and sediment loading results are provided in **Table C4-6**.

Figure C4-4. Typical eroding streambank conditions in Brewster Creek Reach 06-01.

Table C4-6. Sediment loading results for Brewster Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Transportation	Natural	Other
BREW 05-01	Active	0						
	Slow	11	low	37.7	3.4	3.4	96.6	0.0
	Total	11	low	37.7	3.4	3.4	96.6	0.0
BREW 06-01	Active	0						
	Slow	11	moderate	35.3	11.3	0.0	65.7	34.3
	Total	11	moderate	35.3	11.3	0.0	65.7	34.3

C4.2.3 Sediment Loading Results for East Fork Rock Creek

C4.2.3.1 EFRK 01-02

This reach has ten slowly eroding banks. Banks are generally slowly eroding, well-vegetated, undercut banks located on outside meander bends. Recreational trails have contributed to streambank erosion in some places. Typical eroding streambank conditions are depicted for this reach in **Figure C4-5** and sediment loading results are provided in **Table C4-7**.

Figure C4-5. Typical eroding streambank conditions in East Fork Rock Creek Reach 01-02.

C4.2.3.2 EFRK 03-03

This reach has six slowly eroding banks. Eroding banks are generally well-vegetated undercut banks located on outside meander bends. Typical eroding streambank conditions are depicted for this reach in **Figure C4-6** and sediment loading results are provided in **Table C4-7**.

Figure C4-6. Typical eroding streambank conditions in East Fork Rock Creek Reach 03-03.

Table C4-7. Sediment loading results for East Fork Rock Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Irrigation	Natural	Other
EFRK 01-02	Active	0						
	Slow	10	moderate	35.2	9.8	0.0	82.0	18.0
	Total	10	moderate	35.2	9.8	0.0	82.0	18.0
EFRK 03-03	Active	0						
	Slow	6	moderate	49.5	14.7	20.0	70.0	10.0
	Total	6	moderate	49.5	14.7	20.0	70.0	10.0

C4.2.4 Sediment Loading Results for Flat Gulch

C4.2.4.1 FLAT 12-01

Only two eroding streambanks were identified in this reach, but they extended throughout 87% of the reach length. Eroding banks were slowly eroding vegetated banks which were severely trampled by cattle. Typical eroding streambank conditions are depicted in **Figure C4-7** and sediment loading results are provided in **Table C4-8**.

Figure C4-7. Typical eroding streambank conditions in Flat Gulch Reach 12-01.

C4.2.4.2 FLAT 13-01

Six eroding streambanks were identified in this reach with one primary bank type. Eroding banks are low and well vegetated but show evidence of trampling. Typical eroding streambank conditions are depicted in **Figure C4-8** and sediment loading results are provided in **Table C4-8**.

Figure C4-8. Typical eroding streambank conditions in Flat Gulch Reach 13-01.

Table C4-8. Sediment loading results for Flat Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
FLAT 12-01	Active	0						
	Slow	2	high	87.0	14.7	100.0	0.0	0.0
	Total	2	high	87.0	14.7	100.0	0.0	0.0
FLAT 13-01	Active	0						
	Slow	6	moderate	13.2	1.7	0.0	80.0	20.0
	Total	6	moderate	13.2	1.7	0.0	80.0	20.0

C4.2.5 Sediment Loading Results for Miners Gulch

C4.2.5.1 MINE 10-02

Four slowly eroding banks were identified in this reach. Eroding banks were typically slowly eroding well-vegetated banks with high root density. Typical eroding streambank conditions are depicted in **Figure C4-9** and sediment loading results are provided in **Table C4-9**.

Figure C4-9. Typical eroding streambank conditions in Miners Gulch Reach 10-02.

C4.2.5.2 MINE 14-02

This reach had two actively eroding banks and ten slowly eroding banks. Slowly eroding banks were typically low and well vegetated. Actively eroding banks were taller and occur where banks have sloughed into the stream channel. Typical eroding streambank conditions are depicted in **Figure C4-10** and sediment loading results are provided in **Table C4-9**.

Figure C4-10. Typical eroding streambank conditions in Miners Gulch Reach 14-02.

Table C4-9. Sediment loading results for Miners Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)
						Natural
MINE 10-02	Active	0				
	Slow	4	low	86.4	2.2	100.0
	Total	4	low	86.4	2.2	100.0
MINE 14-02	Active	2	low	1.2	0.2	100.0
	Slow	10	low	52.9	3.2	100.0
	Total	12	low	54.1	3.4	100.0

C4.2.6 Sediment Loading Results for Quartz Gulch

C4.2.6.1 QUTZ 09-01

This reach has five slowly eroding streambanks. Eroding banks are well vegetated and located on outside meander bends. Typical eroding streambank conditions are shown in **Figure C4-11** and sediment loading results are provided in **Table C4-10**.

Figure C4-11. Typical eroding streambank conditions in Quartz Creek Reach 09-01.

Table C4-10. Sediment loading results for Quartz Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)	
						Natural	Other
QUTZ 09-01	Active	0					
	Slow	5	high	39.6	30.6	50.0	50.0
	Total	5	high	39.6	30.6	50.0	50.0

C4.2.7 Sediment Loading Results for Scotchman Gulch

C4.2.7.1 SCOT 08-01

This site has eleven slowly eroding banks that are recovering from heavy grazing. Many banks are overhanging and sloughing into the stream channel. Typical eroding streambank conditions are depicted in **Figure C4-12** and sediment loading results are provided in **Table C4-11**.

Figure C4-12. Typical eroding streambank conditions in Scotchman Gulch Reach 08-01.

C4.2.7.2 SCOT 16-01

This reach has five slowly eroding streambanks which are well-vegetated, low, and occur on outside meander bends. Typical eroding streambank conditions are depicted in **Figure C4-13** and sediment loading results are provided in **Table C4-11**.

Figure C4-13. Typical eroding streambank conditions in Scotchman Gulch Reach 16-01.

Table C4-11. Sediment loading results for Scotchman Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
SCOT 08-01	Active	0						
	Slow	11	moderate	82.9	19.1	83.2	15.6	1.2
	Total	11	moderate	82.9	19.1	83.2	15.6	1.2
SCOT 16-02	Active	0						
	Slow	5	low	96.6	4.4	0.0	100.0	0.0
	Total	5	low	96.6	4.4	0.0	100.0	0.0

C4.2.8 Sediment Loading Results for South Fork Antelope Creek

C4.2.8.1 SFAN 06-01

Three slowly eroding streambanks were identified in this reach, but they make up more than 73% of the entire reach. Banks are well vegetated but have been extensively trampled by cattle throughout the reach. Typical eroding streambank conditions are depicted in **Figure C4-14** and sediment loading results are provided in **Table C4-12**.

Figure C4-14. Typical eroding streambank conditions in South Fork Antelope Creek 06-01.

C4.2.8.1 SFAN 13-01

Just two slowly eroding streambanks were identified in this reach, but they comprise nearly 95% of the entire reach. Banks are slowly eroding and well vegetated with a dense root mass, but suffer from extensive cattle grazing. Typical eroding streambank conditions are depicted in **Figure C4-15** and sediment loading results are provided in **Table C4-12**.

Figure C4-15. Typical eroding streambank conditions in South Fork Antelope Creek 13-01.

Table C4-12. Sediment loading results for South Fork Antelope Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)
						Riparian Grazing
SFAN 06-01	Active	0				
	Slow	3	moderate	73.2	6.3	100.0
	Total	3	moderate	73.2	6.3	100.0
SFAN 13-01	Active	0				
	Slow	2	low	94.9	2.7	100.0
	Total	2	low	94.9	2.7	100.0

C4.2.9 Sediment Loading Results for Sluice Gulch

C4.2.9.1 SLUI 14-01

This reach has seven slowly eroding banks, which are recovering from historic grazing and are well vegetated with grasses and weeds with high surface protection. Typical eroding streambank conditions are depicted in **Figure C4-16** and sediment loading results are provided in **Table C4-13**.

Figure C4-16. Typical eroding streambank conditions in Sluice Gulch Reach 14-01.

C4.2.9.2 SLUI 18-02

This reach has two slowly eroding banks that extend throughout the entire reach length. Banks are stable and well vegetated with tall grasses. Signs of recent grazing exist which causes pugging along the entire reach. Typical eroding streambank conditions are depicted in **Figure C4-17** and sediment loading results are provided in **Table C4-13**.

Figure C4-17. Typical eroding streambank conditions in Sluice Gulch Reach 18-02.

Table C4-13. Sediment loading results for Sluice Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
SLUI 14-01	Active	0						
	Slow	7	high	17.6	8.5	0.0	80.0	20.0
	Total	7	high	17.6	8.5	0.0	80.0	20.0
SLUI 18-02	Active	0						
	Slow	2	low	100.0	3.9	20.0	80.0	0.0
	Total	2	low	100.0	3.9	20.0	80.0	0.0

C4.2.10 Sediment Loading Results for Upper Willow Creek

C4.2.10.1 UWIL 11-05

This reach has one actively eroding bank and eleven slowly eroding banks. Slowly eroding banks are typically near vertical and well vegetated, typically occurring on outside meander bends. The actively eroding bank has a cobble bottom that is eroding away. Typical eroding streambank conditions are depicted in **Figure C4-18** and sediment loading results are provided in **Table C4-14**. A slowly eroding bank is shown on the left, and the actively eroding bank is shown on the right.

Figure C4-18. Typical eroding streambank conditions in Upper Willow Creek Reach 11-05.

C4.2.10.2 UWIL 15-01

This site has two distinct banks types, including actively eroding banks with large portions of bank sloughing into the stream, and slowly eroding well-vegetated banks with undercuts. Both occur on outside meander bends. Typical eroding streambank conditions are depicted in **Figure C4-19** and sediment loading results are provided in **Table C4-14**. An actively eroding bank is shown on the left, and a slowly eroding bank is shown on the right.

Figure C4-19. Typical eroding streambank conditions in Upper Willow Creek Reach 15-01.

Table C4-14. Sediment loading results for Upper Willow Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Cropland	Natural
UWIL 11-05	Active	1	moderate	3.9	2.7	0.0	10.0	90.0
	Slow	12	low	43.8	3.7	0.0	1.5	98.5
	Total	13	low	47.6	6.4	0.0	5.0	95.0
UWIL 15-01	Active	4	moderate	21.2	18.5	25.0	25.0	50.0
	Slow	3	moderate	9.5	2.2	0.0	20.0	80.0
	Total	7	moderate	30.7	20.7	22.3	24.5	53.2

C4.2.11 Sediment Loading Results for West Fork Rock Creek

C4.2.11.1 WFRK 14-03

This reach has twelve slowly eroding streambanks that are generally well-vegetated and undercut. One large exposed bank appears to be created from an excavation area and has no vegetation or surface protection. Typical eroding streambank conditions are depicted in **Figure C4-20** and sediment loading results are provided in **Table C4-15**. Typical bank conditions are shown on the left, while the excavated bank is shown on the right.

Figure C4-20. Typical eroding streambank conditions in West Fork Rock Creek 14-03.

C4.2.11.2 WFRK 27-02

This reach has six slowly eroding banks and one actively eroding bank. Slowly eroding banks are typically well vegetated and undercut with dense tree roots. The one actively eroding bank is tall and has sloughed into the channel, but is well armored with large cobble and boulders. Typical eroding streambank conditions are depicted in **Figure C4-21** and sediment loading results are provided in **Table C4-15**. A slowly eroding bank is shown on the left and an actively eroding bank is shown on the right.

Figure C4-21. Typical eroding streambank conditions in West Fork Rock Creek 27-02.

C4.2.11.3 WFRK 30-02

This reach has five slowly eroding banks and one actively eroding bank. Most slowly eroding banks are well-vegetated and undercut with a stratified cobble layer that leads to sloughing of banks. The actively eroding bank is taller with a steeper angle. Typical eroding streambank conditions are depicted in **Figure C4-22** and sediment loading results are provided in **Table C4-15**. A slowly eroding bank is shown on the left and an actively eroding bank is shown on the right.

Figure C4-22. Typical eroding streambank conditions in West Fork Rock Creek 30-02.

Table C4-15. Sediment loading results for West Fork Rock Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
WFRK 14-03	Active	0						
	Slow	12	high	71.9	51.9	0.0	57.6	42.4
	Total	12	high	71.9	51.9	0.0	57.6	42.4
WFRK 27-02	Active	1	moderate	3.2	1.4	0.0	100.0	0.0
	Slow	6	moderate	64.2	19.9	10.0	90.0	0.0
	Total	7	moderate	67.4	21.3	9.3	90.7	0.0
WFRK 30-02	Active	1	high	7.0	5.9	0.0	100.0	0.0
	Slow	5	moderate	24.6	10.4	0.0	100.0	0.0
	Total	6	moderate	31.7	16.4	0.0	100.0	0.0

C4.3 Sediment Loading Results by Reach Type

The following sections provide sediment loading results organized by reach type. Data provided includes sediment load per 1000 feet for each bank type (active, slow and total) and the dominant influence (anthropogenic or natural). If <75% of the bank erosion-influenced load was attributed to natural sources, the load is considered to be anthropogenically influenced.

C4.3.1Sediment Loading Results for Reach Type MR-0-3-U

Six reaches were sampled of reach type MR-0-3-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 3rd order streams within unconfined valleys. Loading results are provided below in **Table C4-16**.

Table C4-16. Sediment loading results for reach type MR-0-3-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
ANTE 21-01	high		high	98.4	0.0	98.4	16.6	0.0	16.6
BREW 06-01	moderate		moderate	35.3	0.0	35.3	11.3	0.0	11.3
UWIL 11-05	low	moderate	low	43.8	3.9	47.6	3.7	2.7	6.4
WFRK 14-03	high		high	71.9	0.0	71.9	51.9	0.0	51.9
WFRK 27-02	moderate	moderate	moderate	64.2	3.2	67.4	19.9	1.4	21.3
WFRK 30-02	moderate	high	moderate	24.6	7.0	31.7	10.4	5.9	16.4
Reach Type Average	**moderate**	**moderate**	**moderate**	**56.4**	**2.4**	**58.7**	**19.0**	**1.7**	**20.7**

C4.3.2 Sediment Loading Results for Reach Type MR-0-4-U

Two reaches were sampled of reach type MR-0-4-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 4th order streams within unconfined valley types. Loading results are provided below in **Table C4-17**.

Table C4-17. Sediment loading results for reach type MR-0-4-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
EFRK 03-03	moderate		moderate	49.5	0.0	49.5	14.7	0.0	14.7
UWIL 15-01	moderate	moderate	moderate	9.5	21.2	30.7	2.2	18.5	20.7
Reach Type Average	**moderate**	**moderate**	**moderate**	**29.5**	**10.6**	**40.1**	**8.5**	**9.3**	**17.7**

C4.3.3 Sediment Loading Results for Reach Type MR-10-1-U

One reach was sampled of reach type MR-10-1-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (>10%), and includes first order streams within unconfined valley types. Loading results are provided below in **Table C4-18**.

Table C4-18. Sediment loading results for reach type MR-10-1-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
FLAT 13-01	moderate		moderate	13.2	0.0	13.2	1.7	0.0	1.7
Reach Type Average	**moderate**		**moderate**	**13.2**	**0.0**	**13.2**	**1.7**	**0.0**	**1.7**

C4.3.4 Sediment Loading Results for Reach Type MR-2-1-U

One site was sampled of reach type MR-2-1-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 1st order streams within unconfined valley types. Loading results are provided below in **Table C4-19**.

Table C4-19. Sediment loading results for reach type MR-2-1-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
SCOT 08-01	moderate		moderate	82.9	0.0	82.9	19.1	0.0	19.1
Reach Type Average	**moderate**		**moderate**	**82.9**	**0.0**	**82.9**	**19.1**	**0.0**	**19.1**

C4.3.5 Sediment Loading Results for Reach Type MR-2-2-C

One reach was sampled of reach type MR-2-2-C. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 2nd order streams within confined valley types. Loading results are provided below in **Table C4-20**.

Table C4-20. Sediment loading results for reach type MR-2-2-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
SLUI 14-01	high		high	17.6	0.0	17.6	8.5	0.0	8.5
Reach Type Average	**high**		**high**	**17.6**	**0.0**	**17.6**	**8.5**	**0.0**	**8.5**

C4.3.6 Sediment Loading Results for Reach Type MR-2-2-U

Two sites were sampled of reach type MR-2-2-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 2nd order streams within unconfined valley types. Loading results are provided below in **Table C4-21**.

Table C4-21. Sediment loading results for reach type MR-2-2-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
MINE 14-02	low	low	low	52.9	1.2	54.1	3.2	0.2	3.4
SLUI 18-02	low		low	100.0	0.0	100.0	3.9	0.0	3.9
Reach Type Average	**low**	**low**	**low**	**76.5**	**0.6**	**77.1**	**3.5**	**0.1**	**3.6**

C4.3.7 Sediment Loading Results for Reach Type MR-2-3-C

Two reaches were sampled of reach type MR-2-3-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 3rd order streams within unconfined valley types. Loading results are provided below in **Table C4-22**.

Table C4-22. Sediment loading results for reach type MR-2-3-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
BREW 05-01	low		low	37.7	0.0	37.7	3.4	0.0	3.4
EFRK 01-02	moderate		moderate	35.2	0.0	35.2	9.8	0.0	9.8
Reach Type Average	**low**		**low**	**36.5**	**0.0**	**36.5**	**6.6**	**0.0**	**6.6**

C4.3.8 Sediment Loading Results for Reach Type MR-4-1-C

One reach was sampled of reach type MR-4-1-C. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 1st order streams within confined valley types. Loading results are provided below in **Table C4-23**.

Table C4-23. Sediment loading results for reach type MR-4-1-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
QUTZ 09-01	high		high	39.6	0.0	39.6	30.6	0.0	30.6
Reach Type Average	**high**		**high**	**39.6**	**0.0**	**39.6**	**30.6**	**0.0**	**30.6**

C4.3.9 Sediment Loading Results for Reach Type MR-4-1-U

Three reaches were sampled of reach type MR-4-1-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 1st order streams within unconfined valley types. Loading results are provided below in **Table C4-24**.

Table C4-24. Sediment loading results for reach type MR-4-1-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
FLAT 12-01	high		high	87.0	0.0	87.0	14.7	0.0	14.7
MINE 10-02	low		low	86.4	0.0	86.4	2.2	0.0	2.2
SCOT 16-02	low		low	96.6	0.0	96.6	4.4	0.0	4.4
Reach Type Average	**moderate**		**moderate**	**90.0**	**0.0**	**90.0**	**7.1**	**0.0**	**7.1**

C4.3.10 Sediment Loading Results for Reach Type MR-4-2-C

One reach was sampled of reach type MR-4-2-C. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 2nd order streams within confined valley types. Loading results are provided below in **Table C4-25**.

Table C4-25. Sediment loading results for reach type MR-4-2-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
SFAN 06-01	moderate		moderate	73.2	0.0	73.2	6.3	0.0	6.3
Reach Type Average	**moderate**		**moderate**	**73.2**	**0.0**	**73.2**	**6.3**	**0.0**	**6.3**

C4.3.11 Sediment Loading Results for Reach Type MR-4-2-U

Two reaches were sampled of reach type MR-4-2-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 2nd order streams within unconfined valley types. Loading results are provided below in **Table C4-26**.

Table C4-26. Sediment loading results for reach type MR-4-2-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
ANTE 07-01	moderate	high	high	81.6	3.6	85.2	10.0	1.8	11.8
SFAN 13-01	low		low	94.9	0.0	94.9	2.7	0.0	2.7
Reach Type Average	**moderate**	**high**	**moderate**	**88.3**	**1.8**	**90.1**	**6.4**	**0.9**	**7.3**

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ATTACHMENT C1 – MAPS

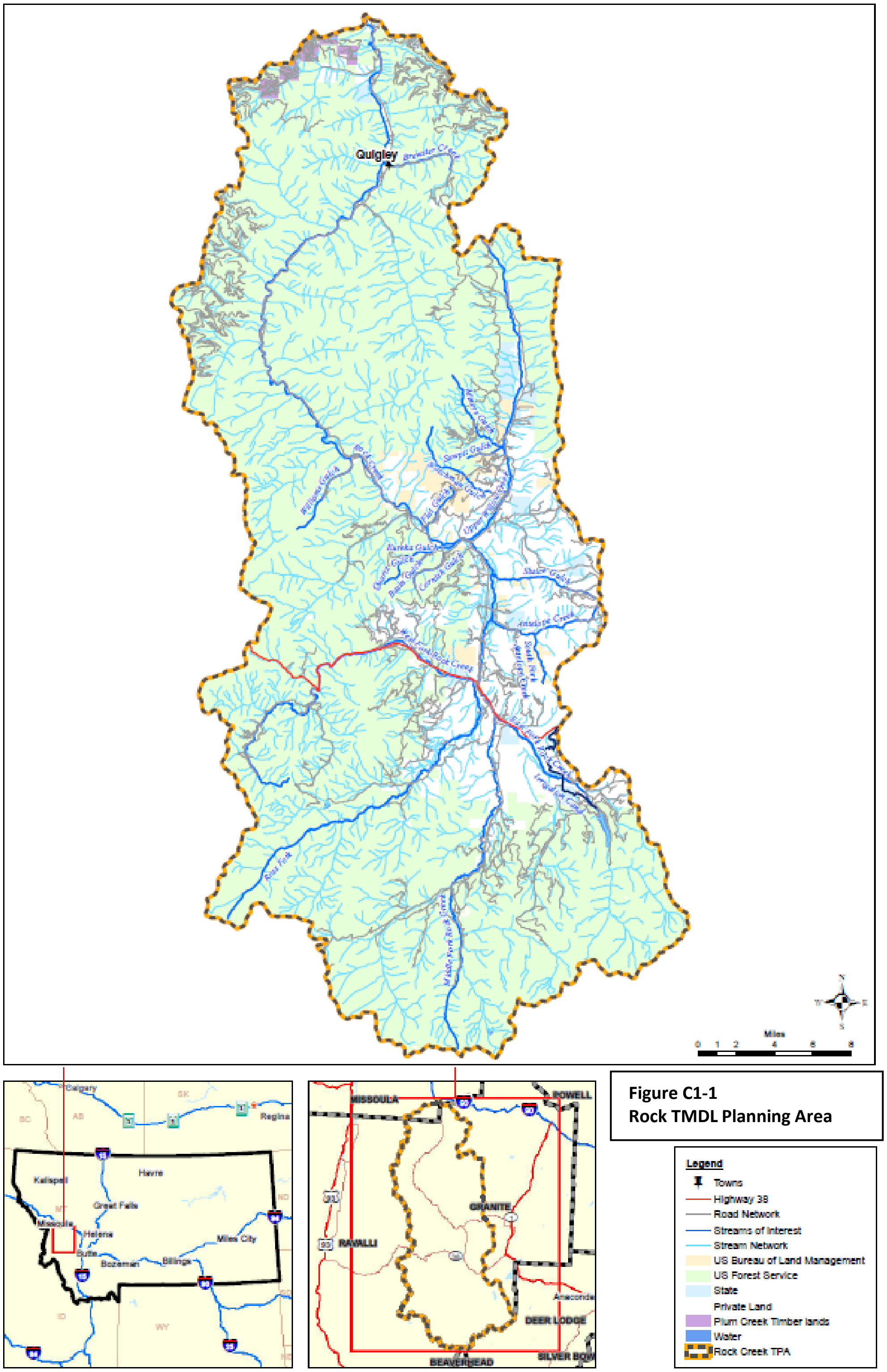

Figure C-1-1. Rock TMDL Planning Area

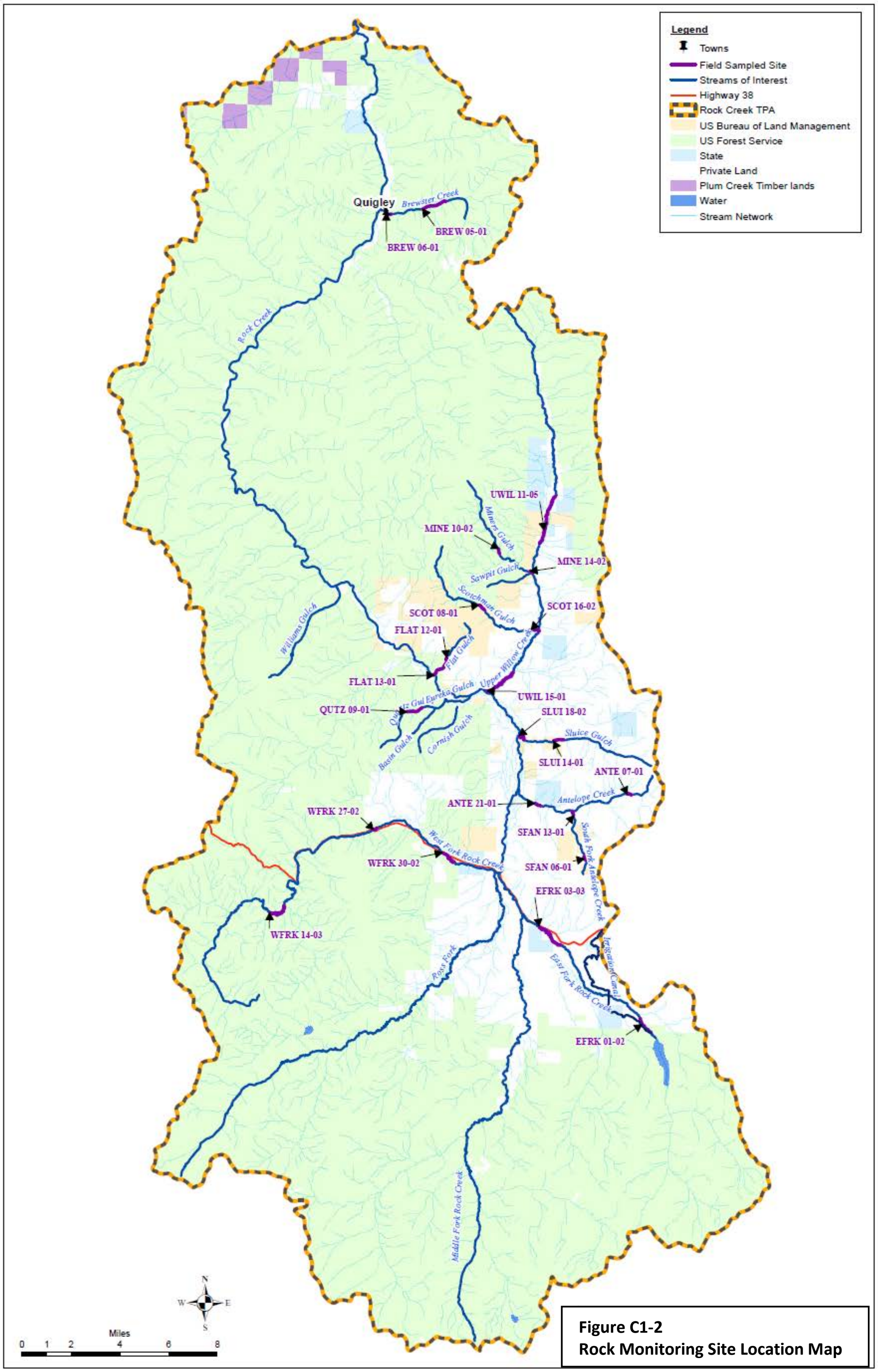

Figure C1-2. Rock Monitoring Site Location Map

APPENDIX D – ROCK TPA BIOLOGICAL SAMPLING 2011: MACROINVERTEBRATE AND PERIPHYTON RESULTS

Appendix D is based report prepared for the DEQ by Watershed Consulting, LLC, Dec. 2011.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

D1.0 STUDY OBJECTIVE AND AREA

This report summarizes results of 2011 biological sampling and analysis conducted in 8 stream reaches of the Rock TMDL Planning Area (TPA). Analysis of the resulting data serves to support the Montana Department of Environmental Quality (DEQ) Total Maximum Daily Load (TMDL) program by documenting the aquatic macroinvertebrate and periphyton taxa present in each project reach. The taxa present are used as supporting information for TMDL development.

Following MTDEQ Standard Operating Procedures (SOP) for both periphyton and macroinvertebrates, a qualified team collected samples and other field data between August 8th and 12th, 2011. Field crew, consisting of the Project Manager and a field technician, followed the EMAP protocol for macroinvertebrate sampling and the Peri-1*mod* method for periphyton. Additional data collected included aquatic vegetation composition, amount, color and condition, water chemistry indicators such as dissolved oxygen (DO), pH, specific conductivity (SC), and air and water temperature, as well as digital photos upstream, downstream and across each reach. All samples were delivered to Rithron Associates of Missoula, a qualified taxonomy laboratory, for analysis. All samples were analyzed for the taxa present and reports provided to DEQ.

Project reaches are listed in **Table D-1** and locations are shown in **Figure D-1**.

Table D-1. Rock TPA Reaches

Reach ID	Stream Name	Date Sampled	F transect Latitude	F transect Longitude
ANTE 08-01	Antelope Creek	8/12/11	46.2744	-113.4190
ANTE 21-03	Antelope Creek	8/10/11	46.2670	-113.4989
QUTZ 08-01 (u.s)	Quartz Gulch (u.s.)	8/09/11	46.3156	-113.6118
QUTZ 08-01 (d.s)	Quartz Gulch (d.s.)	8/09/11	46.3162	-113.6103
UWIL 15-01	Upper Willow Creek	8/08/11	46.3380	-113.5270
UWIL 11-05	Upper Willow Creek	8/08/11	46.4459	-113.4931
WFRK 14-03	West Fork Rock Creek	8/10/11	46.1930	-113.7089
WFRK 30-02	West Fork Rock Creek	8/10/11	46.2329	-113.5669

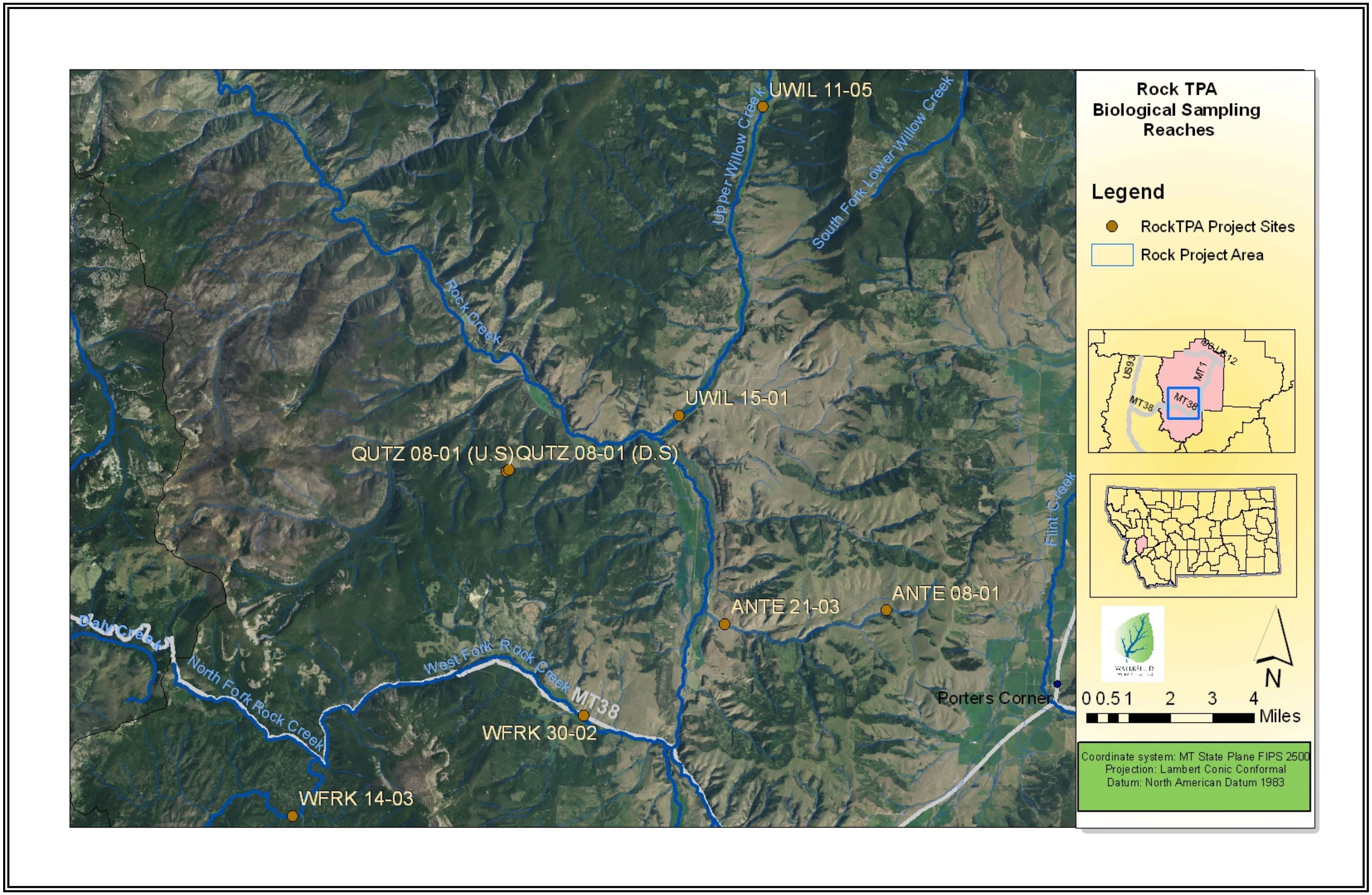

Figure D-1. Rock TPA Sampled Reaches

D2.0 METHODS

Sample sites for this study were selected by DEQ personnel as part of a larger TMDL planning effort for the Rock TPA. Simultaneous sediment/habitat TMDL assessments occurring in the Rock TPA provided site access information, including coordinates for the upstream and downstream ends of each reach to be sampled. Two sites in Williams Gulch were not sampled due to lack of access. Changes in the sampling plan were confirmed by the DEQ project officer.

The Rock project area was visited between August 8th and 12th for sample collection. No inclement weather was observed during the sampling period. Both reaches of the same stream were visited the same day, beginning with the downstream site. An exception was Antelope creek, whose upstream reach was sampled two days after the downstream reach due to access issues. Following protocol outlined in SOP's for macroinvertebrate (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2012) and periphyton (Montana Department of Environmental Quality, 2011) sampling, our team identified a suitable F transect point within the given stream reach where water chemistry data were collected: pH, DO, SC and temperatures. F transects were chosen based on their representation of overall stream conditions. In cases where a reach showed different characteristics between their upstream and downstream portions, the F transect was chosen so that both stream characteristics would be included in the total sampled area. Reach lengths represented 40 times the average wetted width at the F transect.

Macroinvertebrate composite samples were collected using a 500 micron kick net across 11 transects (A-K) and preserved in 99% ethanol, provided by the taxonomy contractor. The 50mL periphyton samples were sub-sampled from a composite of 11 transects and preserved with formalin. Samples were delivered to the qualified taxonomy laboratory upon completion of the field visit. More details of the sample collection procedure followed can be found in the SOPs (Montana Department of Environmental Quality, 2011; Montana Department of Environmental Quality, Water Quality Planning Bureau, 2012).

Laboratory results were provided first to DEQ personnel to be processed and entered into the appropriate data bases. For each reach DEQ personnel used the O/E model to calculate the ratio of the number of taxa observed (O) in the collected sample to the number expected (E) in that site type. O/E scores relate to stream impairment as shown in **Table D-2**. The macroinvertebrate metric is a general impairment indicator which can be affected by both pollutants and non-pollutants.

Table D-2. RIVPACS Impairment classes

RIVPACS	Impairment Class
0.80 - 1.20	Unimpaired
0.44 - 0.79	Moderate
<0.44	Severe

Periphyton results were reported with an impairment probability percentage. Scores greater than 51% are considered impaired for sediment. These results, along with observations for each reach are provided below.

D2.1 Fish Cover/Other

Using the Fish Cover/Other form provided by DEQ, field observations of aquatic vegetation were made between each transect. A total of 11 sub-reaches were documented, which included an inter-transect distance upstream of the upstream K transect. Data collected included a presence score for microalgae, filamentous algae, macrophytes and moss, as well as their color, condition, and thickness.

The habitat type (Riffle, Run/Glide, Pool) for periphyton sample locations were not documented in the field for this assessment. Using field notes and photographs the relative distribution of habitat types was estimated for all field sites and reflect our best estimate of periphyton habitat types sampled, expressed as a percent.

Presence scores for each of the periphyton types were averaged and then rounded to the nearest whole number score. These scores are represented in our findings by their percent (e.g. sites averaging a 1 for microalgae are presented as <10%). A similar averaging approach was used to determine an overall color, condition and length for each periphyton type. In cases where equal numbers were found for two different qualities (for example 5 green and 5 light green color microalgae), the 11th data point, field notes and photographs were used to make a final determination.

Microalgae: Color photographs provided in the periphyton SOP (Montana Department of Environmental Quality, 2011) were the primary guidance used to determine cover scores. The photographs clearly show that as scores approach 4 stream substrates increasingly become covered in mats of material, appearing to “clog”. Scores of 0 or 1, by contrast, indicate “clean” substrate. Often in western Montana streams, substrate can appear “clean” but will be slippery, which would indicate the presence of microalgae. Slippery but “clean” substrate was generally scored as 1.

Moss: Generally moss in streams appears dark, and is often noted in the Fish Cover/Other form as DBB. This notation does not necessarily indicate a decadent vegetative state, but visual appearance. Most often dark-looking moss had bright green new growth.

D3.0 Results

Results of this sampling project are presented by reach in the following subsections. DEQ personnel have run macroinvertebrate and periphyton results through their data entry protocol and have run biometric models, resulting in impairment probability scores (periphyton) and observed/expected ratios (macroinvertebrates) for each stream reach. Those results are presented here along with a summary of site visit information and a short discussion of each reach based on field notes.

General water quality conditions and site visit information are provided in **Table D-3**.

Table D-3. Rock TPA Site Visit Summary Data

Reach ID	Sample Date	Reach Length (ft)	Water temp (°C)	pH	SC (us/cm)	DO (mg/L)
ANTE 08-01	8/12	150	15	8.33	145.7	11.7
ANTE 21-03	8/10	150	13	8.58	321.0	14.0
QUTZ 08-01 (U.S)	8/09	150	11	7.46	118.8	13.4
QUTZ 08-01 (D.S)	8/09	200	11	7.54	64.3	14.1
UWIL 15-01	8/08	290	13	7.64	52.7	14.4
UWIL 11-05	8/08	440	16	7.68	38.4	13.3
WFRK 14-03	8/10	950	10	7.89	22.0	13.7
WFRK 30-02	8/10	1400	12	7.73	25.7	14.8

D3.1 ANTE 08-01

This stream reach is little more than a slow trickle, flowing through a heavily used cattle pasture just downstream from a corral. The channel was poorly defined due to trampling. Judging from non-riparian vegetation growing almost in the center of the stream (curly dock, pasture grasses), it is likely dry in many years. A mat of sediment and worm castings were common on "streambanks" and sometimes coated the entire channel. A cow pie was noted in the stream at transect A.

There was inadequate flow in this reach for a kick net; substrate was collected by hand and hand-washed in the net for 30 seconds. We avoided highly trampled areas and sampled where channel was most well-defined. There was no visible sign of periphyton at the time of sampling. Laboratory results confirm our visual assessments of the stream as impaired, likely due to sediment inputs. An impairment summary is provided in **Table D-4** and summary results of the Fish Cover/Other form are presented in **Table D-5.**

Table D-4. Ante 08-01 Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
ANTE 08-01	72.45%	Impaired	0.28	Severe

Table D-5. Ante 08-01 Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/Glide	Pool
Presence	Absent	Absent	Absent	Absent	0%	100%	0%
Color	----	----	----	----			
Condition	----	----	----	----			
Thickness/ Length	----	----					

D3.2 ANTE 21-03

This reach is only an active channel from its upstream end to an irrigation ditch halfway down the reach. Head gates divert water in two directions above the lower field (which from aerial photographs may appear to contain a stream). The stream at time of sampling was cloudy, deeply incised and buffered by dense mats of grasses.

The stream substrate was small gravels (4-32mm) or clay. Thick grass creates a small undercut. Stream remains cool due to riparian cover but rocks have no "slime" to them. This reach showed a severe impairment class for macroinvertebrates and impairment for periphyton. An impairment summary is provided in **Table D-6** and summary results of the Fish Cover/Other form are presented in **Table D-7.**

Table D-6. Ante 21-03 Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
ANTE 21-03	55.66%	Impaired	0.37	Severe

Table D-7. Ante 21-03 Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/Glide	Pool
Presence	Absent	Absent	Absent	Absent	0%	100%	0%
Color	----	----	----	----			
Condition	----	----	----	----			
Thickness/ Length	----	----					

D3.3 WFRK 14-03

This wide and sinuous stream segment flows through an open meadow. An old fence crosses the stream just upstream of K and pieces of an old bridge and other structures were seen in the stream in several locations. Substrate varied from deep sediment deposits, deep pools, and gravels. The only visible current influence here would be a fishing campsite near A. About 20 cutthroat trout were seen by the remains of an old structure in the stream. Macroinvertebrate results showed a severe impairment class from the RIVPACS scoring. Periphyton was shown to be unimpaired. An impairment summary is provided in **Table D-8** and summary results of the Fish Cover/Other form are presented in **Table D-9.**

Table D-8. WFRK 14-03 Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
WFRK 14-03	25.49%	Unimpaired	0.40	Severe

Table D-9. WFRK 14-03 Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/Glide	Pool
Presence	10-40%	10-40%	10-40%	<10%	0%	75%	25%
Color	Brown	Green	Green	Green			
Condition	Growing	Growing	Growing	Growing			
Thickness/ Length	Thin	Long					

D3.4 WFRK 30-02

The downstream end of this reach is just upstream of a bridge. With a 1400 foot length, our sampling reach encompassed almost the entire stream segment. The upper reaches (G-K) are in a straightened section adjacent to highway 38. Riparian vegetation is reduced on river left in this straight section. Much moss was seen throughout the reach, which had large riffle sections divided by deeper sandy deposits.

As with its upstream reach, impairment for macroinvertebrates was just barely in the severe impairment class while periphyton impairment probability was low. An impairment summary is provided in **Table D-10** and summary results of the Fish Cover/Other form are presented in **Table D-11.**

Table D-10. WFRK 30-02 Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
WFRK 30-02	32.50%	Unimpaired	0.43	Severe

Table D-11. WFRK 30-02 Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/Glide	Pool
Presence	<10%	10-40%	<10%	40-75%	60%	40%	0%
Color	Green/ Light Brown	Green	Green	Dark Brown/ Black			
Condition	Growing	Growing	Growing	Growing			
Thickness/ Length	Thin	Long					

D3.5 UWIL 11-05

Haying dominates land uses throughout this reach. Willow and other shrubs are infrequent along banks, with several decadent representatives. Overhanging grasses provide some shade habitat. The reaches above and below this one have more vigorous riparian shrub growth. Stream has low sinuosity, with current and past land uses as the primary influences on the stream. Cobble substrate and riffles were common. Both periphyton and macroinvertebrates scored as impaired. An impairment summary is provided in **Table D-12** and summary results of the Fish Cover/Other form are presented in **Table D-13.**

Table D-12. UWIL 11-05 Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
UWIL 11-05	55.14%	Impaired	0.57	Moderate

Table D-13. UWIL 11-05 Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/Glide	Pool
Presence	10-40%	10-40%	<10%	<10%	75%	25%	0%
Color	Light Brown	Green	Green	Dark Brown/ Black			
Condition	Growing	Growing	Growing	Growing			
Thickness/ Length	Thin	Long					

D3.6 UWIL 15-01

Agricultural land use surrounds the creek and grazing is evident close to the reach. The reach supports a mature riparian vegetation community in healthy condition. All ages of willow were present, providing good cover along much of the reach. Thick grass cover has impeded weeds. Cobble substrate was dominant in this mostly run/glide system.

Moderate impairment was determined for macroinvertebrates while periphyton results fell in the unimpaired class. An impairment summary is provided in **Table D-14** and summary results of the Fish Cover/Other form are presented in **Table D-15.**

Table D-14. UWIL 15-01 Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	**Impairment Class**	**O/E Score**	**Impairment Class**
UWIL 15-01	37.43%	Unimpaired	0.60	Moderate

Table D-15. UWIL 15-01 Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	**Filamentous Algae**	**Macrophytes**	**Moss**	**Riffle**	**Run/Glide**	**Pool**
Presence	10-40%	10-40%	<10%	<10%	25%	75%	0%
Color	Green/Light Brown	Green	Green	Green			
Condition	Growing	Growing	Growing	Growing			
Thickness/ Length	Thin	Long					

D3.7 QUTZ 08-01 (U.S)

Past activity in this gulch includes logging and mining. It appears mitigation work was also done here, evidenced by erosion control fabric placed on streambanks and within the channel at a gradient change. A pond was created further downstream possibly for sediment catchment. Despite this activity, this reach appears to be in a natural condition, just below the forested area in a transitional meadow. This channel likely has a very flashy character. Mosses and macrophytes appear to do well while microalgae are rarely present and usually in the form of dark and small colonies on some rocks.

At transect G some debris has created a small pool where macros and moss are growing more than usual, with minimal sign of microalgae. Both macroinvertebrates and periphyton showed impairment based on identified taxa. An impairment summary is provided in **Table D-16** and summary results of the Fish Cover/Other form are presented in **Table D-17.**

Table D-16. QUTZ 08-01 (U.S.) Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
QUTZ 08-01 (U.S.)	72.45%	Impaired	0.78	Moderate

Table D-17. QUTZ 08-01 (U.S.) Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/Glide	Pool
Presence	<10%	Absent	<10%	10-40%	60%	40%	0%
Color	Dark Brown/Black	Green/Light Brown	Green	Dark Brown/ Black			
Condition	Growing	Growing	Growing	Growing			
Thickness/ Length	Thin	Long					

D3.8 QUTZ 08-01 (D.S)

This reach is below a sharp slope break mentioned in the previous reach, where the creek temporarily subs under a pile of rocks, and just upstream of a constructed pond. The stream is narrow and cobble-dominated with little periphyton growth observed except for one filamentous algae specimen at transect E. This site is best accessed from an old logging road not clearly visible from the Forest Service road. Periphyton were found to be impaired, while macroinvertebrates were determined to be unimpaired based on collected taxa. An impairment summary is provided in **Table D-18** and summary results of the Fish Cover/Other form are presented in **Table D-19.**

Table D-18. QUTZ 08-01 (D.S.) Periphyton and Macroinvertebrate Impairment Class Summary

Reach ID	Periphyton		Macroinvertebrate	
	Impairment Probability	Impairment Class	O/E Score	Impairment Class
QUTZ 08-01 (D.S)	95.00%	Impaired	0.85	Unimpaired

Table D-19. QUTZ 08-01 (D.S.) Periphyton Cover and Sample Habitat Summary

Characteristic	Periphyton Cover				Sample Habitat (%)		
	Microalgae	Filamentous Algae	Macrophytes	Moss	Riffle	Run/ Glide	Pool
Presence	<10%	<10%	<10%	<10%	10%	90%	0%
Color	Dark Brown/ Black	Green/ Light Brown	Green	Dark Brown/ Black			
Condition	Growing	Growing	Growing	Growing			
Thickness/ Length	Thin	Short					

D4.0 SUMMARY

All stream reaches with exception of the West Fork Rock Creek sites showed impairment in either macroinvertebrates or periphyton, with the Antelope Creek sites, upper Quartz Creek and Upper Willow 11-05 showing impairment in both based on taxa observed in laboratory analysis. A summary table of impairment is provided in **Table D-20** below.

Table D-20. Stream Reach Impairment Summary

Reach ID	Macroinvertebrate	Periphyton
ANTE 08-01	Severely Impaired	Impaired
ANTE 21-03	Severely Impaired	Impaired
QUTZ 08-01 (U.S)	Moderately Impaired	Impaired
QUTZ 08-01 (D.S)	Unimpaired	Impaired
UWIL 15-01	Moderately Impaired	Unimpaired
UWIL 11-05	Moderately Impaired	Impaired
WFRK 14-03	Severely Impaired	Unimpaired
WFRK 30-02	Severely Impaired	Unimpaired

D5.0 REFERENCES

Montana Department of Environmental Quality. 2011. Periphyton Standard Operating Procedure. Helena, MT: Montana Department of Environmental Quality. WQPVWQM-010.

Montana Department of Environmental Quality, Water Quality Planning Bureau. 2012. Sample Collection, Sorting, and Taxonomic Identification of Benthic Macroinvertebrates Standard Operating Procedure. Helena, MT: Montana Department of Environmental Quality. WQPBWQM-009. http://deq.mt.gov/wqinfo/QAProgram/PDF/SOPs/WQPBWQM-009.pdf. Accessed 7/9/2013.

APPENDIX E – STREAMBANK EROSION SOURCE ASSESSMENT – ROCK CREEK TPA

TABLE OF CONTENTS

LIST OF TABLES

E1.0 EXISTING BANK EROSION SEDIMENT LOADS

In order to determine sediment loads from bank erosion, results from the field study (results are presented in **Appendix C**) were used to develop reasonable estimates to represent the total sediment loads from bank erosion for each watershed.

In the Rock Creek TPA, the sediment load for each eroding bank in a sampled reach was calculated, and then the total sediment load for that reach was summed (**Table E-1**). Monitoring site sediment loads were extrapolated to the stream reach, stream segment and sub-watershed scales based on aerial assessment reach type analysis and field verified reach types for assessment sites. Streambank erosion data were extrapolated using the following procedure:

1. Monitoring site sediment loads were extrapolated directly to the stream reach in which the monitoring site was located, based on total loading per 1000/ft.

2. Existing streambank erosion sediment loads were extrapolated to un-assessed reaches based on the average sediment loading/1000ft from assessed sites for each reach type grouping. Some reach types were grouped together in order to have a larger number of sampled reaches to average; based on similarities with stream slope, stream order, and best professional judgment. This produced five groupings with average loads ranging from 8 to 22 tons per year per 1000 feet. In the MR-0-3-U/MR-0-4-U grouping, the load from reach WFRK 14-03 was excluded from the average because it contained one unique bank that was contributing a very large load and was unrepresentative of the rest of that stream segment and other streams in the watershed. Un-assessed reach types were assigned loads from the most applicable and appropriate assessed reach type grouping (**Table E-2**).

Table E-1. Reach Total Sediment Load per 1000 feet

Reach ID	Reach Type	Total Sediment Load per 1000 feet (Tons/Year)
ANTE 21-01	MR-0-3-U	35.2
BREW 06-01	MR-0-3-U	19.5
UWIL 11-05	MR-0-3-U	6.7
WFRK 14-03	MR-0-3-U	110.1
WFRK 27-02	MR-0-3-U	24.1
WFRK 30-02	MR-0-3-U	24.4
EFRK 03-03	MR-0-4-U	16.6
UWIL 15-01	MR-0-4-U	29.9
SCOT 08-01	MR-2-1-U	27.3
SLUI 14-01	MR-2-2-C	18.0
MINE 14-02	MR-2-2-U	3.4
SLUI 18-02	MR-2-2-U	3.9
BREW 05-01	MR-2-3-U	3.4
EFRK 01-02	MR-2-3-U	11.9
QUTZ 09-01	MR-4-1-C	61.1
FLAT 12-01	MR-4-1-U	31.1
MINE 10-02	MR-4-1-U	2.2
SCOT 16-02	MR-4-1-U	4.4
SFAN 06-01	MR-4-2-C	7.2
ANTE 07-01	MR-4-2-U	15.2

Table E-1. Reach Total Sediment Load per 1000 feet

Reach ID	Reach Type	Total Sediment Load per 1000 feet (Tons/Year)
SFAN 13-01	MR-4-2-U	2.7
FLAT 13-01	MR-10-1-U	1.9

Table E-2. Existing Load Reach Groupings and Load Estimates

Reach Type Grouping	Number of Sampled Reaches	Sampled Reaches	Average Existing Bank Erosion Sediment Load per 1000 feet (Tons/Year)
MR-0-1-U	0	applied MR-2-2-U/MR-2-2-C rate	8
MR-0-2-U	0	applied MR-2-2-U/MR-2-2-C rate	8
MR-0-3-C	0	applied MR-0-3-U/MR-0-4-U rate	22
MR-0-3-U/MR-0-4-U	8	ANTE 21-01, BREW 06-01, UWIL 11-05, WFRK 14-03, WFRK 27-02, WFRK 30-02, EFRK 03-03, UWIL 15-01	22
MR-2-1-C	0	applied MR-2-1-U/MR-4-1-U/MR-4-1-C/MR-10-1-U	21
MR-2-1-U/MR-4-1-U/ MR-4-1-C/MR-10-1-U	6	SCOT 08-01, QUTZ 09-01, FLAT 12-01, MINE 10-02, SCOT 16-02, FLAT 13-01	21
MR-2-2-U/MR-2-2-C	3	SLUI 14-01, MINE 14-02, SLUI 18-02	8
MR-2-3-C	0	applied MR-2-3-U	12
MR-2-3-U	2	BREW 05-01, EFRK 01-02	12
MR-4-2-U/MR-4-2-C	3	SFAN 06-01, ANTE 07-01, SFAN 13-01	8
MR-4-3-C	0	applied MR-2-3-U	12
MR-4-3-U	0	applied MR-2-3-U	12
MR-10-1-C	0	applied MR-2-1-U/MR-4-1-U/MR-4-1-C/MR-10-1-U	21
MR-10-2-C	0	applied MR-2-2-U/MR-2-2-C	8

Reach Type values = Level 3 Ecoregion - valley gradient – stream order – valley confinement

E2.0 Establishing the Total Allowable Load

Once the existing bank erosion sediment load was derived, a desired load was established to determine the target conditions and allocation of sediment reductions.

It is difficult to precisely quantify total sediment loads from bank erosion without assessing the entire length of streambanks. However, quantitative data coupled with qualitative information from the sample reaches provides a good basis to estimate the total load and potential for sediment load reduction.

As described in the section above, all streams were delineated into reaches defined by a particular reach type. Each individual reach was also reviewed and human influences on bank erosion were presumed and assigned to that reach based on nearby land use and land management. Reaches that occurred in areas with land management practices conducive to bank stability and streamside vegetative health (such as riparian fencing or healthy wetland/riparian buffers) or areas of little human influence were designated as naturally influenced (70% or more of the reach is attributed to natural influence). Conversely, reaches that were predominantly influenced by the effects of land or stream management that often result in bank instability (no riparian vegetation, channel straightening, road encroachment) were designated as human influenced (70% or more of the reach is attributed to human influence).

Sampled reaches were sorted by their influence category (natural or human), mean BEHI rating, reach type, and the average sediment loads (tons/1000'). In past TMDL bank erosion assessments, efforts to define a reference condition to differentiate between existing conditions and the potential conditions given reasonable land, soil, and water conservation practices relied on comparisons between identified external or internal reference reaches; relationships between the percentages of slowly eroding banks and actively eroding banks; or ratios of load contribution from human influenced and naturally eroding banks.

In the Rock Creek TPA, it was often difficult to distinguish natural vs. human influence because of historical mining, grazing, and logging that has occurred in the watershed. Many reaches were categorized as being predominately natural because they were in a state of recovery, however this potentially neglected past human influence on the stream, making it difficult to determine a reference condition. Because there is high confidence in the BEHI measurements that were performed in the field in 2011, to estimate a potential decrease in sediment loading due to improved streambank stability, mean BEHI rating values (**Table E-3**) in the existing dataset for each reach type that exceeded the "moderate" category were taken out and total loads were again averaged within reach type groupings. These reduced average loads were then extrapolated to reach types that were considered to be human influenced throughout the watershed, based on the extrapolation groupings used for existing loads (**Table E-4**). Reaches that were designated to be naturally influenced were given a desired load matching the existing load. Extrapolated loads by watershed are presented in **Table E-5** (Extrapolated loads by Reach ID are located in **Table E1-1** in **Attachment E-1**).

Table E-3. Mean BEHI rating and Total Sediment Load by Sampled Reach

Reach ID	Reach Type	Mean BEHI Rating
ANTE 21-01	MR-0-3-U	high
WFRK 14-03	MR-0-3-U	high
BREW 06-01	MR-0-3-U	moderate
WFRK 27-02	MR-0-3-U	moderate
UWIL 11-05	MR-0-3-U	low
WFRK 30-02	MR-0-3-U	moderate
UWIL 15-01	MR-0-4-U	moderate
EFRK 03-03	MR-0-4-U	moderate
FLAT 13-01	MR-10-1-U	moderate
SCOT 08-01	MR-2-1-U	moderate
SLUI 14-01	MR-2-2-C	high
SLUI 18-02	MR-2-2-U	low
MINE 14-02	MR-2-2-U	low
EFRK 01-02	MR-2-3-U	moderate
BREW 05-01	MR-2-3-U	low
QUTZ 09-01	MR-4-1-C	high
FLAT 12-01	MR-4-1-U	high
MINE 10-02	MR-4-1-U	low
SCOT 16-02	MR-4-1-U	low
SFAN 06-01	MR-4-2-C	moderate
ANTE 07-01	MR-4-2-U	high
SFAN 13-01	MR-4-2-U	low

Table E-4. Desired Load Reach Groupings and Load Estimates

Reach Type Grouping	Number of Sampled Reaches	Sampled Reaches	Average Desired Bank Erosion Sediment Load per 1000 feet (Tons/Year)
MR-0-1-U	0	applied MR-2-2-U/MR-2-2-C rate	4
MR-0-2-U	0	applied MR-2-2-U/MR-2-2-C rate	4
MR-0-3-C	0	applied MR-0-3-U/MR-0-4-U rate	20
MR-0-3-U/MR-0-4-U	8	ANTE 21-01, BREW 06-01, UWIL 11-05, WFRK 14-03, WFRK 27-02, WFRK 30-02, EFRK 03-03, UWIL 15-01	20
MR-2-1-C	0	applied MR-2-1-U/MR-4-1-U/MR-4-1-C/MR-10-1-U	9
MR-2-1-U/MR-4-1-U/ MR-4-1-C/MR-10-1-U	6	SCOT 08-01, QUTZ 09-01, FLAT 12-01, MINE 10-02, SCOT 16-02, FLAT 13-01	9
MR-2-2-U/MR-2-2-C	3	SLUI 14-01, MINE 14-02, SLUI 18-02	4
MR-2-3-C	0	applied MR-2-3-U	8
MR-2-3-U	2	BREW 05-01, EFRK 01-02	8
MR-4-2-U/MR-4-2-C	3	SFAN 06-01, ANTE 07-01, SFAN 13-01	5
MR-4-3-C	0	applied MR-2-3-U	8
MR-4-3-U	0	applied MR-2-3-U	8
MR-10-1-C	0	applied MR-2-1-U/MR-4-1-U/MR-4-1-C/MR-10-1-U	9
MR-10-2-C	0	applied MR-2-2-U/MR-2-2-C	4

Table E-5. Extrapolated Existing and Desired Loads by Watershed

Sub-watershed	Existing Bank Erosion Load	Desired Bank Erosion Load	Percent Reduction
Antelope Creek (includes SF Antelope Creek)	691	416	40%
Basin Gulch	161	69	57%
Brewster Creek	246	195	21%
East Fork Rock Creek	984	896	9%
Eureka Gulch (includes Basin and Quartz gulches)	712	407	43%
Flat Gulch	280	116	58%
Miners Gulch	473	439	7%
Quartz Gulch	526	324	38%
Scotchman Gulch	683	470	31%
South Fork Antelope Creek	158	87	45%
Sluice Gulch	398	213	46%
Upper Willow Creek (includes Scotchman and Miners gulches)	3548	3019	15%
West Fork Rock Creek	2880	1897	34%

E3.0 ALLOCATIONS AND ACHIEVEMENT

The desired sediment load is a gross estimate based on limited data. As such, the quantified load is not as significant for management and TMDL achievement purposes as the potential percent reduction. Since the desired load is based on the average of BEHI ratings with the “high” category excluded, it is assumed that this is a reasonable estimate for what is achievable in bank stabilization. The percent reduction allocation encompasses all adjacent land use categories and land management practices, and expects land owners to manage their properties with all applicable and reasonable land, water, and soil conservation practices to protect, improve, and restore stable and healthy streambanks and riparian corridors. Reasonable land, water, and conservation practices in this context may include limiting riparian livestock grazing durations to reduce effect on riparian vegetation, directing livestock to designed water gaps or off-site watering locations, establishing a specific riparian corridor with free from human-related activity, or re-establishment of key riparian vegetation. It is acknowledged that recovery of stable banks and improvement of riparian vegetation communities may take many decades to achieve. It is encouraged that, in addition to managing current activities with all reasonable land, soil, and water conservation practices, management decisions to promote floodplain functionality and native vegetation establishment throughout the riparian corridor will be reviewed and implemented wherever and whenever possible.

Although it is difficult to discern between bank erosion influenced from current or historic human practices and bank erosion as a result of natural processes using aerial imagery and GIS methodology, it is possible to identify potential present-day influencing factors with these methods. Through the stratification process used during the assessment method, adjacent land use and potential current influences on bank erosion was noted for each reach. Simple breakouts of the apparent percent influence on major land use types allows a general, but useful, overview of those activities that may be affecting bank erosion. This data can be used to help assist land managers with prioritizing areas to expedite sediment load reductions and eventually achieve the TMDL. Rough estimates of potential influence at the watershed scale are presented in **Table E-6** below.

Table E-6. Natural and Human Influences on Bank Erosion

Watershed	Natural	Transport	Grazing	Cropland	Mining	Forestry	Irrig.	Other
Antelope Creek	10%	4%	67%	12%	0%	1%	6%	0%
Basin Gulch	30%	38%	23%	4%	5%	0%	0%	0%
Brewster Creek	42%	30%	10%	0%	0%	11%	0%	7%
East Fork Rock Creek	26%	12%	26%	4%	0%	0%	29%	3%
Eureka Gulch	0%	20%	4%	0%	76%	0%	0%	0%
Flat Gulch	30%	2%	64%	0%	0%	4%	0%	1%
Miners Gulch	88%	3%	3%	0%	2%	3%	0%	0%
Quartz Gulch	72%	0%	4%	0%	3%	0%	0%	21%
Scotchman Gulch	56%	10%	33%	0%	0%	0%	0%	1%
South Fork Antelope Creek	2%	1%	61%	0%	0%	36%	0%	0%
Sluice Gulch	29%	10%	41%	0%	5%	11%	2%	2%
Upper Willow Creek	37%	4%	36%	4%	0%	0%	19%	0%
West Fork Rock Creek	52%	18%	13%	2%	0%	1%	0%	14%

It is acknowledged that the developed sediment loads and the method by which to attribute human and historic influence are estimates based on aerial photography, best professional judgment, and limited access to on-the-ground reaches. The assignment of bank erosion loads to the various land uses is not definitive; however it does provide helpful guidance for directing focus and efforts at reducing the loads from those causes which are likely having the biggest impacts on the investigated streams. Ultimately, it is the responsibility of local land owners and managers to identify the causes of bank erosion, and adopt practices to reduce bank erosion where ever practicable and possible. Complete TMDLs and allocations are presented in **Section 5-7**.

Assumptions and Considerations:

- The annual streambank erosion rates used to develop the sediment loading numbers were based on Rosgen BEHI studies developed using USDA Forest Service (in Colorado) data for streams found in sedimentary and/or metamorphic geology. While the geologies between the Rosgen research sites and the Rock Creek TPA are not identical, they are similar enough in character to warrant their application.
- The bank erosion data collected during the 2011 field effort is representative of conditions throughout the Rock Creek watershed.
- The assignment of influence to the eroding banks, and distinction between natural and human caused bank erosion is based on best professional judgment by qualified and experienced field personnel.
- The present day erosion has been, and continues to be affected by historic mining, grazing, logging, and other disturbances to the riparian corridor (both anthropogenic and natural, in the case of fires).
- The application of a bank erosion load reductions based on reducing BEHI values assumes that improved management practices will lead to improved streambank stability. The percent reduction is considered reasonable given the amount of human influence throughout the Rock Creek watershed.
- Specific quantification of the load reductions estimated here is not as significant as the complete application of best management practices in each of the watersheds of interest. With application of all reasonable land, soil, water conservation practices it is expected that the allocation will be achieved.

The land use percentages identified in **Table E-6** are general and may not be entirely accurate. They are intended to provide a starting point for further investigation and activity to address bank erosion by land use planners and watershed managers.

ATTACHMENT E-1

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
ANTE 01-01	MR-10-1-U	388	40	60	21	9	8.1	3.5	
ANTE 02-01	MR-4-1-U	433	40	60	21	9	9.1	3.9	
ANTE 03-01	MR-10-1-U	370	40	60	21	9	7.8	3.3	
ANTE 04-01	MR-4-1-U	2583	40	60	21	9	54.2	23.2	
ANTE 05-01	MR-4-1-C	1437	20	80	21	9	30.2	12.9	
ANTE 06-01	MR-2-2-C	2193	20	80	8	4	17.5	8.8	
ANTE 07-01	MR-4-2-U	1041	0	100	15	5	15.6	5.2	
ANTE 08-01	MR-2-2-U	1886	0	100	8	4	15.1	7.5	
ANTE 09-01	MR-2-2-C	1869	0	100	8	4	15.0	7.5	
ANTE 10-01	MR-2-2-U	1513	0	100	8	4	12.1	6.1	
ANTE 11-01	MR-0-2-U	827	0	100	8	4	6.6	3.3	
ANTE 11-02	MR-0-2-U	4376	0	100	8	4	35.0	17.5	
ANTE 12-01	MR-2-2-C	1064	0	100	8	4	8.5	4.3	
ANTE 13-01	MR-4-2-C	745	0	100	8	5	6.0	3.7	
ANTE 14-01	MR-2-2-C	1285	0	100	8	4	10.3	5.1	
ANTE 15-01	MR-4-2-U	452	0	100	8	5	3.6	2.3	
ANTE 16-01	MR-4-3-U	734	0	100	12	8	8.8	5.9	
ANTE 17-01	MR-4-3-U	1085	0	100	12	8	13.0	8.7	
ANTE 18-01	MR-2-3-C	2122	0	100	12	8	25.5	17.0	
ANTE 19-01	MR-4-3-C	722	0	100	12	8	8.7	5.8	
ANTE 20-01	MR-2-3-U	941	0	100	12	8	11.3	7.5	
ANTE 20-02	MR-2-3-U	2698	0	100	12	8	32.4	21.6	
ANTE 21-01	MR-0-3-U	1555	0	100	35	20	54.4	31.1	
ANTE 21-02	MR-0-3-U	497	10	90	22	20	10.9	9.9	
ANTE 21-03	MR-0-3-U	3697	10	90	22	20	81.3	73.9	
ANTE 21-04	MR-0-3-U	1457	10	90	22	20	32.1	29.1	
Antelope Creek Totals							**533.1**	**328.7**	**38%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
BASN 01-01	MR-10-1-U	336	20	80	21	9	7.1	3.0	
BASN 02-01	MR-4-1-U	190	20	80	21	9	4.0	1.7	
BASN 02-02	MR-4-1-U	82	0	100	21	9	1.7	0.7	
BASN 02-03	MR-4-1-U	590	10	90	21	9	12.4	5.3	
BASN 03-01	MR-10-1-U	384	40	60	21	9	8.1	3.5	
BASN 04-01	MR-4-1-U	581	30	70	21	9	12.2	5.2	
BASN 05-01	MR-10-1-U	304	30	70	21	9	6.4	2.7	
BASN 06-01	MR-4-1-U	588	40	60	21	9	12.3	5.3	
BASN 07-01	MR-10-1-C	2054	30	70	21	9	43.1	18.5	
BASN 08-01	MR-4-1-C	1151	40	60	21	9	24.2	10.4	
BASN 09-01	MR-10-1-C	1412	30	70	21	9	29.7	12.7	
Basin Gulch Totals							**161.1**	**69.0**	**57%**
BREW 01-01	MR-4-2-C	3640	80	20	8	8	29.1	29.1	
BREW 02-01	MR-2-2-U	1473	40	60	8	4	11.8	5.9	
BREW 03-01	MR-2-3-U	481	40	60	12	8	5.8	3.8	
BREW 04-01	MR-2-3-C	2959	30	70	12	8	35.5	23.7	
BREW 05-01	MR-2-3-U	5563	97	3	3	3	16.7	16.7	
BREW 05-02	MR-2-3-U	7107	20	80	12	8	85.3	56.9	
BREW 06-01	MR-0-3-U	1316	66	34	20	20	26.3	26.3	
BREW 06-02	MR-0-3-U	1614	30	70	22	20	35.5	32.3	
Brewster Creek Totals							**246.0**	**194.7**	**21%**
EFRK 01-01	MR-2-3-U	1901	20	80	12	8	22.8	15.2	
EFRK 01-02	MR-2-3-U	4688	82	18	12	12	56.3	56.3	
EFRK 01-03	MR-2-3-U	3775	10	90	12	8	45.3	30.2	
EFRK 02-01	MR-0-3-U	2665	10	90	22	20	58.6	53.3	
EFRK 02-02	MR-0-3-U	3930	10	90	22	20	86.5	78.6	
EFRK 02-03	MR-0-3-U	5638	20	80	22	20	124.0	112.8	
EFRK 03-01	MR-0-4-U	2519	20	80	22	20	55.4	50.4	
EFRK 03-02	MR-0-4-U	12030	10	90	22	20	264.7	240.6	
EFRK 03-03	MR-0-4-U	8740	70	30	17	17	148.6	148.6	
EFRK 03-04	MR-0-4-U	2569	10	90	22	20	56.5	51.4	
EFRK 03-05	MR-0-4-U	2951	20	80	22	20	64.9	59.0	
East Fork Rock Creek Totals							**983.6**	**896.3**	**9%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
EURK 01-01	MR-4-2-C	1146	0	100	8	5	9.2	5.7	
EURK 02-01	MR-4-2-U	451	0	100	8	5	3.6	2.3	
EURK 03-01	MR-4-2-U	269	0	100	8	5	2.2	1.3	
EURK 04-01	MR-0-2-U	682	0	100	8	4	5.5	2.7	
EURK 04-02	MR-0-2-U	520	0	100	8	4	4.2	2.1	
Eureka Gulch Totals							**24.5**	**14.1**	**42%**
FLAT 01-01	MR-4-1-U	994	40	60	21	9	20.9	8.9	
FLAT 01-02	MR-4-1-U	824	30	70	21	9	17.3	7.4	
FLAT 02-01	MR-2-1-U	1066	30	70	21	9	22.4	9.6	
FLAT 03-01	MR-4-1-U	896	60	40	21	9	18.8	8.1	
FLAT 04-01	MR-2-1-U	1238	50	50	21	9	26.0	11.1	
FLAT 05-01	MR-4-1-U	680	40	60	21	9	14.3	6.1	
FLAT 06-01	MR-2-1-U	1058	40	60	21	9	22.2	9.5	
FLAT 07-01	MR-4-1-U	961	50	50	21	9	20.2	8.6	
FLAT 08-01	MR-10-1-C	396	30	70	21	9	8.3	3.6	
FLAT 09-01	MR-4-1-C	506	30	70	21	9	10.6	4.6	
FLAT 10-01	MR-10-1-C	585	20	80	21	9	12.3	5.3	
FLAT 11-01	MR-10-1-U	1083	0	100	21	9	22.7	9.7	
FLAT 12-01	MR-4-1-U	1838	0	100	31	9	57.0	16.5	
FLAT 13-01	MR-10-1-U	3639	80	20	2	2	7.3	7.3	
Flat Gulch Totals							**280.3**	**116.4**	**58%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
MINE 01-01	MR-10-1-U	3839	100	0	21	21	80.6	80.6	
MINE 02-01	MR-10-1-C	1154	100	0	21	21	24.2	24.2	
MINE 03-01	MR-10-1-U	719	100	0	21	21	15.1	15.1	
MINE 04-01	MR-4-1-U	452	100	0	21	21	9.5	9.5	
MINE 05-01	MR-10-1-U	313	100	0	21	21	6.6	6.6	
MINE 06-01	MR-4-1-U	486	100	0	21	21	10.2	10.2	
MINE 07-01	MR-10-1-U	349	100	0	21	21	7.3	7.3	
MINE 08-01	MR-4-1-U	3876	100	0	21	21	81.4	81.4	
MINE 09-01	MR-4-1-C	3941	80	20	21	21	82.8	82.8	
MINE 09-02	MR-4-1-C	1626	50	50	21	9	34.1	14.6	
MINE 10-01	MR-4-1-U	918	90	10	21	21	19.3	19.3	
MINE 10-02	MR-4-1-U	1151	100	0	2	2	2.3	2.3	
MINE 10-03	MR-4-1-U	1922	100	0	21	21	40.4	40.4	
MINE 11-01	MR-4-2-U	997	30	70	8	5	8.0	5.0	
MINE 12-01	MR-2-2-C	2538	90	10	8	8	20.3	20.3	
MINE 13-01	MR-4-2-C	2607	60	40	8	5	20.9	13.0	
MINE 14-01	MR-2-2-U	1022	60	40	8	4	8.2	4.1	
MINE 14-02	MR-2-2-U	730	100	0	3	3	2.2	2.2	
Miners Gulch Totals							**473.3**	**438.9**	**7%**
QUTZ 01-01	MR-10-1-U	983	100	0	21	21	20.6	20.6	
QUTZ 02-01	MR-10-1-C	2714	100	0	21	21	57.0	57.0	
QUTZ 03-01	MR-4-1-C	468	100	0	21	21	9.8	9.8	
QUTZ 04-01	MR-10-1-C	726	100	0	21	21	15.2	15.2	
QUTZ 05-01	MR-4-1-C	1324	100	0	21	21	27.8	27.8	
QUTZ 06-01	MR-10-1-C	719	100	0	21	21	15.1	15.1	
QUTZ 07-01	MR-4-1-C	3471	90	10	21	21	72.9	72.9	
QUTZ 08-01	MR-2-1-C	1062	30	70	21	9	22.3	9.6	
QUTZ 09-01	MR-4-1-C	3633	50	50	61	9	221.6	32.7	
QUTZ 10-01	MR-10-1-C	288	80	20	21	21	6.1	6.1	
QUTZ 11-01	MR-4-1-C	446	80	20	21	21	9.4	9.4	
QUTZ 12-01	MR-10-1-C	2278	80	20	21	21	47.8	47.8	
Quartz Gulch Totals							**525.7**	**324.0**	**38%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
SCOT 01-01	MR-10-1-U	394	100	0	21	21	8.3	8.3	
SCOT 02-01	MR-4-1-U	4959	100	0	21	21	104.1	104.1	
SCOT 03-01	MR-4-1-C	1569	100	0	21	21	32.9	32.9	
SCOT 04-01	MR-4-1-U	1943	100	0	21	21	40.8	40.8	
SCOT 05-01	MR-2-1-U	5642	70	30	21	21	118.5	118.5	
SCOT 06-01	MR-4-1-U	1143	50	50	21	9	24.0	10.3	
SCOT 07-01	MR-0-1-U	4294	20	80	8	4	34.4	17.2	
SCOT 08-01	MR-2-1-U	1662	16	84	27	9	44.9	15.0	
SCOT 08-02	MR-2-1-U	2722	30	70	21	9	57.2	24.5	
SCOT 09-01	MR-4-1-U	419	60	40	21	9	8.8	3.8	
SCOT 10-01	MR-2-1-C	1256	50	50	21	9	26.4	11.3	
SCOT 11-01	MR-4-1-C	890	20	80	21	9	18.7	8.0	
SCOT 12-01	MR-10-1-C	314	20	80	21	9	6.6	2.8	
SCOT 13-01	MR-4-1-C	1414	30	70	21	9	29.7	12.7	
SCOT 14-01	MR-10-1-C	396	40	60	21	9	8.3	3.6	
SCOT 15-01	MR-4-1-C	668	30	70	21	9	14.0	6.0	
SCOT 15-02	MR-4-1-C	1904	30	70	21	9	40.0	17.1	
SCOT 16-01	MR-4-1-U	2761	20	80	21	9	58.0	24.9	
SCOT 16-02	MR-4-1-U	1975	100	0	4	4	7.9	7.9	
Scotchman Gulch Totals							**683.4**	**469.7**	**31%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
SFAN 01-01	MR-10-1-U	323	0	100	21	9	6.8	2.9	
SFAN 02-01	MR-4-1-C	1125	0	100	21	9	23.6	10.1	
SFAN 03-01	MR-10-1-C	384	0	100	21	9	8.1	3.5	
SFAN 04-01	MR-4-1-C	433	0	100	21	9	9.1	3.9	
SFAN 05-01	MR-4-1-U	895	0	100	21	9	18.8	8.1	
SFAN 06-01	MR-4-2-C	1365	0	100	7	5	9.6	6.8	
SFAN 06-02	MR-4-2-C	1502	20	80	8	5	12.0	7.5	
SFAN 07-01	MR-10-2-C	354	20	80	8	4	2.8	1.4	
SFAN 08-01	MR-4-2-C	1675	0	100	8	5	13.4	8.4	
SFAN 08-02	MR-4-2-C	2804	0	100	8	5	22.4	14.0	
SFAN 09-01	MR-10-2-C	361	0	100	8	4	2.9	1.4	
SFAN 10-01	MR-4-2-C	1556	0	100	8	5	12.4	7.8	
SFAN 11-01	MR-10-2-C	659	20	80	8	4	5.3	2.6	
SFAN 12-01	MR-4-2-C	1009	40	60	8	5	8.1	5.0	
SFAN 13-01	MR-4-2-U	1025	0	100	3	3	3.1	3.1	
South Fork Antelope Creek							**158.3**	**86.6**	**45%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
SLUI 01-01	MR-10-1-U	567	40	60	21	9	11.9	5.1	
SLUI 02-01	MR-4-1-U	668	40	60	21	9	14.0	6.0	
SLUI 03-01	MR-4-1-C	1354	30	70	21	9	28.4	12.2	
SLUI 04-01	MR-4-1-U	1434	20	80	21	9	30.1	12.9	
SLUI 04-02	MR-4-1-U	189	20	80	21	9	4.0	1.7	
SLUI 05-01	MR-2-1-C	2271	20	80	21	9	47.7	20.4	
SLUI 06-01	MR-4-1-C	667	20	80	21	9	14.0	6.0	
SLUI 07-01	MR-10-1-C	362	20	80	21	9	7.6	3.3	
SLUI 08-01	MR-4-1-U	894	20	80	21	9	18.8	8.0	
SLUI 08-02	MR-4-1-U	527	20	80	21	9	11.1	4.7	
SLUI 09-01	MR-2-2-U	662	20	80	8	4	5.3	2.6	
SLUI 09-02	MR-2-2-U	2970	20	80	8	4	23.8	11.9	
SLUI 10-01	MR-2-2-C	2751	20	80	8	4	22.0	11.0	
SLUI 11-01	MR-2-2-C	3651	20	80	8	4	29.2	14.6	
SLUI 12-01	MR-2-2-U	1111	40	60	8	4	8.9	4.4	
SLUI 13-01	MR-2-2-U	1262	20	80	8	4	10.1	5.0	
SLUI 14-01	MR-2-2-C	2396	80	20	18	18	43.1	43.1	
SLUI 15-01	MR-4-2-U	509	10	90	8	5	4.1	2.5	
SLUI 15-02	MR-4-2-U	461	10	90	8	5	3.7	2.3	
SLUI 16-01	MR-2-2-U	1787	20	80	8	4	14.3	7.1	
SLUI 16-02	MR-2-2-U	2810	10	90	8	4	22.5	11.2	
SLUI 16-03	MR-2-2-U	1089	0	100	8	4	8.7	4.4	
SLUI 17-01	MR-4-2-U	367	0	100	8	5	2.9	1.8	
SLUI 18-01	MR-2-2-U	191	0	100	8	4	1.5	0.8	
SLUI 18-02	MR-2-2-U	2490	80	20	4	4	10.0	10.0	
Sluice Gulch Totals							**397.6**	**213.3**	**46%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
UWIL 01-01	MR-10-1-C	1891	100	0	21	21	39.7	39.7	
UWIL 01-02	MR-10-1-C	1330	50	50	21	9	27.9	12.0	
UWIL 02-01	MR-4-1-C	1033	100	0	21	21	21.7	21.7	
UWIL 03-01	MR-10-1-C	373	90	10	21	21	7.8	7.8	
UWIL 04-01	MR-4-1-C	474	90	10	21	21	10.0	10.0	
UWIL 05-01	MR-10-1-C	779	90	10	21	21	16.4	16.4	
UWIL 06-01	MR-2-1-U	1211	90	10	21	21	25.4	25.4	
UWIL 07-01	MR-4-1-U	1671	90	10	21	21	35.1	35.1	
UWIL 08-01	MR-2-1-U	1301	80	20	21	21	27.3	27.3	
UWIL 09-01	MR-4-1-U	953	80	20	21	21	20.0	20.0	
UWIL 10-01	MR-0-2-U	453	80	20	8	8	3.6	3.6	
UWIL 11-01	MR-0-3-U	2210	70	30	22	22	48.6	48.6	
UWIL 11-02	MR-0-3-U	5939	50	50	22	20	130.7	118.8	
UWIL 11-03	MR-0-3-U	31444	30	70	22	20	691.8	628.9	
UWIL 11-04	MR-0-3-U	1332	20	80	22	20	29.3	26.6	
UWIL 11-05	MR-0-3-U	13490	95	5	7	7	94.4	94.4	
UWIL 11-06	MR-0-3-U	2774	20	80	22	20	61.0	55.5	
UWIL 11-07	MR-0-3-U	1551	20	80	22	20	34.1	31.0	
UWIL 11-08	MR-0-3-U	3166	10	90	22	20	69.6	63.3	
UWIL 11-09	MR-0-3-U	75	20	80	22	20	1.6	1.5	
UWIL 11-10	MR-0-3-U	1487	20	80	22	20	32.7	29.7	
UWIL 12-01	MR-0-3-U	330	20	80	22	20	7.3	6.6	
UWIL 13-01	MR-0-3-U	135	20	80	22	20	3.0	2.7	
UWIL 14-01	MR-0-3-U	8238	20	80	22	20	181.2	164.8	
UWIL 14-02	MR-0-3-U	11023	10	90	22	20	242.5	220.5	
UWIL 14-03	MR-0-3-U	1873	10	90	22	20	41.2	37.5	
UWIL 14-04	MR-0-3-U	5484	10	90	22	20	120.7	109.7	
UWIL 14-05	MR-0-3-U	618	10	90	22	20	13.6	12.4	
UWIL 15-01	MR-0-4-U	11281	53	47	30	20	338.4	225.6	
UWIL 16-01	MR-0-4-U	276	20	80	22	20	6.1	5.5	
UWIL 16-02	MR-0-4-U	391	10	90	22	20	8.6	7.8	
Upper Willow Creek Totals							**2391.5**	**2110.4**	**12%**

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
WFRK 01-01	MR-4-1-U	300	100	0	21	21	6.3	6.3	
WFRK 02-01	MR-10-1-U	612	70	30	21	21	12.8	12.8	
WFRK 03-01	MR-4-1-U	1356	70	30	21	21	28.5	28.5	
WFRK 04-01	MR-2-1-U	1754	50	50	21	9	36.8	15.8	
WFRK 05-01	MR-0-1-U	1618	90	10	8	8	12.9	12.9	
WFRK 06-01	MR-0-2-U	525	90	10	8	8	4.2	4.2	
WFRK 07-01	MR-2-2-U	3154	80	20	8	8	25.2	25.2	
WFRK 08-01	MR-0-2-U	2751	30	70	8	4	22.0	11.0	
WFRK 09-01	MR-2-2-U	702	80	20	8	8	5.6	5.6	
WFRK 09-02	MR-2-2-U	636	80	20	8	8	5.1	5.1	
WFRK 10-01	MR-0-2-U	1175	90	10	8	8	9.4	9.4	
WFRK 10-02	MR-0-2-U	3379	40	60	8	4	27.0	13.5	
WFRK 10-03	MR-0-2-U	3090	20	80	8	4	24.7	12.4	
WFRK 10-04	MR-0-2-U	1828	20	80	8	4	14.6	7.3	
WFRK 11-01	MR-2-2-U	1871	20	80	8	4	15.0	7.5	
WFRK 12-01	MR-4-2-U	552	30	70	8	5	4.4	2.8	
WFRK 13-01	MR-0-2-U	1712	40	60	8	4	13.7	6.8	
WFRK 13-02	MR-0-2-U	2107	30	70	8	4	16.9	8.4	
WFRK 13-03	MR-0-2-U	2147	30	70	8	4	17.2	8.6	
WFRK 13-04	MR-0-2-U	2094	30	70	8	4	16.8	8.4	
WFRK 13-05	MR-0-2-U	3336	30	70	8	4	26.7	13.3	
WFRK 14-01	MR-0-3-U	5699	30	70	22	20	125.4	114.0	
WFRK 14-02	MR-0-3-U	8828	50	50	22	20	194.2	176.6	
WFRK 14-03	MR-0-3-U	7363	58	42	110	20	809.9	147.3	
WFRK 14-04	MR-0-3-U	1164	70	30	22	22	25.6	25.6	
WFRK 14-05	MR-0-3-U	6479	60	40	22	20	142.5	129.6	
WFRK 14-06	MR-0-3-U	3292	40	60	22	20	72.4	65.8	
WFRK 15-01	MR-2-3-U	5791	30	70	12	8	69.5	46.3	
WFRK 16-01	MR-2-3-C	3068	30	70	12	8	36.8	24.5	
WFRK 17-01	MR-0-3-C	2345	40	60	22	20	51.6	46.9	
WFRK 18-01	MR-2-3-C	1129	20	80	12	8	13.5	9.0	
WFRK 19-01	MR-2-3-C	547	30	70	12	8	6.6	4.4	
WFRK 20-01	MR-2-3-U	1435	30	70	12	8	17.2	11.5	

Table E1-1. Sediment Load Reductions by Reach and Subwatershed

REACH_ID	REACH TYPE	LENGTH_FT	% Natural	% Anthro	Existing Rate (ton/1000 ft)	Desired Rate (ton/1000 ft)	Existing Load Estimate	Desired Load Estimate	% Reduction
WFRK 21-01	MR-0-3-U	2207	40	60	22	20	48.5	44.1	
WFRK 22-01	MR-2-3-U	1892	40	60	12	8	22.7	15.1	
WFRK 23-01	MR-0-3-U	2525	50	50	22	20	55.6	50.5	
WFRK 24-01	MR-2-3-U	1639	80	20	12	12	19.7	19.7	
WFRK 25-01	MR-0-3-U	2462	80	20	22	22	54.2	54.2	
WFRK 26-01	MR-2-3-U	2813	60	40	12	8	33.8	22.5	
WFRK 27-01	MR-0-3-U	233	30	70	22	20	5.1	4.7	
WFRK 27-02	MR-0-3-U	919	91	9	24	24	22.1	22.1	
WFRK 27-03	MR-0-3-U	3531	30	70	22	20	77.7	70.6	
WFRK 28-01	MR-2-3-U	4028	50	50	12	8	48.3	32.2	
WFRK 28-02	MR-2-3-U	1600	30	70	12	8	19.2	12.8	
WFRK 29-01	MR-0-3-U	1469	30	70	22	20	32.3	29.4	
WFRK 29-02	MR-0-3-U	3403	40	60	22	20	74.9	68.1	
WFRK 30-01	MR-0-3-U	4451	40	60	22	20	97.9	89.0	
WFRK 30-02	MR-0-3-U	4531	100	0	24	24	108.7	108.7	
WFRK 30-03	MR-0-3-U	1329	60	40	22	20	29.2	26.6	
WFRK 30-04	MR-0-3-U	6540	50	50	22	20	143.9	130.8	
WFRK 30-05	MR-0-3-U	2439	40	60	22	20	53.7	48.8	
WFRK 31-01	MR-0-4-U	957	30	70	22	20	21.0	19.1	
West Fork Rock Creek Totals							**2879.7**	**1896.4**	**34%**

APPENDIX F - ROCK TPA ASSESSMENT OF UPLAND SEDIMENT SOURCES FOR TMDL DEVELOPMENT

Appendix F is based report prepared for the DEQ by ATKINS, August 2012.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

F1.0 INTRODUCTION

An assessment of the sediment loading from hillslope erosion within the Rock TMDL Planning Area (TPA) was performed to facilitate the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. Upland sediment loading from hillslope erosion was modeled using a Universal Soil Loss Equation (USLE) based model, which was combined with a sediment delivery ratio (SDR) and riparian health assessment to predict the amount of sediment delivered to streams in the Rock TPA. The USLE based model was implemented as a watershed-scale, raster-based, GIS model using ArcGIS software.

F1.1 SEDIMENT IMPAIRMENTS

The Rock TPA encompasses an area of approximately 890 square miles in Granite and Missoula counties in western Montana. The Rock TPA is contained within the Flint-Rock Creeks HUC8 (17010202). Within the Rock TPA, there are nine waterbody segments listed on the 2012 303(d) List for sediment-related impairments, including Eureka Gulch, Brewster Creek, South Fork Antelope Creek, Quartz Gulch, East Fork Rock Creek, Miners Gulch, Flat Gulch, Sluice Gulch, and Scotchman Gulch (**Table F1-1**). The Antelope Creek watershed, Upper Willow Creek watershed, and West Fork Rock Creek watershed were also included in this assessment to provide supporting information, though these streams do not appear on the 2012 303(d) List as impaired for sediment.

Table F1-1. Waterbody Segments Addressed during the USLE Assessment

TPA	Segment ID	Waterbody Description
Rock	MT76E002_090	EUREKA GULCH, confluence of Quartz Gulch and Basin Gulch to mouth (Rock Creek)
Rock	MT76E002_050	BREWSTER CREEK, East Fork to mouth (Rock Creek)
Rock	MT76E002_060	SOUTH FORK ANTELOPE CREEK, headwaters to mouth (Antelope Creek), T6N R15W S22
Rock	MT76E002_070	QUARTZ GULCH, headwaters to mouth (Eureka Gulch)
Rock	MT76E002_020	EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)
Rock	MT76E002_160	MINERS GULCH, headwaters to mouth (Upper Willow Creek), T8N R15W S23
Rock	MT76E002_120	FLAT GULCH, headwaters to mouth (Rock Creek)
Rock	MT76E002_110	SLUICE GULCH, headwaters to mouth (Rock Creek)
Rock	MT76E002_100	SCOTCHMAN GULCH, headwaters to mouth (Upper Willow Creek)
Rock	MT76E002_061	ANTELOPE CREEK, headwaters to mouth (Rock Creek)
Rock	MT76E002_040	UPPER WILLOW CREEK, headwaters to the mouth (Rock Creek)
Rock	MT76E002_030	WEST FORK ROCK CREEK, headwaters to mouth (Rock Creek)

F2.0 METHODS

Upland sediment loading from hillslope erosion was modeled using a Universal Soil Loss Equation (USLE) based model, which was combined with a sediment delivery ratio (SDR) and riparian health assessment to predict the amount of sediment delivered to streams in the Rock TPA. Methods used in this assessment are described in *Quality Assurance Project Plan: Assessment of Upland Sediment Sources for TMDL Development (Task Order 18: Task 2c)* (U.S. Environmental Protection Agency, 2011) and summarized in the following sections.

F2.1 Subwatershed Delineation

Prior to USLE model development, subwatersheds were delineated in which the Rock TPA upland sediment assessment would be conducted. Subwatersheds were delineated on the basis of the U.S. Geological Survey (USGS) 6th Hydrologic Unit Code (HUC12) layer and modified where necessary to delineate the subwatersheds of interest (**Table F2-1** and **Figure F2-1**). The following subwatersheds were smaller than the USGS HUC12 subwatersheds and were created using watershed delineation tools in ArcGIS and a 30-meter DEM: Basin Gulch, Eureka Gulch, Flat Gulch, Quartz Gulch, Sluice Gulch, South Fork Antelope Creek, Miners Gulch, and Scotchman Gulch. These are identified with a subwatershed ID of “sub6code” in **Table F2-1** and **Figure F2-1**. The delineated portion of the Eureka Gulch subwatershed extends along the listed segment of Eureka Gulch downstream of the confluence with Basin Gulch and Quartz Gulch. In addition, two HUC12 subwatersheds encompass smaller delineated subwatersheds: the Middle Upper Willow Creek HUC12, which contains the Miners Gulch and Scotchman Gulch subwatersheds, and the Antelope Creek HUC12, which contains the South Fork Antelope Creek subwatershed. The remaining portions of the HUC12 outside of which the “sub6code” subwatersheds occur are identified as “remainder”.

Table F2-1. Subwatersheds in the Rock TPA

HUC10 Name	HUC12 Name	Subwatershed ID
East Fork Rock Creek	East Fork Reservoir	East Fork Reservoir
	East Fork Rock Creek	East Fork Rock Creek
	Meadow Creek	Meadow Creek
Lower Rock Creek	Brewster Creek	Brewster Creek
Upper Rock Creek	Rock Creek-Flat Gulch	Basin Gulch_sub6code
		Eureka Gulch_sub6code(segment)
		Flat Gulch_sub6code
		Quartz Gulch_sub6code
	Rock Creek-Mallard Creek	RockMallard_remainder(Antelope)
		South Fork Antelope Creek_sub6code
	Rock Creek-Sluice Gulch	Sluice Gulch_sub6code
Upper Willow Creek	Lower Upper Willow Creek	Lower Upper Willow Creek
	Middle Upper Willow Creek	Middle Upper Willow Creek_remainder
		Miners Gulch_sub6code
		Scotchman Gulch_sub6code
	Upper Upper Willow Creek	Upper Upper Willow Creek
	Upper Willow Creek Headwaters	Upper Willow Creek Headwaters
West Fork Ross Creek*	Lower West Fork Ross Creek*	Lower West Fork Rock Creek
	Middle West Fork Ross Creek*	Middle West Fork Rock Creek
	Upper West Fork Ross Creek*	Upper West Fork Rock Creek
	West Fork Ross Creek Headwaters*	West Fork Rock Creek Headwaters

*USGS HUC10 and HUC12 mis-identify the West Fork Rock Creek watershed as the West Fork Ross Creek

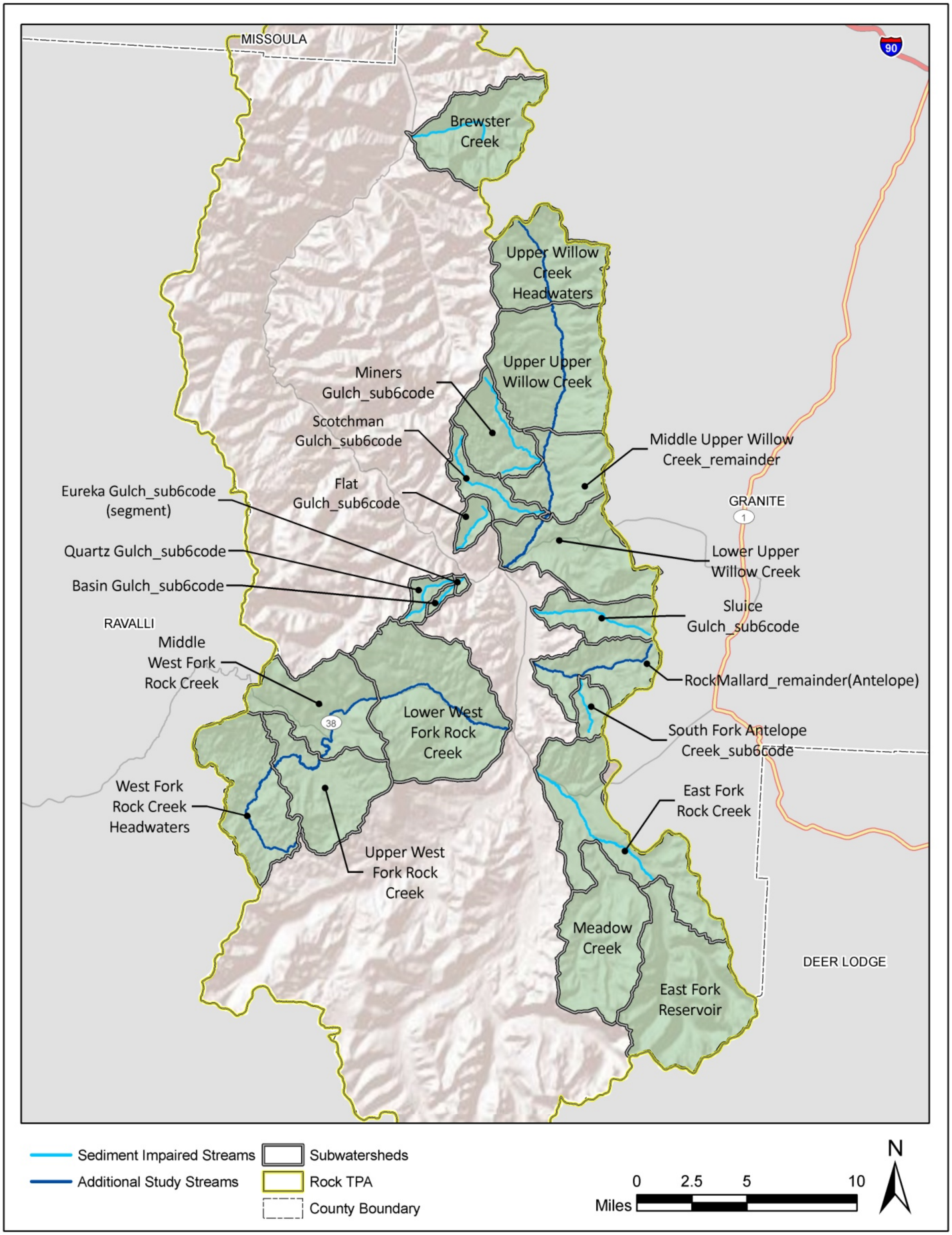

Figure F2-1. Subwatersheds in the Rock TPA

F2.2 ULSE MODEL INPUT PARAMETERS

The USLE model requires five landscape factors that are combined to predict upland soil loss, including a rainfall factor (R), soil erodibility factor (K), length and slope factors (LS), cropping factor (C), and management practices factor (P). The general form of the USLE equation has been widely used for upland sediment erosion modeling and is presented as (Brooks et al., 1997):

A = RK(LS)CP (in tons per acre per year)

For this assessment, the USLE based model was parameterized using a number of published data sources, including information from: (1) U.S. Geological Survey (USGS), (2) Spatial Climate Analysis Service (SCAS), and (3) Natural Resource Conservation Service (NRCS). Additionally, local information regarding specific land cover was acquired from the U.S. Forest Service (USFS) and the NRCS. Specific GIS data layers used in the modeling effort are presented in the following sections.

F2.2.1 R-Factor

The **R-factor** characterizes the effect of raindrop impact and runoff rates associated with a rainstorm, which is reported in 100s of ft-tons rainfall/ac-yr. The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service of Oregon State University at a 4 km grid cell resolution based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. The R-factor is determined using the kinetic energy of a rainfall event and the maximum 30-minute rainfall intensity for an area. For the purposes of this analysis, the SCAS R-factor grid was projected to Montana State Plane Coordinates and interpolated to a 10m grid cell (**Figure F2-2**).

F2.2.2 K-Factor

The **K-factor** is a soil erodibility factor that quantifies the susceptibility of soil to erosion. It is a measure of the average soil loss from a particular soil in continuous fallow derived from experimental data (tons soil/100 ft tons rainfall). Polygon data of K-factor values in the Rock TPA was obtained from the NRCS General Soil Map (STATSGO) database and the NRCS Soil Survey Geographic (SSURGO) database. The SSURGO database was used where available, which included all of the subwatersheds in the Rock TPA except Brewster Creek. While the SSURGO database has higher resolution and is more current than the STATSGO database, the SSURGO database for the Rock TPA did not contain the required K-factor for the entire study area. When the SSURGO database lacked K-factor values, the K-factor was derived from the STATSGO database in which the USLE K-factor is a standard component. Soils polygon data was summarized and interpolated to a 10m grid cell (**Figure F2-2**).

F2.2.3 LS-Factor

The **LS-factor** is a function of the slope and flow length of the eroding slope or cell (units are dimensionless). The LS-factor was derived from 10m USGS digital elevation model (DEM) grid data and interpolated to a 10m grid cell. For the purpose of computing the LS-factor, slope is defined as the average land surface gradient per cell, while the flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. The equation used for calculating the slope length and slope factor is given in the updated definition of RUSLE, as published in USDA handbook #703 (Renard et al., 1997).

L, the slope length factor in the RUSLE equation, serves to reference the erosion estimate for a horizontally projected slope length to the experimentally measured erosion for a 72.6 foot (22.1 meters) plot.

$L = (\lambda/72.6)^m$

where:

λ = the horizontal projection of slope length

72.6 = the RUSLE unit plot length in feet

m = the variable slope length component, related to the ratio (β) of rill erosion (caused by flow) to interrill erosion (caused by raindrop impact) defined in the following equation:

$= \beta/(1 + \beta)$

And $\beta = (\sin \Theta/0.0896) / [3.0(\sin \Theta)^{0.8} + 0.56]$

Soil loss increases more rapidly with slope steepness than it does with slope length. This is quantified by S, the slope steepness factor of the RUSLE.

$S = 10.8 \sin \theta + 0.03$ for $\theta < 9\%$

$= 16.8 \sin \theta - 0.50$ for $\theta \geq 9\%$

where:

θ = the slope angle

Combined, these factors can be written:

$$LS = S_i (\lambda_i^{m+1} - \lambda_{i-1}^{m+1}) / (\lambda_I - \lambda_{i-1}) (72.6)^m$$

where:

λ_i = length in feet from top of slope to lower end of the segment. This value was determined by applying GIS based surface analysis procedures to the each DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters.

S_i = slope steepness factor for the segment

$= 10.8 \sin \theta + 0.03$ for $\theta < 9\%$

$= 16.8 \sin \theta - 0.50$ for $\theta \geq 9\%$

The LS-Factor was calculated using a C++ program which automatically processes the DEM input (U.S. Environmental Protection Agency, 2011; Van Remortel et al., 2004). The program evaluates each individual grid cell based on the LS factors mentioned above. The C++ program begins with a fill function of any depressions or sinks found on the DEM input. The highest elevation points on the DEM are then identified by the program and the flow direction is determined. In situations of converging flow, the flow direction of steepest decent takes precedence. The distance between the centers of one grid cell to the next grid cell is then calculated by the C++ program as the non-cumulative slope length (NCSL). A cumulative slope length is then computed by summing the NCSL from each grid cell, beginning at a high point and moving down along the direction of steepest descent. The calculated slope angle of each cell is first examined by the C++ program, and a sub-routine calls for a table lookup function. The range in which the slope angle falls within the table is indentified and a corresponding slope length exponent (m) is assigned. The program has a function called the cutoff slope angle and is defined as the ratio of change in slope angle from one grid cell to the next along the flow direction. When the slope angle decreases sufficiently, the cumulative slope length calculation stops and then resumes when the land surface extends further downhill in order to recognize areas of deposition versus erosion. The final grid produced combines all the factors into the final LS factor in the formula given above (**Figure F2-2**).

F2.2.3.1 Digital Elevation Model

The digital elevation model (DEM) is the base layer used for developing the LS factor for the USLE analysis. The USGS 10m (1/3 Arc-second) DEM was used for this analysis. The 10m DEM was projected into Montana State Plan Coordinates and interpolated to a 10m grid cell to render the delineated stream network more representative of the actual size of Rock TPA streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m DEM was subjected to standard hydrologic preprocessing, including filling of sinks to create a positive drainage condition for all areas of the watershed (**Figure F2-2**).

F2.2.3.2 Stream Network Delineation

The stream network for each subwatershed in the Rock TPA was derived from the 10m DEM using TauDEM (Terrain Analysis Using Digital Elevation Models) software developed by the Utah State University Hydrology Research Group (http://hydrology.usu.edu/taudem/taudem5.0/index.html). The stream network was generated using TauDEM with the threshold adjusted to most closely mirror the 1:24,000 NHD stream layer.

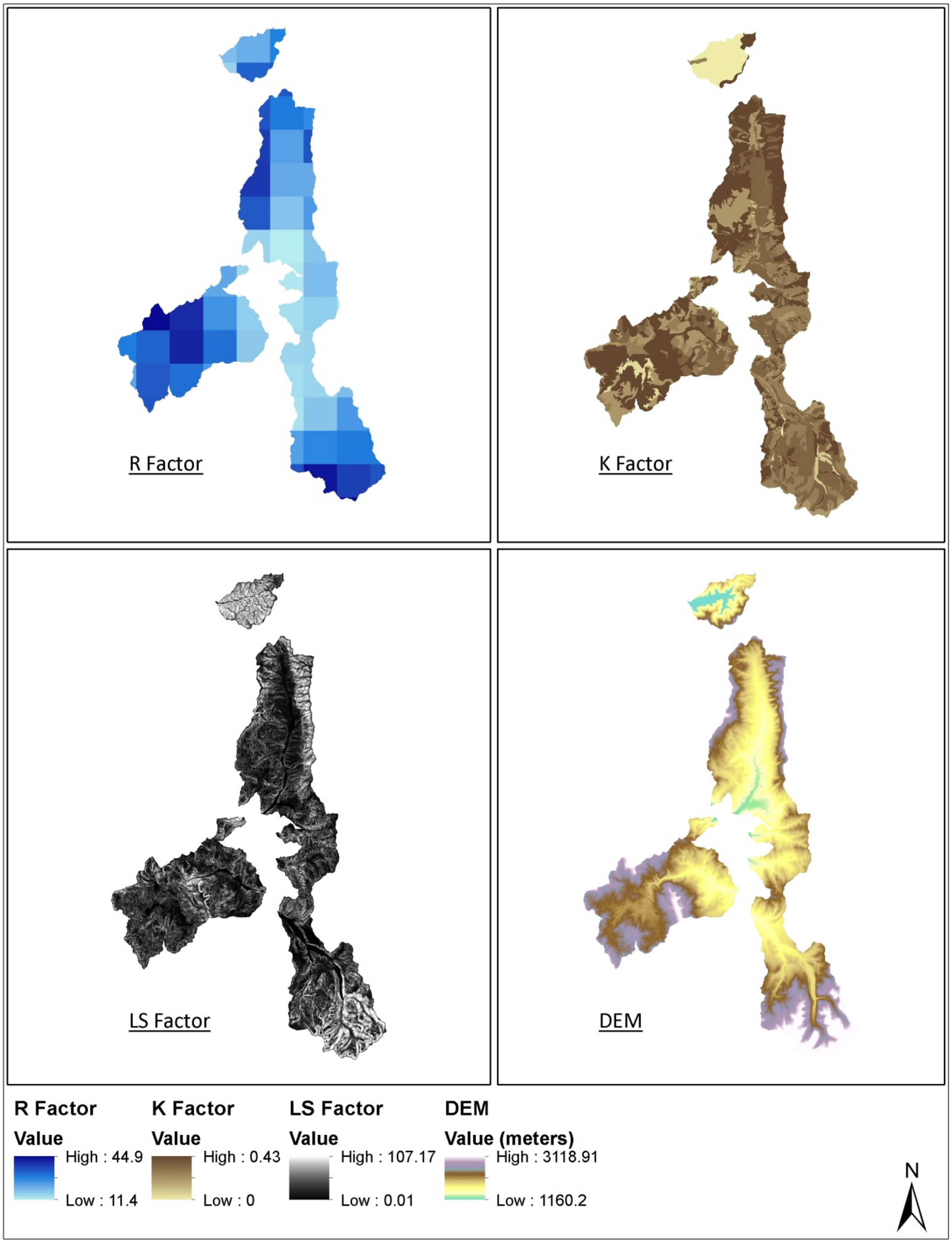

Figure F2-2. R-Factor, K-Factor, LS-Factor, and DEM for the Rock TPA

F2.2.4 C-Factor

The **C-factor** is a crop management value that represents the ratio of soil erosion from a specific cover type compared to the erosion that would occur on a clean-tilled fallow under identical slope and rainfall. The C-factor integrates a number of variables that influence erosion including vegetative cover, plant litter, soil surface, and land management. Original ULSE C-factors were experimentally determined for agricultural crops and have since been modified to include rangeland and forested land cover types. For this assessment, the C-factor was estimated for various land cover types using the National Land Cover Database and C-factor interpretations applied during previous USLE modeling projects conducted for sediment TMDL development. C-factors are intended to be conservatively representative of conditions within the Rock TPA.

F2.2.4.1 National Land Cover Database

The 2006 National Land Cover Database (NLCD) was obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium and used for establishing USLE C-factors in the Rock TPA. The 2006 NLCD is a categorized 30 meter Landsat Thematic Mapper image shot in 2006. The NLCD image was projected to Montana State Plane Coordinates and interpolated to a 10m grid cell (**Figure F2-3**). For this analysis, areas described as ‘cultivated crops’ in the NLCD database were redefined as ‘hay/pasture’ to better represent agricultural practices in the Rock TPA based on input from the local Natural Resources Conservation Service representative. NLCD land cover types for the Rock TPA are described in **Attachment F1**.

F2.2.4.2 C-Factor Derivation

USLE C-factors for existing conditions were assigned to the NLCD land cover types in the Rock TPA based on ground cover percentages in *Table 10 – Factor C for permanent pasture, range, and idle land* as presented in Predicting Rainfall Erosion Losses: A Guide to Conservation Planning (Wischmeier and Smith, 1978) and summarized in **Table F2-2** and **Attachment F2**. In order to estimate the potential sediment reduction that might be achieved under a Best Management Practices (BMP) scenario, the USLE-based model was also run using C-factors representing desired conditions. Land cover types identified as ‘shrub/scrub’, ‘grasslands/ herbaceous’, and ‘hay/pasture’ were conservatively adjusted to reflect a 10% improvement in ground cover over existing conditions as depicted in **Table F2-3**.

Table F2-2. C-factors for Existing and Desired Conditions

NLCD Code	Description	C-Factor Existing Conditions	C-Factor Desired Conditions
0*	Transitional*	0.006	0.006
11	Open Water	-	-
21	Developed, Open Space	0.003	0.003
22	Developed, Low Intensity	0.001	0.001
31	Barren Land	0.001	0.001
42	Evergreen Forest	0.003	0.003
52	Shrub/Scrub	0.046	0.031
71	Grassland/Herbaceous	0.042	0.035
81	Hay/Pasture	0.020	0.013
90	Woody Wetlands	0.003	0.003

* A code of "0" and a description of "Transitional" was developed to describe areas of Fire or Timber Harvest

Table F2-3. Percent Ground Cover for Existing and Desired Land Cover Types

Land Cover	Existing % ground cover	Desired % ground cover
Shrub/Scrub	55	65
Grassland/Herbaceous	55	65
Hay/Pasture	75	85

It is acknowledged that land cover is variable within and across watersheds and changes seasonally. The C-factors used for the USLE-based model are intended to represent typical annual conditions at a coarse scale and the percent of improvement achievable via the implementation of BMPs.

F2.2.4.3 Fire and Timber Harvest Adjustments

The 2006 NLCD layer was adjusted to quantify the amount of fire and timber harvest that have occurred since 2006 and also to identify previously disturbed areas that have become reforested over that same period. Areas with fire or timber harvest since 2006 were coded ‘0’, defined as ‘transitional’, and assigned a C-factor of 0.006 (**Table F2-2** and **Figure F2-3**). Adjustments on U.S. Forest Service lands were performed based on fire and timber harvest record polygons provided by the U.S. Forest Service, while a digitized polygon layer of adjustments for fire and timber harvest on non-USFS property was created by comparing the 2006 NLCD layer with the 2011 NAIP aerial imagery. Adjustments for reforestation were also examined by comparing the 2006 NLCD layer with the 2011 NAIP aerial imagery, though no areas of reforestation were observed.

In the Rock TPA, recent timber harvest was observed on both private and public lands in the Upper Willow Creek watershed and the West Fork Rock Creek watershed, with the only large fires since 2006 occurring in the Upper Willow Creek watershed (**Figure F2-4**). Timber harvest mapped from the 2011 NAIP imagery in the Upper Willow Creek watershed has occurred primarily on U.S. Bureau of Land Management and Montana Department of Natural Resources and Conservation lands, while in the West Fork Rock Creek watershed recent timber harvest has occurred on private lands. Recent timber harvest is limited on USFS land and generally occurs adjacent to the other timber harvests.

F2.2.5 P-Factor

The **P-factor,** or conservation practice factor, is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing and contouring, and is applicable only to agricultural lands. Values of the P-factor compare straight-row farming practices with that of certain agriculturally based conservation practices. The P-factor was set to one for this analysis based on existing practices within the Rock TPA.

F2.3 Distance and Riparian Health Assessment based Sediment Delivery Ratio

Results from the USLE hillslope erosion assessment were combined with a sediment delivery ratio (SDR) and riparian health assessment to predict the amount of sediment delivered to streams in the Rock TPA. Soil lost from one area on a hillslope due to erosive processes is typically re-deposited a short distance downslope and therefore not all of the sediment produced from a hillslope erosion event is delivered to a stream channel. As TMDLs deal specifically with sediment delivered to the stream, a method for accounting for sediment re-deposition and ultimate delivery to streams was developed. In the Rock TPA, sediment re-deposition is accounted for through the application of a sediment delivery ratio (SDR) which estimates the percentage of hillslope sediment produced that is ultimately delivered to the stream. This distance based sediment delivery ratio reflects the relationship between downslope travel distance and ultimate sediment delivery. In addition to sediment re-deposition during hillslope transport processes, riparian zones also reduce sediment inputs to stream channels. The width and quality of the riparian vegetation buffer zone determines its effectiveness as a sediment filter. Thus, a riparian health assessment was included along with the distance based sediment delivery analysis.

F2.3.1 Riparian Health Assessment

A riparian health assessment was conducted during the aerial assessment reach stratification process in which reaches were delineated based on a combination of physical attributes (ecoregion, valley slope, valley confinement, and stream order) and the presence and degree of adjacent human activity. For each reach, a riparian health assessment was performed using aerial photos, field notes, and best professional judgment. Riparian health for each reach was designated as ‘poor’, ‘poor/fair’, ‘fair’, ‘fair/good’, or ‘good’ based on adjacent land use practices, streamside vegetation, and the presence or absence of human activities (**Figure F2-5**). The cumulative length of the reaches within each riparian health category was tallied for each stream segment and the percent of stream length in each riparian health category was calculated. This information was then used to refine estimates of sediment delivery to streams from upland sources by incorporating the results of the riparian health assessment into the distance based sediment delivery ratio calculation.

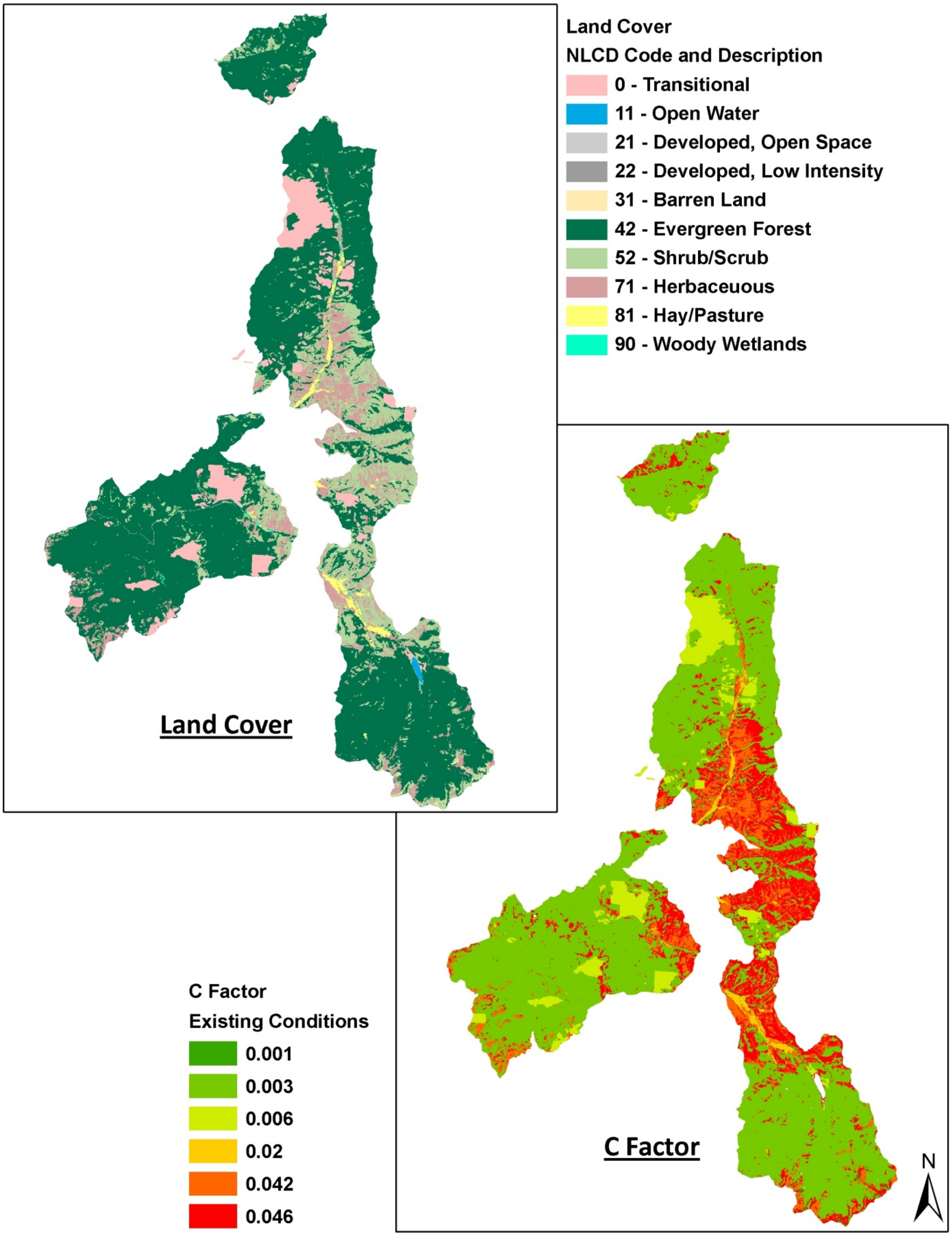

Figure F2-3. Land Cover and C-Factors for the Rock TPA

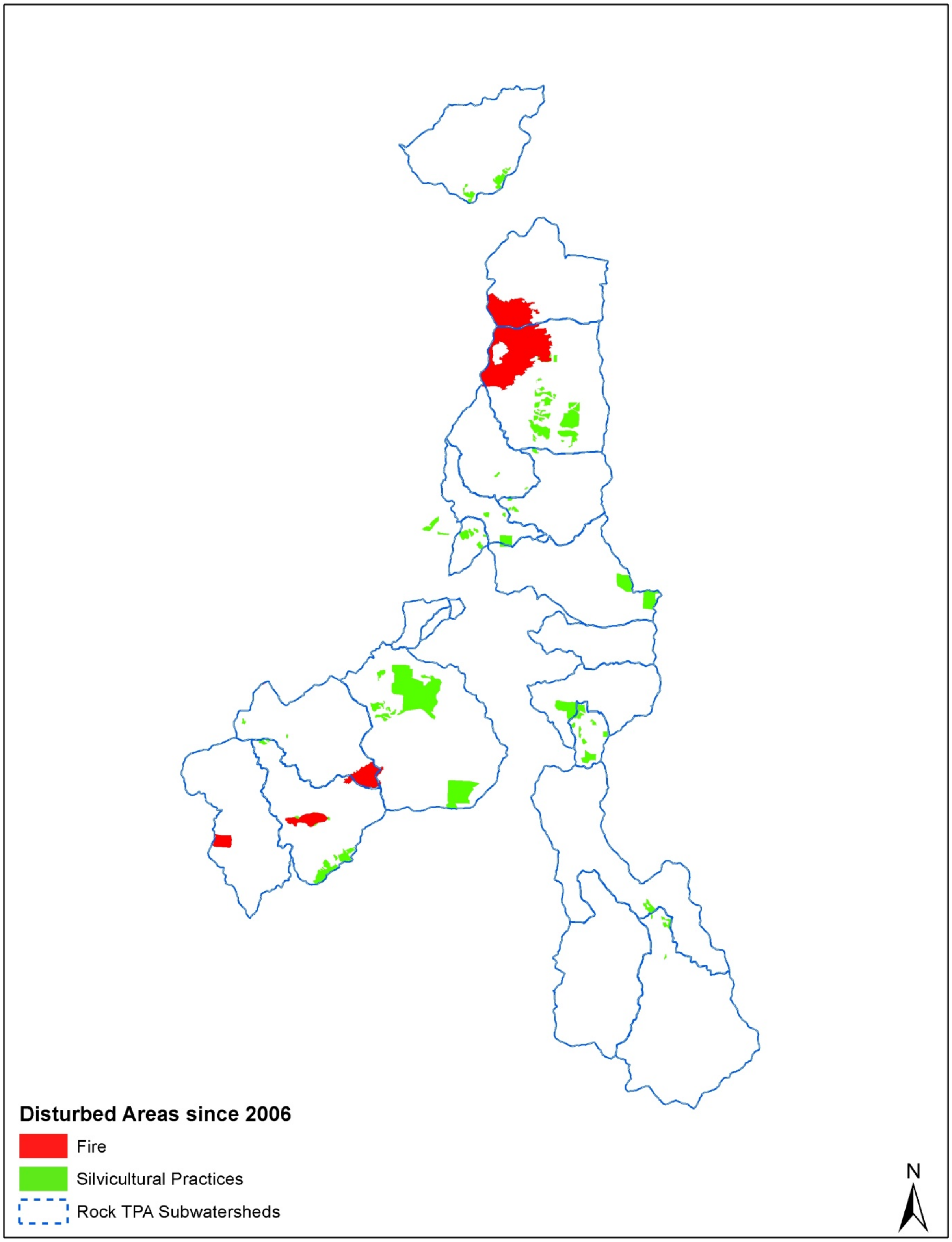

Figure F2-4. Fire and Timber Harvest Areas in the Rock TPA since 2006

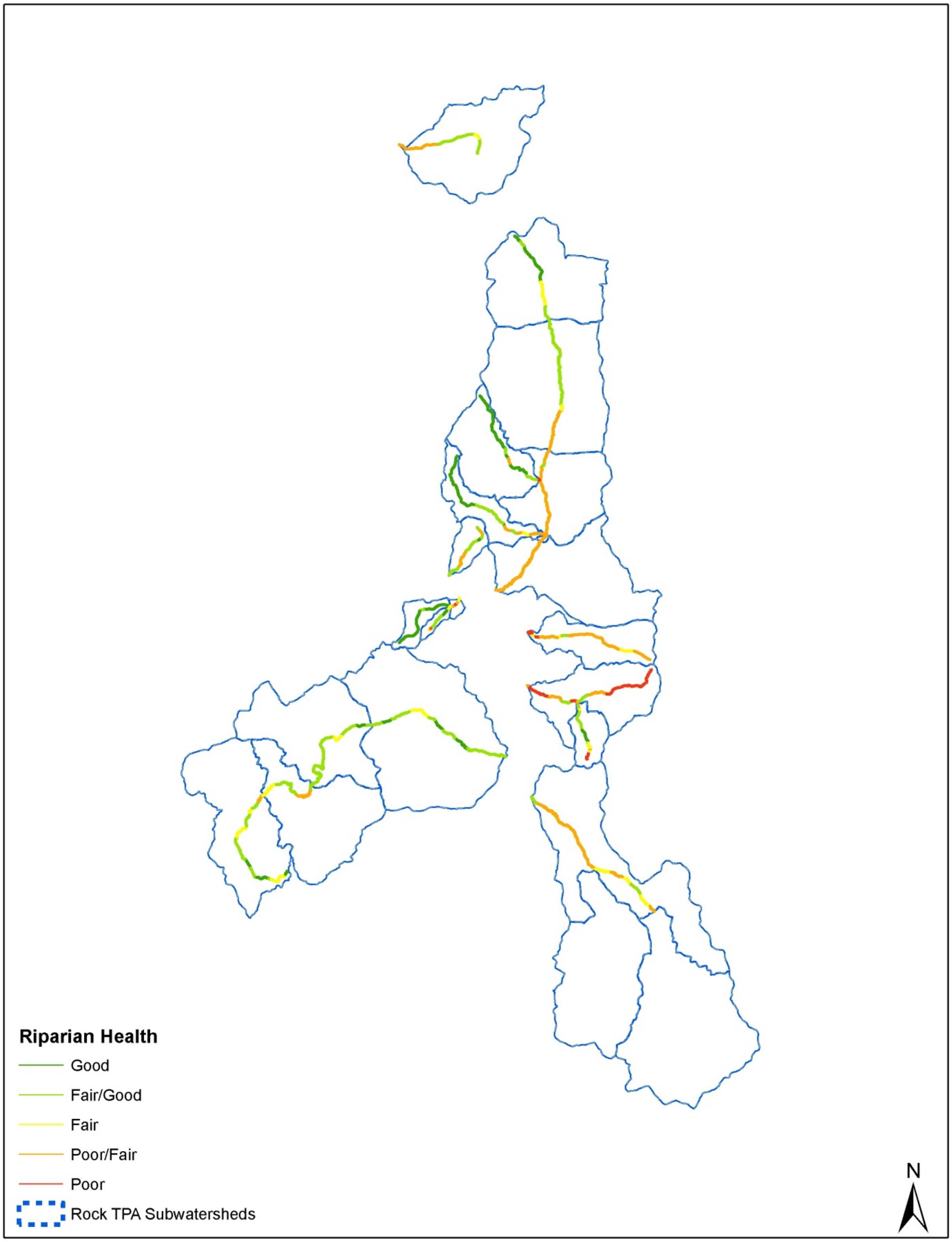

Figure F2-5. Aerial Assessment Reach Stratification Riparian Health Assessment

F2.3.2 Distance based Sediment Delivery Ratio

The distance based sediment delivery ratio was calculated in the model for each grid cell based on the observed relationship between the distance from the delivery point to the stream and the percent of eroded sediment delivered to the stream using an equation developed by Megehan and Ketcheson (1996). Megahan and Ketcheson (1996) found that the relationship between the percentage (by volume) of sediment that travels a given percentage of the maximum distance is as shown in **Figure F2-6**. Megahan and Ketcheson's logarithmic regression of the data permits this relationship to be expressed by the equation presented in **Figure F2-6**, which may be restated as a function of three variables:

Volume % = or 103.62*EXP(-((D/Dtotal)*100)/32.88))-5.55

where:

Volume% = the percentage of sediment mobilized from a source that travels at least distance D from that source

D = distance from the sediment source, and

Dtotal = the maximum distance that sediment travels from the source.

As the Megehan and Ketcheson equation is dimensionless, to serve as an SDR it was scaled to the field conditions of the Rock TPA by evaluating the equation with site -specific values for D and Volume% at a single point and then solving for Dtotal. Having established a site specific Dtotal, the Megahan and Kecheson equation reduces to the two variables that define a distance based SDR: distance and percent sediment delivered beyond that distance. This SDR was then used to estimate sediment delivery at all points on the sediment delivery path extending from the streambank to a distance Dtotal.

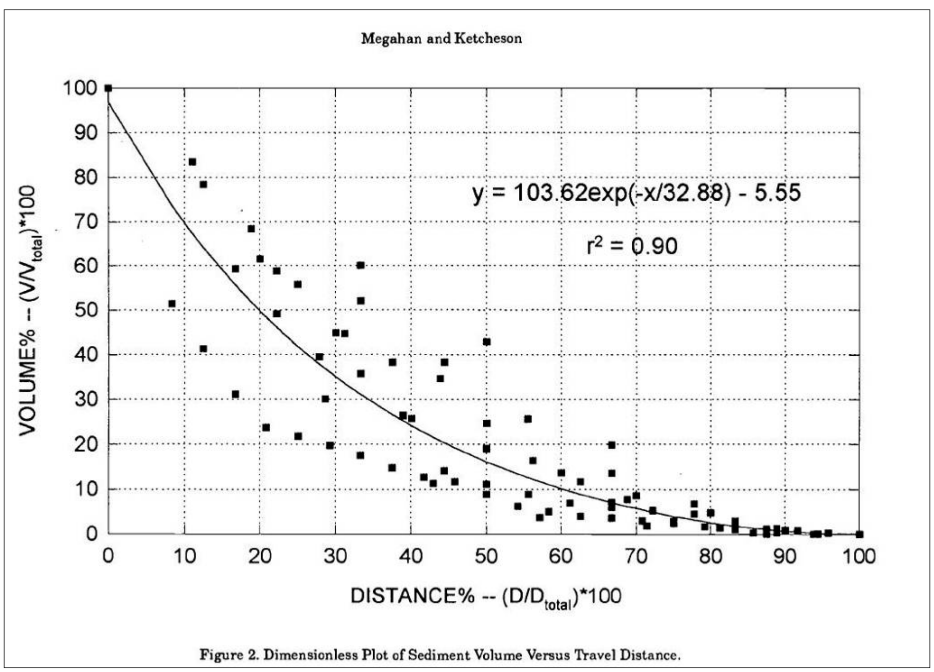

Figure F2-6 Sediment Volume vs. Travel Distance (Megahan and Ketcheson, 1996)

F2.3.3 Subwatershed Specific Sediment Delivery Ratio Scale Factors

Riparian zone sediment filtering capacity is typically expressed as a given percent reduction in delivery of sediment entering a riparian zone of a given buffer width. This rating of a known percent delivery (Volume%) from a known distance from the stream (D) permits scaling of the Megahan and Ketcheson's dimensionless equation (**Section F2.3.2**) for use in predicting percent delivery from other distances. Literature review (Knutson and Naef, 1997; Wegner, 1999) indicates that a 100 foot wide, well vegetated riparian buffer zone can be expected to filter 75-90% of incoming sediment from reaching its stream channel. Accordingly, this analysis conservatively assumes that a sediment reduction efficiency (SRE) of 75% represents the performance of a 100 foot wide, high quality ('good') vegetated riparian buffer. Conversely, this analysis conservatively assumes that a 100 foot wide riparian zone without vegetation cover ('none') would only filter 10% of incoming sediment from reaching its stream. An approximately equal apportionment of the remaining range in sediment reduction efficiency between the 'poor', 'moderately fair' (i.e. 'poor/fair'), 'fair', and 'moderately good' (i.e. 'fair/good') riparian assessment categories results in the riparian buffer sediment reduction efficiencies depicted in **Figure F2-7**.

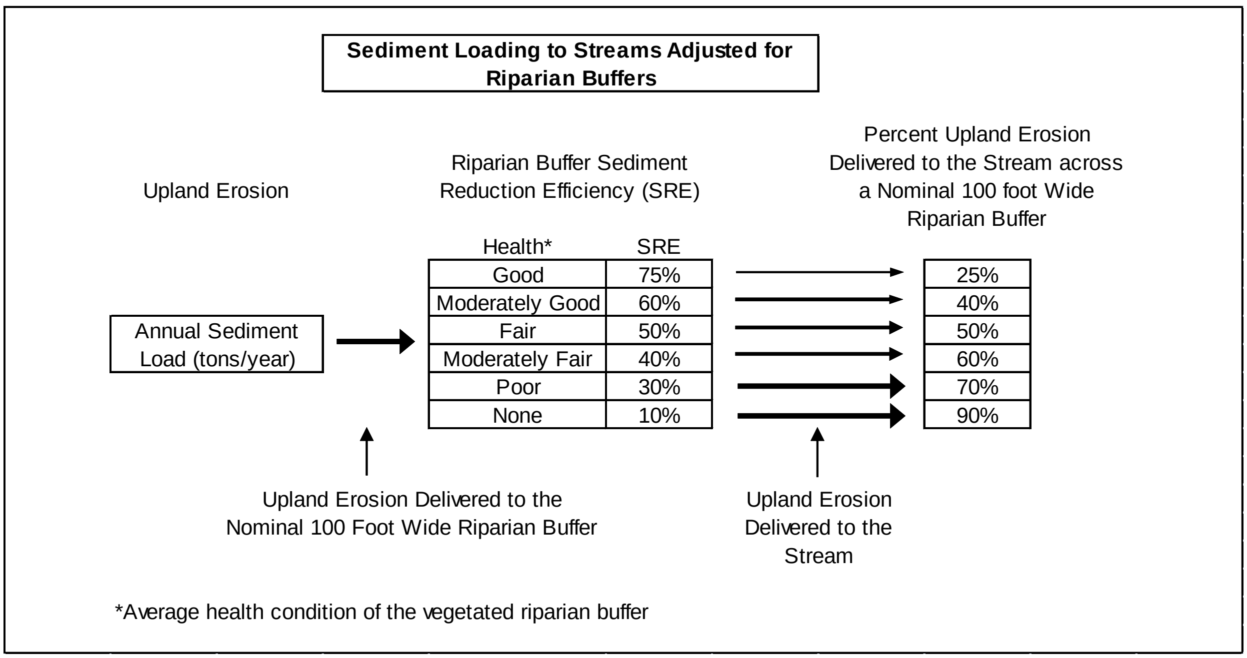

Figure F2-7. USLE Upland Sediment Load Delivery Adjusted for Riparian Buffer Capacity

The Rock TPA riparian health assessment was used to develop a riparian health score based on the sediment reduction percentage for each individual stream segment subwatershed. This value represents the percent reduction in sediment delivery from a nominal 100 foot wide riparian buffer under existing conditions. For the BMP scenario, it was assumed that the implementation of BMPs on those activities that affect the overall health of the vegetated riparian buffer will increase riparian health. The potential to improve riparian health was evaluated for each reach based on best professional judgment through a review of color aerial imagery from 2009 and on-the-ground reconnaissance.

F2.4 Model Scenarios

Management scenarios include: (1) an existing conditions scenario that considers the current land cover, management practices, and riparian health in the watershed; (2) an upland BMP conditions scenario that considers improved grazing and cover management; (3) a riparian health BMP conditions scenario that considers improved riparian buffer zones; and (4) a riparian health BMP and upland BMP conditions scenario that considers improved riparian buffer zones and grazing and cover management. For each scenario, erosion was differentiated into two source categories: (1) natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. For scenarios 2 and 4, land cover types identified as 'shrub/scrub', 'grasslands/ herbaceous', and 'hay/pasture' were conservatively adjusted to reflect a 10% improvement in ground cover over existing conditions as discussed in Section 2.2.4.2 and depicted in **Table F2-3**. For scenarios 3 and 4, the riparian health score was adjusted to reflect improvements in riparian health as discussed in **Section 2.3.3.**

F3.0 Results

Several hillslope erosion modeling scenarios were assessed in the Rock TPA, including an assessment of existing conditions (Scenario 1) and several Best Management Practices (BMP) scenarios examining upland and riparian BMPs (Scenarios 2 through 4) as follows:

Scenario 1 - Existing conditions scenario that considers the current land cover, management practices, and riparian health in the watershed;

Scenario 2 - Upland BMP conditions scenario that considers improved grazing and cover management;

Scenario 3 - Riparian health BMP conditions scenario that considers improved riparian buffer zones;

Scenario 4 - Riparian health BMP and upland BMP conditions scenario that considers improved riparian buffer zones and grazing and cover management.

The results of this assessment are summarized in **Table F3-1**, with the complete modeling results presented for each subwatershed in **Table F3-2**.

Table F3-1. Summary of Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
		Upland Erosion Sediment Load for **Existing Conditions** and **Existing Riparian** Health (tons/year)	Upland Erosion Sediment Load for **BMP Conditions** and **Existing Riparian** Health (tons/year)	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing Conditions** and **BMP Riparian** Health (tons/year)	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP Conditions** and **BMP Riparian** Health (tons/year)	**Percent Change from Existing**
West Fork Rock Creek Headwaters	12,944	197.5	168.7	-15%	176.4	-11%	150.9	-24%
Upper West Fork Rock Creek	11,851	72.2	70.3	-3%	65.0	-10%	63.2	-12%
Middle West Fork Rock Creek	12,084	250.5	208.4	-17%	224.1	-11%	187.3	-25%
Lower West Fork Rock Creek	22,486	392.5	316.1	-19%	355.3	-9%	287.4	-27%
West Fork Rock Creek Total	**59,366**	**912.8**	**763.4**	**-16%**	**820.8**	**-10%**	**688.9**	**-25%**
East Fork Reservoir	19,443	555.0	475.2	-14%	242.3	-56%	213.3	-62%
Meadow	14,843	317.9	267.6	-16%	135.4	-57%	116.6	-63%
East Fork Rock Creek	16,367	862.9	621.1	-28%	399.1	-54%	286.8	-67%
East Fork Rock Creek Total	**50,653**	**1735.8**	**1363.9**	**-21%**	**776.8**	**-55%**	**616.7**	**-64%**
Upper Willow Creek Headwaters	11,553	271.2	236.9	-13%	178.6	-34%	156.1	-42%
Upper Upper Willow Creek	17,608	295.6	261.3	-12%	204.5	-31%	179.6	-39%
Middle Upper Willow Creek	8,413	401.3	301.6	-25%	279.1	-30%	209.4	-48%
Lower Upper Willow Creek	12,344	788.0	569.6	-28%	535.3	-32%	386.8	-51%
Miners Gulch	6,998	64.9	55.1	-15%	62.4	-4%	53.0	-18%
Scotchman Gulch	3,963	42.3	33.7	-20%	34.3	-19%	27.5	-35%
Upper Willow Creek Total	**60,879**	**1863.3**	**1458.3**	**-22%**	**1294.3**	**-31%**	**1012.6**	**-46%**
Antelope Creek (Rock Mallard)	7,831	817.3	580.3	-29%	446.4	-45%	317.8	-61%
South Fork Antelope Creek	2,241	50.8	39.9	-22%	40.2	-21%	31.6	-38%
Antelope Creek Total	**10,072**	**868.1**	**620.1**	**-29%**	**486.6**	**-44%**	**349.5**	**-60%**
Quartz Gulch	1,632	25.6	20.2	-21%	24.7	-4%	19.5	-24%
Basin Gulch	492	11.0	8.7	-21%	9.2	-16%	7.4	-33%
Eureka Gulch	208	13.1	9.4	-28%	6.2	-53%	4.4	-66%
Eureka Gulch Total	**2,332**	**49.7**	**38.3**	**-23%**	**40.1**	**-19%**	**31.3**	**-37%**

Table F3-1. Summary of Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
		Upland Erosion Sediment Load for **Existing Conditions** and **Existing Riparian** Health (tons/year)	Upland Erosion Sediment Load for **BMP Conditions** and **Existing Riparian** Health (tons/year)	**Percent Change from Existing**	Upland Erosion Sediment Load for **Existing Conditions** and **BMP Riparian** Health (tons/year)	**Percent Change from Existing**	Upland Erosion Sediment Load for **BMP Conditions** and **BMP Riparian** Health (tons/year)	**Percent Change from Existing**
Brewster Creek	11,682	40.1	33.7	-16%	26.0	-35%	22.3	-44%
Flat Gulch	1,728	34.3	24.2	-29%	28.1	-18%	21.4	-37%
Sluice Gulch	5,453	529.8	379.2	-28%	294.6	-44%	211.4	-60%

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	**Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)**	**Percent Change from Existing**	**Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)**	**Percent Change from Existing**	**Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)**	**Percent Change from Existing**
West Fork Rock Creek Headwaters	Transitional	257	3.9	3.9	0%	3.5	-10%	3.5	-10%
	Evergreen Forest	10,423	73.5	73.5	0%	66.1	-10%	66.1	-10%
	Shrub/Scrub	528	52.9	35.4	-33%	47.9	-9%	32.3	-39%
	Herbaceous	1,736	67.3	55.8	-17%	58.8	-13%	49.0	-27%
	Woody Wetlands	1	0.0	0.0	0%	0.0	-4%	0.0	-4%
	Total	**12,944**	**197.5**	**168.7**	**-15%**	**176.4**	**-11%**	**150.9**	**-24%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
Upper West Fork Rock Creek	Transitional	1,042	4.8	4.8	0%	4.2	-12%	4.2	-12%
	Barren Land	0	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	10,239	58.4	58.4	0%	52.8	-10%	52.8	-10%
	Shrub/Scrub	242	2.6	1.7	-33%	2.3	-11%	1.6	-40%
	Herbaceous	281	6.4	5.3	-17%	5.7	-12%	4.7	-26%
	Hay/Pasture	3	0.0	0.0	-35%	0.0	-19%	0.0	-47%
	Woody Wetlands	44	0.0	0.0	0%	0.0	-7%	0.0	-7%
	Total	**11,851**	**72.2**	**70.3**	**-3%**	**65.0**	**-10%**	**63.2**	**-12%**
Middle West Fork Rock Creek	Transitional	658	6.1	6.1	0%	5.5	-10%	5.5	-10%
	Open Water	10	0.0	0.0	0%	0.0	0%	0.0	0%
	Developed, Open Space	101	3.5	3.5	0%	3.2	-9%	3.2	-9%
	Barren Land	0	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	10,446	112.6	112.6	0%	102.2	-9%	102.2	-9%
	Shrub/Scrub	765	127.1	85.2	-33%	112.2	-12%	75.6	-41%
	Herbaceous	98	1.2	1.0	-17%	1.0	-16%	0.8	-30%
	Woody Wetlands	4	0.0	0.0	0%	0.0	-17%	0.0	-17%
	Total	**12,084**	**250.5**	**208.4**	**-17%**	**224.1**	**-11%**	**187.3**	**-25%**
Lower West Fork Rock Creek	Transitional	3,025	42.9	42.9	0%	38.8	-10%	38.8	-10%
	Open Water	5	0.0	0.0	0%	0.0	0%	0.0	0%
	Developed, Open Space	64	0.1	0.1	0%	0.1	-15%	0.1	-15%
	Barren Land	12	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	14,333	87.1	87.1	0%	79.7	-8%	79.7	-8%
	Shrub/Scrub	3,166	198.3	132.9	-33%	178.1	-10%	120.0	-39%
	Herbaceous	1,681	63.5	52.7	-17%	58.0	-9%	48.4	-24%
	Hay/Pasture	91	0.5	0.3	-35%	0.5	-7%	0.3	-40%
	Woody Wetlands	110	0.2	0.2	0%	0.2	-6%	0.2	-6%
	Total	**22,486**	**392.5**	**316.1**	**-19%**	**355.3**	**-9%**	**287.4**	**-27%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
West Fork Rock Creek Total	Transitional	4,983	57.6	57.6	0%	51.9	-10%	51.9	-10%
	Open Water	15	0.0	0.0	0%	0.0	0%	0.0	0%
	Developed, Open Space	166	3.7	3.7	0%	3.3	-9%	3.3	-9%
	Barren Land	12	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	45,440	331.7	331.7	0%	300.9	-9%	300.9	-9%
	Shrub/Scrub	4,701	380.8	255.2	-33%	340.5	-11%	229.4	-40%
	Herbaceous	3,797	138.3	114.8	-17%	123.5	-11%	102.9	-26%
	Hay/Pasture	94	0.5	0.3	-35%	0.5	-7%	0.3	-40%
	Woody Wetlands	158	0.2	0.2	0%	0.2	-6%	0.2	-6%
	Total	**59,366**	**912.8**	**763.4**	**-16%**	**820.8**	**-10%**	**688.9**	**-25%**
East Fork Reservoir	Transitional	101	0.2	0.2	0%	0.1	-55%	0.1	-55%
	Open Water	301	0.0	0.0	0%	0.0	0%	0.0	0%
	Barren Land	303	0.8	0.8	0%	0.2	-77%	0.2	-77%
	Evergreen Forest	15,447	259.3	259.3	0%	132.5	-49%	132.5	-49%
	Shrub/Scrub	1,992	192.4	129.7	-33%	66.8	-65%	45.0	-77%
	Herbaceous	1,300	102.4	85.3	-17%	42.7	-58%	35.6	-65%
	Total	**19,443**	**555.0**	**475.2**	**-14%**	**242.3**	**-56%**	**213.3**	**-62%**
Meadow	Open Water	5	0.0	0.0	0%	0.0	0%	0.0	0%
	Barren Land	2	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	13,269	147.2	147.2	0%	68.9	-53%	68.9	-53%
	Shrub/Scrub	1,008	136.1	91.7	-33%	48.2	-65%	32.5	-76%
	Herbaceous	447	33.6	28.0	-17%	17.7	-47%	14.8	-56%
	Hay/Pasture	101	1.0	0.7	-35%	0.6	-46%	0.4	-65%
	Woody Wetlands	11	0.0	0.0	0%	0.0	-39%	0.0	-39%
	Total	**14,843**	**317.9**	**267.6**	**-16%**	**135.4**	**-57%**	**116.6**	**-63%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
East Fork Rock Creek	Transitional	103	2.0	2.0	0%	0.6	-69%	0.6	-69%
	Developed, Open Space	109	0.9	0.9	0%	0.4	-52%	0.4	-52%
	Developed, Low Intensity	28	0.2	0.2	0%	0.1	-38%	0.1	-38%
	Barren Land	3	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	6,224	79.4	79.4	0%	36.0	-55%	36.0	-55%
	Shrub/Scrub	6,066	692.9	466.8	-33%	321.7	-54%	216.7	-69%
	Herbaceous	2,713	80.9	67.4	-17%	36.5	-55%	30.4	-62%
	Hay/Pasture	1,062	6.5	4.2	-35%	3.7	-43%	2.4	-63%
	Woody Wetlands	59	0.1	0.1	0%	0.1	-32%	0.1	-32%
	Total	**16,367**	**862.9**	**621.1**	**-28%**	**399.1**	**-54%**	**286.8**	**-67%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
East Fork Rock Creek Total	Transitional	204	2.1	2.1	0%	0.7	-68%	0.7	-68%
	Open Water	306	0.0	0.0	0%	0.0	0%	0.0	0%
	Developed, Open Space	109	0.9	0.9	0%	0.4	-52%	0.4	-52%
	Developed, Low Intensity	28	0.2	0.2	0%	0.1	-38%	0.1	-38%
	Barren Land	308	0.8	0.8	0%	0.2	-77%	0.2	-77%
	Evergreen Forest	34,940	485.9	485.9	0%	237.4	-51%	237.4	-51%
	Shrub/Scrub	9,066	1021.4	688.2	-33%	436.7	-57%	294.3	-71%
	Herbaceous	4,459	216.9	180.7	-17%	96.9	-55%	80.7	-63%
	Hay/Pasture	1,162	7.5	4.8	-35%	4.2	-43%	2.7	-64%
	Woody Wetlands	71	0.1	0.1	0%	0.1	-32%	0.1	-32%
	Total	**50,653**	**1735.8**	**1363.9**	**-21%**	**776.8**	**-55%**	**616.7**	**-64%**
Upper Willow Creek Headwaters	Transitional	1,450	16.9	16.9	0%	11.4	-33%	11.4	-33%
	Evergreen Forest	9,636	147.6	147.6	0%	97.0	-34%	97.0	-34%
	Shrub/Scrub	354	103.4	69.7	-33%	67.8	-34%	45.7	-56%
	Herbaceous	88	3.1	2.6	-17%	2.3	-27%	1.9	-39%
	Hay/Pasture	10	0.1	0.1	-35%	0.1	-35%	0.1	-58%
	Woody Wetlands	14	0.1	0.1	0%	0.0	-21%	0.0	-21%
	Total	**11,553**	**271.2**	**236.9**	**-13%**	**178.6**	**-34%**	**156.1**	**-42%**
Upper Upper Willow Creek	Transitional	4,632	58.3	58.3	0%	38.7	-34%	38.7	-34%
	Evergreen Forest	11,262	125.3	125.3	0%	84.6	-32%	84.6	-32%
	Shrub/Scrub	789	95.1	64.1	-33%	69.1	-27%	46.6	-51%
	Herbaceous	512	14.2	11.8	-17%	10.0	-29%	8.4	-41%
	Hay/Pasture	284	2.5	1.6	-35%	1.8	-28%	1.2	-53%
	Woody Wetlands	129	0.3	0.3	0%	0.3	-22%	0.3	-22%
	Total	**17,608**	**295.6**	**261.3**	**-12%**	**204.5**	**-31%**	**179.6**	**-39%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
Middle Upper Willow Creek	Transitional	86	0.1	0.1	0%	0.0	-46%	0.0	-46%
	Evergreen Forest	3,053	39.0	39.0	0%	26.2	-33%	26.2	-33%
	Shrub/Scrub	2,959	243.4	164.0	-33%	170.3	-30%	114.7	-53%
	Herbaceous	2,037	116.1	96.8	-17%	80.6	-31%	67.2	-42%
	Hay/Pasture	277	2.7	1.7	-35%	1.9	-28%	1.3	-54%
	Woody Wetlands	1	0.0	0.0	0%	0.0	-36%	0.0	-36%
	Total	**8,413**	**401.3**	**301.6**	**-25%**	**279.1**	**-30%**	**209.4**	**-48%**
Lower Upper Willow Creek	Transitional	560	3.6	3.6	0%	2.5	-31%	2.5	-31%
	Developed, Open Space	59	0.8	0.8	0%	0.7	-17%	0.7	-17%
	Developed, Low Intensity	24	0.0	0.0	0%	0.0	-15%	0.0	-15%
	Barren Land	9	0.1	0.1	0%	0.0	-36%	0.0	-36%
	Evergreen Forest	2,189	31.1	31.1	0%	21.1	-32%	21.1	-32%
	Shrub/Scrub	4,985	580.5	391.2	-33%	395.2	-32%	266.3	-54%
	Herbaceous	4,162	170.1	141.7	-17%	114.5	-33%	95.4	-44%
	Hay/Pasture	357	1.7	1.1	-36%	1.3	-24%	0.8	-51%
	Total	**12,344**	**788.0**	**569.6**	**-28%**	**535.3**	**-32%**	**386.8**	**-51%**
Miners Gulch	Transitional	42	0.4	0.4	0%	0.4	-4%	0.4	-4%
	Evergreen Forest	6,606	34.5	34.5	0%	33.1	-4%	33.1	-4%
	Shrub/Scrub	315	29.4	19.7	-33%	28.4	-4%	19.1	-35%
	Herbaceous	34	0.6	0.5	-17%	0.5	-5%	0.5	-21%
	Hay/Pasture	0	0.0	0.0	-35%	0.0	-4%	0.0	-31%
	Total	**6,998**	**64.9**	**55.1**	**-15%**	**62.4**	**-4%**	**53.0**	**-18%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
Scotchman Gulch	Transitional	190	0.3	0.3	0%	0.2	-20%	0.2	-20%
	Evergreen Forest	3,116	13.7	13.7	0%	11.4	-16%	11.4	-16%
	Shrub/Scrub	463	23.9	16.0	-33%	19.0	-21%	12.8	-47%
	Herbaceous	189	4.4	3.7	-17%	3.7	-16%	3.1	-30%
	Hay/Pasture	1	0.0	0.0	-35%	0.0	-16%	0.0	-46%
	Woody Wetlands	4	0.0	0.0	0%	0.0	-13%	0.0	-13%
	Total	**3,963**	**42.3**	**33.7**	**-20%**	**34.3**	**-19%**	**27.5**	**-35%**
Upper Willow Creek Total	Transitional	6,961	79.4	79.4	0%	53.2	-33%	53.2	-33%
	Developed, Open Space	59	0.8	0.8	0%	0.7	-17%	0.7	-17%
	Developed, Low Intensity	24	0.0	0.0	0%	0.0	-15%	0.0	-15%
	Barren Land	9	0.1	0.1	0%	0.0	-36%	0.0	-36%
	Evergreen Forest	35,863	391.2	391.2	0%	273.4	-30%	273.4	-30%
	Shrub/Scrub	9,866	1075.7	724.6	-33%	749.8	-30%	505.2	-53%
	Herbaceous	7,023	308.5	257.0	-17%	211.6	-31%	176.3	-43%
	Hay/Pasture	927	7.0	4.5	-35%	5.1	-27%	3.3	-53%
	Woody Wetlands	148	0.5	0.5	0%	0.4	-21%	0.4	-21%
	Total	**60,879**	**1863.3**	**1458.3**	**-22%**	**1294.3**	**-31%**	**1012.6**	**-46%**
Antelope Creek (Rock Mallard)	Transitional	330	9.8	9.8	0%	4.9	-50%	4.9	-50%
	Evergreen Forest	1,359	17.0	17.0	0%	8.3	-51%	8.3	-51%
	Shrub/Scrub	4,151	639.7	428.6	-33%	351.8	-45%	237.0	-63%
	Herbaceous	1,879	149.1	123.8	-17%	80.3	-46%	66.9	-55%
	Hay/Pasture	112	1.7	1.1	-35%	1.1	-37%	0.7	-59%
	Woody Wetlands	0	0.0	0.0	0%	0.0	-3%	0.0	-3%
	Total	**7,831**	**817.3**	**580.3**	**-29%**	**446.4**	**-45%**	**317.8**	**-61%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
South Fork Antelope Creek	Transitional	399	8.6	8.6	0%	6.8	-21%	6.8	-21%
	Evergreen Forest	1,155	8.6	8.6	0%	6.8	-21%	6.8	-21%
	Shrub/Scrub	505	32.7	21.9	-33%	26.0	-20%	17.6	-46%
	Herbaceous	182	0.9	0.8	-17%	0.6	-30%	0.5	-41%
	Total	**2,241**	**50.8**	**39.9**	**-22%**	**40.2**	**-21%**	**31.6**	**-38%**
Antelope Creek Total	Transitional	729	18.4	18.4	0%	11.6	-37%	11.6	-37%
	Evergreen Forest	2,514	25.6	25.6	0%	15.1	-41%	15.1	-41%
	Shrub/Scrub	4,656	672.4	450.5	-33%	377.8	-44%	254.6	-62%
	Herbaceous	2,061	150.0	124.5	-17%	81.0	-46%	67.5	-55%
	Hay/Pasture	112	1.7	1.1	-35%	1.1	-37%	0.7	-59%
	Woody Wetlands	0	0.0	0.0	0%	0.0	-3%	0.0	-3%
	Total	**10,072**	**868.1**	**620.1**	**-29%**	**486.6**	**-44%**	**349.5**	**-60%**
Quartz Gulch	Transitional	0	0.0	0.0	0%	0.0	0%	0.0	0%
	Evergreen Forest	1,439	9.1	9.1	0%	8.8	-3%	8.8	-3%
	Shrub/Scrub	181	16.5	11.1	-33%	15.9	-4%	10.7	-35%
	Herbaceous	12	0.0	0.0	-17%	0.0	-15%	0.0	-29%
	Total	**1,632**	**25.6**	**20.2**	**-21%**	**24.7**	**-4%**	**19.5**	**-24%**
Basin Gulch	Evergreen Forest	452	4.1	4.1	0%	3.5	-15%	3.5	-15%
	Shrub/Scrub	39	6.9	4.6	-33%	5.7	-17%	3.9	-44%
	Herbaceous	1	0.0	0.0	0%	0.0	0%	0.0	0%
	Total	**492**	**11.0**	**8.7**	**-21%**	**9.2**	**-16%**	**7.4**	**-33%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
Eureka Gulch	Developed, Open Space	1	0.0	0.0	0%	0.0	-59%	0.0	-59%
	Developed, Low Intensity	0	0.0	0.0	0%	0.0	-98%	0.0	-98%
	Evergreen Forest	179	1.9	1.9	0%	0.8	-58%	0.8	-58%
	Shrub/Scrub	26	11.1	7.5	-33%	5.3	-52%	3.6	-68%
	Hay/Pasture	0	0.0	0.0	-35%	0.0	-10%	0.0	-42%
	Woody Wetlands	2	0.0	0.0	0%	0.0	-28%	0.0	-28%
	Total	**208**	**13.1**	**9.4**	**-28%**	**6.2**	**-53%**	**4.4**	**-66%**
Eureka Gulch Total	Transitional	0	0.0	0.0	0%	0.0	0%	0.0	0%
	Developed, Open Space	1	0.0	0.0	0%	0.0	-59%	0.0	-59%
	Developed, Low Intensity	0	0.0	0.0	0%	0.0	-98%	0.0	-98%
	Evergreen Forest	2,070	15.1	15.1	0%	13.1	-13%	13.1	-13%
	Shrub/Scrub	246	34.6	23.1	-33%	26.9	-22%	18.1	-47%
	Herbaceous	13	0.0	0.0	-17%	0.0	-15%	0.0	-29%
	Hay/Pasture	0	0.0	0.0	-35%	0.0	-10%	0.0	-42%
	Woody Wetlands	2	0.0	0.0	0%	0.0	-28%	0.0	-28%
	Total	**2,332**	**49.7**	**38.3**	**-23%**	**40.1**	**-19%**	**31.3**	**-37%**
Brewster Creek	Transitional	262	1.0	1.0	0%	0.5	-48%	0.5	-48%
	Developed, Open Space	3	0.0	0.0	0%	0.0	-31%	0.0	-31%
	Evergreen Forest	10,204	19.4	19.4	0%	14.0	-28%	14.0	-28%
	Shrub/Scrub	1,155	19.1	12.9	-33%	11.1	-42%	7.4	-61%
	Herbaceous	44	0.4	0.3	-17%	0.2	-39%	0.2	-49%
	Hay/Pasture	8	0.2	0.1	-35%	0.1	-17%	0.1	-46%
	Woody Wetlands	6	0.0	0.0	0%	0.0	-17%	0.0	-17%
	Total	**11,682**	**40.1**	**33.7**	**-16%**	**26.0**	**-35%**	**22.3**	**-44%**

Table F3-2. Delivered Sediment Load by Land Cover Type in the Rock Creek TPA

Subwatershed	Land Cover Classification	Area (acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)		Scenario 4 (BMP 3)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (tons/year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for Existing Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (tons/year)	Percent Change from Existing
Flat Gulch	Transitional	180	0.0	0.0	0%	0.0	-47%	0.0	-47%
	Evergreen Forest	968	4.5	4.5	0%	3.6	-21%	3.6	-21%
	Shrub/Scrub	394	19.3	12.9	-33%	16.0	-17%	10.8	-44%
	Herbaceous	186	10.4	6.8	-35%	8.5	-18%	7.1	-32%
	Woody Wetlands	0	0.0	0.0	0%	0.0	0%	0.0	0%
	Total	**1,728**	**34.3**	**24.2**	**-29%**	**28.1**	**-18%**	**21.4**	**-37%**
Sluice Gulch	Evergreen Forest	1,776	36.1	36.1	0%	20.0	-45%	20.0	-45%
	Shrub/Scrub	2,581	416.9	279.3	-33%	234.3	-44%	157.9	-62%
	Herbaceous	1,095	76.9	63.8	-17%	40.3	-48%	33.6	-56%
	Total	**5,453**	**529.8**	**379.2**	**-28%**	**294.6**	**-44%**	**211.4**	**-60%**

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Attachment F1 - National Land Cover Database Land Cover Type Descriptions

11. Open Water - areas of open water, generally with less than 25 percent cover of vegetation or soil.

21. Developed, Open Space - Includes areas with a mixture of constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

31. Barren Land (Rock/Sand/Clay) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

71. Grasslands/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

ATTACHMENT F2 - ASSIGNMENT OF USLE C-FACTORS TO NLCD LAND COVER TYPES

TABLE 10.—*Factor C for permanent pasture, range, and idle land*[1]

Vegetative canopy		Cover that contacts the soil surface						
			Percent ground cover					
Type and height[2]	Percent cover[3]	Type[4]	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

C-Factors for land cover types in the Rock TPA for Existing Conditions

NLCD Code	Description	Type and Height of Raised Canopy	Percent Canopy Cover	Type	Percent Ground Cover	C-Factor
11*	Open Water	-	-	-	-	-
21	Developed, Open Space	no appreciable canopy	-	G	95-100	0.003
22	Developed, Low Intensity	-	-	-	-	0.001
31	Barren Land	-	-	-	-	0.001
42	Evergreen Forest	trees	75	G	95-100	0.003
52	Shrub/Scrub	appreciable brush	25	G	55	0.046
71	Grassland/Herbaceous	no appreciable canopy	-	G	55	0.042
81	Hay/Pasture	no appreciable canopy	-	G	75	0.020
90	Woody Wetlands	trees	25	G	95-100	0.003

*Water Land Classes will not be counted as surfaces contributing erosion

NLCD Code	Description	Type and Height of Raised Canopy				
11*	Open Water	-				
21	Developed, Open Space	no appreciable canopy				
22	Developed, Low Intensity	-				
31	Barren Land	-				
42	Evergreen Forest	trees				
52	Shrub/Scrub	appreciable brush				
71	Grassland/Herbaceous	no appreciable canopy				
81	Hay/Pasture	no appreciable canopy				
90	Woody Wetlands	trees				

APPENDIX G - ROCK CREEK TPA ROAD SEDIMENT ASSESSMENT & MODELING

Appendix G is based report prepared for the DEQ by ATKINS, July 2012.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

G1.0 Introduction

An assessment of the road network within the Rock TMDL Planning Area (TPA) was performed as part of the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. This assessment employed GIS, field data collection, and sediment modeling to assess sediment inputs from the unpaved road network. In addition, sediment inputs from failed culverts were also evaluated, along with an evaluation of fish passage at assessed crossings.

G1.1 Sediment Impairments

The Rock TPA encompasses an area of approximately 890 square miles in Granite and Missoula counties in western Montana. The Rock TPA is contained within the Flint-Rock Creeks HUC8 (17010202). Within the Rock TPA, there are nine waterbody segments listed on the 2012 303(d) List for sediment-related impairments, including Eureka Gulch, Brewster Creek, South Fork Antelope Creek, Quartz Gulch, East Fork Rock Creek, Miners Gulch, Flat Gulch, Sluice Gulch, and Scotchman Gulch (**Table G1-1**). Additional supporting information was also collected in the Antelope Creek watershed, Upper Willow Creek watershed, and the West Fork Rock Creek watershed.

Table G1-1. Waterbody Segments Addressed during the Road Assessment

TPA	Segment ID	Waterbody Description
Rock	MT76E002_090	EUREKA GULCH, confluence of Quartz Gulch and Basin Gulch to mouth (Rock Creek)
Rock	MT76E002_050	BREWSTER CREEK, East Fork to mouth (Rock Creek)
Rock	MT76E002_060	SOUTH FORK ANTELOPE CREEK, headwaters to mouth (Antelope Creek), T6N R15W S22
Rock	MT76E002_070	QUARTZ GULCH, headwaters to mouth (Eureka Gulch)
Rock	MT76E002_020	EAST FORK ROCK CREEK, East Fork Reservoir to mouth (Middle Fork Rock Creek)
Rock	MT76E002_160	MINERS GULCH, headwaters to mouth (Upper Willow Creek), T8N R15W S23
Rock	MT76E002_120	FLAT GULCH, headwaters to mouth (Rock Creek)
Rock	MT76E002_110	SLUICE GULCH, headwaters to mouth (Rock Creek)
Rock	MT76E002_100	SCOTCHMAN GULCH, headwaters to mouth (Upper Willow Creek)
Rock	MT76E002_061	ANTELOPE CREEK, headwaters to mouth (Rock Creek)
Rock	MT76E002_040	UPPER WILLOW CREEK, headwaters to the mouth (Rock Creek)
Rock	MT76E002_030	WEST FORK ROCK CREEK, headwaters to mouth (Rock Creek)

G2.0 Methods

Methods employed in this assessment are outlined in *Quality Assurance Project Plan and Sampling and Analysis Plan: Assessment of Unpaved Roads for TMDL Development (Task Order 18: Task 2b)* (U.S. Environmental Protection Agency, 2011) and *Road Sediment Assessment and Modeling: Rock TMDL Planning Area Road GIS Layers and Summary Statistics* (Atkins Water Resource Group, 2011) and summarized below.

G2.1 Sediment Inputs from Unpaved Roads

Sediment inputs from unpaved roads were evaluated through a combination of GIS analysis, field data collection and computer modeling.

G2.1.1 GIS Analysis

Prior to field data collection, GIS data layers representing land ownership, road network, stream network, watersheds, and ecoregions were used to identify road crossings throughout the Rock TPA. Land ownership was divided into four categories: U.S. Forest Service, U.S. Bureau of Land Management, Montana State Trust Lands, and Private. The roads layer was primarily derived from the Travel Routes for Region 1 geodatabase developed by the U.S. Forest Service and available from the Northern Region Geospatial Library (http://www.fs.fed.us/r1/gis/), supplemented with the State of Montana Base Map Service Center Transportation Framework Theme data. Stream layers were developed using the National Hydrography Dataset (NHD) 1:24,000 high-resolution flowline layer. Flowlines were limited to streams/rivers and artificial paths; ditches and pipelines were not included. Watersheds were delineated on the basis of the USGS 6th Hydrologic Unit Code (HUC12) layer and modified where necessary to delineate the subwatersheds of interest. Landscapes were delineated according to the EPA 2002 level IV ecoregions (Woods et al., 2002). These GIS layers were utilized to develop a database of stream crossings and parallel road segments that includes land ownership, road surface type, subwatershed, and ecoregion attributes in one attribute table.

Through GIS analysis, 339 road crossings were identified within the Rock TPA, 207 of which were identified as unpaved road crossings (gravel or native material) based on attribute information contained in the roads database (**Table G2-1**). During this initial GIS analysis, 125 crossings were identified with an 'unknown' surface type. Following the initial GIS analysis, road surface types were assigned to the 125 crossings with an 'unknown' surface type based on an assessment of proximal road segments located within the vicinity of each crossing lacking road surface type information. Additional GIS analysis of proximal road segments indicates 122 of these crossings are likely unpaved, resulting in an estimated total of 329 unpaved road crossings in the Rock TPA (**Table G2-1**).

Table G2-1. Road Surface Types in the Rock TPA

Road Surface Type	Number of Crossings based on GIS Attribute Information	Number of Crossings Re-classified based on Attributes of Proximal Road Segments	Total Number of Crossings
Paved	7	3	10
Gravel	42	4	46
Native	165	118	283
Unknown	125		
Total Crossings	**339**	**125**	**339**
Total Unpaved Crossings	**207**	**122**	**329**

Through GIS analysis, 411.58 miles of road were identified within the Rock TPA, with only 5.63 miles (1.4%) identified as paved roads. Parallel road segments located within 150 feet of streams were also identified using GIS, totaling 57.24 miles (13.9%), 32.24 miles of which were identified as unpaved road segments within 150 feet of a stream channel. An additional 23.53 miles were classified as 'unknown' based on attribute information in the roads database, the majority of which are likely unpaved.

G2.1.2 Field Data Collection

A field assessment of unpaved roads was conducted by performing an inspection of road crossings and parallel road segments throughout the Rock TPA in October 2011. For each unpaved crossing, a series of measurements were performed to characterize road design, maintenance level, condition, culvert size, and sediment loading potential. Field measurements included the length, gradient, and width of road contributing sediment from each side of a stream crossing. Additional information was collected describing road design, road surface type, soil type, rock content, traffic level, and the presence of any Best Management Practices (BMPs).

G2.1.2.1 Crossing Assessment Sites

A total of 45 unpaved road crossings were randomly selected prior to field data collection. Out of the 45 pre-selected sites, 34 sites were visited in the field in October of 2011 and field forms were completed at 23 sites. Notes regarding road condition were recorded at the remaining 11 pre-selected sites, including if the road was closed preventing access to the site, though no actual data was collected. An additional 7 alternate sites were also visited and field forms were completed, for a total of 41 field assessed sites. Out of the 41 field assessed sites, field forms were completed at a total of 30 sites, while five out of the 41 assessed sites were not observed on-the-ground due to closed roads. Of the remaining six field assessed sites, one site was on a paved road, four sites had no defined stream channel, and one site lacked a crossing due to errors in the GIS stream and road layers which indicated a crossing where there is only a parallel road segment. Out of the 30 sites for which field forms were completed, three were on roads that were closed, but not re-vegetated or obliterated.

During field data collection, an additional examination of the road network in the South Fork Antelope Creek was conducted since no roads were identified in the GIS data layers. Based on color aerial imagery from 2011 and on-the-ground reconnaissance, two unpaved road crossings were identified in the South Fork Antelope Creek watershed, both of which were assessed in the field. Thus, a total of 441 unpaved road crossings were identified in the Rock TPA, 41 of which were assessed in the field, with field data collection completed at 30 sites. The 30 sites where field data collection was completed were analyzed using the Water Erosion Prediction Project (WEPP) soil erosion model, while the remaining 11 field assessed sites were used to refine the road database developed through GIS analysis (**Figure G2-1**).

G2.1.2.2 Parallel Road Segment Assessment Sites

A total of 32.24 miles of unpaved parallel road segments within 150 feet of streams were identified in the Rock TPA, while an additional 23.53 miles were classified as ‘unknown’, the majority of which are likely unpaved as well. During field data collection, sediment inputs to stream channels from parallel road segments were not observed. Thus, no field data was collected along parallel road segments in the Rock TPA.

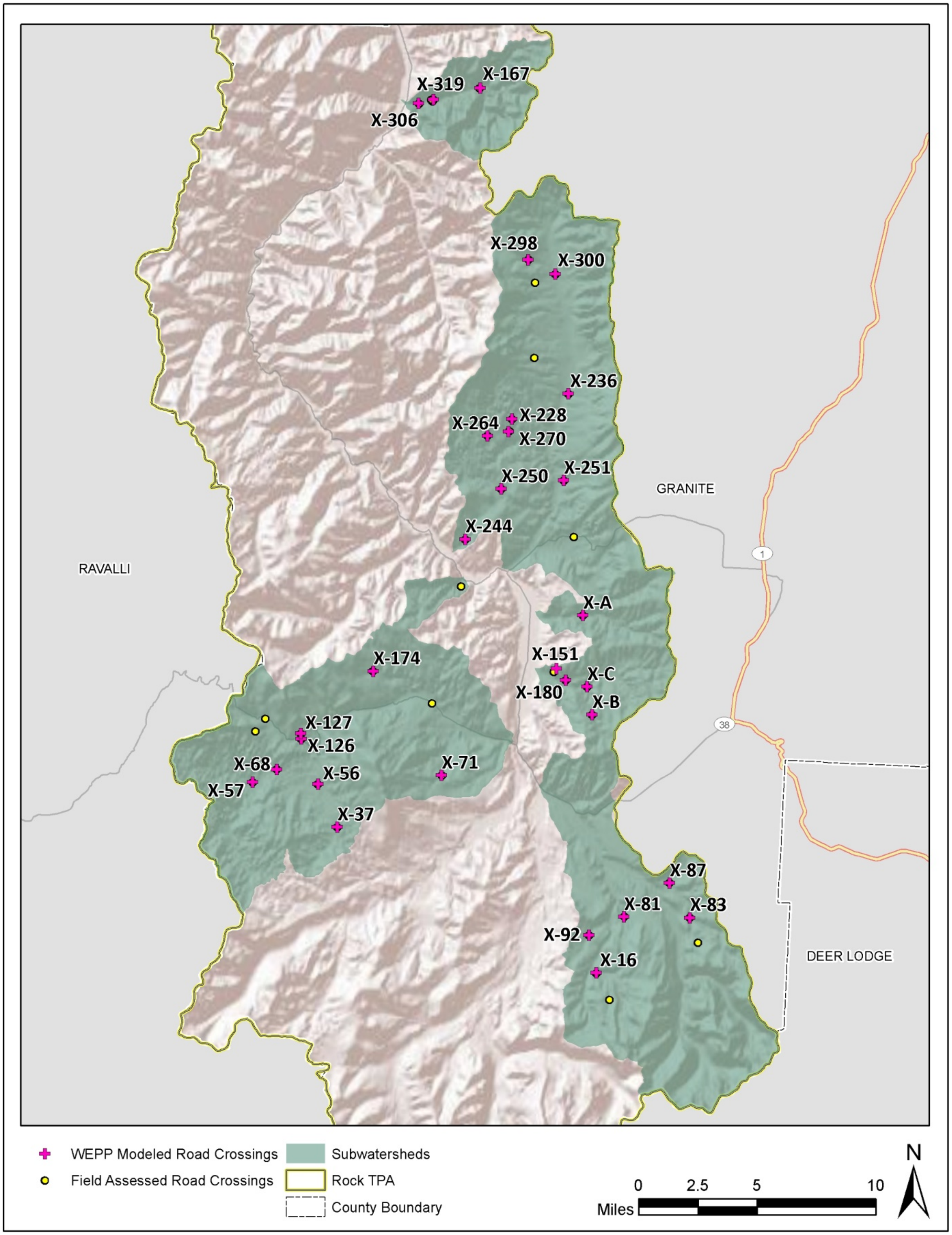

Figure G2-1. Field Assessed Road Crossings and WEPP Modeled Road Crossings in the Rock TPA

G2.1.3 WEPP Modeling

Sediment loading from unpaved road crossings was estimated using the WEPP:Road soil erosion model version 2011.12.20 (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) model developed by the U.S. Forest Service and other agencies, and is used to predict runoff, erosion, and sediment delivery from forest roads. The WEPP:Road model predicts sediment yields based on specific soil, climate, ground cover, and topographic conditions. Field data collected from each field assessed site provided the following input data necessary to run the WEPP:Road model:

- Road design: insloped, bare ditch; insloped, vegetated or rocked ditch; outsloped, rutted; outsloped unrutted
- Road surface: native, graveled, paved
- Traffic level: high, low, none
- Soil texture: clay loam, silt loam, sandy loam, loam
- Rock content
- Gradient, length and width of the road, fill and buffer
- Climate data
- Years to simulate

The WEPP:Road model was used to evaluate existing conditions at each road crossing based on the field collected data. The WEPP:Road model was also used to estimate the potential to reduce sediment loads through the application of Best Management Practices (BMPs). During field data collection, the location of potential BMPs, such as water bars and rolling dips, were identified and the distance to the stream crossing was measured. During the BMP modeling scenario, the contributing road length was reduced from the existing length to the potential BMP length based on the field measured values.

G2.1.4 Potential Culvert Failures

A coarse assessment for each culvert was preformed on-site in order to measure and identify characteristics of the culvert, including measurements of structure type, structure diameter, structure gradient, bankfull width upstream of the culvert, fill height, fill length, fill width, outlet invert, and the presence of streambed materials in the culvert. This information was then used to estimate potential sediment loads from a culvert failure. At each culvert assessed in the field, flood frequencies for the 2, 5, 10, 25, 50, and 100-year events were determined based on the bankfull width upstream of the culvert using U.S. Geological Survey Southwest Montana Region regression equations (Parrett and Johnson, 1998). The Urban Drainage and Flood Control District Sewer and Culvert Hydraulics Version 2.0 (http://www.udfcd.org/) spreadsheet model was then utilized to establish the flow capacity of each field assessed culvert. The amount of sediment contributed during a culvert failure was calculated based on the volume of road fill overlaying the culvert with the assumption that culvert failure would erode sediment to a width equal to the bankfull width of the stream channel upstream of the culvert. For this analysis, an estimated soil weight of 1.66 tons/yard^3 was utilized based on the maximum unit weight for dry well-graded subangular sand presented in Table 1:4 of *Introductory Soil Mechanics and Foundations: Geotechnical Engineering Forth Edition (Sowers, 1979)*.

G2.2 Fish Passage Analysis

At each field assessed unpaved road crossing site, an evaluation of the culvert was performed, including measurements of structure type, structure diameter, structure gradient, bankfull width upstream of the culvert, outlet invert, and the presence of streambed materials in the culvert. These measurements were used to determine if the culvert represented a fish passage barrier at various flow conditions based on the U.S. Forest Service Region 10 Fish Passage Evaluation Criteria as described in *A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on National Forests in Alaska (U.S. Department of Agriculture, Forest Service, Alaska Region, 2002)*.

G3.0 RESULTS

The results of this assessment examining sediment loading from roads to streams within the Rock TPA are presented in the following sections. The road and stream network developed through GIS data analysis is presented in **Figure G3-1**, while field assessed sites are presented by landownership in **Figure G3-2** and by level IV ecoregion in **Figure G3-3**. Sediment modeling and extrapolation was based on PRISM precipitation zones (**Figure G3-4**) and calculated by subwatershed for each of the 6th code subwatersheds (**Figure G3-5**) within the Rock TPA.

G3.1 SEDIMENT INPUTS FROM UNPAVED ROADS

Sediment inputs from unpaved road crossings were evaluated using the WEPP:Road model. The potential to reduce sediment loads from unpaved roads through the application of Best Management Practices (BMPs) were also evaluated using the WEPP:Road model. During field data collection, potential locations for the application of BMPs, including water bars and rolling dips, were identified and the distance to the stream crossing was measured. For the BMP scenario, this distance was applied in the WEPP:Road model to estimate the potential to decrease sediment contributions through the application of BMPs. In addition, sediment inputs from potential culvert failures were also evaluated.

G3.1.1 WEPP Model Input Parameters

Road condition data collected throughout the Rock TPA in October 2011 was input directly into the WEPP:Road model following guidance outlined in *WEPP Interface for Predicting Forest Road Runoff, Erosion and Sediment Delivery Technical Documentation*, which is available on the Internet at http://forest.moscowfsl.wsu.edu/fswepp/docs/wepproaddoc.html. In addition to field collected data, the WEPP:Road model requires the selection of site-specific climate data to provide an estimate of mean annual precipitation. The WEPP Climate Generator was used to create a climate station based on weather data from the Philipsburg Ranger Station climate station maintained by the U.S. Forest Service (Western Regional Climate Center Cooperative Station ID# 246472) with a period of record from 1955 to the present. Precipitation in the Rock TPA ranges from 16-18” to 38-42” annually based on data collected from 1971 to 2000 and compiled by the PRISM Group at Oregon State University (http://nris.mt.gov/nsdi/nris/precip71_00.html). Road crossing assessments in the Rock TPA were conducted at sites located in precipitation zones ranging from 16-18” to 30-34”. For the Rock TPA, stream crossings were grouped into three precipitation zones for the purposes of sediment load modeling and extrapolation: <20”, 20-26”, and >26”. The mean precipitation value of 14.6” at the Philipsburg Montana climate station was adjusted by 20%, 60%, and 90% to approximate the mean values within the <20”, 20-26”, and >26” precipitation zones, respectively, as presented in **Table G3-1** and **Figure G3-4**. Mean annual sediment loads from unpaved road crossings were estimated using field collected data and site-specific precipitation data in the WEPP:Road model.

Table G3-1. Precipitation Data Applied in the WEPP:Road Model

Climate Station	Mean Precipitation (Inches)	Percent Adjustment	Adjusted Mean Precipitation (Inches)	PRISM Precipitation Zone (Inches)
Phillipsburg, MT	14.6	20%	17.5	<20
Phillipsburg, MT	14.6	60%	23.2	20-26
Phillipsburg, MT	14.6	90%	27.9	>26

G3.1.2 Unpaved Road Crossings

Out of 441 unpaved road crossings delineated in GIS and during on-the-ground reconnaissance, 41 were assessed in the field and field data was collected at 30 sites (**Figure G3-6**). From these 30 crossings, the estimated mean annual sediment load is 0.012 tons, with a mean annual sediment load of 0.004 tons contributed from each assessed unpaved road crossing (**Attachment G1**). For extrapolation to the subwatershed scale, unpaved road crossings were grouped based on precipitation zone as presented in **Table G3-2** and **Attachment G2**.

Table G3-2. Unpaved Road Crossing Mean Annual Sediment Loads for Precipitation Zones

PRISM Precipitation Zone (inches)	Number of sites Assessed	Mean Annual Load (Tons)	Mean Annual Load with BMP's (Tons)
<20	5	0.0029	0.0027
20-26	17	0.0181	0.0052
>26	8	0.0047	0.0025

The number of crossings identified in GIS was corrected for assumed errors in the GIS database by reducing the total number of GIS identified crossings based on the difference in the number of field assessed sites and the number of sites which were positively identified as unpaved road crossings of streams. During the field assessment, 30 of the 41 GIS-identified crossings (73%) were found to be unpaved road crossings of streams. Thus, it was assumed that the GIS data analysis over-estimated the number of crossings by 27%. Based on this assumption, the total number crossings identified in GIS in each sub-watershed was reduced by 27%, with the exception of South Fork Antelope Creek, where the two crossings identified through aerial imagery as discussed in **Section G2.1.2.1** were both verified during field data collection. Both the GIS identified number of crossings and the corrected number of crossings are presented in **Table G3-3** for each subwatershed, along with mean annual sediment load for the existing conditions and the mean annual sediment load achievable through the application of BMPs. For assessed stream segments within the Rock TPA, the estimated existing mean annual sediment load from unpaved road crossings is 2.636 tons (**Table G3-3**). Through the application of BMPs, it is estimated that this load can be reduced to 0.959 tons. A complete evaluation of sediment loads at the subwatershed scale is presented in **Attachment G3**.

Table G3-3. Unpaved Road Crossing Mean Annual Sediment Loads by Subwatershed

Subwatershed	Number of Crossings Identifed in GIS	Corrected Number of Crossings based on Field Data	Mean Annual Load (Tons)	Mean Annual Load with BMPs (Tons)	Percent Reduction
West Fork Rock Creek Headwaters	12	9	0.042	0.022	47%
Upper West Fork Rock Creek	25	18	0.087	0.046	47%
Middle West Fork Rock Creek	18	13	0.062	0.033	47%
Lower West Fork Rock Creek	59	43	0.597	0.194	67%
West Fork Rock Creek Total	**114**	**83**	**0.787**	**0.296**	**62%**
East Fork Reservoir	0	0	0.000	0.000	0%
Meadow Creek	30	22	0.241	0.083	66%
East Fork Rock Creek	30	22	0.299	0.098	67%
East Fork Rock Creek Total	**60**	**44**	**0.541**	**0.181**	**66%**
Upper Willow Creek Headwaters	15	11	0.101	0.038	63%
Upper Upper Willow Creek	30	22	0.354	0.107	70%
Middle Upper Willow Creek	16	12	0.035	0.032	7%
Lower Upper Willow Creek	27	20	0.125	0.065	48%
Miners Gulch	20	15	0.199	0.066	67%
Scotchman Gulch	2	1	0.015	0.006	62%
Upper Willow Creek Total	**110**	**80**	**0.828**	**0.313**	**62%**
Antelope Creek (Rock Mallard)	12	9	0.070	0.031	56%
South Fork Antelope Creek	2	2	0.021	0.008	62%
Antelope Creek Total	**14**	**11**	**0.091**	**0.039**	**57%**
Quartz Gulch	1	1	0.013	0.004	71%
Basin Gulch	1	1	0.002	0.002	7%
Eureka Gulch	2	1	0.004	0.004	7%
Eureka Gulch Total	**4**	**3**	**0.020**	**0.010**	**50%**
Brewster Creek Total	**29**	**21**	**0.236**	**0.081**	**66%**
Flat Gulch Total	**4**	**3**	**0.053**	**0.015**	**71%**
Sluice Gulch Total	**6**	**4**	**0.080**	**0.023**	**71%**
Rock TPA Total	**341**	**250**	**2.636**	**0.959**	**64%**

G3.1.3 Unpaved Parallel Road Segments

A total of 32.24 miles of unpaved parallel road segments within 150 feet of streams were identified in the Rock TPA, while an additional 23.53 miles were classified as 'unknown', the majority of which are likely unpaved as well (**Figure G3-7**). During field data collection, sediment inputs to stream channels from parallel road segments were not observed. Thus, no field data was collected along parallel road segments in the Rock TPA and no sediment load analysis was performed.

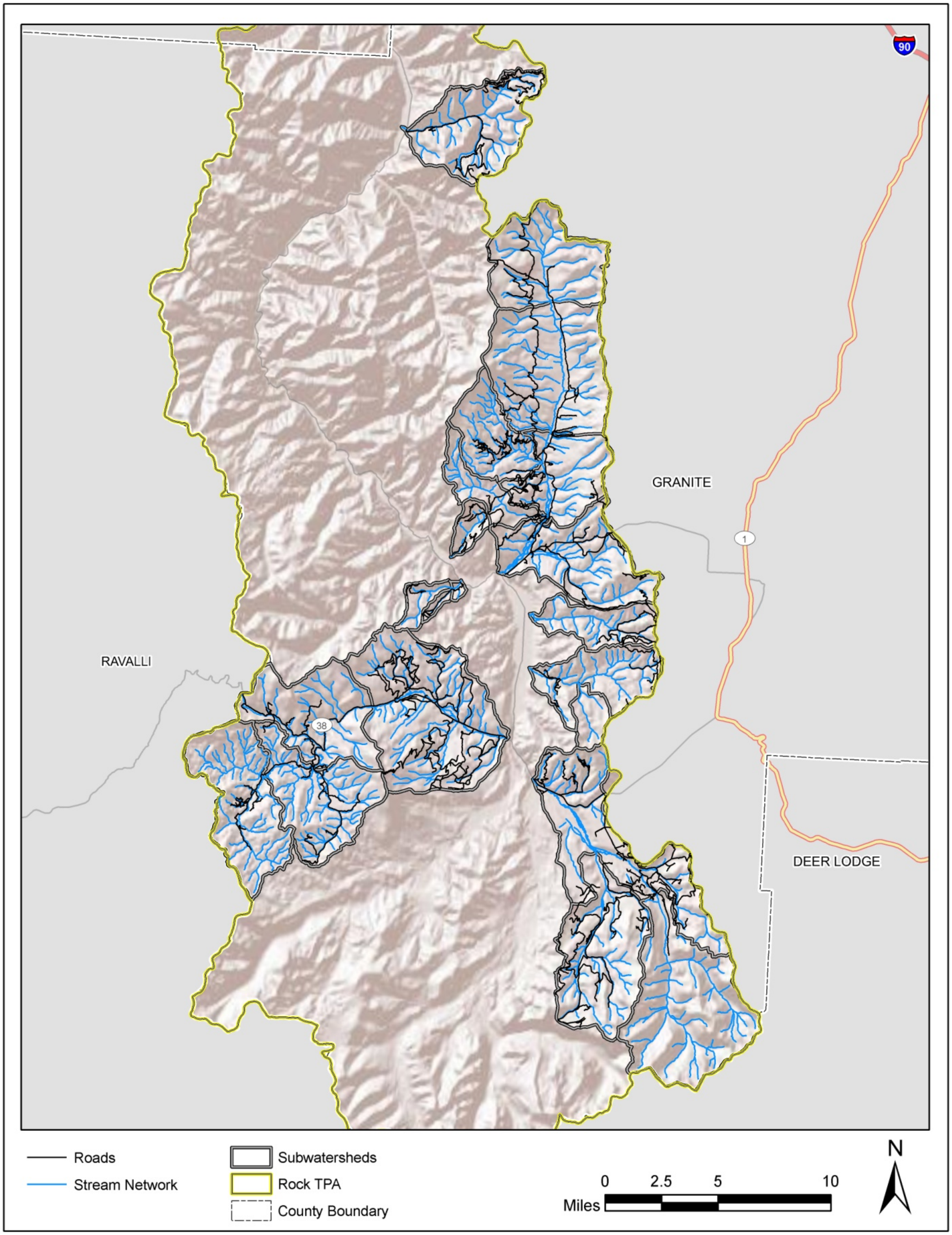

Figure G3-1. Road and Stream Networks in the Rock TPA

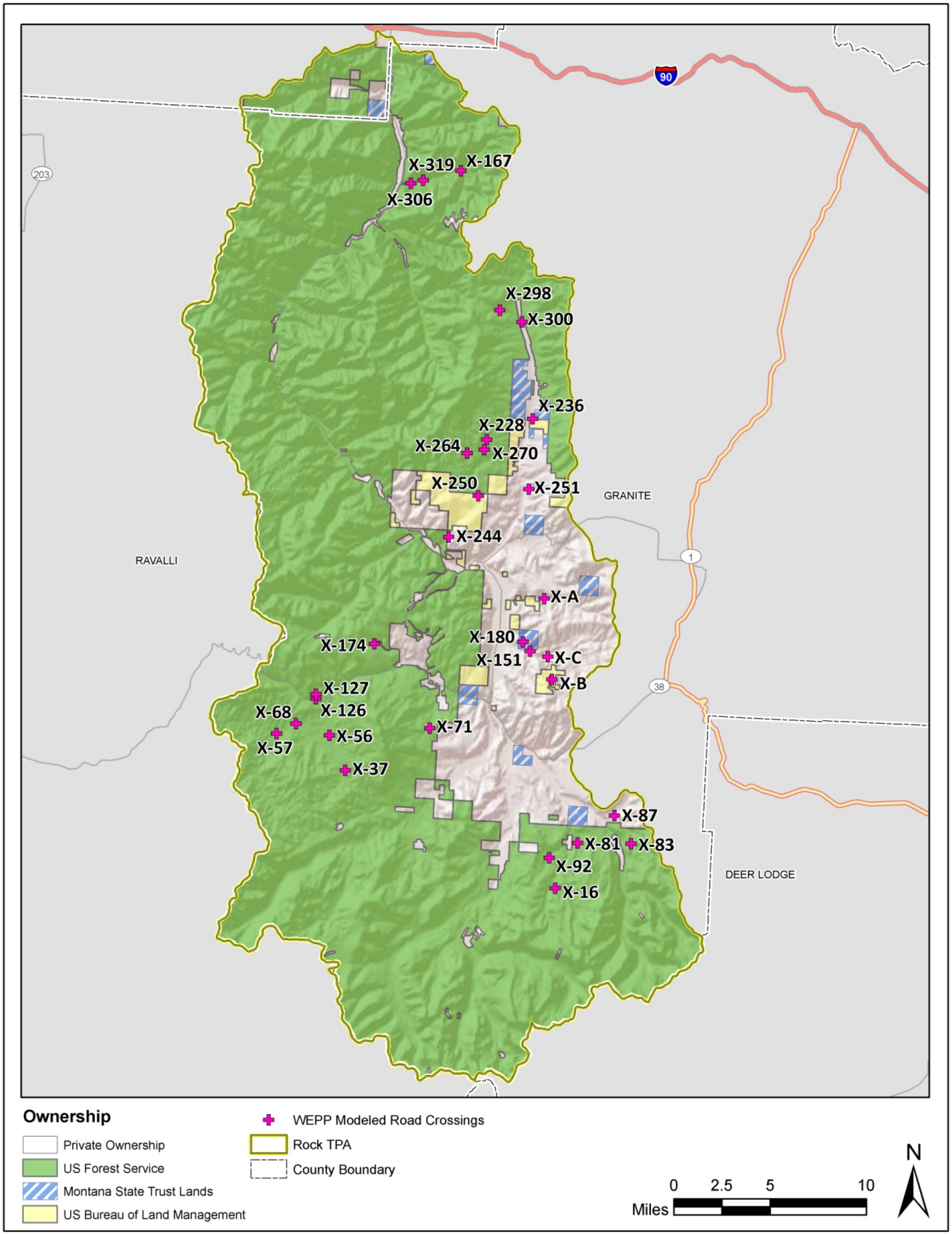

Figure G3-2. Landownership in the Rock TPA

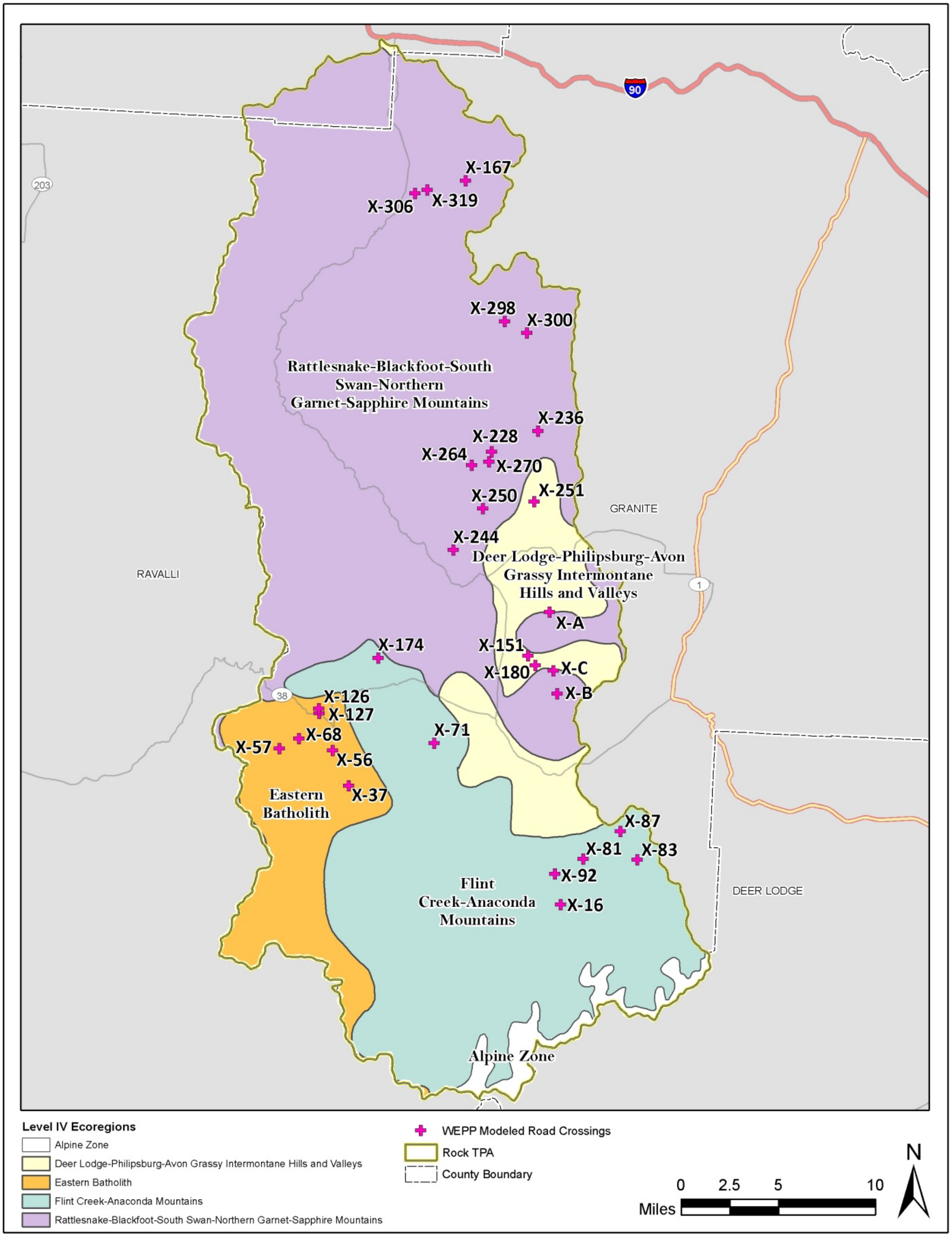

Figure G3-3. Level IV Ecoregions in the Rock TPA

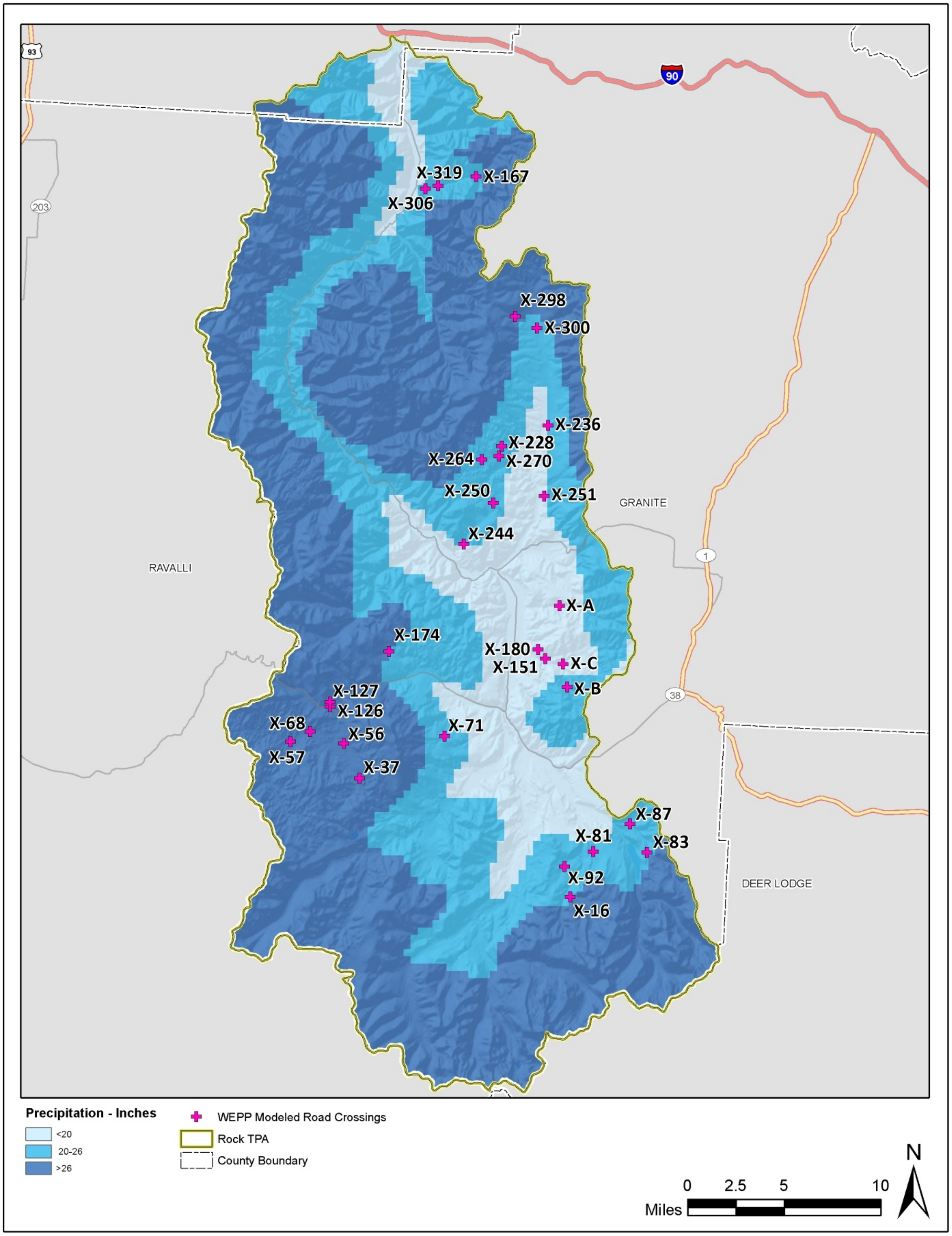

Figure G3-4. Precipitation Patterns in the Rock TPA

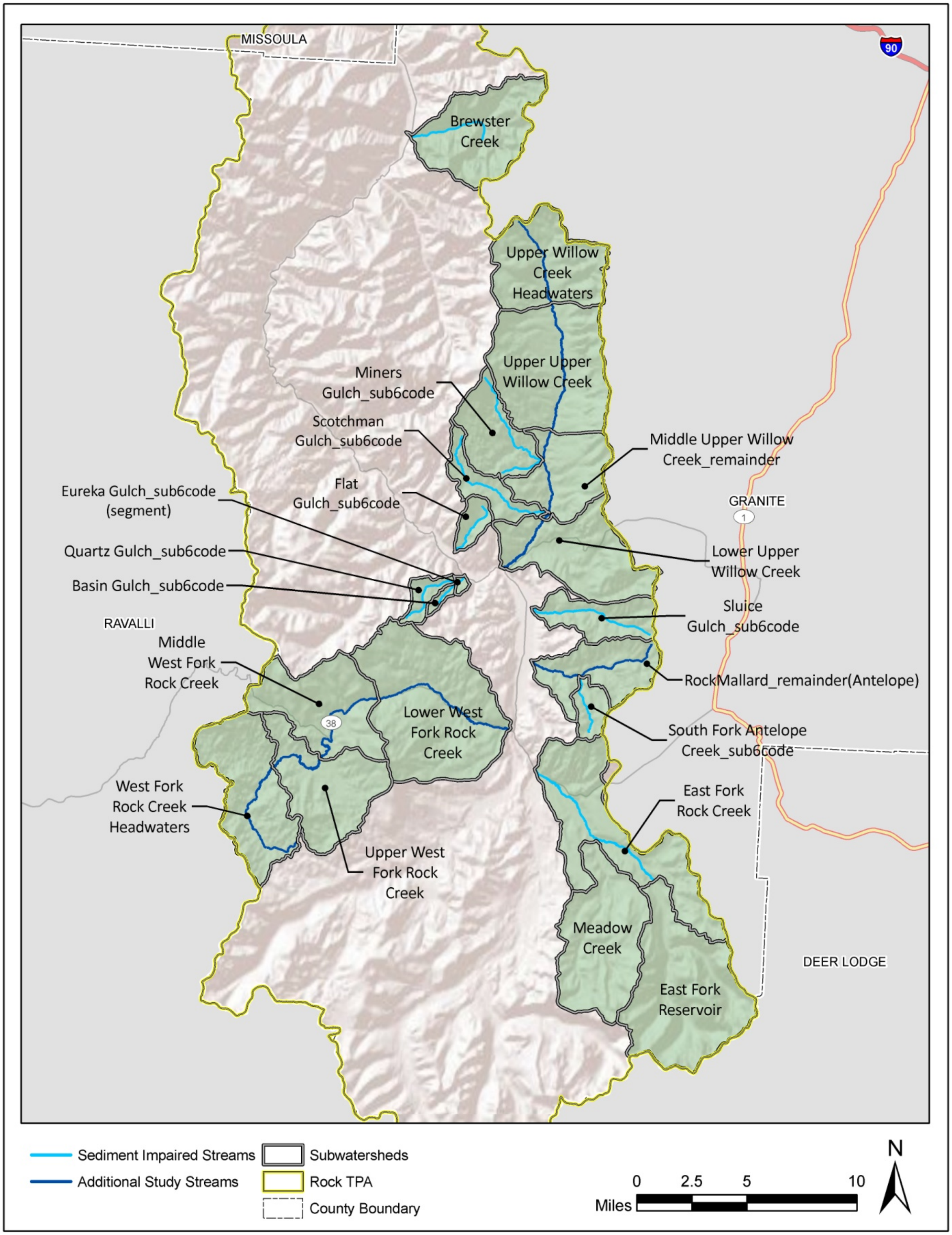

Figure G3-5. Subwatersheds in the Rock TPA

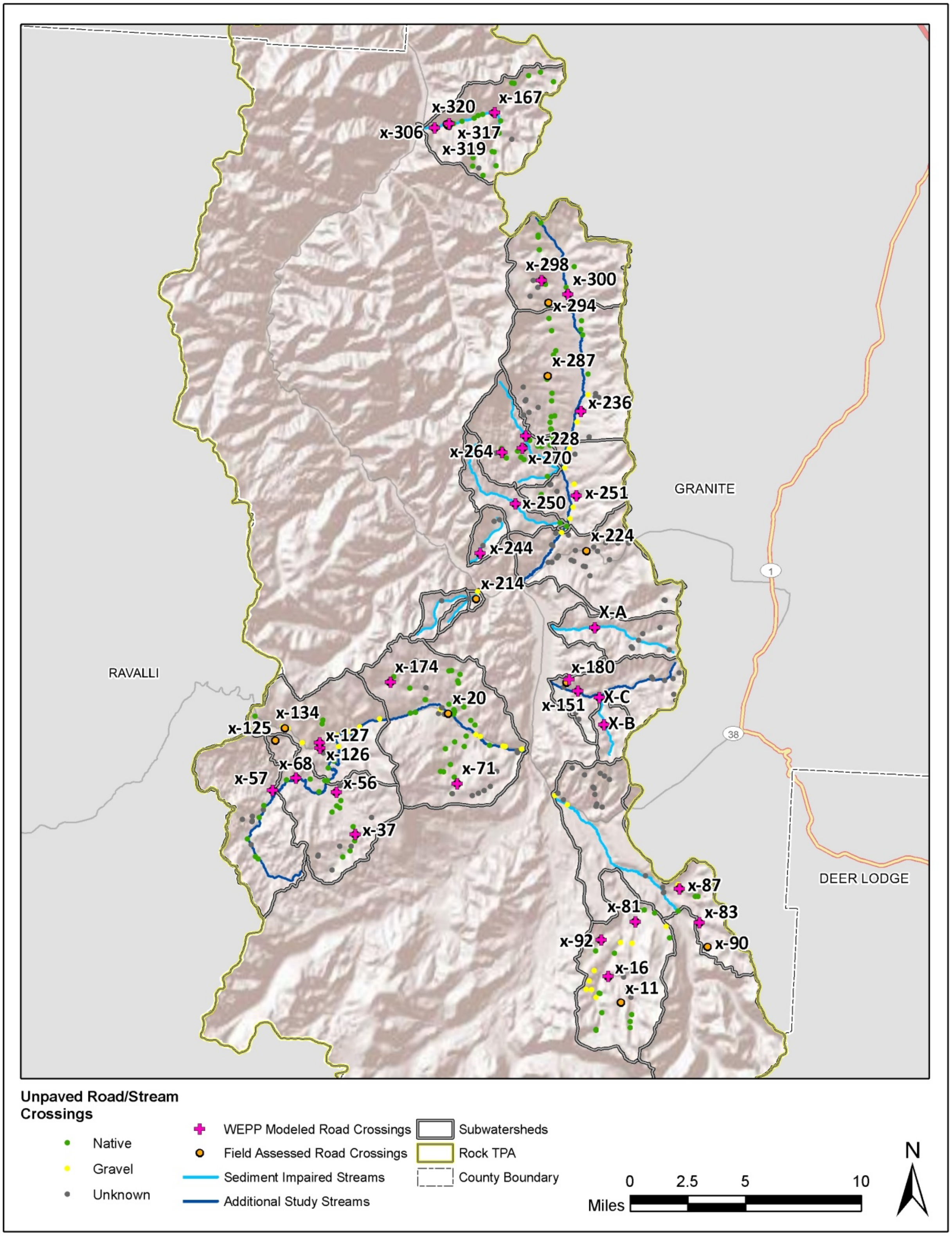

Figure G3-6. Unpaved Road Crossings in the Rock TPA

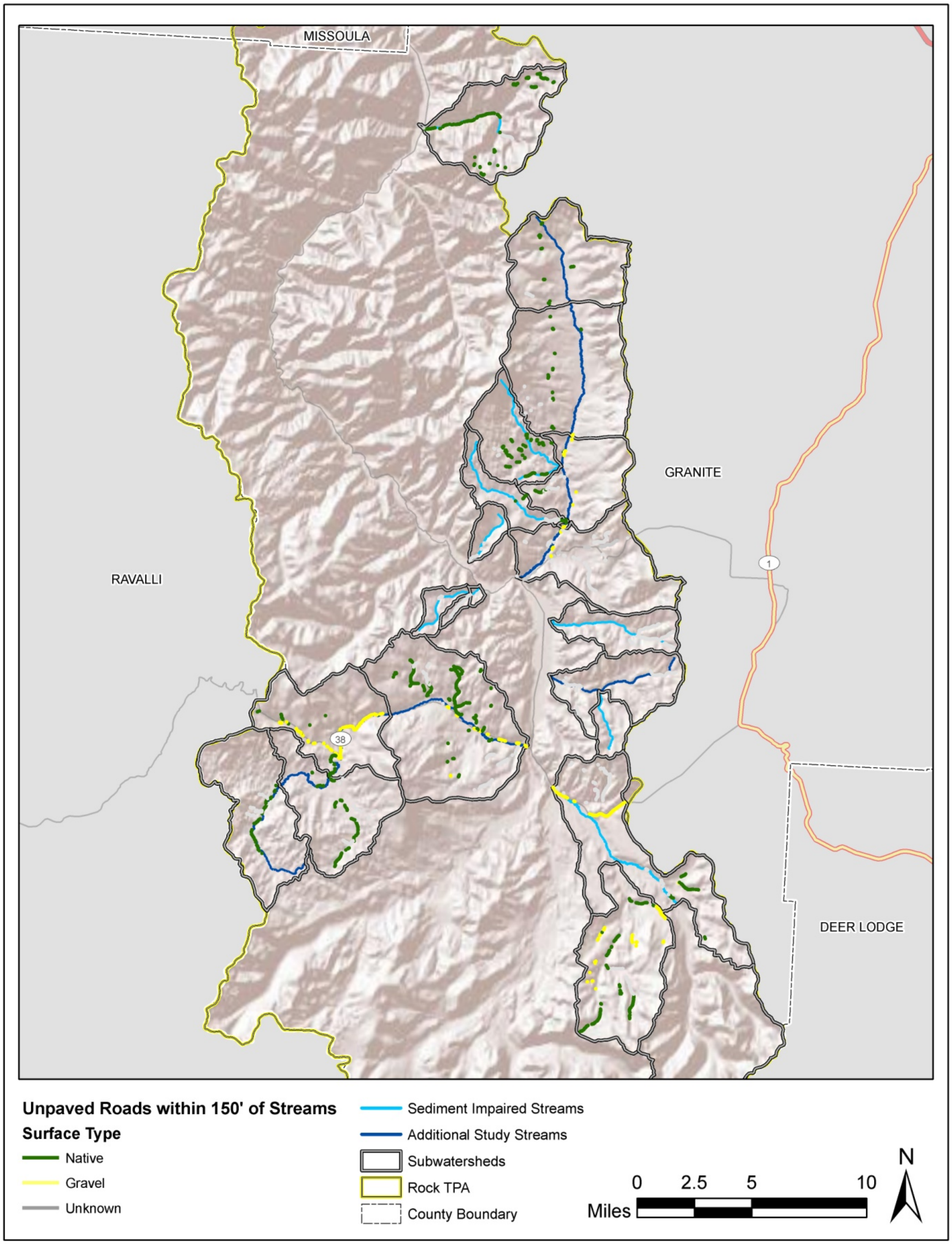

Figure G3-7. Unpaved Parallel Road Segments in the Rock TPA

G3.1.4 Potential Culvert Failures

Within the Rock TPA, 23 out of 27 culverts assessed in the field (85%) are capable of passing the two-year flood event, while only 9 of these culverts (33%) pass a 100-year flood event (**Tables G3-4** and **G3-5**, **Attachment G4**). Once a culvert's carrying capacity is exceeded, the potential for culvert failure increases, though the point at which a given culvert will fail remains uncertain. Hydraulic analysis of a culvert is extremely complex and potential sediment loads from the eroding fill as presented in **Table G3-4** are estimates assuming the entire height and length of road fill are eroded to a width equal to the bankfull width of the stream.

Table G3-4. Culvert Failure and Potential Sediment Load Evaluation

Location ID	Q2	Q5	Q10	Q25	Q50	Q100	Estimated Maximum Culvert Capacity (cfs)	Potential Sediment Load if Culvert Fails (Tons)
X-174	7	14	19	28	36	43	112	48
X-126	7	14	19	28	36	43	26	68
X-127	4	9	13	19	24	30	13	24
X-68	17	32	45	63	79	94	51	59
X-37	13	25	35	50	63	76	12	48
X-71	39	69	92	126	156	185	149	122
X-251	4	9	13	19	24	30	100	52
X-236	6	11	16	23	30	36	9	33
X-B	4	9	13	19	24	30	124	148
X-C	60	104	138	184	227	268	27	111
X-151	32	59	79	108	135	160	16	24
X-180	6	11	16	23	30	36	49	125
X-87	45	80	107	144	179	211	177	80
X-83	10	19	27	38	48	59	53	394
X-81	32	59	79	108	135	160	61	159
X-16	10	19	27	38	48	59	179	74
X-92	7	14	19	28	36	43	51	55
X-250	4	9	13	19	24	30	95	52
X-228	10	19	27	38	48	59	146	133
X-270	2	4	6	8	11	14	11	6
X-264	3	7	10	15	19	24	6	6
X-300	7	14	19	28	36	43	40	10
X-298	7	14	19	28	36	43	115	512
X-244	17	32	45	63	79	94	8	11
X-167	10	19	27	38	48	59	54	33
X-319	32	59	79	108	135	160	107	43
X-306	7	14	19	28	36	43	9	7

Grey cells indicate culvert fails to pass a given discharge

Table G3-5. Culvert Failure Summary

Flood Frequency	Number of Culverts Passing	Number of Culverts Failing	Percent Passing	Percent Failing
Q2	23	4	85%	15%
Q5	20	7	74%	26%
Q10	18	9	67%	33%
Q25	15	12	56%	44%
Q50	12	15	44%	56%
Q100	9	18	33%	67%

If a culvert fails for a given event, the replacement culvert should address several issues. First, culverts typically cause changes in the upstream elevation and the new culvert should mitigate these effects to ensure that culvert placement does not negatively affect the surrounding habitat. Next, environmental considerations such as fish passage need to be accurately predicted. New three-sided culverts, where the bottom of the culvert is typically the natural channel bottom, allow better holding habitat and maintain a continuous stream channel bottom. The hydrology of the area should also be determined and directly related to the culvert design size for the given watershed. Following these principals will help improve the stream system, increase fish habitat, and reduce potential sediment loads from failed culverts.

G3.2 Fish Passage Analysis

Out of 30 road crossings evaluated in the field, 27 had culverts, each of which was assessed as a potential fish passage barrier based on the U.S. Forest Service Region 10 Fish Passage Evaluation Criteria. This analysis uses site-specific information to evaluate fish passage at culverts, which are classified as "green", "red", or "grey" (**Table G3-6**). Culvert slope, the culvert span-to-bedwidth ratio, and the outlet perch are evaluated as potential limiting factors affecting fish passage. In the Rock TPA, none of the culverts allowed fish passage, while 26 culverts (96%) were classified as fish passage barriers (**Attachment G5**). In general, too steep of slope led to these culverts being classified as fish passage barriers.

Table G3-6. Fish Passage Evaluation

Fish Passage Evaluation Categories	Fish Passage Evaluation Criteria	Number of Culverts	Percentage of Total Culverts Assessed
Green[1]	conditions that have a high certainty of meeting juvenile fish passage at all desired stream flows	0	0%
Red[2]	conditions that have a high certainty of not providing juvenile fish passage at all desired stream flows	26	96%
Grey[3]	conditions are such that additional and more detailed analysis is required to determine their juvenile fish passage ability	1	4%

G4.0 Discussion

Within the Rock TPA, there are nine waterbody segments listed on the 2012 303(d) List for sediment-related impairments, including Eureka Gulch, Brewster Creek, South Fork Antelope Creek, Quartz Gulch, East Fork Rock Creek, Miners Gulch, Flat Gulch, Sluice Gulch, and Scotchman Gulch. Mean annual sediment contributions from unpaved roads at stream crossings for these nine stream segments range from 0.013 tons in Quartz Gulch to 0.541 tons in the East Fork Rock Creek (**Table G4-1**). Through the application of Best Management Practices, existing sediment loads from unpaved road crossings could be reduced by 50% to 71%.

Table G4-1. Unpaved Road Crossing Mean Annual Sediment Loads for Sediment Impaired Stream Segments

Subwatershed	Mean Annual Load (Tons)	Mean Annual Load with BMPs (Tons)	Percent Reduction
East Fork Rock Creek Total	0.541	0.181	66%
Miners Gulch	0.199	0.066	67%
Scotchman Gulch	0.015	0.006	62%
South Fork Antelope Creek	0.021	0.008	62%
Quartz Gulch	0.013	0.004	71%
Eureka Gulch Total	0.020	0.010	50%
Brewster Creek Total	0.236	0.081	66%
Flat Gulch Total	0.053	0.015	71%
Sluice Gulch Total	0.080	0.023	71%

G5.0 References

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Attachment G1 - Unpaved Road Crossing Field Data and WEPP Modeled Sediment Load

Waterbody	Location ID	Date	Latitude	Longitude	Level 4 Ecoregion	Estimated Mean Annual Precipitation (inches)	Soil Type	% Rock	Insloped/ Outsloped	Road Surface	Traffic Level	Years Modeled	Gradient CRL1 (%)	Length CRL1 (Feet)	Width CRL1 (Feet)	Gradient Fill (%)	Length Fill (Feet)	Gradient Buffer (%)	Length Buffer (Feet)	WEPP LOAD (lbs)	Gradient CRL1 (%)	Length CRL1 (Feet)	Width CRL1 (Feet)	Gradient Fill (%)	Length Fill (Feet)	Gradient Buffer (%)	Length Buffer (Feet)	WEPP LOAD (lbs)	MEAN ANNUAL LOAD (lbs)	MEAN ANNUAL LOAD with BMPs (lbs)
													L	L	L	L	L	L	L	L	R	R	R	R	R	R	R	R		
unnamed	X-174	10/10/11	46.26431	-113.65053	FCAM	>26	Sand L	10	Insloped Veg/rock ditch	Native	Low	30	3.0	325	14	0.3	1	7	30	6.66	3.5	270	14	0.3	1	55	10	3.96	10.6	3.3
unnamed	X-126	10/10/11	46.22073	-113.71071	EB	>26	Sand L	10	Outsloped Unrutted	Part. Grav.	High	30	1.5	30	23	70	6	0.3	1	8.39	0.5	25	23	70	6	0.3	1	8.23	16.6	16.6
unnamed	X-127	10/10/11	46.22410	-113.71119	EB	>26	Sand L	30	Outsloped Unrutted	Gravel	Low	30	8.0	475	14	38	4	18	13	15.27	2.0	32	14	38	4	18	1	2.02	17.3	5.7
unnamed	X-68	10/10/11	46.20123	-113.73086	EB	>26	Sand L	20	Outsloped Unrutted	Native	Low	30	-	-	-	-	-	-	-	0.00	1.0	47	13	30	7	0.3	1	1.20	1.2	1.2
Bowles Creek	X-57	10/10/11	46.19284	-113.75145	EB	>26	Sand L	30	Outsloped Unrutted	Native	Low	30	-	-	-	-	-	-	-	0.00	3.0	160	14	0.3	1	0.3	1	0.09	0.1	0.0
Sod Basin Creek	X-56	10/10/11	46.19366	-113.69390	EB	>26	Sand L	20	Outsloped Unrutted	Native	Low	30	0.5	20	12	0.3	1	0.3	1	0.03	0.5	12	12	0.3	1	0.3	1	0.02	0.1	0.1
unnamed	X-37	10/10/11	46.16811	-113.67477	EB	>26	Sand L	20	Outsloped Unrutted	Native	Low	30	1.0	103	13	42	9	0.3	1	2.69	0.5	5	13	42	9	0.3	1	2.68	5.4	5.4
unnamed	X-71	10/10/11	46.20314	-113.58571	FCAM	20-26	Sand L	40	Outsloped Unrutted	Gravel	Low	30	1.0	35	12	40	7	0.3	1	0.78	0.5	17	12	40	7	0.3	1	0.34	1.1	1.1
unnamed	X-251	10/10/11	46.38665	-113.49159	DLPAGIHV	<20	Sand L	30	Outsloped Unrutted	Gravel	Low	50	3.0	172	23	55	10	0.3	1	13.87	7.0	250	23	0.3	1	10	72	0.00	13.9	13.9
unnamed	X-236	10/10/11	46.43948	-113.49134	RBSSNGSM	20-26	Sand L	20	Outsloped Unrutted	Gravel	Low	30	2.0	170	18	50	7	0.3	1	7.87	6.0	315	18	50	7	0.3	1	23.01	30.9	23.6
Sluice Gulch	X-A	10/11/11	46.30498	-113.46892	DLPAGIHV	<20	Sand L	0	Outsloped Unrutted	Native	Low	50	-	-	-	-	-	-	-	0.00	4.0	104	7	0.3	1	0.3	1	0.05	0.1	0.1
South Fork Antelope Creek	X-B	10/11/11	46.24460	-113.45621	RBSSNGSM	20-26	Sand L	20	Outsloped Unrutted	Native	Low	30	9.0	195	-	48	30	0.3	1	16.13	6.0	195	15	48	30	0.3	1	10.39	26.5	10.3
South Fork Antelope Creek	X-C	10/11/11	46.26152	-113.46180	RBSSNGSM	<20	Sand L	5	Outsloped Unrutted	Native	Low	50	4.0	104	12	50	1	0.3	1	3.90	11.0	240	12	0.3	1	14	15	0.00	3.9	1.7
Antelope Creek	X-151	10/11/11	46.26487	-113.48116	DLPAGIHV	<20	Sand L	20	Outsloped Unrutted	Native	Low	50	-	-	-	-	-	-	-	0.00	0.5	11	10	40	6	0.3	1	0.23	0.2	0.2
unnamed	X-180	10/11/11	46.27171	-113.48958	DLPAGIHV	<20	Sand L	30	Insloped Veg/rock ditch	Native	Low	50	2.0	113	10	45	15	0.3	1	4.31	4.0	103	10	75	21	0.3	1	7.12	11.4	11.4
East Fork trib	X-87	10/11/11	46.14455	-113.38101	FCAM	20-26	Sand L	40	Outsloped Unrutted	Gravel	Low	30	6.0	825	14	40	7	0.3	1	35.98	-	-	-	-	-	-	-	0.00	36.0	4.8
LF trib	X-83	10/11/11	46.12396	-113.36141	FCAM	20-26	Sand L	40	Outsloped Unrutted	Gravel	Low	30	-	-	-	-	-	-	-	0.00	4.0	700	42	70	42	0.3	1	211.20	211.2	44.1
Meadow Creek trib	X-81	10/11/11	46.12259	-113.41927	FCAM	20-26	Sand L	20	Outsloped Unrutted	Native	Low	30	1.0	60	15	47	10	0.3	1	1.96	2.0	40	15	47	10	0.3	1	1.35	3.3	3.3
Brewster Creek	X-16	10/11/11	46.08766	-113.44123	FCAM	20-26	Sand L	40	Outsloped Unrutted	Native	Low	30	6.0	800	16	65	15	0.3	1	69.78	-	-	-	-	-	-	-	0.00	69.8	27.5
unnamed	X-92	10/11/11	46.11030	-113.44905	FCAM	20-26	Sand L	10	Outsloped Rutted	Native	Low	30	7.0	629	13	45	8	0.3	1	107.48	5.0	350	13	45	8	0.3	1	30.21	137.7	27.6
Scotchman Gulch	X-250	10/11/11	46.37957	-113.54624	RBSSNGSM	20-26	Sand L	30	Outsloped Unrutted	Native	Low	30	7.0	402	4	50	10	0.3	1	3.75	8.0	679	4	50	10	0.3	1	6.94	10.7	1.8
Miners Gulch	X-228	10/12/11	46.42228	-113.54019	RBSSNGSM	20-26	Sand L	10	Outsloped Unrutted	Native	Low	30	1.0	39	20	62	27	0.3	1	2.49	0.5	42	20	62	27	0.3	1	2.66	5.2	5.2
Trib to Miners	X-270	10/12/11	46.41455	-113.54243	RBSSNGSM	20-26	Sand L	5	Outsloped Unrutted	Native	Low	30	0.5	6	10	42	6	0.3	1	0.09	0.5	5	10	42	6	0.3	1	0.08	0.2	0.2
unnamed	X-264	10/12/11	46.41131	-113.56084	RBSSNGSM	20-26	Sand L	5	Insloped Bare	Native	Low	30	7.0	330	12	120	2.5	0.3	1	55.05	-	-	-	-	-	0.3	1	0.00	55.1	13.5
Corduroy Creek	X-300	10/12/11	46.51202	-113.50842	RBSSNGSM	20-26	Sand L	30	Outsloped Unrutted	Native	Low	30	0.5	4	10	35	5	0.3	1	0.07	0.5	5	10	35	5	0.3	1	0.08	0.2	0.2
unnamed	X-298	10/12/11	46.51984	-113.53307	RBSSNGSM	>26	Sand L	40	Outsloped Unrutted	Native	Low	30	3.0	80	14	60	22	0.3	1	3.57	7.0	278	14	60	22	0.3	1	20.94	24.5	8.1
Flat Gulch	X-244	10/12/11	46.34762	-113.57588	RBSSNGSM	20-26	Sand L	30	Outsloped Unrutted	Native	Low	30	6.0	49	9	46	5	0.3	1	1.37	9.0	152	9	46	5	0.3	1	6.47	7.8	2.6
Brewster Creek	X-167	10/12/11	46.62303	-113.58331	RBSSNGSM	20-26	Sand L	30	Outsloped Unrutted	Native	Low	30	8.0	240	11	65	6	0.3	1	13.41	1.0	155	11	65	6	0.3	1	3.74	17.2	10.5
Brewster Creek	X-319	10/12/11	46.61457	-113.62405	RBSSNGSM	20-26	Sand L	30	Outsloped Unrutted	Native	Low	30	4.0	210	12	60	6	5	7	3.29	-	-	-	-	-	-	-	0.00	3.3	1.3
Fourth of July Creek	X-306	10/12/11	46.61165	-113.63725	RBSSNGSM	20-26	Sand L	20	Outsloped Unrutted	Native	Low	30	0.5	13	11	45	3.5	0.3	1	0.25	0.5	18	11	45	3.5	0.3	1	0.35	0.6	0.6

Waterbody	Location ID	Segment 1 Installed BMPs		Segment 1 Potential BMPs		Road Crossing and BMP Notes/Comments
		L	R	L	R	
unnamed	X-174	none	none	water bar at 170'	water bar at 135'	RR contributes to d/s end, RL contributes to u/s end, vegetated fill on d/s side
unnamed	X-126	none	none	none	none	road outsloped, recently bladed
unnamed	X-127	rolling dip at 475'	none	rolling dip at 115'	none	well gravel road as BMP for steep slope
unnamed	X-68	-	none	-	none	gravel added to road, road sloping from right to left
Bowles Creek	X-57	-	none	-	water bar at 75'	road closed - administrative use only; sediment from road onto wooden bridge and into channel
Sod Basin Creek	X-56	none	none	none	none	relatively flat road, contribution from bridge deck, not fill slope
unnamed	X-37	none	-	none	none	relatively flat road, contribution from bridge deck, not fill slope
unnamed	X-71	none	none	slash filter	slash filter	dramatically outsloped with recent gravel
unnamed	X-251	-	none	veg to buffer	none	add veg to buffer as BMP on RL
unnamed	X-236	none	none	water bar at 75'	water bar at 85'	
Sluice Gulch	X-A	-	vegetated road bed	-	none	grassy road, no contribution on RL, small bare area on RL
South Fork Antelope Creek	X-B	rolling dip at 195'	rolling dip at 195'	rolling dip at 60'	rolling dip at 100'	streambed aggraded u/s end of culvert 1.5'
South Fork Antelope Creek	X-C	none	none	rolling dip at 45'	rolling dip at 39'	RR delivery u/s of culvert, RL too | vegetated road bed | 2 roads convey from RR
Antelope Creek	X-151	-	none	-	none	small distance from RR, none from RL, no buffer | not a source
unnamed	X-180	-	-	none	none	inputs at u/s end of culvert on R
East Fork trib	X-87	none	-	water bars at 340' and 110'	-	well maintained road, long contributing length, but relatively hardened road
LF trib	X-83	-	none	-	sediment basin at 146'	wide road at sharp curve with headcut on fillslope
Meadow Creek trib	X-81	none	none	none	none	no BMPs since outsloped
Brewster Creek	X-16	cross drain at 800'	-	rolling dip at 315'	-	RL flows past culvert, then contributes on d/s side
unnamed	X-92	none	none	192 bar	146 water bar	rolling dips on road on way to crossing
Scotchman Gulch	X-250	none	none	water bar at 90'	water bar at 90'	vegetated median 50 2x2 | at the ditch relief culvert ditch relief culverts on both sides along cutslope
Miners Gulch	X-228	none	none	none	none	relatively flat slope, pine trees growing on fill
Trib to Miners	X-270	none	none	none	none	little used road with main route
unnamed	X-264	none	-	rolling dip at 130'	-	-
Corduroy Creek	X-300	none	none	none	none	-
unnamed	X-298	none	none	none	rolling dip at 60'	closed road "Admin" hardened gravel surface limits erosion
Flat Gulch	X-244	none	none	none	rolling dip at 29'	ranch access road
Brewster Creek	X-167	none	none	rolling dip at 120'	none	-
Brewster Creek	X-319	berms on side of road	-	water bar at 80'	-	well maintained
Fourth of July Creek	X-306	none	none	none	none	reportedly dusty in summer graded once in spring

ATTACHMENT G2 - UNPAVED ROAD CROSSING PRECIPITATION ANALYSIS

Location ID	PRISM Precipitation Zone (Inches)	Number of Sites Assessed	Mean Annual Load (Tons)	Mean Annual Load with BMPs (Tons)	Potential Reduction in Sediment Load with BMPs (Tons)	Percent Reduction in Sediment Load
X-251	<20		0.0069	0.0069	0.0000	0%
X-A	<20		0.0000	0.0000	0.0000	0%
X-C	<20		0.0020	0.0008	0.0011	57%
X-151	<20		0.0001	0.0001	0.0000	0%
X-180	<20		0.0057	0.0057	0.0000	0%
Mean	**<20**	**5**	**0.0029**	**0.0027**	**0.0002**	**7%**
X-71	20-26		0.0006	0.0006	0.0000	0%
X-236	20-26		0.0154	0.0118	0.0037	24%
X-B	20-26		0.0133	0.0051	0.0081	61%
X-87	20-26		0.0180	0.0024	0.0156	87%
X-83	20-26		0.1056	0.0220	0.0836	79%
X-81	20-26		0.0017	0.0017	0.0000	0%
X-16	20-26		0.0349	0.0137	0.0212	61%
X-92	20-26		0.0688	0.0138	0.0550	80%
X-250	20-26		0.0053	0.0009	0.0045	84%
X-228	20-26		0.0026	0.0026	0.0000	0%
X-270	20-26		0.0001	0.0001	0.0000	0%
X-264	20-26		0.0275	0.0068	0.0208	75%
X-300	20-26		0.0001	0.0001	0.0000	0%
X-244	20-26		0.0039	0.0013	0.0026	67%
X-167	20-26		0.0086	0.0052	0.0034	39%
X-319	20-26		0.0016	0.0006	0.0010	62%
X-306	20-26		0.0003	0.0003	0.0000	0%
Mean	**20-26**	**17**	**0.0181**	**0.0052**	**0.0129**	**71%**
X-174	>26		0.0053	0.0016	0.0037	69%
X-126	>26		0.0083	0.0083	0.0000	0%
X-127	>26		0.0086	0.0029	0.0058	67%
X-68	>26		0.0006	0.0006	0.0000	0%
X-57	>26		0.0000	0.0000	0.0000	56%
X-56	>26		0.0000	0.0000	0.0000	0%
X-37	>26		0.0027	0.0027	0.0000	0%
X-298	>26		0.0123	0.0040	0.0082	67%
Mean	**>26**	**8**	**0.0047**	**0.0025**	**0.0022**	**47%**

ATTACHMENT G3 - UNPAVED ROAD CROSSING SUBWATERSHED SEDIMENT LOADS

Subwatershed	Jurisdiction	PRISM Precipitation Zone (Inches)	Number of Crossings Identified in GIS	Corrected Number of Crossings based on Field Data	MEAN ANNUAL LOAD per CROSSING (Tons)	MEAN ANNUAL LOAD per CROSSING with BMPs (Tons)	MEAN ANNUAL LOAD (Tons)	MEAN ANNUAL LOAD with BMPs (Tons)	Percent Reduction
West Fork Rock Creek Headwaters	USFS	>26	6	4	0.0047	0.0025	0.021	0.011	**47%**
			6[1]	4[1]			0.021[1]	0.011[1]	**47%[1]**
West Fork Rock Creek Headwaters	Private	>26	6	4	0.0047	0.0025	0.021	0.011	**47%**
			6[1]	4[1]			0.021[1]	0.011[1]	**47%[1]**
West Fork Rock Creek Headwaters			**12[2]**	**9[2]**			**0.042[2]**	**0.022[2]**	**47%[2]**
Upper West Fork Rock Creek	USFS	>26	18	13	0.0047	0.0025	0.062	0.033	**47%**
			18[1]	13[1]			0.062[1]	0.033[1]	**47%[1]**
Upper West Fork Rock Creek	Private	>26	7	5	0.0047	0.0025	0.024	0.013	**47%**
			7[1]	5[1]			0.024[1]	0.013[1]	**47%[1]**
Upper West Fork Rock Creek			**25[2]**	**18[2]**			**0.087[2]**	**0.046[2]**	**47%[2]**
Middle West Fork Rock Creek	USFS	>26	8	6	0.0047	0.0025	0.028	0.015	**47%**
			8[1]	6[1]			0.028[1]	0.015[1]	**47%[1]**
Middle West Fork Rock Creek	State	>26	9	7	0.0047	0.0025	0.031	0.017	**47%**
			9[1]	7[1]			0.031[1]	0.017[1]	**47%[1]**
Middle West Fork Rock Creek	Private	>26	1	1	0.0047	0.0025	0.003	0.002	**47%**
			1[1]	1[1]			0.003[1]	0.002[1]	**47%[1]**
Middle West Fork Rock Creek			**18[2]**	**13[2]**			**0.062[2]**	**0.033[2]**	**47%[2]**
Lower West Fork Rock Creek	USFS	<20	4	3	0.0029	0.0027	0.009	0.008	**7%**
Lower West Fork Rock Creek	USFS	20-26	16	12	0.0181	0.0052	0.212	0.061	**71%**
Lower West Fork Rock Creek	USFS	>26	2	1	0.0047	0.0025	0.007	0.004	**47%**
			22[1]	16[1]			0.228[1]	0.073[1]	**68%[1]**
Lower West Fork Rock Creek	State	<20	5	4	0.0029	0.0027	0.011	0.010	**7%**
Lower West Fork Rock Creek	State	20-26	2	1	0.0181	0.0052	0.027	0.008	**71%**
			7[1]	5[1]			0.037[1]	0.018[1]	**53%[1]**
Lower West Fork Rock Creek	Private	<20	6	4	0.0029	0.0027	0.013	0.012	**7%**
Lower West Fork Rock Creek	Private	20-26	24	18	0.0181	0.0052	0.318	0.092	**71%**
			30[1]	22[1]			0.331[1]	0.104[1]	**69%[1]**
Lower West Fork Rock Creek			**59[2]**	**43[2]**			**0.597[2]**	**0.194[2]**	**67%[2]**
West Fork Rock Creek Total			**114[3]**	**83[3]**			**0.787[3]**	**0.296[3]**	**62%[3]**
Meadow Creek	USFS	20-26	14	10	0.0181	0.0052	0.186	0.054	**71%**
Meadow Creek	USFS	>26	12	9	0.0047	0.0025	0.042	0.022	**47%**
			26[1]	19[1]			0.227[1]	0.076[1]	**67%[1]**
Meadow Creek	Private	>26	4	3	0.0047	0.0025	0.014	0.007	**47%**
			4[1]	3[1]			0.014[1]	0.007[1]	**47%[1]**
Meadow Creek			**30[2]**	**22[2]**			**0.241[2]**	**0.083[2]**	**66%[2]**
East Fork Rock Creek	USFS	20-26	1	1	0.0181	0.0052	0.013	0.004	**71%**
East Fork Rock Creek	USFS	>26	1	1	0.0047	0.0025	0.003	0.002	**47%**
			2[1]	1[1]			0.017[1]	0.006[1]	**66%[1]**
East Fork Rock Creek	State	<20	1	1	0.0029	0.0027	0.002	0.002	**7%**
			1[1]	1[1]			0.002[1]	0.002[1]	**7%[1]**
East Fork Rock Creek	County	<20	1	1	0.0029	0.0027	0.002	0.002	**7%**
East Fork Rock Creek	County	20-26	4	3	0.0181	0.0052	0.053	0.015	**71%**
			5[1]	4[1]			0.055[1]	0.017[1]	**69%[1]**
East Fork Rock Creek	Private	<20	6	4	0.0029	0.0027	0.013	0.012	**7%**
East Fork Rock Creek	Private	20-26	16	12	0.0181	0.0052	0.212	0.061	**71%**
			22[1]	16[1]			0.225[1]	0.073[1]	**67%[1]**
East Fork Rock Creek			**30[2]**	**22[2]**			**0.299[2]**	**0.098[2]**	**67%[2]**
East Fork Rock Creek Total			**60[3]**	**44[3]**			**0.541[3]**	**0.181[3]**	**66%[3]**
Upper Willow Creek Headwaters	USFS	20-26	5	4	0.0181	0.0052	0.066	0.019	**71%**
Upper Willow Creek Headwaters	USFS	>26	7	5	0.0047	0.0025	0.024	0.013	**47%**
			12[1]	9[1]			0.091[1]	0.032[1]	**65%[1]**
Upper Willow Creek Headwaters	Private	>26	3	2	0.0047	0.0025	0.010	0.006	**47%**

Subwatershed	Jurisdiction	PRISM Precipitation Zone (Inches)	Number of Crossings Identified in GIS	Corrected Number of Crossings based on Field Data	MEAN ANNUAL LOAD per CROSSING (Tons)	MEAN ANNUAL LOAD per CROSSING with BMPs (Tons)	MEAN ANNUAL LOAD (Tons)	MEAN ANNUAL LOAD with BMPs (Tons)	Percent Reduction
			3[1]	2[1]			0.010[1]	0.006[1]	47%[1]
Upper Willow Creek Headwaters			**15[2]**	**11[2]**			**0.101[2]**	**0.038[2]**	**63%[2]**
Upper Upper Willow Creek	USFS	<20	3	2	0.0029	0.0027	0.006	0.006	7%
Upper Upper Willow Creek	USFS	20-26	15	11	0.0181	0.0052	0.199	0.057	71%
			18[1]	13[1]			0.206[1]	0.063[1]	69%[1]
Upper Upper Willow Creek	County	<20	1	1	0.0029	0.0027	0.002	0.002	7%
Upper Upper Willow Creek	County	20-26	2	1	0.0181	0.0052	0.027	0.008	71%
			3[1]	2[1]			0.029[1]	0.010[1]	66%[1]
Upper Upper Willow Creek	Private	20-26	9	7	0.0181	0.0052	0.119	0.034	71%
			9[1]	7[1]			0.119[1]	0.034[1]	71%[1]
Upper Upper Willow Creek			**30[2]**	**22[2]**			**0.354[2]**	**0.107[2]**	**70%[2]**
Middle Upper Willow Creek	USFS	<20	3	2	0.0029	0.0027	0.006	0.006	7%
			3[1]	2[1]			0.006[1]	0.006[1]	7%[1]
Middle Upper Willow Creek	County	<20	9	7	0.0029	0.0027	0.019	0.018	7%
			9[1]	7[1]			0.019[1]	0.018[1]	7%[1]
Middle Upper Willow Creek	Private	<20	4	3	0.0029	0.0027	0.009	0.008	7%
			4[1]	3[1]			0.009[1]	0.008[1]	7%[1]
Middle Upper Willow Creek			**16[2]**	**12[2]**			**0.035[2]**	**0.032[2]**	**7%[2]**
Lower Upper Willow Creek	County	<20	5	4	0.0029	0.0027	0.011	0.010	7%
Lower Upper Willow Creek	County	20-26	2	1	0.0181	0.0052	0.027	0.008	71%
			7[1]	5[1]			0.037[1]	0.018[1]	53%[1]
Lower Upper Willow Creek	Private	<20	16	12	0.0029	0.0027	0.035	0.032	7%
Lower Upper Willow Creek	Private	20-26	4	3	0.0181	0.0052	0.053	0.015	71%
			20[1]	15[1]			0.088[1]	0.047[1]	46%[1]
Lower Upper Willow Creek			**27[2]**	**20[2]**			**0.125[2]**	**0.065[2]**	**48%[2]**
Miners Gulch	USFS	<20	6	4	0.0029	0.0027	0.013	0.012	7%
Miners Gulch	USFS	20-26	10	7	0.0181	0.0052	0.133	0.038	71%
			16[1]	12[1]			0.146[1]	0.050[1]	65%[1]
Miners Gulch	Private	20-26	4	3	0.0181	0.0052	0.053	0.015	71%
			4[1]	3[1]			0.053[1]	0.015[1]	71%[1]
Miners Gulch			**20[2]**	**15[2]**			**0.199[2]**	**0.066[2]**	**67%[2]**
Scotchman Gulch	County	<20	1	1	0.0029	0.0027	0.002	0.002	7%
Scotchman Gulch	County	20-26	1	1	0.0181	0.0052	0.013	0.004	71%
			2[1]	1[1]			0.015[1]	0.006[1]	62%[1]
Scotchman Gulch			**2[2]**	**1[2]**			**0.015[2]**	**0.006[2]**	**62%[2]**
Upper Willow Creek Total			**110[3]**	**80[3]**			**0.828[3]**	**0.313[3]**	**62%[3]**
Antelope Creek (Rock Mallard)	Private	<20	8	6	0.0029	0.0027	0.017	0.016	7%
Antelope Creek (Rock Mallard)	Private	20-26	4	3	0.0181	0.0052	0.053	0.015	71%
			12[1]	9[1]			0.070[1]	0.031[1]	56%[1]
Antelope Creek (Rock Mallard)			**12[2]**	**9[2]**			**0.070[2]**	**0.031[2]**	**56%[2]**
South Fork Antelope Creek	Private	<20	1	1	0.0029	0.0027	0.003	0.003	7%
South Fork Antelope Creek	Private	20-26	1	1	0.0181	0.0052	0.018	0.005	71%
			2[1]	2[1]			0.021[1]	0.008[1]	62%[1]
South Fork Antelope Creek			**2[2]**	**2[2]**			**0.021[2]**	**0.008[2]**	**62%[2]**
Antelope Creek Total			**14[3]**	**11[3]**			**0.091[3]**	**0.039[3]**	**57%[3]**
Quartz Gulch	Private	20-26	1	1	0.0181	0.0052	0.013	0.004	71%
			1[1]	1[1]			0.013[1]	0.004[1]	71%[1]
Quartz Gulch			**1[2]**	**1[2]**			**0.013[2]**	**0.004[2]**	**71%[2]**

Subwatershed	Jurisdiction	PRISM Precipitation Zone (Inches)	Number of Crossings Identified in GIS	Corrected Number of Crossings based on Field Data	MEAN ANNUAL LOAD per CROSSING (Tons)	MEAN ANNUAL LOAD per CROSSING with BMPs (Tons)	MEAN ANNUAL LOAD (Tons)	MEAN ANNUAL LOAD with BMPs (Tons)	Percent Reduction
Basin Gulch	Private	<20	1	1	0.0029	0.0027	0.002	0.002	**7%**
			1[1]	1[1]			0.002[1]	0.002[1]	**7%[1]**
Basin Gulch			**1[2]**	**1[2]**			**0.002[2]**	**0.002[2]**	**7%[2]**
Eureka Gulch	County	<20	1	1	0.0029	0.0027	0.002	0.002	**7%**
			1[1]	1[1]			0.002[1]	0.002[1]	**7%[1]**
Eureka Gulch	Private	<20	1	1	0.0029	0.0027	0.002	0.002	**7%**
			1[1]	1[1]			0.002[1]	0.002[1]	**7%[1]**
Eureka Gulch			**2[2]**	**1[2]**			**0.004[2]**	**0.004[2]**	**7%[2]**
Eureka Gulch Total			**4[3]**	**3[3]**			**0.020[3]**	**0.010[3]**	**50%[3]**
Brewster Creek	USFS	20-26	11	8	0.0181	0.0052	0.146	0.042	**71%**
Brewster Creek	USFS	>26	12	9	0.0047	0.0025	0.042	0.022	**47%**
			23[1]	17[1]			0.188[1]	0.064[1]	**66%[1]**
Brewster Creek	County	<20	1	1	0.0029	0.0027	0.002	0.002	**7%**
			1[1]	1[1]			0.002[1]	0.002[1]	**7%[1]**
Brewster Creek	Private	20-26	3	2	0.0181	0.0052	0.040	0.011	**71%**
Brewster Creek	Private	>26	2	1	0.0047	0.0025	0.007	0.004	**47%**
			5[1]	4[1]			0.047[1]	0.015[1]	**68%[1]**
Brewster Creek Total			**29[2]**	**21[2]**			**0.236[2]**	**0.081[2]**	**66%[2]**
Flat Gulch	Private	20-26	4	3	0.0181	0.0052	0.053	0.015	**71%**
			4[1]	3[1]			0.053[1]	0.015[1]	**71%[1]**
Flat Gulch Total			**4[2]**	**3[2]**			**0.053[2]**	**0.015[2]**	**71%[2]**
Sluice Gulch	Private	20-26	6	4	0.0181	0.0052	0.080	0.023	**71%**
			6[1]	4[1]			0.080[1]	0.023[1]	**71%[1]**
Sluice Gulch Total			**6[2]**	**4[2]**			**0.080[2]**	**0.023[2]**	**71%[2]**
Rock TPA Total			**341**	**250**			**2.636**	**0.959**	**64%**

Meaning of colors in the table

1	**Subtotal for each subwatershed by land ownership**
2	**Total for all land ownerships**
3	**Total for all of the subwatersheds**

ATTACHMENT G4 - CULVERT FAILURE ANALYSIS

Location ID	Structure Type	Culvert Dimensions	Culvert Slope	Bankfull Width	Q2	Q5	Q10	Q25	Q50	Q100	Estimated Maximum Capacity at Cross Section	Headwater Height (Fill Height)	Field Measured Fill Width	Modeled Fill Width*	Fill Length	Fill Volume*	Fill Volume*	Potential Sediment Load if Culvert Fails*
		(ft)	(%)	(ft)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft³)	(CY)	(tons)
X-174	CMP	3	5	5	7	14	19	28	36	43	112	4.5	34	5	35	787.5	29	48
X-126	CMP	2	9	5	7	14	19	28	36	43	26	4	34	5	55	1100	41	68
X-127	CMP	1.5	16	4	4	9	13	19	24	30	13	3	31	4	32	384	14	24
X-68	Squash CMP	3.3 span 2.3 rise	2	8	17	32	45	63	79	94	51	4	14	8	30	960	36	59
X-37	CMP	1.5	1	7	13	25	35	50	63	76	12	4	30	7	28	784	29	48
X-71	Squash CMP	6 span 2.66 rise	6	12	39	69	92	126	156	185	149	5.5	30	12	30	1980	73	122
X-251	Cement Pipe	2.3	2	4	4	9	13	19	24	30	100	7	40	4	30	840	31	52
X-236	CMP	1.25	5	4.5	6	11	16	23	30	36	9	4	35	4.5	30	540	20	33
X-B	CMP	3	9	4	4	9	13	19	24	30	124	15	70	4	40	2400	89	148
X-C	CMP	2	2	15	60	104	138	184	227	268	27	5	25	15	24	1800	67	111
X-151	Smooth Pipe	1.66	5	11	32	59	79	108	135	160	16	3.5	17	11	10	385	14	24
X-180	CMP	2	8	4.5	6	11	16	23	30	36	49	15	60	4.5	30	2025	75	125
X-87	Squash CMP	4.58 span 2.91 rise	3	13	45	80	107	144	179	211	177	4	30	13	25	1300	48	80
X-83	Squash CMP	4 rise 3 span	5	6	10	19	27	38	48	59	53	2.91	154	6	367	6407.82	237	394
X-81	CMP	3	4	11	32	59	79	108	135	160	61	5	35	11	47	2585	96	159
X-16	CMP	4.5	5	6	10	19	27	38	48	59	179	8	42	6	25	1200	44	74
X-92	CMP	2.5	8	5	7	14	19	28	36	43	51	6	34	5	30	900	33	55
X-250	CMP	3.5	1.5	4	4	9	13	19	24	30	95	7	36	4	30	840	31	52
X-228	CMP	4	5	6	10	19	27	38	48	59	146	8	46	6	45	2160	80	133
X-270	CMP	1.5	8	2.5	2	4	6	8	11	14	11	2.5	24	2.5	15	93.75	3	6
X-264	CMP	1.5	2	3.5	3	7	10	15	19	24	6	1.5	22	3.5	19	99.75	4	6
X-300	Squash CMP	3.5 span 2.5 rise	0.5	5	7	14	19	28	36	43	40	3	21	5	11	165	6	10
X-298	CMP	3	5	5	7	14	19	28	36	43	115	16	81	5	104	8320	308	512
X-244	Squash CMP	1.5 span 1 rise	4	8	17	32	45	63	79	94	8	2	19	8	11	176	7	11
X-167	CMP	3	2.5	6	10	19	27	38	48	59	54	4.5	26	6	20	540	20	33
X-319	Squash CMP	6 span 4 rise	7	11	32	59	79	108	135	160	107	3.5	28	11	18	693	26	43
X-306	Squash CMP	1.5	4	5	7	14	19	28	36	43	9	2	21	5	12	120	4	7

*Assuming a fill width equal to the bankfull width

culvert fails to pass discharge

ATTACHMENT G5 - FISH PASSAGE ASSESSMENT

Location ID	Structure Type	Evaluation Method	Culvert Dimensions (ft)	Width (ft)	Culvert Slope (%)	Bankfull Width (ft)	Culvert/ Bankfull Ratio	Outlet Perch (inches)	Final Classification (# of failures)
X-174	CMP	3	3	3	5[2]	5	0.60[3]	0[1]	1[2]
X-126	CMP	3	2	2	9[2]	5	0.40[2]	6[2]	3[2]
X-127	CMP	3	1.5	1.5	16[2]	4	0.38[2]	0[1]	2[2]
X-68	Squash CMP	3	2.3	3.3	2[2]	8	0.41[2]	0[1]	2[2]
X-37	CMP	3	1.5	1.5	1[3]	7	0.21[2]	0[1]	1[2]
X-71	Squash CMP	3	2.66	6	6[2]	12	0.50[3]	0[1]	1[2]
X-251	Cement Pipe	3	2.3	2.3	2[2]	4	0.58[3]	0[1]	1[2]
X-236	CMP	3	1.25	1.25	5[2]	4.5	0.28[2]	0[1]	2[2]
X-B	CMP	3	3	3	9[2]	4	0.75[3]	8[2]	2[2]
X-C	CMP	3	2	2	2[2]	15	0.13[2]	1[3]	2[2]
X-151	Smooth Pipe	3	1.66	1.66	5[2]	11	0.15[2]	1[3]	2[2]
X-180	CMP	3	2	2	8[2]	4.5	0.44[2]	2.5[3]	2[2]
X-87	Squash CMP	3	2.91	4.58	3[2]	13	0.35[2]	0[1]	2[2]
X-83	Squash CMP	3	4	4	5[2]	6	0.67[3]	0[1]	1[2]
X-81	CMP	3	3	3	4[2]	11	0.27[2]	6[2]	3[2]
X-16	CMP	4	4.5	4.5	5[2]	6	0.75[3]	0[1]	1[2]
X-92	CMP	3	2.5	2.5	8[2]	5	0.50[3]	6[2]	2[2]
X-250	CMP	3	3.5	3.5	1.5[2]	4	0.88[1]	0[1]	1[2]
X-228	CMP	3	4	4	5[2]	6	0.67[3]	12[2]	2[2]
X-270	CMP	3	1.5	1.5	8[2]	2.5	0.60[3]	0[1]	1[2]
X-264	CMP	3	1.5	1.5	2[2]	3.5	0.43[2]	6[2]	3[2]
X-300	Squash CMP	3	2.5	3.5	0.5[3]	5	0.70[3]	0[1]	0[3]
X-298	CMP	3	3	3	5[2]	5	0.60[3]	0[1]	1[2]
X-244	Squash CMP	3	1	1.5	4[2]	8	0.19[2]	0[1]	2[2]
X-167	CMP	3	3	3	2.5[2]	6	0.50[3]	0[1]	1[2]
X-319	Squash CMP	3	4	6	7[2]	11	0.55[3]	0[1]	1[2]
X-306	Squash CMP	3	1.5	1.5	4[2]	5	0.30[2]	0[1]	2[2]

Note: Evaluation Method based on Table:1 Fish Passage Evaluation Criteria located in *A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska*

1 (green)	conditions that have a high certainty of meeting juvenile fish passage at all desired stream flows	
2 (red)	conditions that have a high certainty of <u>not</u> providing juvenile fish passage at all desired stream flows	
3 (gray)	conditions are such that additional and more detailed analysis is required to determine their juvenile fish passage ability	

APPENDIX H – SEDIMENT TOTAL MAXIMUM DAILY LOADS

H1.0 OVERVIEW

In this appendix the TMDL is expressed using daily loads to satisfy an additional EPA required TMDL element. Daily loads should not be considered absolute limits for a given day and may be refined in the future as part of the adaptive management process. The TMDLs may not be feasible at all locations within the watershed but if the allocations are followed, pollutant loads are expected to be reduced to a degree that the targets are met and beneficial uses are no longer impaired. It is not expected that daily loads will drive implementation activities.

H2.0 SEDIMENT DAILY LOAD APPROACH

The preferred approach for calculating daily sediment loads is to use a nearby water quality gage with a long-term dataset for flow and suspended sediment. Within the Rock Creek watershed, there are only two long-term gage stations: Middle Fork Rock Creek near Philipsburg MT (12332000) and Rock creek near Clinton MT (12334510). Neither of these gage stations have a continuous daily record of suspended sediment data.

Although no continuous suspended sediment data is associated with these gages, the average daily hydrograph can be used to infer an estimated daily sediment load. A daily sediment load was determined using the means of daily mean values for discharge in cfs per day from the USGS gage station on Middle Fork Rock Creek (12332000). This USGS station was selected to represent the daily variability in flows because it is located on a tributary to Rock Creek and the TMDLs in this document are all tributary streams. It is assumed in this representation that the sediment loads will generally follow the hydrograph, as increased flows often reflect increased runoff that carries sediment from upland erosion and is more likely to influence bank erosion. Therefore, the percentage of the mean of daily mean value for discharge, in relation to the sum of the mean of daily mean discharge values can be derived and applied to the sediment loads for a watershed of interest.

The mean of daily mean values for discharge, in cfs, was calculated based on approximately 75 years of record (October 1, 1937 – September 30, 2012) from the Middle Fork Rock Creek USGS station (**Table H-1**). **Figure H-1** visually represents the average daily percentage of the total yearly discharge for each day of the calendar year.

To conserve resources, this appendix only provides the base data from the USGS stream gage, and the daily percentages of the total annual load. For specific streams, all daily TMDLs may be derived by using the daily percentages in **Table H-2** and the TMDLs expressed as an average annual load, which are discussed in **Section 5.7**. For example, the total allowable annual sediment load for East Fork Rock Creek was estimated to be 1,559 tons per year. To determine the TMDL for East Fork Rock Creek on January 1, this value is multiplied by 0.074% which provides a daily load of 1.15 tons.

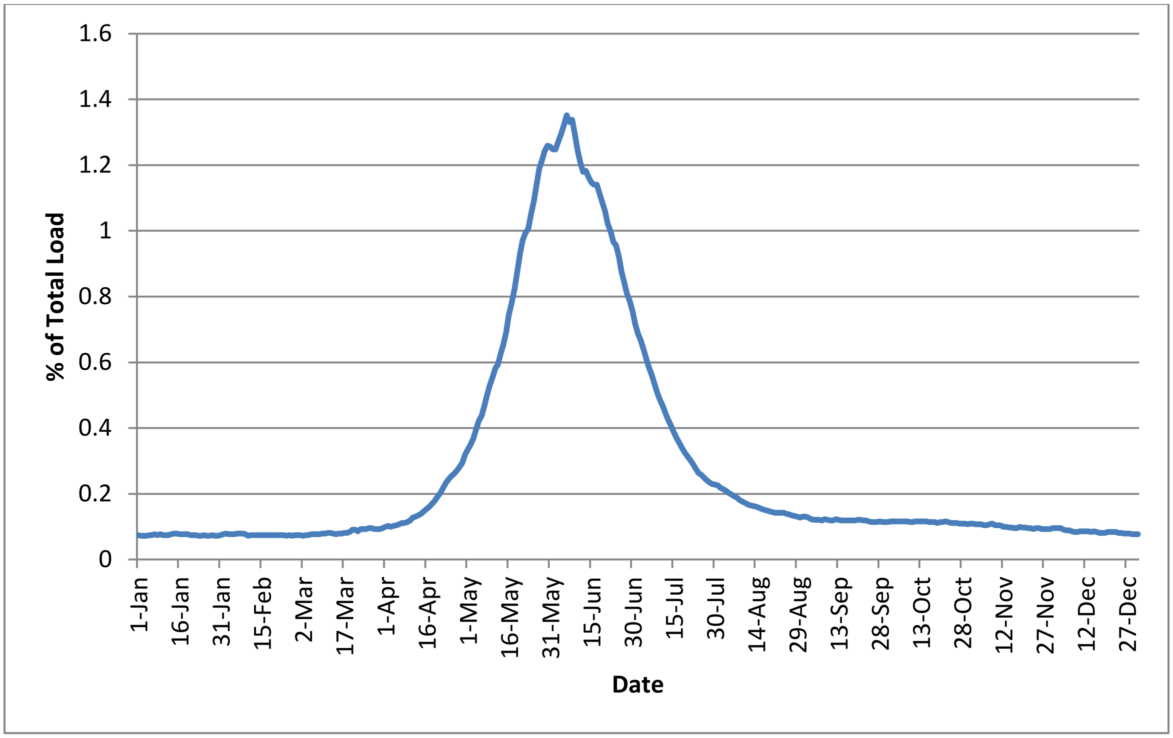


Figure H-1. Average daily percentage of the total mean yearly discharge

Figure H-1 illustrates the shape of the average hydrograph for the Middle Fork Rock Creek, driven by climate and precipitation, and typical of many western Montana streams. In general, it appears that flows (and thereby increased sediment loads) increase in the late spring as winter snowpack in the high elevations melts and drains to the waterways below. Peak flows typically occur in the month of May, followed by a declining hydrograph into August where flows near baseflow levels.

The approach outlined above provides a simple approximation for a reasonable portioning of the total annual load among days throughout the year. It is acknowledged that a direct linear relationship between sediment load and the hydrograph may not exist. Sediment loading is frequently episodic and dependent on many differing physical, climatological, and anthropogenic factors. However, the approach for daily loads in this context does provide us with insight into those times of the year where sediment loading is most likely to occur, and thereby gives us a guide for assessment and management of sediment loading in the watershed.

Table H-1. Mean of daily mean discharge values for each day for 74 - 75 years of record in, cfs (Calculation Period 1937-10-01 -> 2012-09-30)

Day of Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	32	33	32	43	144	536	308	94	56	49	47	41
2	31	34	31	44	150	536	295	92	55	50	46	41
3	31	33	32	43	158	547	287	90	53	50	46	41
4	31	33	32	44	169	557	275	87	52	50	46	39
5	32	33	33	45	181	568	262	85	52	50	45	38
6	32	34	33	46	188	581	251	83	52	50	45	38
7	33	34	33	48	200	572	241	81	51	50	46	37
8	32	34	33	48	215	575	230	78	53	50	47	36
9	33	33	34	49	227	557	218	76	52	49	45	36
10	32	31	34	51	238	535	209	74	51	49	45	37
11	32	32	35	55	250	518	201	72	51	50	45	37
12	32	32	35	56	255	507	191	71	53	50	43	37
13	33	32	34	58	270	508	183	70	52	50	43	37
14	34	32	33	60	281	500	175	69	51	50	42	36
15	34	32	34	63	298	493	167	68	51	50	42	37
16	33	32	34	66	320	490	159	66	51	49	41	36
17	33	32	35	69	336	490	153	65	51	49	41	35
18	33	32	35	73	354	478	146	64	51	49	43	35
19	33	32	36	77	375	467	140	63	51	48	42	35
20	32	32	39	82	400	455	135	62	52	49	42	36
21	32	32	39	87	417	439	130	61	52	49	41	36
22	32	32	37	94	427	429	125	61	51	50	41	36
23	31	32	40	100	433	415	119	61	51	49	40	36
24	31	31	40	105	451	411	113	61	50	48	41	35
25	32	32	40	109	468	396	111	60	49	48	41	35
26	31	31	41	112	488	377	107	59	49	48	40	34
27	31	32	41	116	511	362	104	58	49	47	40	34
28	32	32	40	121	521	348	101	57	50	47	40	34
29	31	34	40	127	534	338	99	56	49	47	40	33
30	31		40	137	541	324	98	55	49	46	41	33
31	32		41		540		97	56		47		33

Table H-2. Percentage of mean of daily mean discharge values per day based on the sum of all mean of daily mean discharge values

Day of Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.074	0.077	0.074	0.100	0.335	1.247	0.717	0.219	0.130	0.114	0.109	0.095
2	0.072	0.079	0.072	0.102	0.349	1.247	0.686	0.214	0.128	0.116	0.107	0.095
3	0.072	0.077	0.074	0.100	0.368	1.273	0.668	0.209	0.123	0.116	0.107	0.095
4	0.072	0.077	0.074	0.102	0.393	1.296	0.640	0.202	0.121	0.116	0.107	0.091
5	0.074	0.077	0.077	0.105	0.421	1.322	0.610	0.198	0.121	0.116	0.105	0.088
6	0.074	0.079	0.077	0.107	0.437	1.352	0.584	0.193	0.121	0.116	0.105	0.088
7	0.077	0.079	0.077	0.112	0.465	1.331	0.561	0.188	0.119	0.116	0.107	0.086
8	0.074	0.079	0.077	0.112	0.500	1.338	0.535	0.181	0.123	0.116	0.109	0.084
9	0.077	0.077	0.079	0.114	0.528	1.296	0.507	0.177	0.121	0.114	0.105	0.084
10	0.074	0.072	0.079	0.119	0.554	1.245	0.486	0.172	0.119	0.114	0.105	0.086
11	0.074	0.074	0.081	0.128	0.582	1.205	0.468	0.168	0.119	0.116	0.105	0.086
12	0.074	0.074	0.081	0.130	0.593	1.180	0.444	0.165	0.123	0.116	0.100	0.086
13	0.077	0.074	0.079	0.135	0.628	1.182	0.426	0.163	0.121	0.116	0.100	0.086
14	0.079	0.074	0.077	0.140	0.654	1.163	0.407	0.161	0.119	0.116	0.098	0.084
15	0.079	0.074	0.079	0.147	0.693	1.147	0.389	0.158	0.119	0.116	0.098	0.086
16	0.077	0.074	0.079	0.154	0.745	1.140	0.370	0.154	0.119	0.114	0.095	0.084
17	0.077	0.074	0.081	0.161	0.782	1.140	0.356	0.151	0.119	0.114	0.095	0.081
18	0.077	0.074	0.081	0.170	0.824	1.112	0.340	0.149	0.119	0.114	0.100	0.081
19	0.077	0.074	0.084	0.179	0.872	1.087	0.326	0.147	0.119	0.112	0.098	0.081
20	0.074	0.074	0.091	0.191	0.931	1.059	0.314	0.144	0.121	0.114	0.098	0.084
21	0.074	0.074	0.091	0.202	0.970	1.021	0.302	0.142	0.121	0.114	0.095	0.084
22	0.074	0.074	0.086	0.219	0.993	0.998	0.291	0.142	0.119	0.116	0.095	0.084
23	0.072	0.074	0.093	0.233	1.007	0.966	0.277	0.142	0.119	0.114	0.093	0.084
24	0.072	0.072	0.093	0.244	1.049	0.956	0.263	0.142	0.116	0.112	0.095	0.081
25	0.074	0.074	0.093	0.254	1.089	0.921	0.258	0.140	0.114	0.112	0.095	0.081
26	0.072	0.072	0.095	0.261	1.135	0.877	0.249	0.137	0.114	0.112	0.093	0.079
27	0.072	0.074	0.095	0.270	1.189	0.842	0.242	0.135	0.114	0.109	0.093	0.079
28	0.074	0.074	0.093	0.282	1.212	0.810	0.235	0.133	0.116	0.109	0.093	0.079
29	0.072	0.079	0.093	0.295	1.242	0.786	0.230	0.130	0.114	0.109	0.093	0.077
30	0.072	0.000	0.093	0.319	1.259	0.754	0.228	0.128	0.114	0.107	0.095	0.077
31	0.074	0.000	0.095	0.000	1.256	0.000	0.226	0.130	0.000	0.109	0.000	0.077

Appendix I – East Fork Rock Creek Temperature Modeling Report

Appendix I is based on a report prepared for the DEQ by Tetra Tech, October 2012.

Table of Contents

TABLES

FIGURES

Acronyms and Abbreviations

DNRC	Montana Department of Natural Resources and Conservation
DEQ	Montana Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
MRLC	Multi-Resolution Land Characteristics Consortium
NLCD	National Land Cover Dataset
QUAL2K	River and Stream Water Quality Model
TMDL	total maximum daily load
TPA	TMDL Planning Area
WET	Water & Environmental Technologies, PC
WRCC	Western Regional Climate Center

UNITS OF MEASURE

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

EXECUTIVE SUMMARY

East Fork Rock Creek is in the Rocky Mountains of western Montana, is impaired by elevated water temperatures, and is on Montana's Clean Water Act section 303(d) list. A QUAL2K model was developed to evaluate the instream water temperature response to various model scenarios. The existing conditions scenario was evaluated with existing conditions, low-flow conditions, increased shading, and attaining a 15% water savings from improved irrigation delivery and application efficiencies; and allowing that conserved water to flow down East Fork Rock Creek downstream from the point of the diversion of the East Fork Rock Creek. These model scenarios were evaluated to assess a potential worst-case scenario.

Low-flow conditions scenarios resulted in slightly increased daily maximum and mean temperatures as compared to the existing condition scenario. Increasing to full potential shade resulted in cooler instream water temperatures than both the existing condition and low-flow condition scenarios. Increasing the instream discharge also resulted in cooler temperatures in East Fork Rock Creek.

I1.0 BACKGROUND

This section of the document presents background information including a brief description of the study reach, the applicable water quality standards, and project history. Note that the temperature standards in Montana are in degrees Fahrenheit (°F), and thus, are reported in °F in this section.

I1.1 PROBLEM STATEMENT

East Fork Rock Creek is classified as a B-1 stream. The lower 9.74 miles (MT76E002_020) is partially supporting its Aquatic Life and Primary Contact Recreation designated uses (Montana Department of Environmental Quality, 2012). Six potential causes of impairment have been identified, including water temperature, the subject of this document (Montana Department of Environmental Quality, 2012). DEQ found that, "water temperatures are elevated above the peak growth rate for bull trout during the summer months and [elevated temperatures are] most likely limiting the fishery" (Montana Department of Environmental Quality, 2012, p. 16).

I1.2 MONTANA TEMPERATURE STANDARD

For a waterbody with a use classification of B-1, the following temperature criteria apply:[1] A 1 °F maximum increase above naturally occurring water temperature is allowed within the range of 32 °F to 66 °F; within the naturally occurring range of 66 °F to 66.5 °F, no discharge is allowed [that] will cause the water temperature to exceed 67 °F; and where the naturally occurring water temperature is 66.5 °F or greater, the maximum allowable increase in water temperature is 0.5 °F. A 2 °F per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55 °F. A 2 °F maximum decrease below naturally occurring water temperature is allowed within the range of 55 °F to 32 °F.

The model results will ultimately be compared to these criteria.

[1] ARM 17.30.623(2)(e).

I1.3 Project History

Temperature and flow data were collected in the East Fork Rock Creek in 2010 by DEQ. Water & Environmental Technologies, PC (WET), under contract with DEQ, prepared a Quality Assurance Project Plan for temperature monitoring and modeling in the Rock Creek TMDL Planning Area in 2011. A field team from WET and DEQ collected data on August 1, 25, 30, and 31 in 2011 to characterize meteorology (i.e., air temperature, dew point, wind speed, and cloud cover), channel geometry, flow, and shade in support of the modeling effort. Tetra Tech was contracted by EPA in February 2012 to develop the QUAL2K temperature model using the data and information compiled by WET and DEQ.

I1.4 Study Area

East Fork Rock Creek is in the Rocky Mountains of western Montana and is part of the Rock Creek TMDL Planning Area (**Figure I-1**). The East Fork Rock Creek watershed is a 12-digit HUC (17010202 07 03) and is in the Flint-Rock 8-digit HUC (17010202). The impaired segment is 9.74 miles long and extends from the outlet of East Fork Reservoir to the mouth.

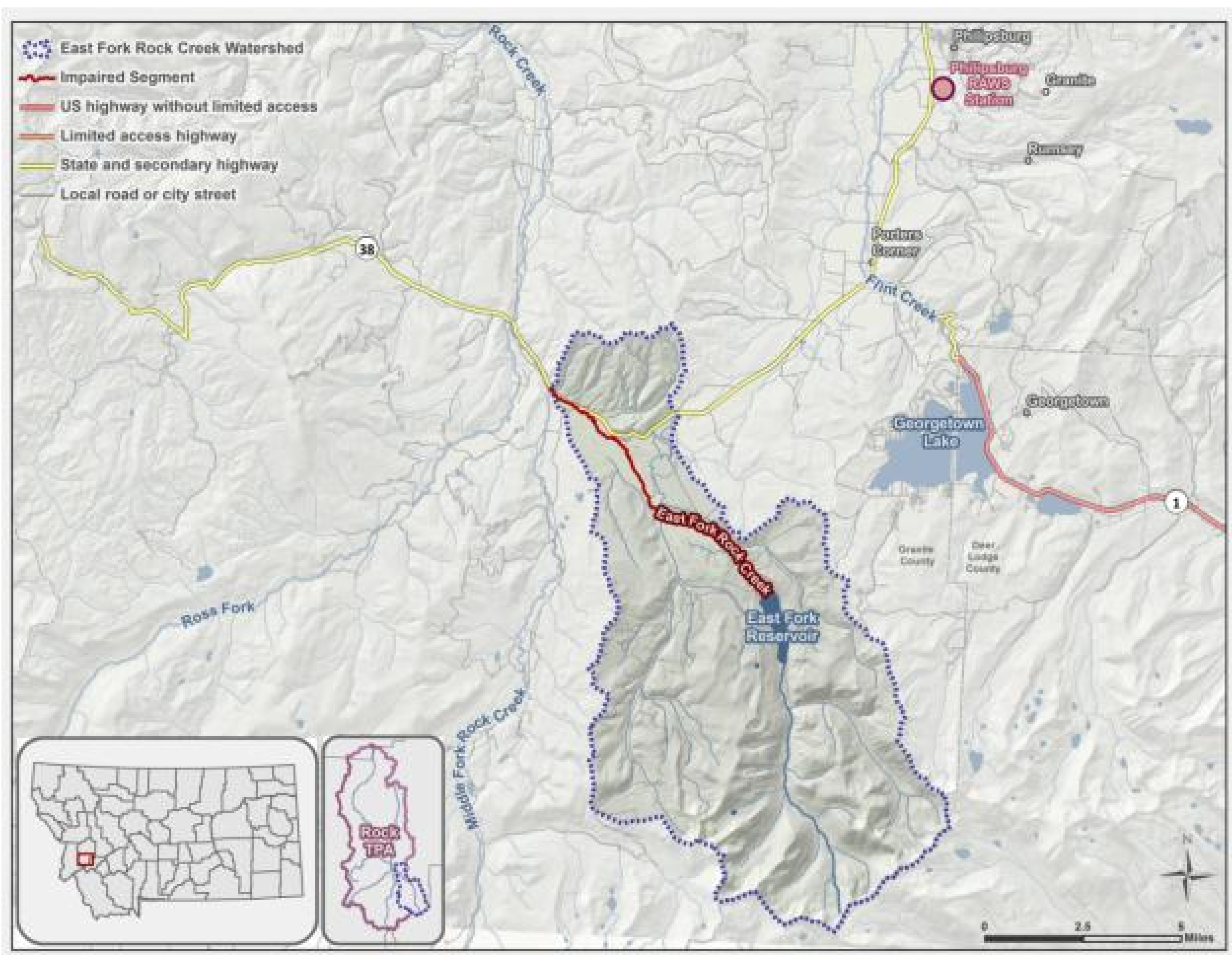


Figure I-1. East Fork Rock Creek watershed.

This stream originates in the high elevations of the Pintler Range (more than 8,000 feet above mean sea level [MSL]) and flows approximately 6 miles through the Beaverhead Deerlodge National Forest. The creek transitions from relatively steep, mountainous, coniferous forest in the headwater to more gentle, open, scrub/shrub/grassland in the lower reaches of the watershed (**Figure I-2**). This transition occurs fairly dramatically just below the East Fork Reservoir, an impoundment constructed in 1938.

A siphon and a transfer pipeline were also constructed in 1939 to facilitate irrigation in the adjacent Flint Creek watershed. The Montana Department of Natural Resources and Conservation (DNRC) manages the reservoir, siphon, and transfer pipeline. The segment (MT76E002_020) addressed in this report begins at the outlet of the dam on East Fork Reservoir and ends at the mouth of East Fork Rock Creek (its confluence with Middle Fork Rock Creek).

Source: (Google, 2013)
Figure I-2. Topography of the East Fork Rock Creek watershed.

The upper half of the East Fork Rock Creek watershed is primarily forested (**Figure I-3** and **Figure I-4**). Most of the valley bottom below the East Fork Reservoir (i.e., the areas along the impaired reach) is irrigated pasture or hay land (**Figure I-3**). The 2006 National Land Cover Dataset (NLCD) erroneously identifies areas of irrigated hay and pasture as cultivated crops. The upland areas in the lower watershed are predominantly open rangeland (scrub/shrub and native grasslands).

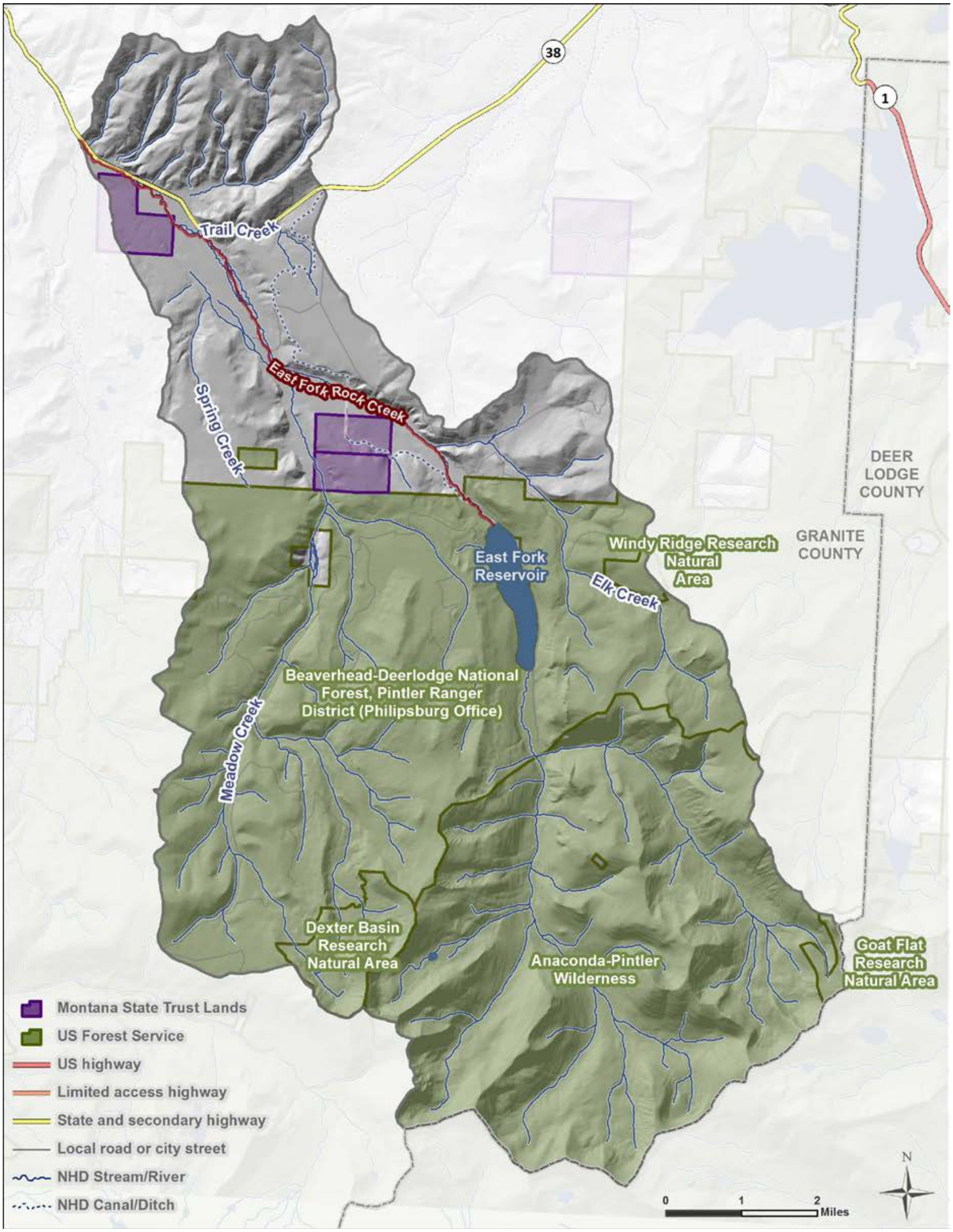
The U.S. Forest Service owns and manages much of the watershed. The upper reaches of the East Fork Rock Creek watershed are in the Anaconda-Pintler Wilderness (**Figure I-5**). Historically, timber harvest has occurred outside the wilderness area, predominantly in the Meadow Creek subwatershed, which drains to the impaired segment of East Fork Rock Creek (**Figure I-4**). With the exception of two small areas in the lower half of the watershed under state ownership, the lower watershed is privately owned.

Source of land cover: NLCD 2006 (Multi-Resolution Land Characteristics Consortium, 2006)
Note: The NLCD 2006 (Multi-Resolution Land Characteristics Consortium, 2006) erroneously identifies areas of irrigated hay and pasture as cultivated crops.

Figure I-3. Land cover in the East Fork Rock Creek watershed.

Source of aerial imagery: 2009 NAIP (Montana State Library, 2013)

Figure I-4. East Fork Rock Creek watershed.



Source of land ownership: (Montana State Library, 2013)

Figure I-5. Land ownership in the East Fork Rock Creek watershed.

I2.0 FACTORS POTENTIALLY INFLUENCING STREAM TEMPERATURE

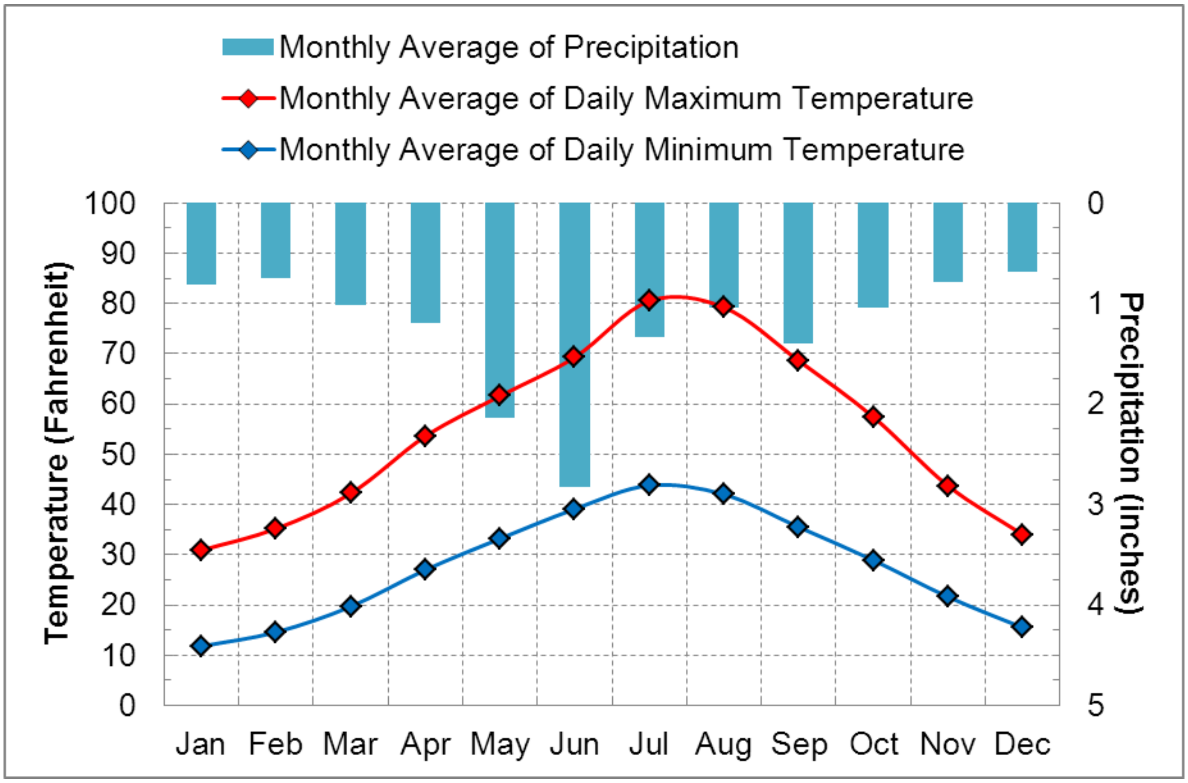
Interactions between external drivers of stream temperature and the internal integrated stream system (i.e., the channel, riparian zone, and alluvial aquifer) ultimately determine stream temperature (Poole and Berman, 2001). The external drivers are climate (e.g., solar radiation, air temperature, and near-stream wind speed), stream morphology, groundwater influences, and riparian canopy condition (Poole and Berman, 2001). External drivers could also be point source discharges, dams, and irrigation withdrawals and returns.

This section provides a summary of the external and internal factors that could influence stream temperature in East Fork Rock Creek. It is necessary to understand these watershed characteristics to adequately simulate the existing conditions and model scenarios that might be needed for TMDL development.

I2.1 CLIMATE

The nearest weather station to the East Fork Rock Creek watershed is 15 miles to the northeast in Philipsburg, Montana: Philipsburg Remote Automated Weather Station (National Weather Service ID 243002). Average annual precipitation is 15.7 inches with the greatest amounts falling in June and July (**Figure I-6**) (Western Regional Climate Center, 2012). Average maximum temperatures occur in July and August and are 80.9 and 79.2 °F, respectively. The most cloud-free days occur between June and September.

Note that the Philipsburg weather station is at an elevation of 5,280 feet above MSL, compared to the impaired reach of East Fork Rock Creek, which ranges in elevation from approximately 5,300 to 6,000 feet above MSL.



Source of monthly data: Western Regional Climate Center 2012

Figure I-6. Monthly average temperatures and precipitation at Philipsburg, Montana.

I2.2 Riparian Vegetation

Riparian vegetation data along the mainstem of East Fork Rock Creek were collected in 2011 to support shade characterization, ultimately for model development (Water & Environmental Technologies, 2011). DEQ collected vegetation/canopy height, canopy density, vegetative cover percent, and channel overhang at three transects each at all six of its sampling locations (shown in **Figure I-7**). These data are presented in **Appendix IA.** A summary of the data that relate to shade estimation is presented in **Section I2.3**.

In addition, a detailed assessment of the riparian vegetation community was performed in 2011 at two sites (EFRC Shade 1 and EFRC Shade 5). At the upper site (EFRC Shade 1), sedges and rushes are abundant along the stream edge, with a willow understory and some young conifers. Grass species occur in abundance upgradient from the stream edge. Weeds are minimal throughout the reach. At the lower site (EFRC Shade 5), the stream edge is dominated by sedges with intermixed rushes. Grass exists on outside bends where sloughing has occurred. The site has no overstory and minimal understory vegetation. Very little willow was observed, with no mature species. Upland grasses are smooth brome, timothy and canary reed grass. Bull thistle and mustard were also observed. Site EFRC Shade 5 is typical of current riparian conditions throughout much of the lower watershed.

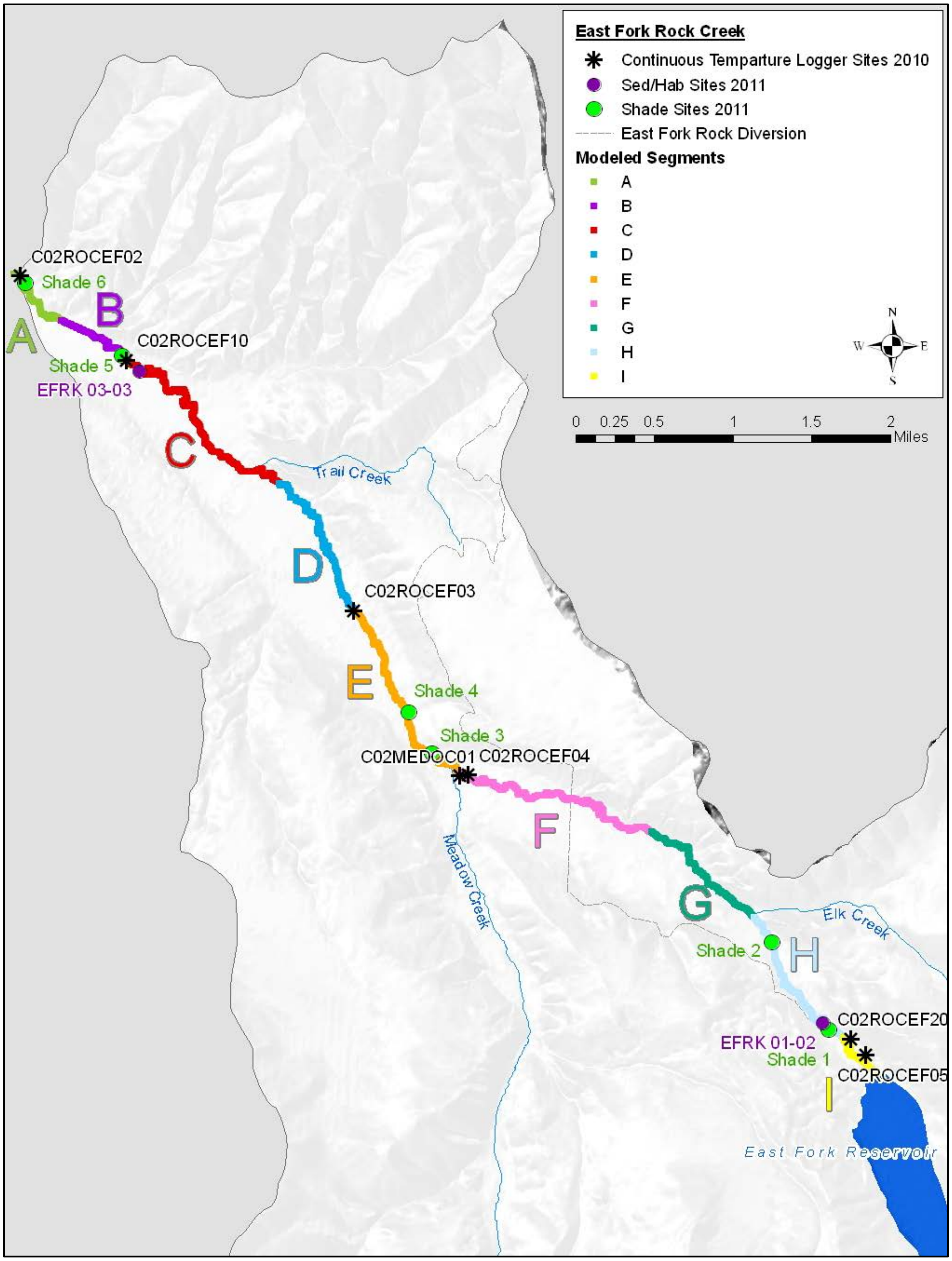


Figure I-7. Shade sites along the mainstem of East Fork Rock Creek.

I2.3 SHADE

Shade is a key input to the QUAL2K model. Shade is defined as the fraction of potential solar radiation that is blocked by topography and vegetation. DEQ used a Solar Pathfinder™ to collect shade data at six sites along East Fork Rock Creek: EFRC 1 through EFRC 6 (**Figure I-7**). Three sets of measurements were recorded at each site; with the exception of EFRC 5, vegetative shade exceeded topographic shade.

An analysis of aerial imagery showed that shading along East Fork Rock Creek was highly variable because of agricultural practices, changes in elevation along the stream, and such. Therefore, shade was also evaluated using the spreadsheet Shadev3.0.xls[2] (referred to throughout as the Shade Model). DEQ collected data to support development of the Shade Model **(Appendix IA**, Water & Environmental Technologies, 2011). The riparian vegetation information (i.e., height, density, and overhang that are displayed in **Appendix IA**) were calculated as the typical values for each category of vegetation on the basis of field work conducted in 2011, except where noted in the following paragraph (Water & Environmental Technologies, 2011).

The Shade Model uses these data with the spatial riparian cover and hydrography data to calculate vegetative shade (Water & Environmental Technologies, 2011). The topographic shade component was calculated using both TTools[3] and field data (Water & Environmental Technologies, 2011). Elevation, aspect, and the directional topographic shades were calculated in TTools using a digital elevation model and the previously mentioned digitized hydrography. Wetted width, near shore zone width and center to left, and channel incision were measured during field work conducted in 2011 (Water & Environmental Technologies, 2011). The Shade Model yielded shade estimates at a finer scale than the available Solar Pathfinder data (i.e., every 15 meters along the creek compared to three sites along the creek)

Figure I-8 presents shade estimates from both the Solar Pathfinder and Shade Model. As estimated by the Shade Model, shade varied over a large range above river mile 7 and varied over fairly constant ranges from river mile 7 to the mouth. The effective shade derived using the spreadsheet tool Shadev3.0.xls was compared to the field measurements from the Solar Pathfinder, aerial imagery, and site photographs. The Shadev3.0.xls output was found to be reasonably accurate (i.e., within 10 percent or less at all sites with Solar Pathfinder data; see **Figure I-8**). Additional plots of these data sets are presented in **Appendix IB**.

[2] Shadev3.0.xls contains Visual Basic for applications routines adapted from the Oregon Department of Environmental Quality (ODEQ) by Washington State Department of Ecology (http://www.ecy.wa.gov/programs/eap/models.html) to calculate topographic and canopy shade using solar time and position relative to the earth, and the solar position relative to the stream position, topographic, and vegetative canopy.

[3] A GIS analysis was performed using TTools (version 7.5.6), developed by the ODEQ in 2009, which is an ArcGIS template, to generate input values for Shadev3.0.xls. TTools requires hydrography that is accurate to a very fine scale (1:5,000 or finer) (Oregon Department of Environmental Quality, 2001). Aerial imagery from 2009 and a digital elevation model were used to digitize the centerline and shores of East Fork Rock Creek. The one-third arc second (approximately 33 feet) digital elevation map was obtained from USGS's National Elevation Dataset. Land cover along the approximately 164-foot-wide riparian corridor was digitized in GIS (Water & Environmental Technologies, 2011).

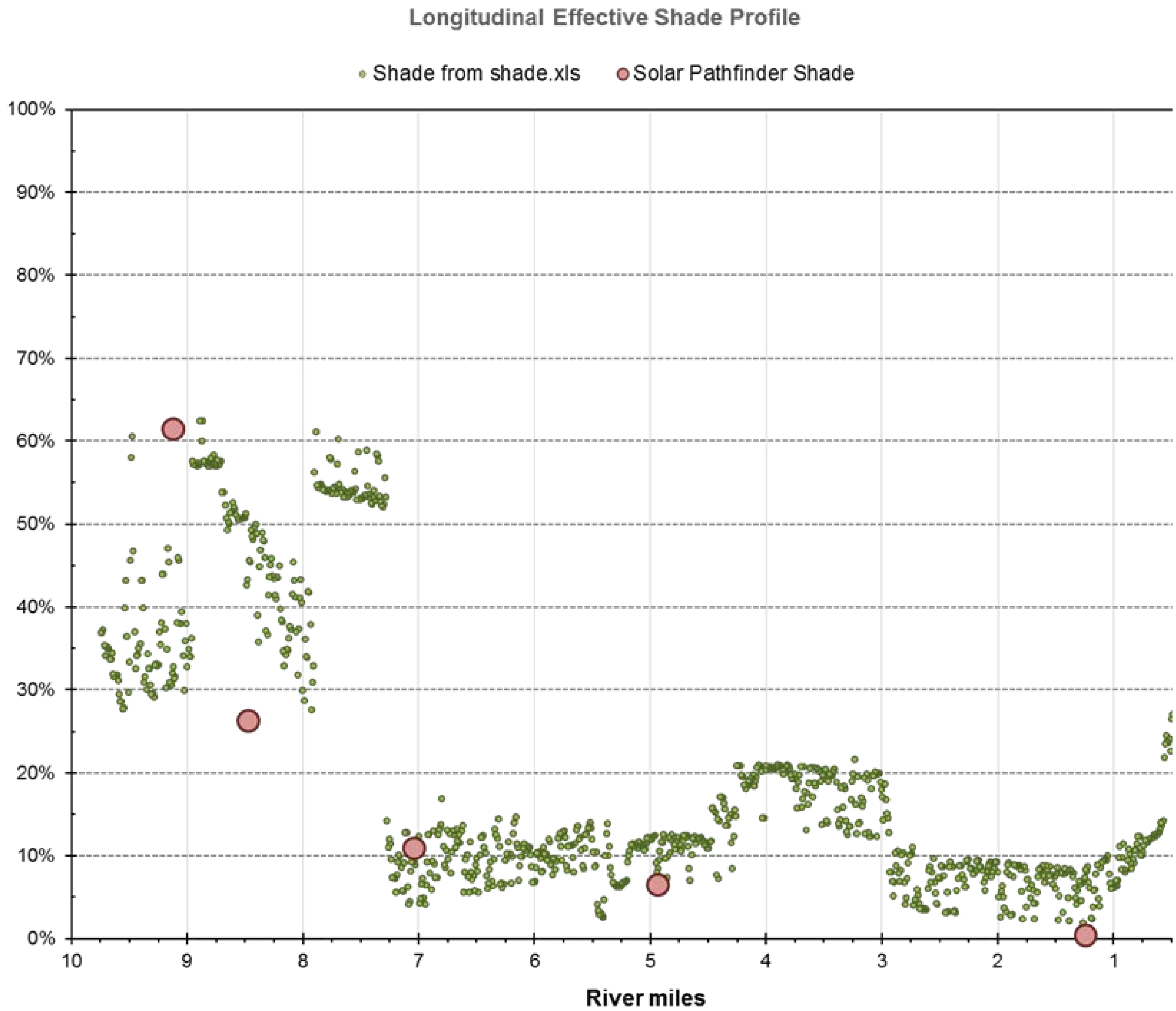


Figure I-8. Effective shade output from Shade.xls.

I2.4 Stream Morphology

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

Channel morphology measurements were taken at five cross-sections at two sites on East Fork Rock Creek, which coincide with EFRC Shade 1 and EFRC Shade 5 (**Figure I-7**). Representative bankfull width to depth ratios for the two sites are based on the reach average of those measurements, which averaged 22.2 at the upper site (EFRC Shade 1) and 14.3 at the lower site (EFRC Shade 5). Field observations are that the channel is overwidened at some discrete locations. However, both of the average reach values are within the acceptable and expected values for East Fork Rock Creek; therefore, no altered channel morphology scenario will be completed in the model to assess the influence of physical geometry on the overall heat balance of the stream.

I2.5 Hydrology

The hydrology of East Fork Rock Creek is significantly affected by anthropogenic flow modification. In 1938, the stream was dammed and a transfer pipeline (siphon) was constructed to move the impounded water to the Flint Creek drainage. The East Fork Rock Creek Dam is owned by DNRC and operated by the Flint Creek Water Users Association. It is an earthen embankment dam, 88 feet high and 1,083 feet long. The reservoir stores 16,040 acre-feet at normal pool covering 390 acres (Montana Department of Natural Resources and Conservation, 2012).

The transfer pipeline diverts about one-quarter of a mile below the dam and follows a northwesterly direction to Trout Creek, which is used as a carrier for the diversion of water by other canals in the Flint Creek valley below (State Engineers Office, 1959). The canal has a maximum capacity of 200 cubic feet per second (cfs) (Norberg, M., personal communication 2012). On the basis of flow data collected by DNRC in 2010 and 2011, water is typically diverted into the canal from late May through September with flow rates in the range of 50 to 150 cfs (Norberg, M., personal communication 2012). In 2010, the canal diverted between 34 and 98 percent (median 94 percent) of the flow discharged from East Fork Reservoir.

DEQ collected instantaneous flow measurements in 2010 during temperature data logger deployment and retrieval; these data are presented in **Table I-1**. Montana DNRC has maintained continuously recording gages on East Fork Rock Creek for most years starting in 1994 at four locations (**Table I-2** and **Figure I-9** [EF Rock above Res, EF Rock below Res, EF Rock Main Channel, and EF Rock above Elk]). **Figure I-10** and **Figure I-11** present DNRC's flow data from the years 2010 and 2011, respectively.[4]

According to DNRC, after spring snowmelt, flow in the creek decreases considerably as much of the flow is diverted to the irrigation canal. Flows are always lowest just below the irrigation canal diversion. The stream gains between 24 and 32 cfs from just below the irrigation diversion canal to the mouth. Flow occasionally decreases or remains relatively constant in the lower half of the creek; this might be because of the cumulative effect of multiple small irrigation withdrawals, which divert to pivot and some flood irrigation (Norberg, M., personal communication 2012).

Table I-1. DEQ instantaneous flow measurements (cfs)

Date	C02ROCEF02	C02ROCEF10	C02ROCEF03	C02MEDOC01	C02ROCEF04	C02ROCEF20	C02ROCEF05
July 26-29, 2010	38.04	38.12	41.51	12.37	25.78	6.18	114.7
August 30, 2010	--	34.62	28.41	--	14.20	--	77.6
September 28, 2010	28.62	30.38	13.61	6.37	11.56	4.97	4.0

Note: DEQ reports that flow was estimated at site C02ROCEF05.

[4] It is noteworthy that DNRC peak flows monitored in 1994 and 1999 through 2004 were considerably lower than peak flows from 1995 through 1998 and 2007 through 2011.

Table I-2. Period of record for DNRC flow gages

Year	EFRC above EFR	EFRC below EFR	Main Canal	EFRC above Elk Creek
1994	Jun 2 – Oct 8	Jun 22 – Oct 8	May 1 – Sep 30	--
1995	May 29 – Oct 19	May 29 – Oct 19	May 1 – Sep 30	--
1996	May 12 – Oct 2	May 12 – Oct 2	May 1 – Sep 30	--
1997	May 12 – Oct 11	May 12 – Oct 11	May 1 – Oct 2	--
1998	May 5 – Oct 23	Apr 22 – Oct 23	May 1 – Sep 30	--
1999	May 20 – Oct 4	May 4 – Oct 4	May 1 – Sep 30	--
2000	May 1 – Oct 4	May 1 – Oct 4	Apr 1 – Sep 30	--
2001	May 10 – Oct 24	May 4 – Oct 24	--	--
2002	May 19 – Sep 29	--	Jul 1 – Sept 30	--
2003	May 29 – Sep 30	May 29 – Oct 28	May 1 – Oct 1	--
2004	Apr 1 – Sep 30	Mar 30 – Sep 30	Apr 29 – Sep 30	--
2005	--	--	--	--
2006	--	--	--	--
2007	Jun 5 – Oct 2	Apr 25 – Oct 2	Apr 11 – Oct 10	--
2008	Jun 2 – Sep 23	Apr 16 – Sep 23	Jun 2 – Sep 8	--
2009	May 28 – Oct 23	Apr 23 – Oct 19	May 22 – Sep 30	--
2010	May 22 – Oct 9	Apr 23 – Oct 27	May 24 – Sep 30	Jun 10 – Oct 27
2011	May 26 – Oct 8	May 3 – Sep 30	May 12 – Sep 30	Apr 14 – Sep 30

Notes: EFRC = East Fork Rock Creek; EFR = East Fork Reservoir

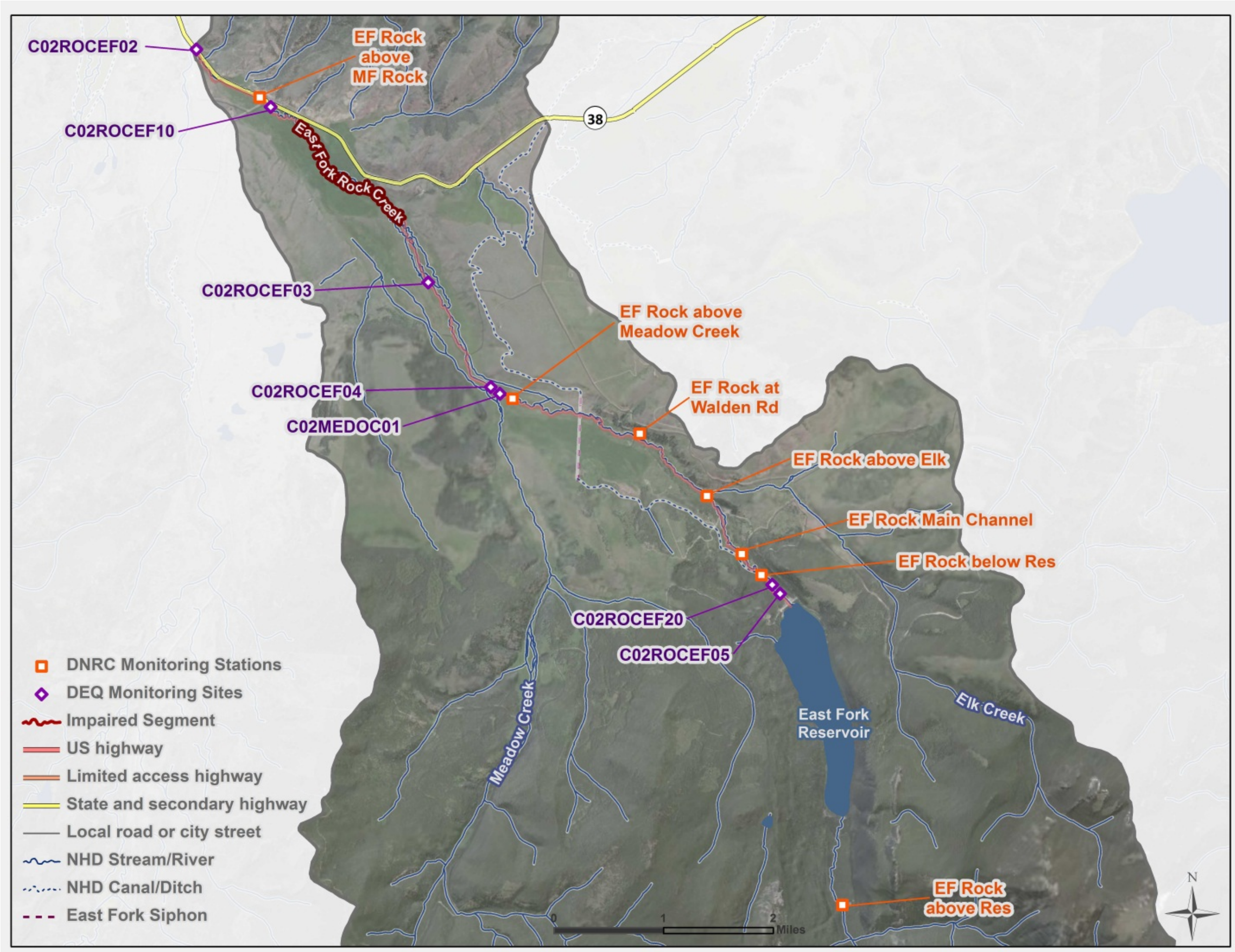


Figure I-9. Flow and temperature monitoring locations.

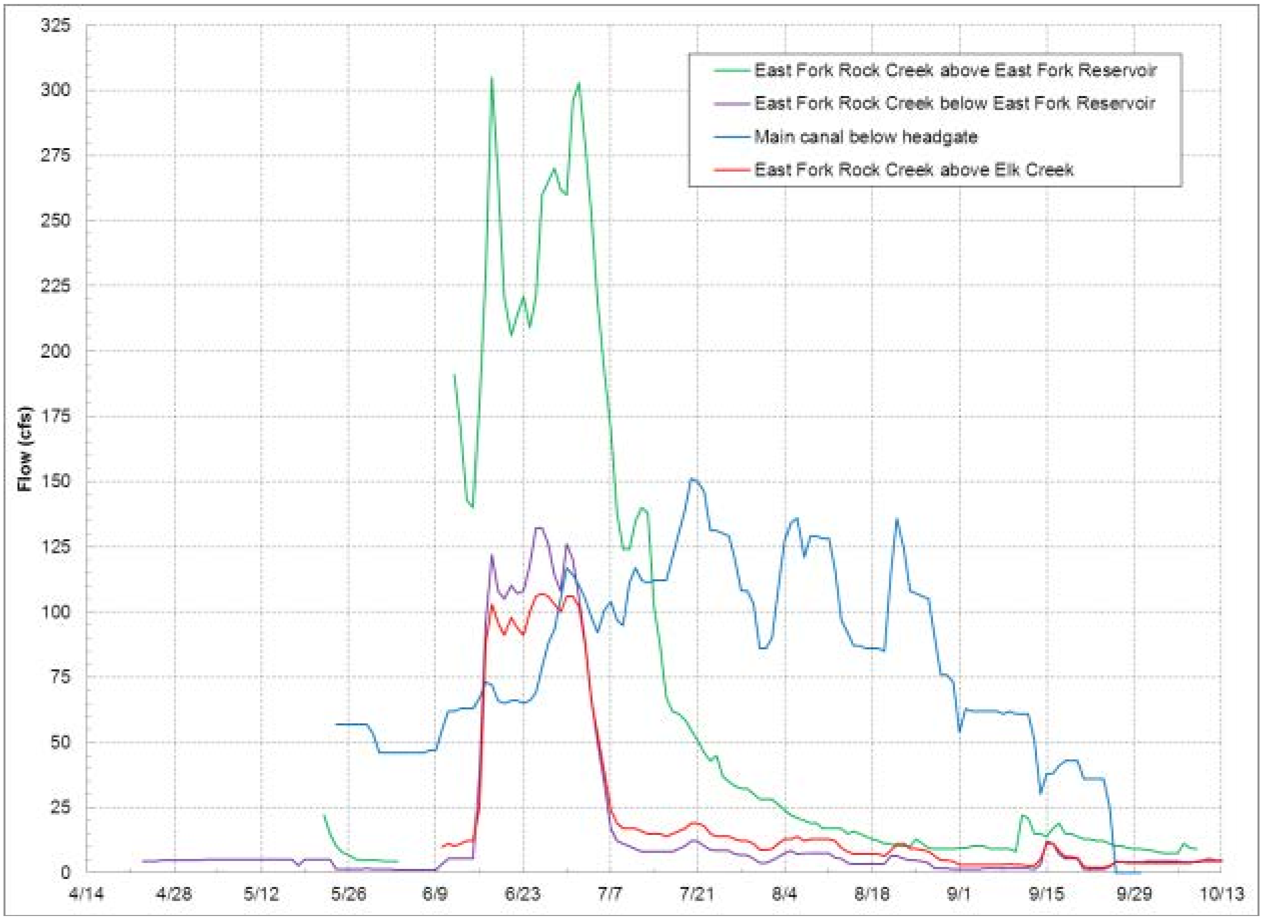


Figure I-10. DNRC continuous flow data collected in 2010.

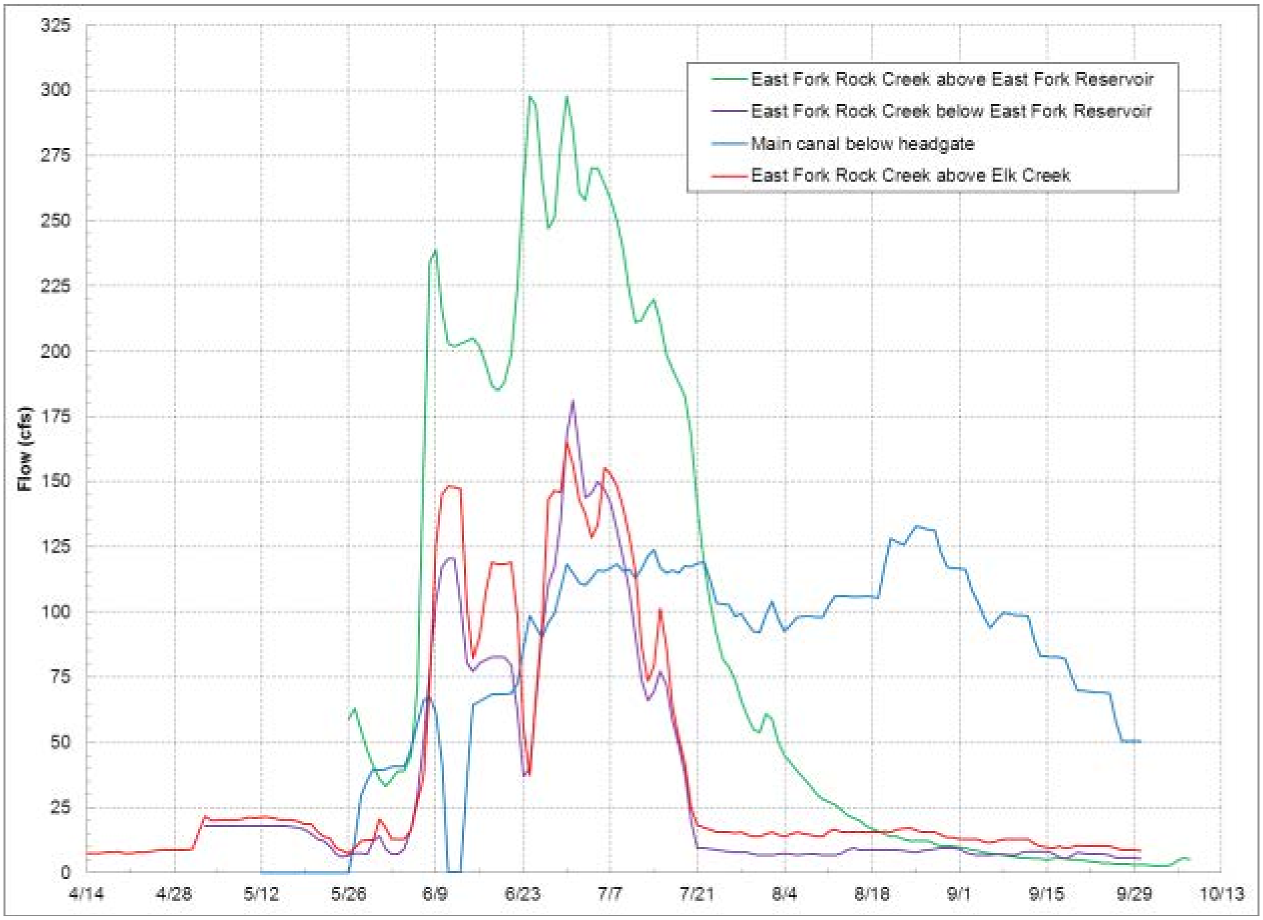


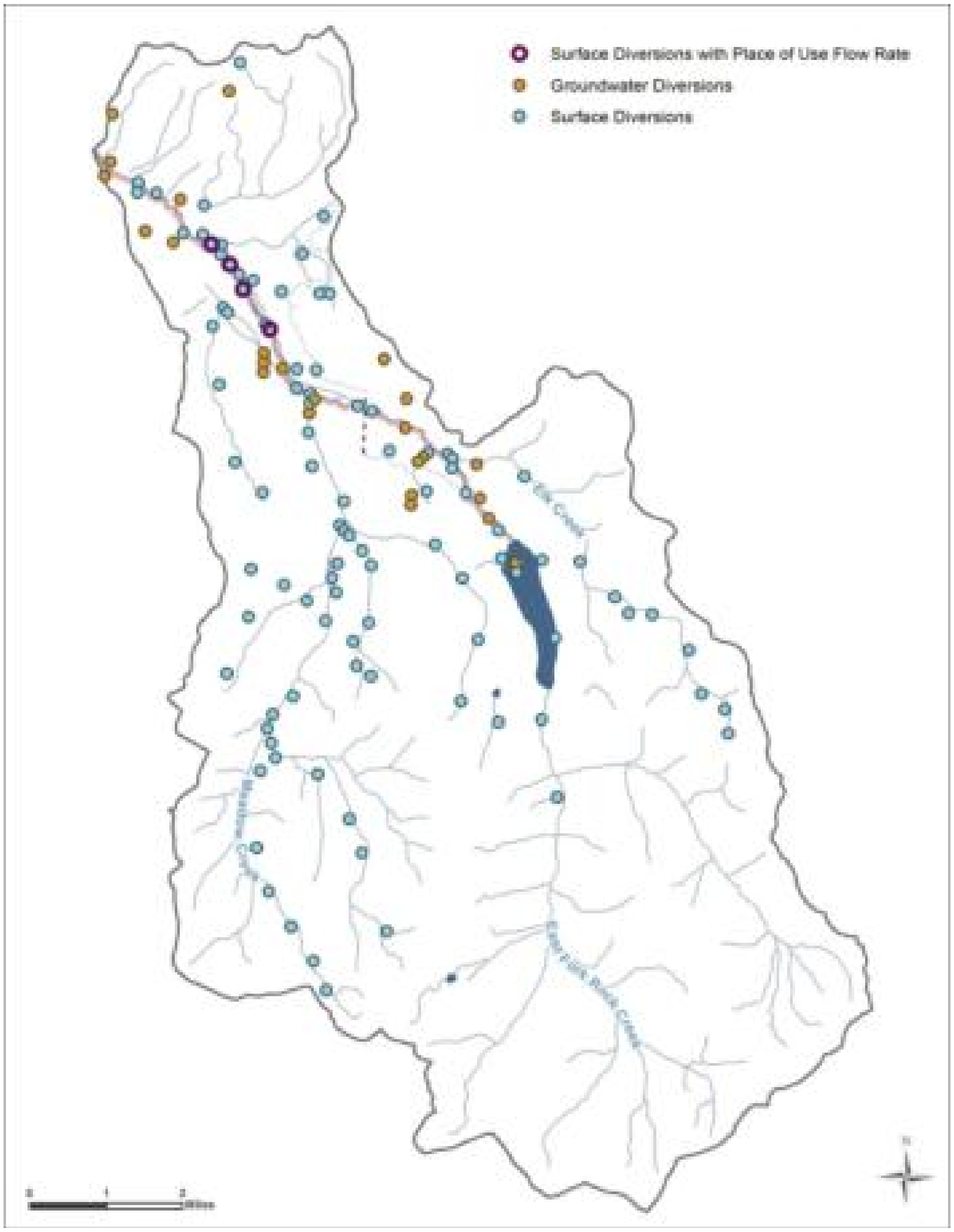
Figure I-11. DNRC continuous flow data collected in 2011.

On the basis of a review of online water rights data (ftp://nris.mt.gov/dnrc), 164 surface and groundwater diversions are in the East Fork Rock Creek watershed (**Figure I-12**). *Points of diversion* and *places of use* spatial data were obtained from the Montana Natural Resource Information System (Montana State Library, 2013). Of the 164 diversions in the East Fork Rock Creek watershed, 44 are directly from East Fork Rock Creek, 35 are along the creek below East Fork Reservoir, and rate and acreage data are available for four of these diversions (**Figure I-12**). These four diversions correspond to places of use, and all four diversions are listed with an active status for flood irrigation. Maximum allowable flow rates for these four diversions are shown in **Table I-3**.

Table I-3. Surface water rights along the mainstem of East Fork Rock Creek

WR ID	WR number	River kilometer	Means of diversion	Rate[a] (cfs)	Acreage[b]
223563	76E 136895 00	7.13	Direct from source	0.75	30
293491	76E 15477 00	5.1	Headgate	5.75	10
205791	76E 116992 00	4.35	Headgate	5.75	8
223563	76E 136895 00	6	Direct from source	8.55	70

Notes: cfs = cubic feet per second; WR = water right.
[a] Maximum water flow rate allowed by the water right.
[b] Acreage of land that is irrigated at the place of use.



Source of points of diversion data: (Montana State Library, 2013)

Figure I-12. Surface and groundwater diversions in the East Fork Rock Creek watershed.

I3.0 STREAM TEMPERATURE

Stream temperature data were collected in 2010 by DEQ and 2011 by DNRC. Monitoring locations are shown in **Figure I-9**. These data are summarized separately below because they represent different periods influenced by weather and hydrology unique to those periods. A brief discussion of all the available temperature data and factors that could be influencing stream temperature follows.

I3.1 2011 Stream Temperature Data

DNRC collected continuous temperature data at six locations along East Fork Rock Creek in 2011: above and below East Fork Reservoir, above Elk Creek, at Walden Bridge, above Meadow Creek, and above the mouth on Middle Fork Rock Creek (**Figure I-9**). Data loggers recorded temperatures every half hour for 4 months between June 20–21, 2011, and October 9–10, 2011. Box plots of these data show that stream temperatures are much cooler above the reservoir than below (**Figure I-13**). Above the reservoir, temperatures ranged from 35.9 to 47.9 °F; below the reservoir temperatures ranged from 37.9 to 62.5 °F. Below the reservoir, median temperatures are fairly constant from the upstream-most site, which is below the reservoir, downstream to the mouth.

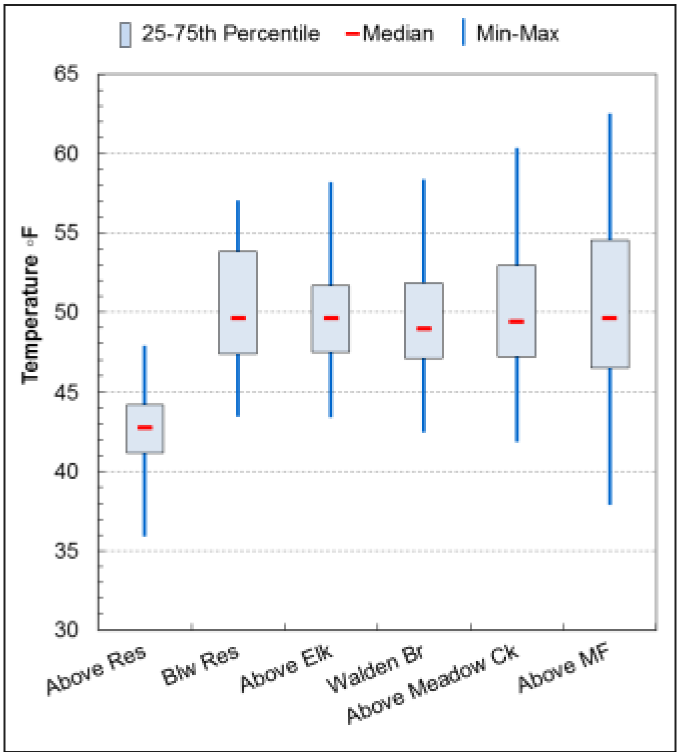


Figure I-13. Box-and-whisker plots of DNRC temperature data collected between June 20 and October 10, 2011.

As shown in **Figure I-13**, maximum temperatures at these monitoring locations appear to increase gradually in a downstream direction from 57.1 to 62.5 °F. Between the beginning of the monitoring period and the end of August, the daily variability in maximum temperatures between sites was high (**Figure I-14**). Beginning in September, the between site variability in daily maximum temperatures virtually disappears.

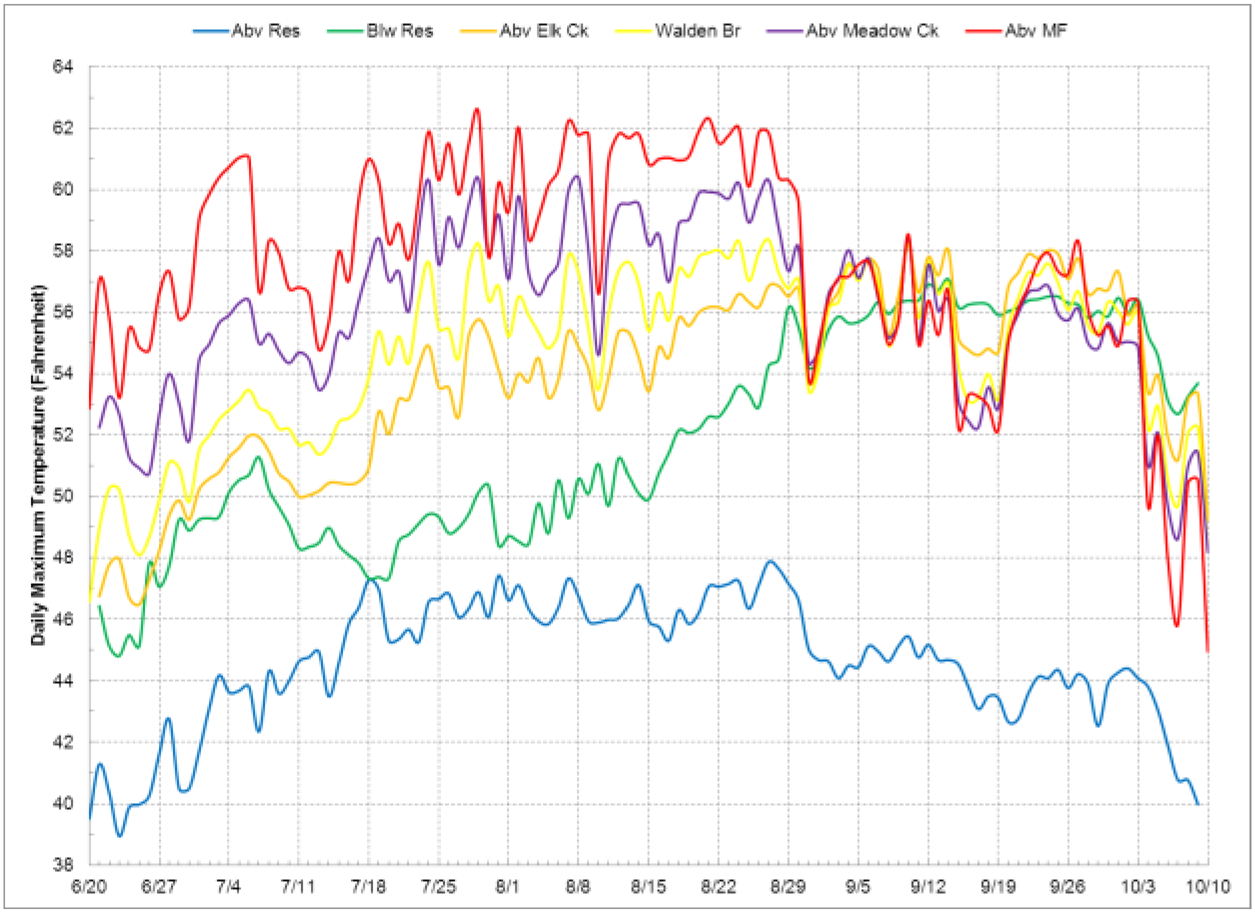


Figure I-14. Daily maximum temperature, East Fork Rock Creek, June 20 to October 10, 2011.

I3.2 2010 Stream Temperature Data

DEQ collected continuous temperature data at six locations along East Fork Rock Creek (i.e., sites C02ROCEF02, C02ROCEF03, C02ROCEF04, C02ROCEF05, C02ROCEF10, and C02ROCEF20) and at one location along Meadow Creek (C02MEDOC01) in 2010 (**Figure I-9**). Data loggers recorded temperatures every half hour for 2 months between July 27 and 28, 2010, and September 26 and 27, 2010. Field parameters (including water temperature) were collected during data logger deployment and retrieval. DEQ also collected instantaneous water temperatures during water quality monitoring in 2004 and 2011. These data are summarized in **Table I-4**.

DEQ's upstream-most site is below the East Fork Dam, upstream of the canal diversion (C02ROCEF05). Maximum recorded temperatures generally increased in a downstream direction ranging from 58.0 °F below the dam (C02ROCEF05) to a maximum of 64.4 °F approximately one mile below the confluence with Meadow Creek (C02ROCEF03). With one exception, unlike 2011, the between-site variability in daily maximum temperatures is relatively constant throughout the 2010 monitoring period. The exception is that the maximum daily temperatures at the two uppermost sites (C02ROCEF05 and C02ROCEF20) are lower than those recorded at the downstream sites between the beginning of the monitoring period and mid-August (**Figure I-15**).

For the monitoring period, the maximum temperatures in Meadow Creek were among the highest (i.e., 63.8 °F).

Table I-4. Instantaneous water temperature measurements (°F)

Station	7/26/ 2004	7/27/2004	7/12/2007	7/26-29/2010	8/30/2010	9/28/2010
C02ROCEF05	--	--	--	47.7	55.9	53.4
C02ROCEF20	59.3	--	--	49.1	--	53.8
C02ROCEF04	--	--	--	52.5	52.7	57.0
C02ROCEF03	--	--	--	50.0	50.7	55.2
C02ROCEF10	--	61.7	64.8	55.4	49.6	49.8
C02ROCEF02	--	--	--	52.7	--	47.5

Note: Temperatures were originally reported in degrees Celsius and were converted to degrees Fahrenheit.

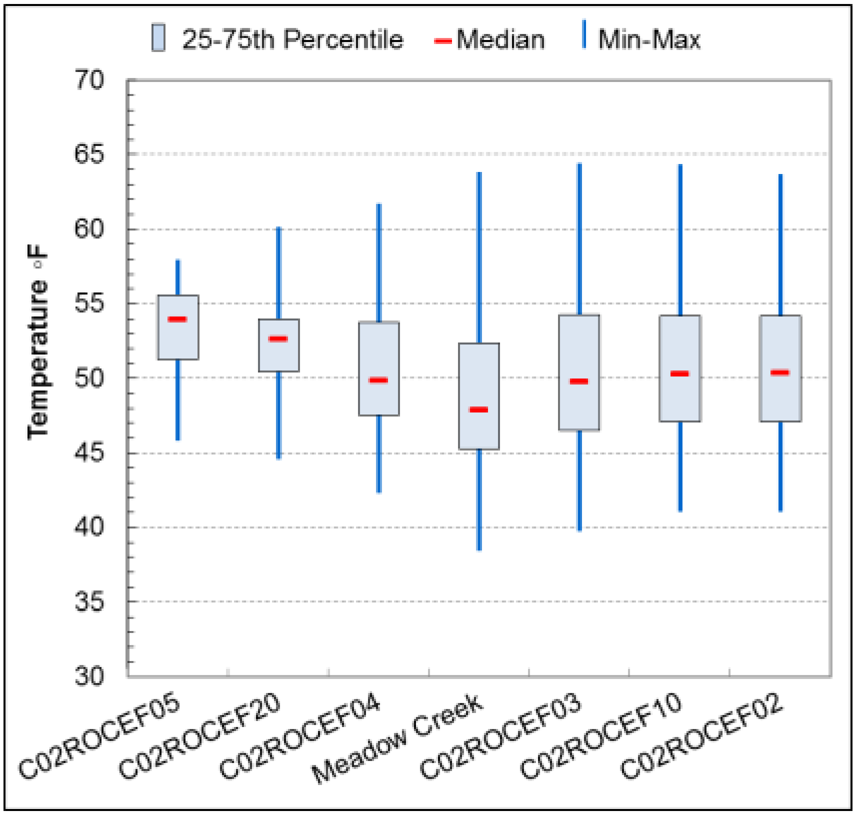


Figure I-15. Box-and-whisker plots of DEQ temperature data collected between July 27 and September 27, 2010.

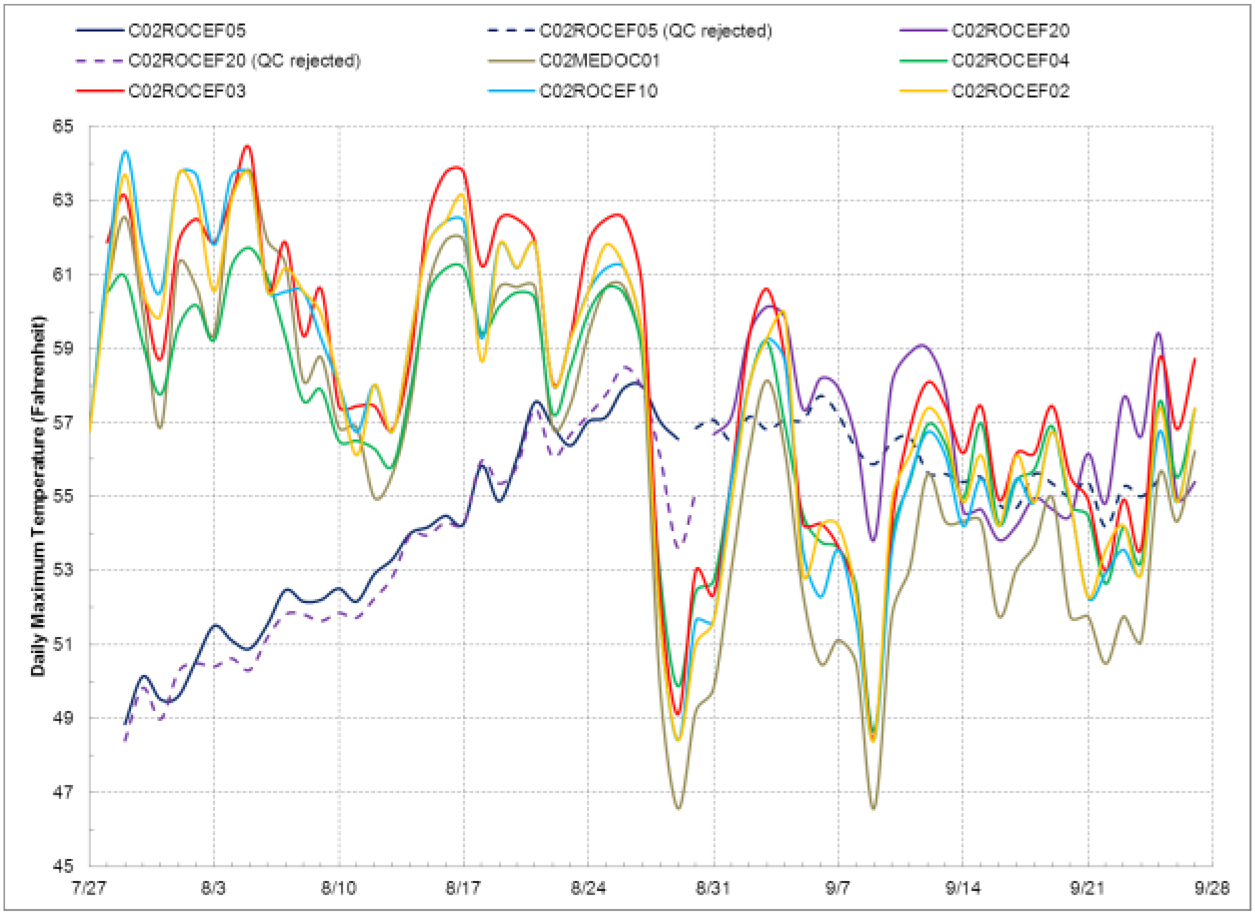


Figure I-16. Daily maximum temperature, East Fork Rock Creek, July 27 to October 27, 2010.

I3.3 Stream Temperature Summary

The 2011 stream temperatures are much cooler upstream of the East Fork Reservoir than downstream (**Figure I-13**). This could be a result of the water warming in the East Fork Reservoir and subsequent release of the warmed water below the dam. It could also be a result of a fairly significant change in landform/topography and vegetation that occurs roughly where the dam was built (i.e., transition from relatively steep, mountainous, coniferous forest in the headwater to more gentle, open, scrub/shrub/grassland in the lower reaches of the watershed). The 2011 data also suggest that diversion of up to approximately 130 cfs into the canal (**Figure I-11**) could be influencing daily maximum stream temperatures downstream from the dam (**Figure I-14**).

The 2010 stream temperature data, especially without data upstream of East Fork Reservoir, do not exemplify similar influences from the East Fork Reservoir or the canal. The most striking observation with the 2010 data is the difference in maximum daily temperatures between the upstream and downstream monitoring sites between the beginning of the monitoring period and mid-August (**Figure I-16**). This suggests some kind of warming influence downstream from site C02ROCEF20. While this could be a natural phenomenon as the stream flows through the more open valley downstream, potential anthropogenic influences are irrigation withdrawals and returns, degradation of the riparian vegetation, and altered stream morphology.

I4.0 MODEL SETUP

EPA and DEQ selected the QUAL2K model to simulate temperatures in East Fork Rock Creek. QUAL2K is supported by EPA and has been used extensively for TMDL development and point source permitting across the country. The QUAL2K model is suitable for simulating hydraulics and water quality conditions of small rivers and creeks. It is a one-dimensional uniform flow model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, nonpoint source loading, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K can address nutrient cycles, algal growth, and dissolved oxygen dynamics. QUAL2K also simulates instream temperatures via a heat balance that accounts “for heat transfers from adjacent elements, loads, withdrawals, the atmosphere, and the sediments” (Chapra et al., 2008, p. 19).

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

The following describes the process that was used to setup the QUAL2K models for East Fork Rock Creek.

I4.1 CHANNEL FLOW-PATH

East Fork Rock Creek, as delineated in the National Hydrography Dataset, is a 19.0-mile perennial stream. The outlet of East Fork Reservoir is at RM 9.7. DEQ evaluated multiple locations along the creek from its mouth upstream to the dam on East Fork Reservoir. DNRC evaluated multiple sites along East Fork Rock Creek from the mouth upstream to the dam and evaluated one site upstream of the reservoir. The QUAL2K model for East Fork Rock Creek was developed for the 9.7-mile portion of the creek from the confluence with Middle Fork Rock Creek upstream to the dam at East Fork Reservoir.

In the National Hydrography Dataset the U.S. Geological Survey has delineated multiple named tributaries to East Fork Rock Creek. Elk Creek (RM 8.2) and Meadow Creek (RM 5.5) were explicitly modeled, as point sources, in the QUAL2K model. All other tributaries were implicitly modeled as part of the net diffuse flow.

The modeled flow path is shown in **Figure I-17**.

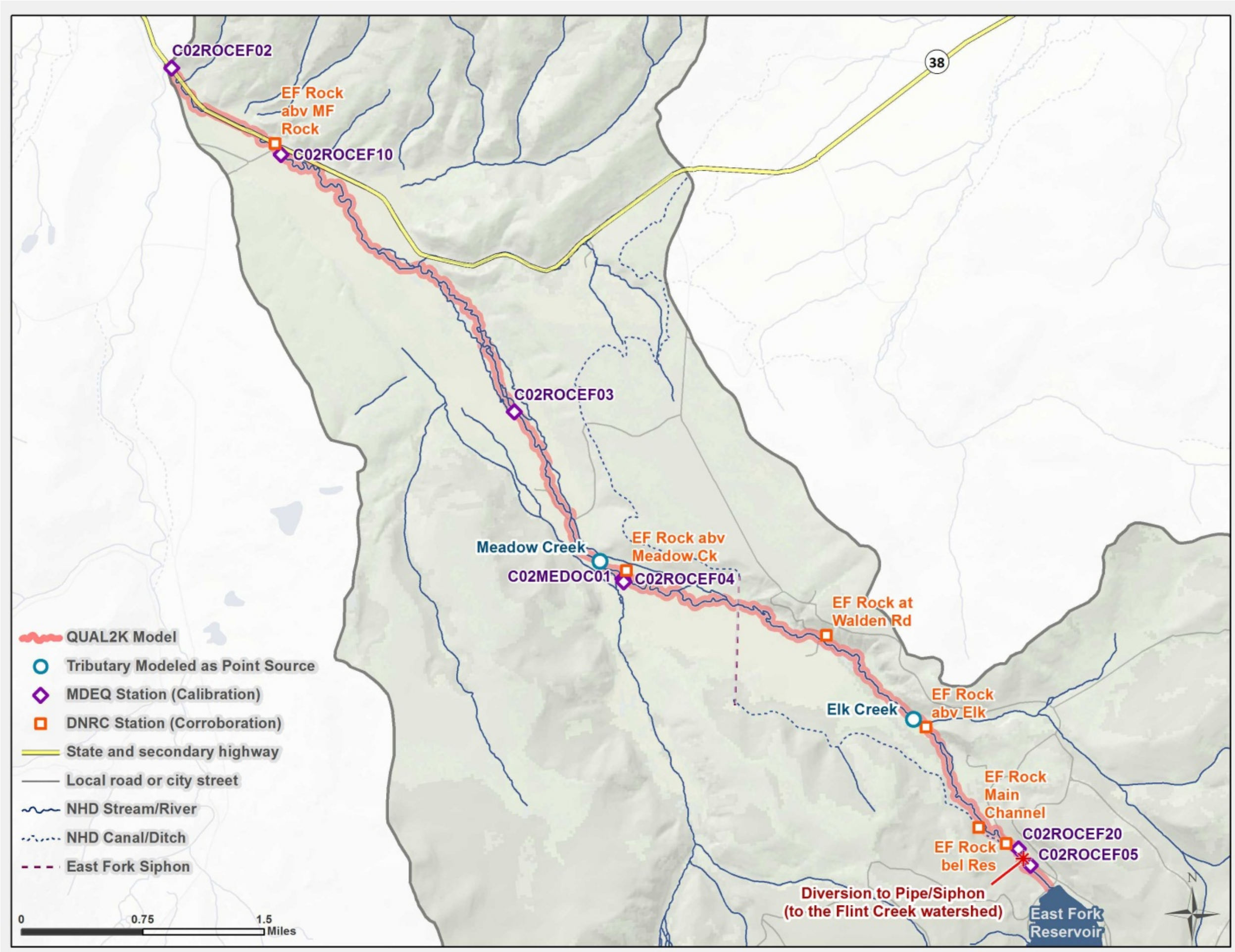


Figure I-17. QUAL2K model.

I4.2 Stream Segmentation

The East Fork Rock Creek's impaired segment was divided into nine linked segments (**Figure I-18**) identified as A, B, C, D, E, F, G, H, and I (mouth to dam on East Fork Reservoir). The segmentation locations were selected on the basis of available diurnal temperature and flow data (available at the DEQ and DNRC sample sites), changes in vegetation (**Figure I-7**), and changes in effective shade (**Figure I-8**). The existing conditions scenario is defined as segments I, H, G, F, E, D, C, B, and A; DEQ collected data along these segments that were used to develop the model.

Each of the eight linked segments was further subdivided into elements or computational units. The number of computational units was determined on the basis of the estimated velocity/computational time step to ensure the containment of the heat load calculation within each element per time step. The element length was selected to be short enough to increase the spatial resolution and long enough to support model stability.

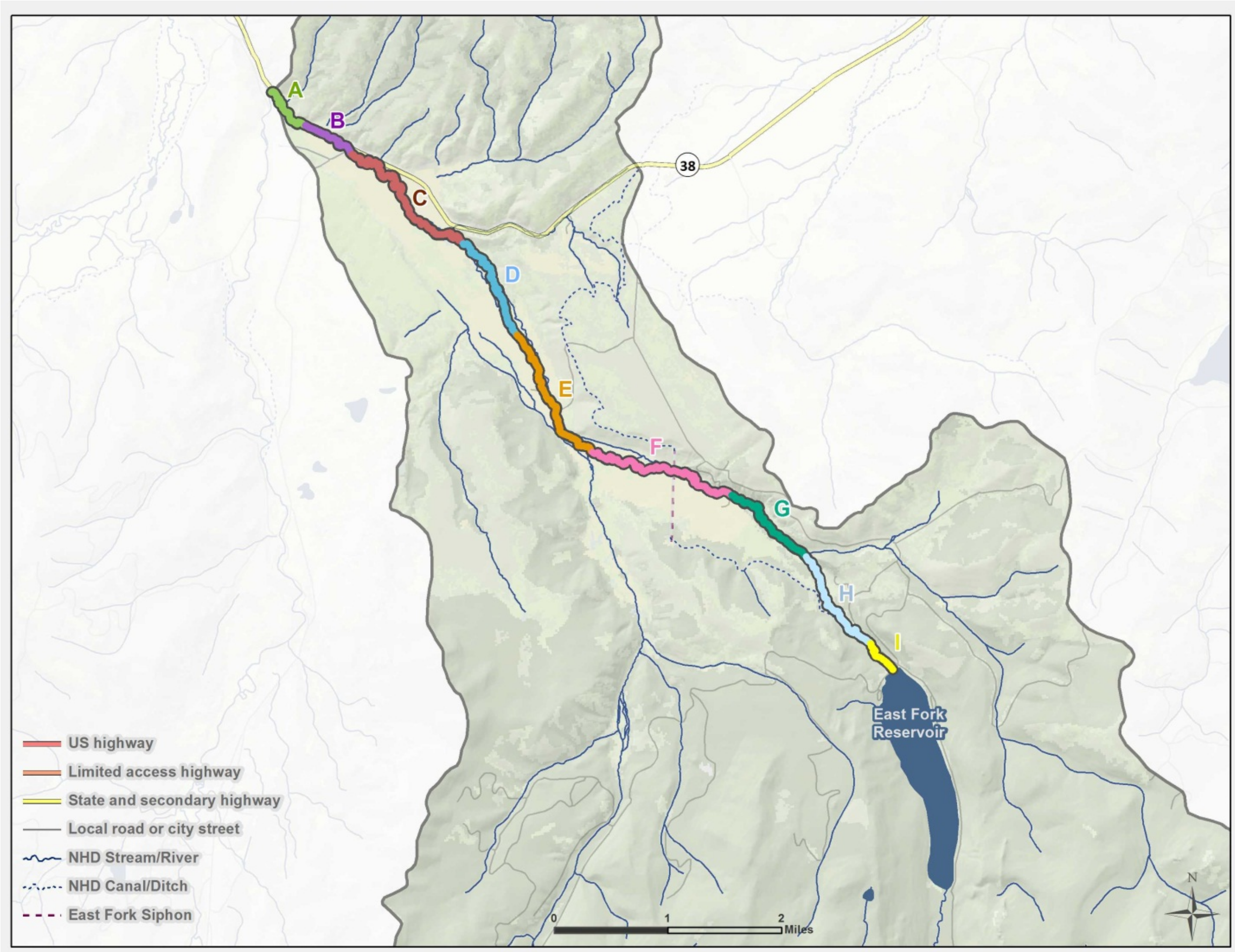
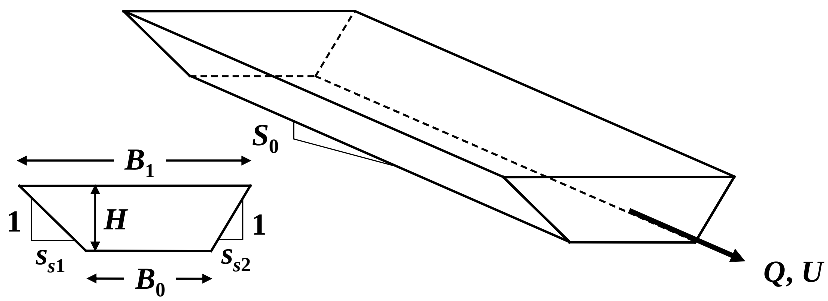


Figure I-18. Model segmentation along East Fork Rock Creek.

I4.3 Channel Geometry

The channel geometry data that was input into QUAL2K was derived from DEQ field work (for the original data, see **Appendix IA**; and for the model inputs and assumptions, see **Appendix IC**). Manning's n was estimated during a field visit (Water & Environmental Technologies, 2011). Channel slope were calculated using field-collected elevation data (Water & Environmental Technologies, 2011). Stream bottom width and the sides of the trapezoidal cross-section assumed for modeling (**Figure I-19**) were estimated using flow-interval data collected when flow was measured at sites C02ROCEF20, C02ROCEF04, C02ROCEF03, C02ROCEF10, and C02ROCEF02 (Water & Environmental Technologies, 2011); these sites are in reaches I, F, E, C, and A, respectively.[5]. The stream bottom widths and sides of the assumed trapezoidal cross-section for modeling for the reaches without flow-interval data were estimated via linear interpolation between the sites with flow-interval data.

[5] The five cross-sections developed from flow-interval data collected on the same day were found to be more representative of the channel and yielded a better calibration than the cross-sections collected at three sites in 2011 (Shade 4, EFRK 01-02, and EFRK 03-03).



Source: Chapra et al. 2008.

Note: B_0 is stream bottom width, S_{s1} and S_{s2} are side lengths relative to one, and S_0 is channel slope.

Figure I-19. Idealized trapezoidal channel assumed in QUAL2K.

I4.4 Hydrologic Simulation

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

The observed data collected in 2010 by DEQ and DNRC along the mainstem were used to derive the flow inputs required to run the QUAL2K model for the calibration day of July 29, 2010 (**Appendix IC**, **Table IC-6**)**.** DEQ measured flow at the mouth of Meadow Creek (i.e., C02MEDOC01) on July 29, 2010, and the flow (12.37 cfs) was input into QUAL2K.

The only available flow measurement on Elk Creek occurred on August 30, 2011 (1.53 cfs). Flow for July 29, 2010, was estimated using the drainage area ratio method and the DNRC flow gage on East Fork Rock Creek above East Fork Reservoir. This DNRC flow gage was used with the drainage area ratio method because all other measured flows occurred at sites downstream of East Fork Reservoir. Sites below the reservoir are influenced by reservoir and dam operation and are not suitable for applying the drainage area ratio method.

The headwaters inflow (the upstream boundary condition in QUAL2K) was assumed to be equivalent to the flow estimated at site C02ROCEF05 (114.7 cfs), which was based on a water balance of flows measured at C02ROCEF20 and in the main channel of the diversion canal.

A water balance was used to estimate diffuse flow, with the difference between each observation assumed to be diffuse flow. Diffuse flow in reaches I through F was positive (i.e., inflow), whereas diffuse flow from reaches E through A was negative (i.e., outflow). Irrigation diversions are along reaches E through A. The negative flow balances could indicate that the irrigation diversion outflows exceeded the tributary and irrigation return inflows. The flow balance is summarized in **Figure I-20**.

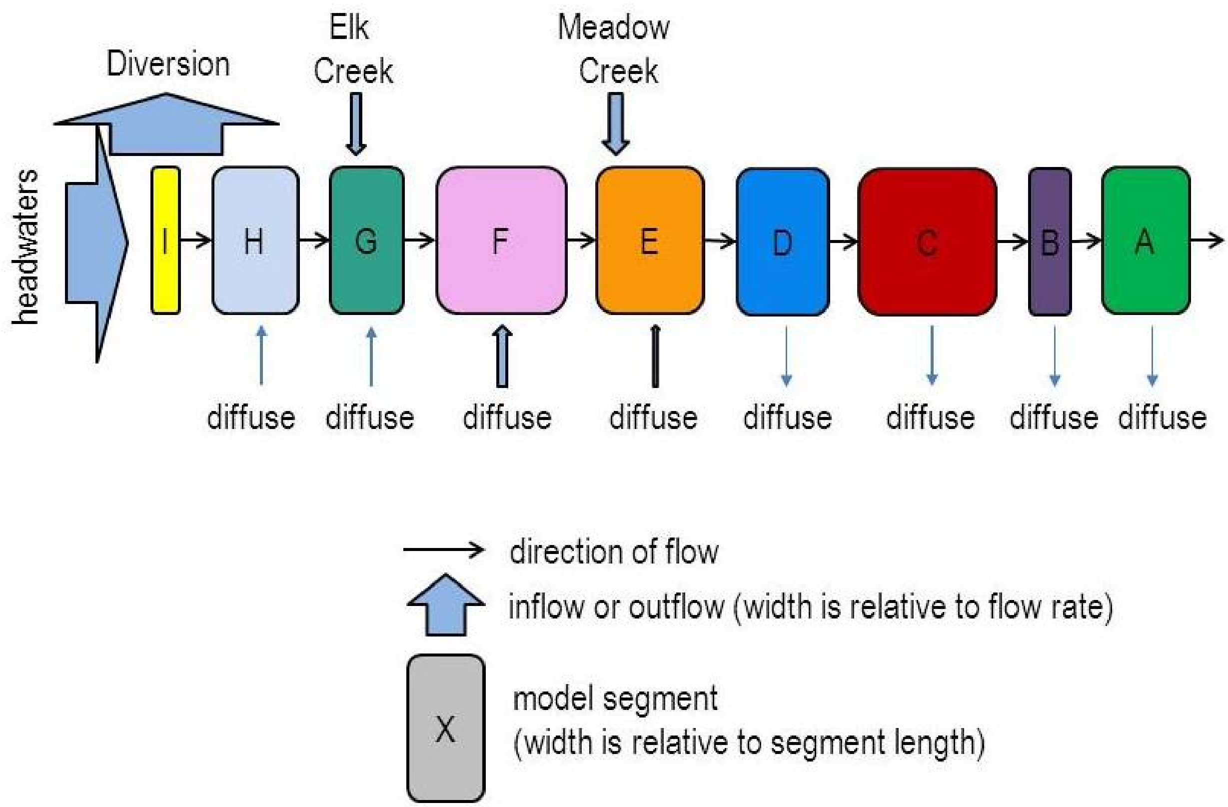


Figure I-20. Schematic representation of inflows and outflows to East Fork Rock Creek.

I4.5 Weather

Weather inputs were compiled from the closest station recording the necessary data (**Appendix IC**, **Table IC-9** and **Table IC-10**). These data were used as model input for the July 29, 2010 critical date. Air temperature, wind speed, relative humidity, and solar radiation data were obtained from the Philipsburg RAWS, which is at an elevation of 5,280 feet (**Figure I-2**). Air temperature and dew point temperature data from this station were corrected to account for the elevation difference between the station and the impaired stream. Wind speed was corrected for the height differences of the sensor at Philipsburg RAWS (reported as 20 feet) and the assumed height in QUAL2K (7 meters, which is approximately 23 feet). Cloud cover was estimated on the basis of available hourly data at the Butte municipal airport (WBAN 24135) weather station that is operated by the National Weather Service, which is the closest weather station that measures cloud cover. Zero percent cloud cover was observed at the Butte municipal airport on July 29, 2010; therefore, zero percent was input for all 24 hours in the QUAL2K model.

I4.6 Shade

Shade is a key input to the QUAL2K model. As recommended in the QUAL2K model documentation, estimates of shading are developed separately using the spreadsheet Shadev3.0.xls. This file contains Visual Basic for applications routines adapted from the Oregon Department of Environmental Quality by Washington State Department of Ecology to calculate topographic and canopy shade using solar time and position relative to the earth, and the solar position relative to the stream position, topographic, and vegetative canopy.

Riparian shade was estimated using GIS and the Shadev3.0.xls (for a discussion of how shade was estimated, see **Section I2.3**). The hourly shade inputs per reach for the proposed QUAL2K model segments are summarized in **Figure I-21**; the input values are also presented in **Appendix IC** in **Table IC-11**.

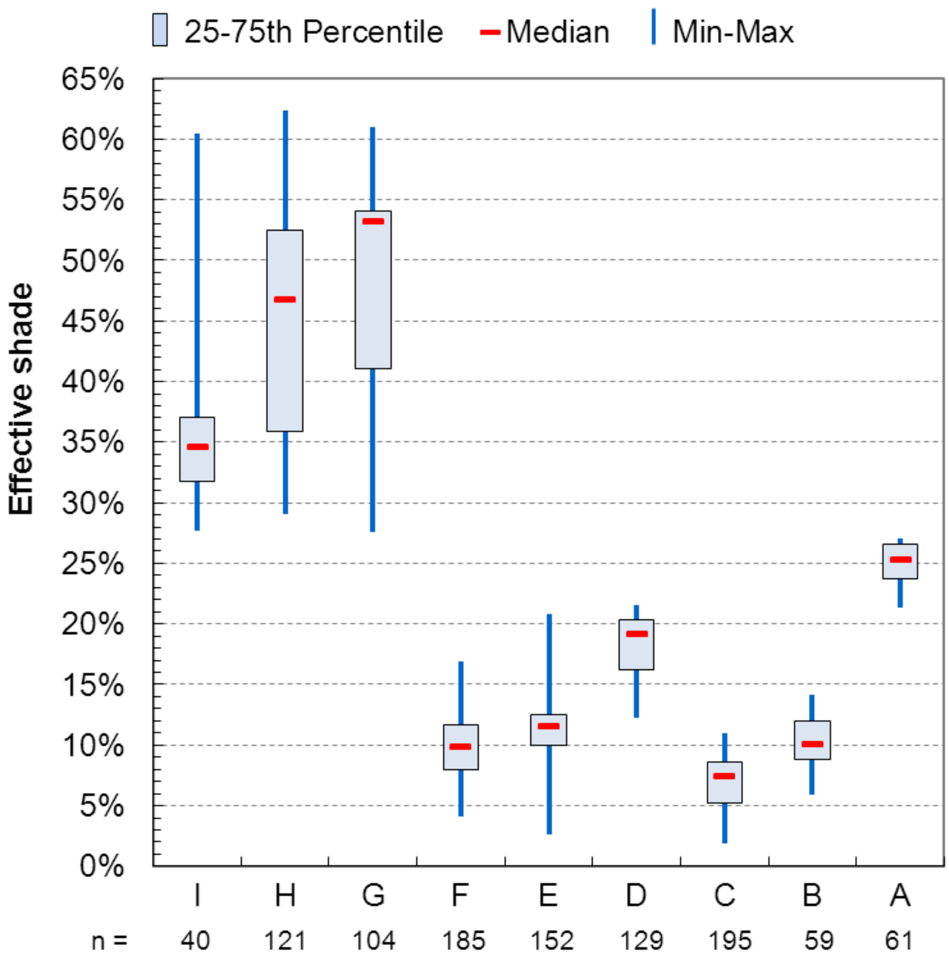


Figure I-21. Box-and-whisker plot evaluation of effective shade output.

I4.7 Heat

QUAL2K users can select various heat transfer model input parameters. For this project, default values recommended by Chapra et al. (2008) were used; the inputs are presented in **Table IC-12** in **Appendix IC**.

I5.0 Calibration and Validation

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

Discussions of calibration and validation are in the *Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling* (Tetra Tech, Inc, 2012).

I5.1 Error Analysis

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

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

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

I5.2 Calibration and Validation Periods

The period for calibration and validation for developing the temperature QUAL2K model were selected on the basis of the available data. The available flow and stream geometry data suggest that travel time in the East Fork Rock Creek, from East Fork Reservoir to the mouth, is less than one day. Average velocities were calculated from depth-velocity interval data recorded when flow was monitored on 13 occasions across 5 sites. Average velocities, at sites below the pipeline diversion, typically increased from upstream to downstream. Average velocity ranged from 0.81 to 2.57 feet per second, with an average of 1.74 feet per second. Such velocities yield travel times of 5.5 to 28 hours, with an average of 9.3 hours.

Available precipitation data were also considered during the selection of calibration and validation periods (see thermographs with daily precipitation in **Appendix ID**). The warmest stream temperatures occurred during July when there was no precipitation. Precipitation events resulted in cooling, rather than warming, the stream, likely because of cooler ambient air temperatures.

Therefore, a single day each was selected for the calibration period and the validation period. The calibration period (July 29, 2010) and validation period (August 21, 2011) consisted of a warm day without precipitation on that day or preceding days during summer low-flows, which allows for calibration to conditions that would be similar to that of critical conditions (i.e., warm water with low flows). On the calibration period and preceding week, the canal diverted 94 percent of the flow from East Fork Reservoir; similarly, the canal diverted 95 percent of the flow during the validation period and 96 percent of the flow during the week preceding the validation period. The model run-time was three days, with one day of input for all the parameters (calibration or validation period); this ensures that water had enough time to travel through the entire system.

I5.3 Calibration Results

Temperature calibration for the East Fork Rock Creek QUAL2K model relied on a comparison of model predictions to observations at the six temperature loggers in the temperature-impaired segment (C02ROCEF05, C02ROCEF20, C02ROCEF04, C02ROCEF03, C02ROCEF10, and C02ROCEF02).

All the modeled minima, means, and maxima are within 2 °C of the corresponding observed minima, means, and maxima (see **Appendix IC**, **Table IC-13**). All but two of the relative differences are less than 10 percent; these two exceptions are the daily minima at C02ROCEF10 (15 percent) and C02ROCEF02 (11 percent). Therefore, in accordance with the QAPP (Tetra Tech, Inc, 2012), the calibration is acceptable.

The calibration results are displayed in **Figure I-22** and **Table I-5** in Fahrenheit to facilitate comparisons with model scenarios that are discussed in **Section I6.0**.

Table I-5. Model calibration results for July 29, 2010 (°F)

Daily temperature	Source	C02ROCEF*					
		***05**	***20**	***04**	***03**	***10**	***02**
Maximum	QUAL2K	49.6	50.7	58.2	60.4	65.6	66.4
	Observed	48.8	49.8	60.9	63.1	64.3	63.7
	Difference	+0.8	+0.9	-2.7	-2.8	+1.3	+2.7
Mean	QUAL2K	47.4	47.8	50.4	51.9	53.9	54.3
	Observed	47.6	47.4	52.9	53.9	54.9	54.8
	Difference	-0.2	+0.4	-2.5	-2.0	-1.0	-0.5
Minimum	QUAL2K	46.2	46.2	45.6	45.2	44.8	44.9
	Observed	45.8	46.2	46.6	46.5	47.1	46.5
	Difference	+0.4	0.0	-1.0	-1.3	-2.3	-1.6

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree. The difference is calculated as the QUAL2K minus observed.

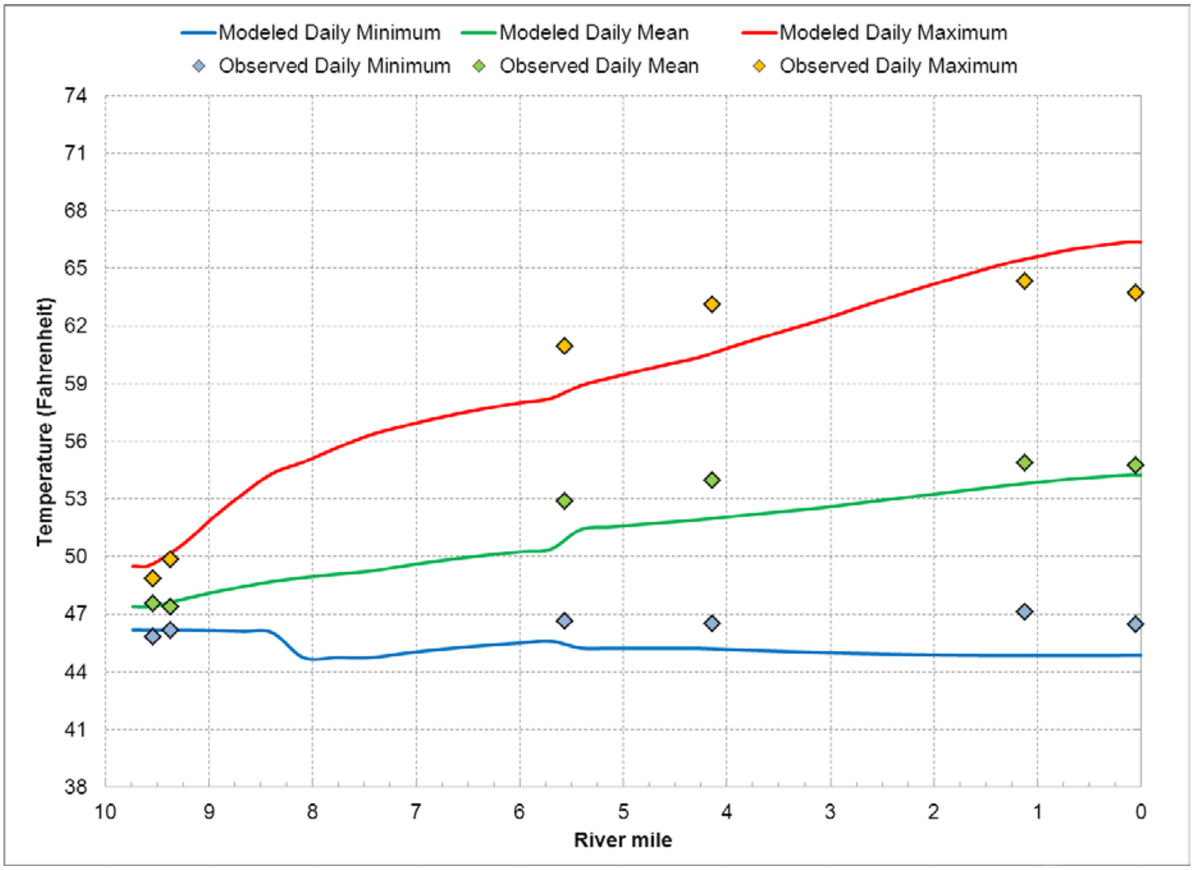


Figure I-22. Calibration time period (July 29, 2010).

I5.4 Validation Results

Model validation was determined by a second model run that was conducted under different hydrological and weather conditions (August 21, 2011). DNRC temperature and flow data were used to validate.

All the modeled minima, means, and maxima are within 2 °C of the corresponding observed minima, means, and maxima (see **Appendix IC**, **Table IC-14**). All but one of the relative differences is less than 10 percent; this exception is the maximum at the site above Elk Creek (11 percent). Therefore, in accordance with the QAPP (Tetra Tech, Inc, 2012), the validation is acceptable.

The validation results are displayed in **Table I-6** and **Figure I-23** in Fahrenheit to facilitate comparisons with model scenarios that are discussed in **Section I6.0**.

Table I-6. Model validation results for August 21, 2011 in Fahrenheit

Daily temperature	Source	blw Res	abv Elk Ck	Walden Br	abv Meadow	abv MF
Maximum	QUAL2K	53.2	53.6	56.0	60.0	62.3
	Observed	52.6	56.2	57.9	59.9	62.3
	Difference	+0.6	-2.6	-1.9	+0.1	0
Mean	QUAL2K	50.4	49.2	49.6	50.5	51.9
	Observed	50.6	50.6	50.9	52.0	53.2
	Difference	-0.2	-1.4	-1.4	-1.5	-1.2
Minimum	QUAL2K	49.0	47.0	46.3	45.5	45.2
	Observed	49.3	47.5	46.8	46.9	45.6
	Difference	-0.3	-0.5	-0.5	-1.4	-0.4

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree. The difference is calculated as the QUAL2K minus observed.

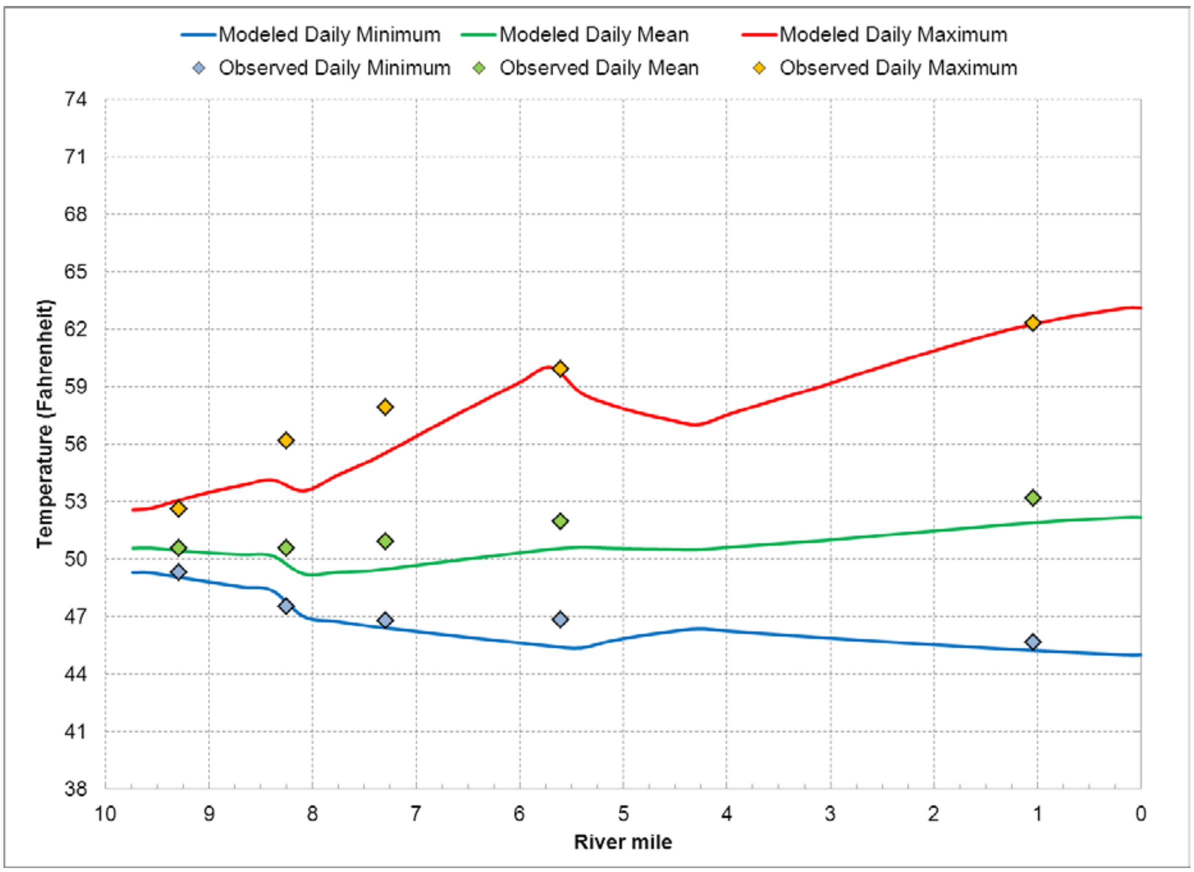


Figure I-23. Validation period (August 21, 2011).

I6.0 Model Scenarios

The East Fork Rock Creek QUAL2K model was used to evaluate instream temperature response associated with the following scenarios in **Table I-7**. The table summarizes the alterations to input parameters for each model scenario.

Table I-7. Model scenarios and summary of inputs

Scenario	Inputs
Existing conditions (calibration)	As discussed in **Section I6.1**
Existing conditions with low flow	Flow below the Flint Creek diversion is set to 5 cfs
Full potential shade	Shade increased in each reach depending on the vegetation
Full potential shade with low flow	Flow below the Flint Creek diversion is set to 5 cfs and shade increased in each reach depending on the vegetation
15% water savings from improved irrigation delivery and application efficiencies, and allowing that water savings to flow down East Fork Rock Creek past the main diversion	Increase inflows (reduce Flint Creek diversion by 15%)
15% water savings and full potential shade	Increase inflows (reduce Flint Creek diversion by 15%) and shade increased in each reach depending on the vegetation

The following sections present a discussion of the modifications to the QUAL2K models and the results for each scenario.

I6.1 Existing Conditions

The calibration model serves as the existing conditions scenario (i.e., baseline) for which to construct the other scenarios and compare the results against. This model represents dry conditions during July. The construction of the model and its inputs are discussed in **Section I4.0**.

I6.2 Existing Conditions with Low Flow

In this scenario, the flow inputs to the QUAL2K model are decreased to represent low-flow conditions, simulating the stream dynamics during an exceptionally dry season. DNRC, which manages East Fork Reservoir and the diversion to the Flint Creek watershed, maintains at least 5 cfs below the diversion. In this scenario, the water balance was altered such that 5 cfs of flow was present in the model just below the diversion.

This low-flow condition scenario resulted in slightly higher temperatures along most of the stream. Daily mean temperatures increased, as compared to the existing condition scenario, by 0.1 °F and the daily maximum temperatures increased between 0.1 and 0.3 °F. **Table I-8** presents the results at the DEQ sample sites and **Figure I-24** presents the continuous results along East Fork Rock Creek.

Table I-8. Low-flow conditions results

Daily temperature	Source	C02ROCEF*					
		*05	*20	*04	*03	*10	*02
Maximum	Existing	49.6	50.7	58.2	60.4	65.6	66.4
	Scenario	49.6	50.9	58.5	60.5	65.9	66.6
	Difference	***<-0.05***	+0.2	+0.3	+0.1	+0.3	+0.2
Mean	Existing	47.4	47.8	50.4	51.9	53.9	54.3
	Scenario	47.4	47.9	50.5	52.0	54.0	54.4
	Difference	***<-0.05***	+0.1	+0.1	+0.1	+0.1	+0.1
Minimum	Existing	46.2	46.2	45.6	45.2	44.8	44.9
	Scenario	46.2	46.2	45.6	45.2	44.8	44.9
	Difference	<+0.05	<+0.05	***<-0.05***	***<-0.05***	<+0.05	<+0.05

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

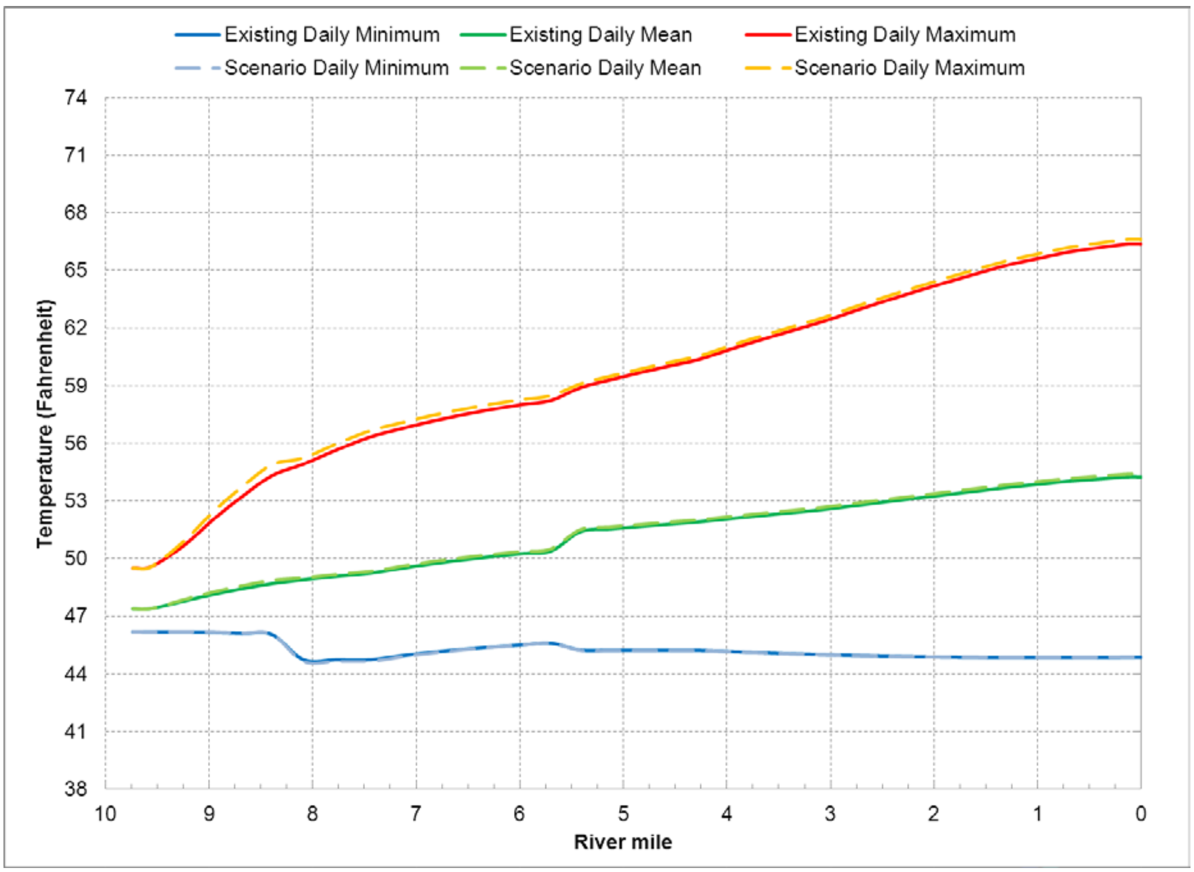


Figure I-24. Low-flow conditions results.

I6.3 Full Potential Shade

The full potential shade scenario uses the existing conditions model and increases shading along the creek depending on the vegetation present in each reach. The shade in reaches A through F was set equivalent to the 24-hour shade input in reach A. The shade in reach G remained the same, and the shade in reaches H and I was set equivalent to the 24-hour shade input in reach H. These full potential shade assignments are based on analyses performed by DEQ; the results of these analyses are summarized in the following paragraph.

On the basis of an DEQ review of the vegetation data and aerial photos, it appears that vegetation conditions similar to the EFRC Shade 1 (see the vegetation map **Figure I-7**), which is characterized by medium conifer in the overstory with dense willows and shrubs in the understory, would be achievable in East Fork Rock Creek below East Fork Reservoir, in reaches H and I. The potential cover for reach G is mixed high level based on data from Shade 2. The potential cover for reaches A through F is based on site Shade 6, which is medium willow and shrub; however, most of the stream along these reaches is below this potential condition.

This scenario resulted in cooler water temperatures along most of East Fork Rock Creek. Daily mean temperatures decreased, as compared to the existing condition scenario, between 0.0 and 0.8 °F and daily maximum temperatures decreased between 0.0 and 1.8 °F. **Table I-9** presents the results at the DEQ sample sites and **Figure I-25** presents the continuous results along East Fork Rock Creek.

Table I-9. Full potential shade results

Daily temperature	Source	C02ROCEF*					
		*05	*20	*04	*03	*10	*02
Maximum	Existing	49.6	50.7	58.2	60.4	65.6	66.4
	Scenario	49.6	50.7	57.6	59.5	63.8	64.6
	Difference	***<-0.05***	***<-0.05***	***-0.6***	***-0.9***	***-1.8***	***-1.8***
Mean	Existing	47.4	47.8	50.4	51.9	53.9	54.3
	Scenario	47.4	47.8	50.1	51.6	53.1	53.5
	Difference	***<-0.05***	***<-0.05***	***-0.3***	***-0.3***	***-0.8***	***-0.8***
Minimum	Existing	46.2	46.2	45.6	45.2	44.8	44.9
	Scenario	46.2	46.2	45.6	45.2	44.8	44.8
	Difference	0	0	***<-0.05***	***<-0.05***	***<-0.05***	***<-0.05***

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree. The difference is calculated as the existing subtracted from the scenario. Negative, ***italic bold*** results indicate that the scenario yields cooler instream temperatures as compared to the existing condition; positive, shaded results indicate that the scenario yielded warmer instream temperatures as compared to the existing conditions.

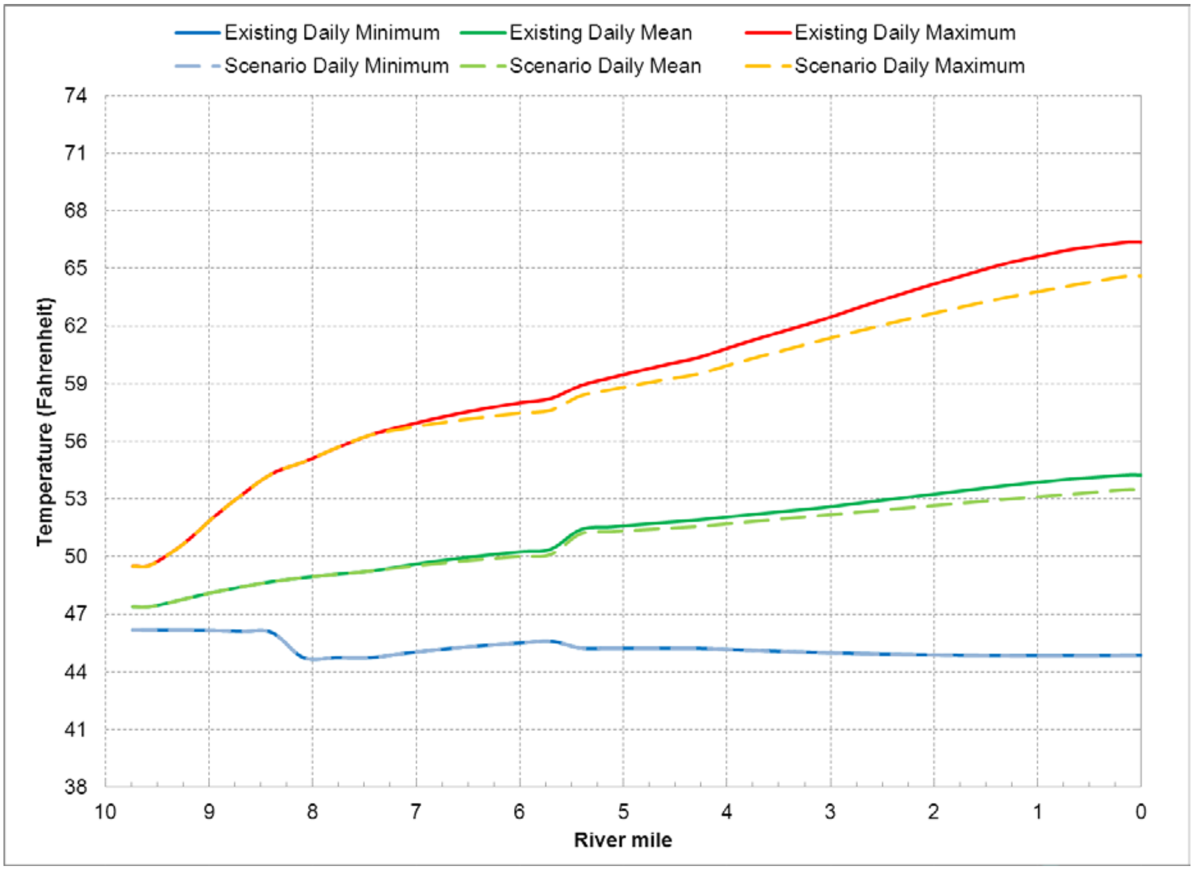


Figure I-25. Full potential shade results.

I6.4 Full Potential Shade with Low-Flow

The full potential shade scenario using low-flow conditions is a combination of the scenarios presented in **Sections I6.2** and **I6.3**. Flow conditions were designed to replicate a dry season, and shading was increased to approximate a mature riparian corridor.

This scenario resulted in cooler water temperatures along the lower portions of East Fork Rock Creek. Daily mean temperatures changed, as compared to the existing condition scenario, between –0.7 and 0.1 °F and daily maximum temperatures changed between –1.6 and 0.2°F. **Table I-10** presents the results at the DEQ sample sites and **Figure I-26** presents the continuous results along East Fork Rock Creek.

Table I-10. Full potential shade with low-flow conditions results

Daily temperature	Source	C02ROCEF*					
		*05	*20	*04	*03	*10	*02
Maximum	Existing	49.6	50.7	58.2	60.4	65.6	66.4
	Scenario	49.6	50.9	57.8	59.7	64.0	64.8
	Difference	***<-0.05***	+0.2	***-0.4***	***-0.7***	***-1.6***	***-1.6***
Mean	Existing	47.4	47.8	50.4	51.9	53.9	54.3
	Scenario	47.4	47.9	50.2	51.7	53.2	53.6
	Difference	***<-0.05***	+0.1	***-0.2***	***-0.2***	***-0.7***	***-0.7***
Minimum	Existing	46.2	46.2	45.6	45.2	44.8	44.9
	Scenario	46.2	46.2	45.6	45.2	44.8	44.8
	Difference	<+0.05	<+0.05	***<-0.05***	***<-0.05***	***<-0.05***	***<-0.05***

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference is calculated as the existing subtracted from the scenario. Negative, ***bold italic*** results indicate that the scenario yields cooler instream temperatures as compared to the existing condition; positive, shaded results indicate that the scenario yielded warmer instream temperatures as compared to the existing conditions.

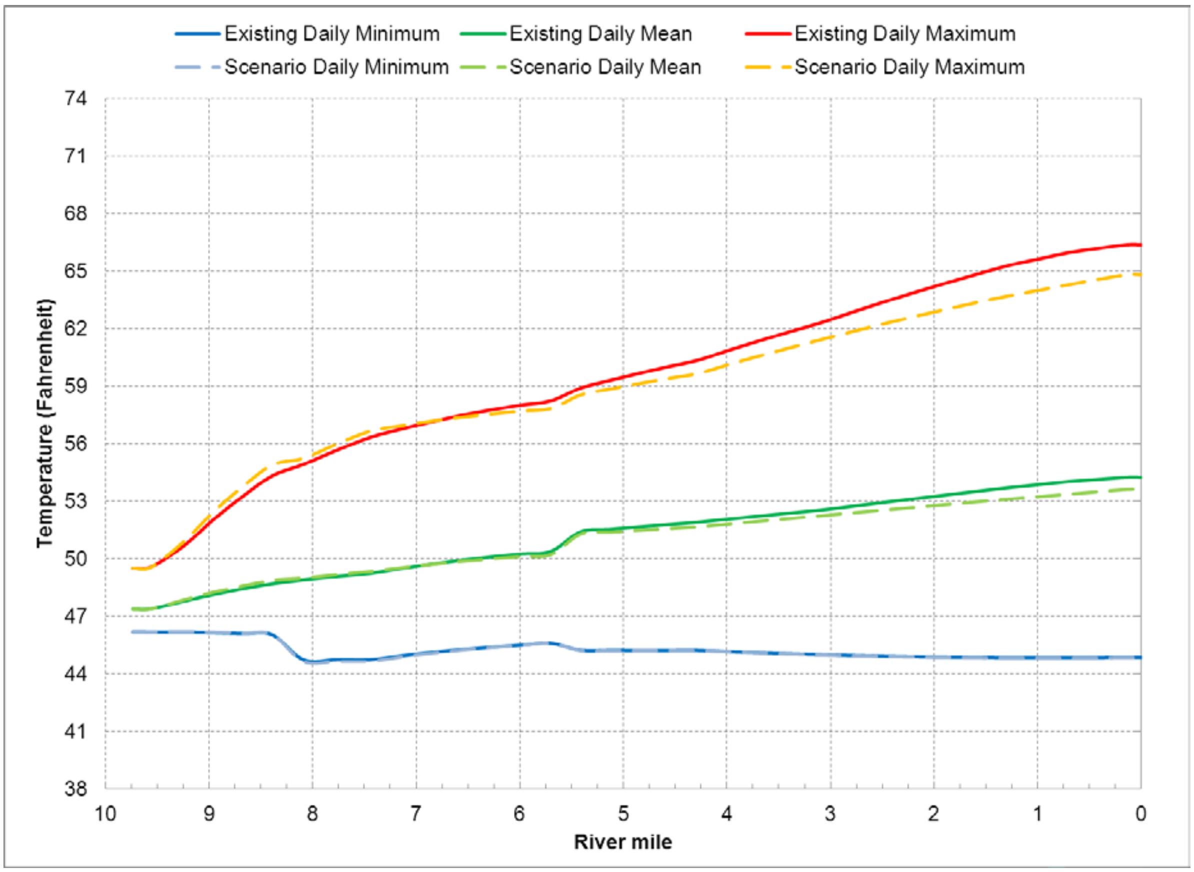


Figure I-26. Full potential shade with low-flow conditions results.

I6.5 Increased Flow Scenario

The increased flow scenario is used to describe the potential thermal effect of water savings and flow augmentation on water temperatures in East Fork Rock Creek. This scenario assumes that improved water delivery and application efficiency could create a water savings of 15% and that the conserved water could be allowed to flow down East Fork Rock Creek past the main diversion, thereby increasing instream flow. For modeling purposes, the diversion flow rate was reduced by 15 percent, and the additional water was allowed to flow down East Fork Rock Creek.

This scenario resulted in cooler water temperatures along most of East Fork Rock Creek. Daily mean temperatures decreased, as compared to the existing condition scenario, between 0.2 and 1.4 °F and daily maximum temperatures decreased between 0.6 and 2.5 °F. **Table I-11** presents the results at the DEQ sample sites and **Figure I-27** presents the continuous results along East Fork Rock Creek.

Table I-11.Increased flow results

Daily temperature	Source	C02ROCEF*					
		*05	*20	*04	*03	*10	*02
Maximum	Existing	49.6	50.7	58.2	60.4	65.6	66.4
	Scenario	49.6	50.1	56.0	58.4	63.2	63.9
	Difference	<+0.05	***-0.6***	***-2.2***	***-2.0***	***-2.4***	***-2.5***
Mean	Existing	47.4	47.8	50.4	51.9	53.9	54.3
	Scenario	47.4	47.6	49.5	50.9	52.6	52.9
	Difference	<+0.05	***-0.2***	***-0.9***	***-1.0***	***-1.3***	***-1.4***
Minimum	Existing	46.2	46.2	45.6	45.2	44.8	44.9
	Scenario	46.2	46.1	45.7	45.4	44.9	44.9
	Difference	***<-0.05***	***<-0.05***	+0.1	+0.2	+0.1	<+0.05

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference is calculated as the existing subtracted from the scenario. Negative, ***bold italic*** results indicate that the scenario yields cooler instream temperatures as compared to the existing condition; positive, shaded results indicate that the scenario yielded warmer instream temperatures as compared to the existing conditions.

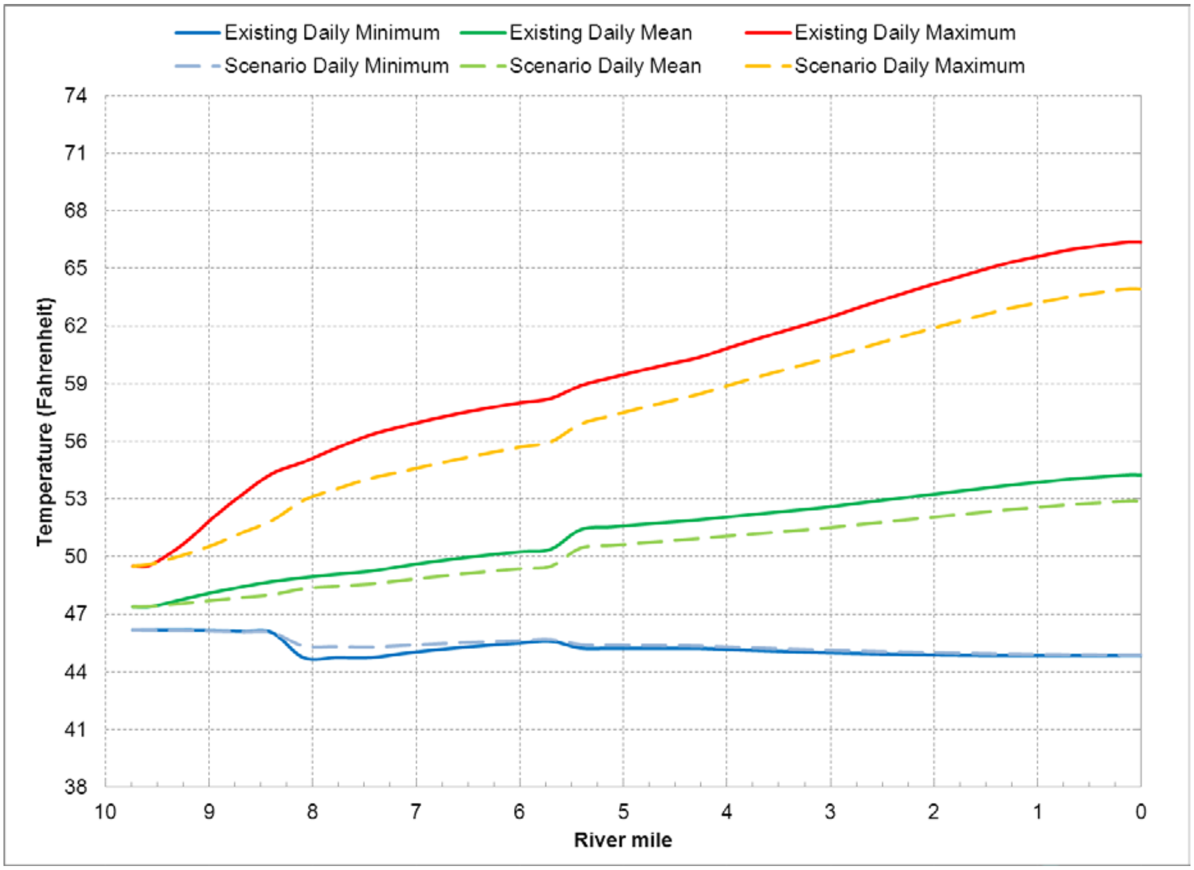


Figure I-27. Increased flow results.

I6.6 Increased Flow with Full Potential Shade

A combination of the scenarios presented in **Sections I6.3** and **I6.5** are used (full potential shade scenario and a 15% water savings). Shading was increased to approximate a mature riparian corridor, and for the 15% water savings, the diversion was reduced by 15 percent in the model.

This scenario resulted in cooler water temperatures along most of East Fork Rock Creek. Daily mean temperatures decreased, as compared to the existing condition scenario, between 0.2 and 2.0 °F and daily maximum temperatures decreased between 0.6 and 3.9 °F. **Table I-12** presents the results at the DEQ sample sites and **Figure I-28** presents the continuous results along East Fork Rock Creek.

Table I-12.Increased flow and full shade results

Daily temperature	Source	C02ROCEF*					
		*05	*20	*04	*03	*10	*02
Maximum	Existing	49.6	50.7	58.2	60.4	65.6	66.4
	Scenario	49.6	50.1	55.6	57.8	61.7	62.5
	Difference	<+0.05	***-0.6***	***-2.6***	***-2.6***	***-3.9***	***-3.9***
Mean	Existing	47.4	47.8	50.4	51.9	53.9	54.3
	Scenario	47.4	47.6	49.3	50.7	52.0	52.3
	Difference	<+0.05	***-0.2***	***-1.1***	***-1.2***	***-1.9***	***-2.0***
Minimum	Existing	46.2	46.2	45.6	45.2	44.8	44.9
	Scenario	46.2	46.1	45.7	45.4	44.9	44.9
	Difference	***<-0.05***	***<-0.05***	+0.1	+0.2	+0.1	<+0.05

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The difference is calculated as the existing subtracted from the scenario. Negative, ***bold italics*** results indicate that the scenario yields cooler instream temperatures as compared to the existing condition; positive, shaded results indicate that the scenario yielded warmer instream temperatures as compared to the existing conditions.

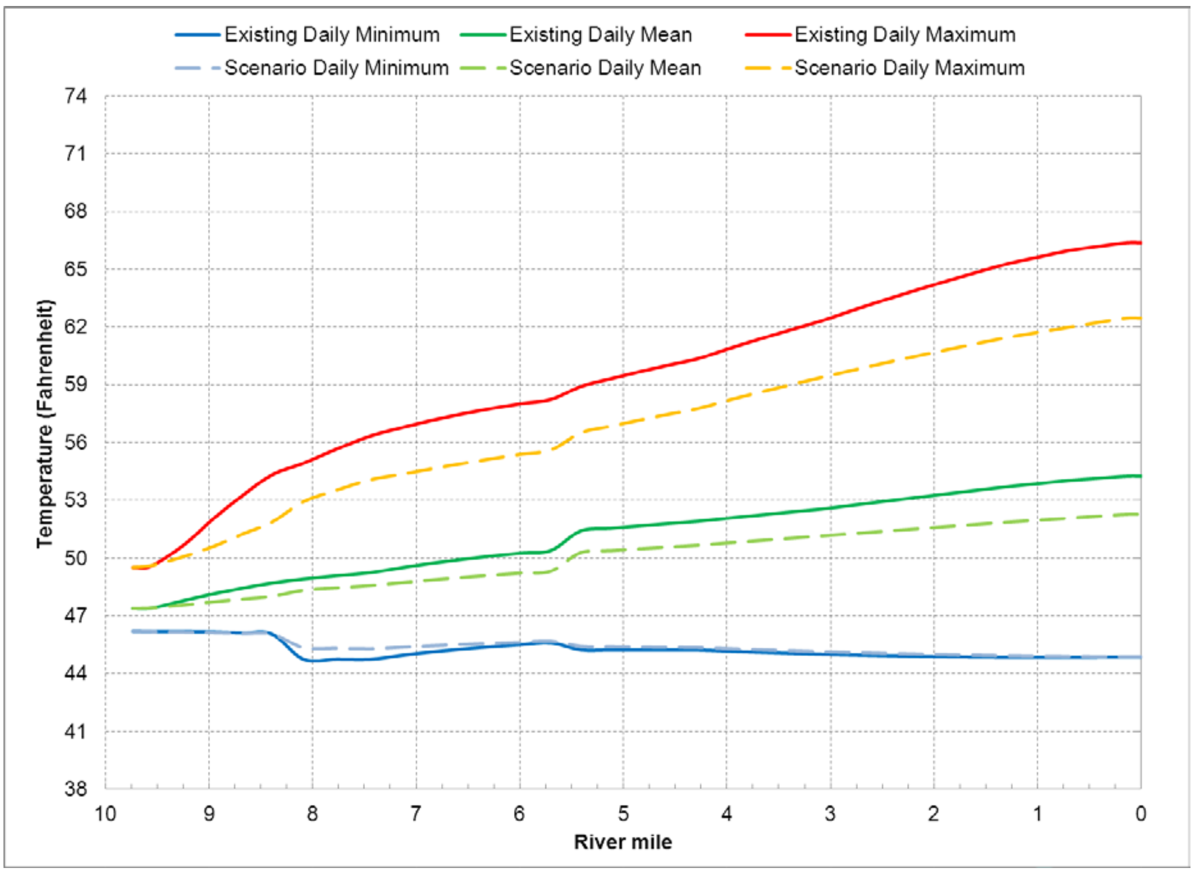


Figure I-28. Increased flow and shade results.

I6.7 Scenario Results and Discussion

Scenarios were developed in QUAL2K to evaluate the impacts of various factors that might affect instream water temperatures in East Fork Rock Creek. Reducing flow such that only 5 cfs was present in East Fork Rock Creek below the main diversion resulted in higher instream temperatures, which increased up to 0.3 °F. Increasing shade to replicate the effect of re-vegetation lowered stream temperatures by as much as 1.8 °F. Increasing shade with critical low-flow conditions resulted in higher instream temperatures in some parts of East Fork Rock Creek, but generally downstream, it reduced the temperatures (by as much as 1.6 °F). Attaining a 15% water savings from improved water delivery and application efficiency, and allowing that conserved water to flow down East Fork Rock Creek past the main diversion, lowered temperatures by as much as 2.5°F. Increasing flow and increasing to full potential shade lowered instream temperatures by as much as 3.9 °F. **Figure I-29** presents a summary of the results.

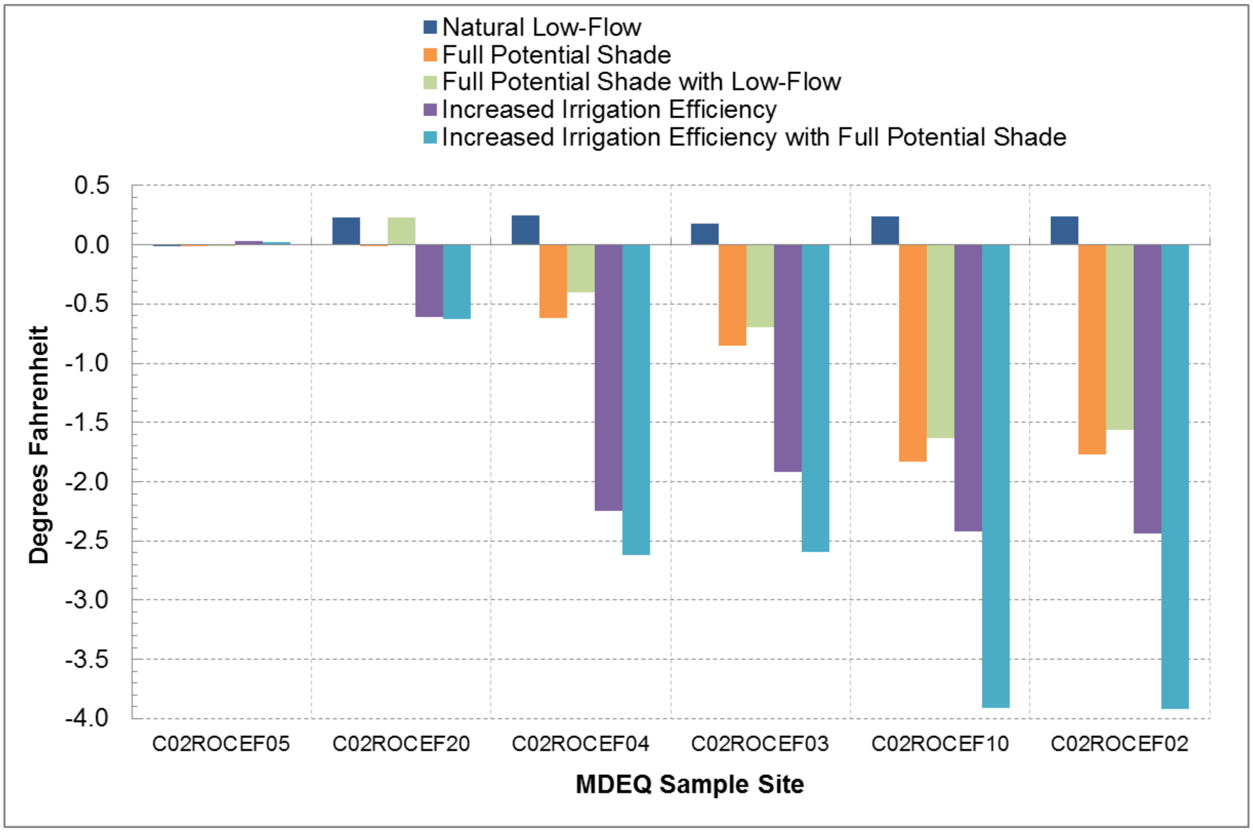


Figure I-29. Comparisons to the existing condition scenario (shown as the difference in simulated maximum daily water temperatures).

I7.0 REFERENCES

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APPENDIX IA. FIELD DATA (WATER & ENVIRONMENTAL TECHNOLOGIES, 2011)

Table IA-1. Shade measurements (Water & Environmental Technologies, 2011)

Site ID	Location and bank	Wetted width (feet)	Vegetation	Vegetation height (feet)	Density (percent)	Bank height (feet)	Overhang (feet)
EFRC Shade -6	A - LB	22	medium willow/shrub	8	65%	3	4
	A - RB	n/a	medium willow/shrub	8	82%	1.5	0
	B - LB	21	medium willow/shrub	8	94%	2.3	5
	B - RB	n/a	grass	3	35%	7.1	0.7
	C - LB	26.5	dense willow/shrub	10	100%	3	2
	C - RB	n/a	dense willow/shrub	13	71%	0.7	1.5
EFRC Shade -5	A - LB	19.3	grass	1.9	47%	1.8	1.1
	A - RB	n/a	grass	2	6%	3.2	0.5
	B - LB	17.7	grass	1.7	7%	1.4	0.8
	B - RB	n/a	grass	1.7	41%	2.4	0.6
	C - LB	17.6	grass	1.7	53%	2.1	1.5
	C - RB	n/a	grass	2	29%	0.9	0.4
EFRC Shade -4	A - LB	19.45	grass	2	100%	1.5	1
	A - RB	n/a	medium willow/shrub	10	76%	9	5
	B - LB	23.5	grass	2.2	35%	1.5	1.5
	B - RB	n/a	grass	2	59%	2.3	1
	C - LB	18.5	grass	2	17.65%	2	0.3
	C - RB	n/a	grass	2	53%	1	0.8
EFRC Shade -3	A - LB	13.5	sparse willow/shrub	7	94%	2	4.5
	A - RB	n/a	medium willow/shrub	12.5	100%	0.7	0
	B - LB	14	grass	1	0%	1.4	0
	B - RB	n/a	sparse willow/shrub	7	53%	1.3	4
	C - LB	17	sparse willow/shrub	11	100%	3.5	0
	C - RB	n/a	sparse willow/shrub	12	100%	0.9	0
EFRC Shade -2	A - LB	18	MHL	13 to 25	100%	0.8	0
	A - RB	n/a	medium conifer	25.5	94%	0.9	0
	B - LB	19.5	medium conifer	23.4	71%	12	0
	B - RB	n/a	medium conifer	52.3	88%	1.1	0
	C - LB	27	MHL	22.3	100%	7	1.5
	C - RB	n/a	MHL	26.7	100%	4.5	0
EFRC Shade -1	A - LB	16	dense willow/shrub	6	100%	12	6
	A - RB	n/a	grass	1.5	29%	1.2	0.7
	B - LB	24.5	medium conifer	37.9	94%	12	0
	B - RB	n/a	sparse conifer	41.4	94%	0.9	0
	C - LB	16	dense conifer	54.9	94%	3	1.5
	C - RB	n/a	sparse conifer	53.3	100%	0.8	0

Table IA-2. Riparian summary (Water & Environmental Technologies, 2011)

Vegetation description	Height (feet)	Density (percent)	Overhang (feet)
Dense Conifer	54.9	89%	1.5
Medium Conifer	34.8	49%	0
Sparse Conifer	47.4	34%	0
Mixed High Level	24.7	83%	0.5
Dense Willow/Shrub	9.7	75%	3.2
Medium Willow/Shrub	9.3	63%	2.8
Sparse Willow/Shrub	9.3	35%	2.1
Grass	1.9	36%	0.8

Table IA-3. Channel cross-section data, EFRK 01-02 (Water & Environmental Technologies, 2011)

Cell	Feature	Bankfull channel width (feet)	Channel cross-sectional area (square feet)	Bankfull mean depth (feet)	Width/depth ratio	Maximum depth (feet)	Flood-prone width (feet)	Entrenchment ratio
1	riffle	20.7	22.7	1.10	18.9	1.8	68.7	3.3
2	riffle	24.0	24.2	1.01	23.8	1.5	30.0	1.3
3	riffle	26.5	31.7	1.20	22.1	1.6	48.5	1.8
4	riffle	22.0	28.5	1.30	17.0	1.6	28.0	1.3
5	riffle	30.0	31.1	1.04	29.0	1.8	36.0	1.2

Table IA-4. Channel cross-section data, EFRK 03-03 (Water & Environmental Technologies, 2011)

Cell	Feature	Bankfull channel width (feet)	Channel cross-sectional area (square feet)	Bankfull mean depth (feet)	Width/depth ratio	Maximum depth (feet)	Flood-prone width (feet)	Entrenchment ratio
1	riffle	23.5	34.7	1.48	15.9	1.7	57.5	2.4
2	riffle	20.3	30.3	1.49	13.6	2.1	70.3	3.5
3	riffle	21.0	31.3	1.49	14.1	2.0	76.0	3.6
4	riffle	21.8	34.8	1.60	13.7	2.1	141.8	6.5
5	riffle	20.5	29.3	1.43	14.3	2.1	140.5	6.8

APPENDIX IB. SHADE ANALYSES

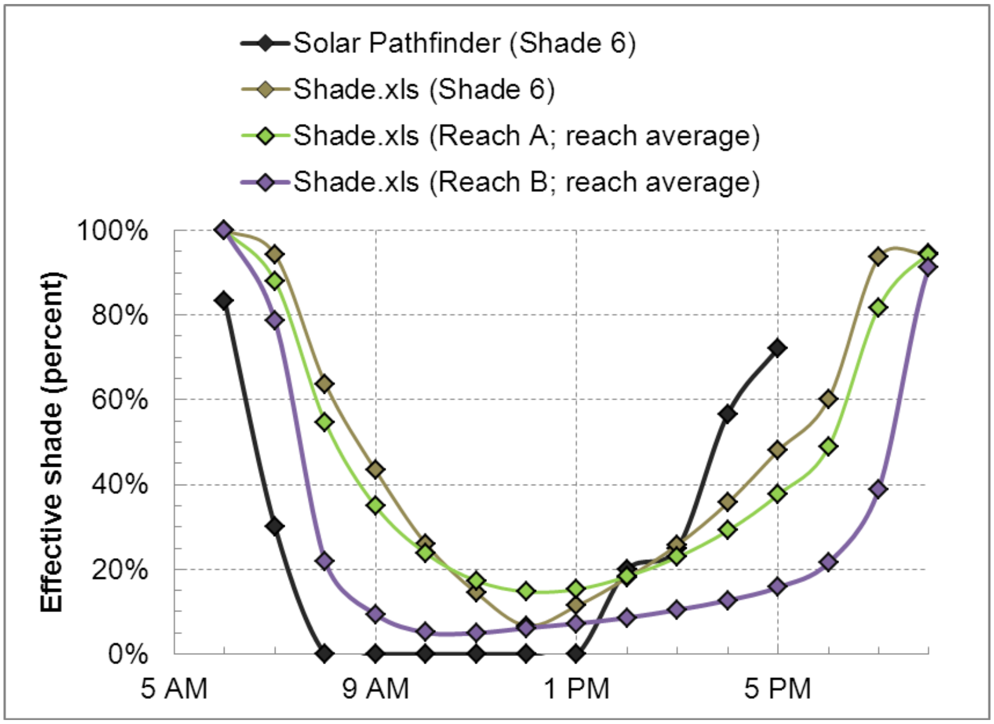

Figure IB-1. Shade analysis in reaches A and B.

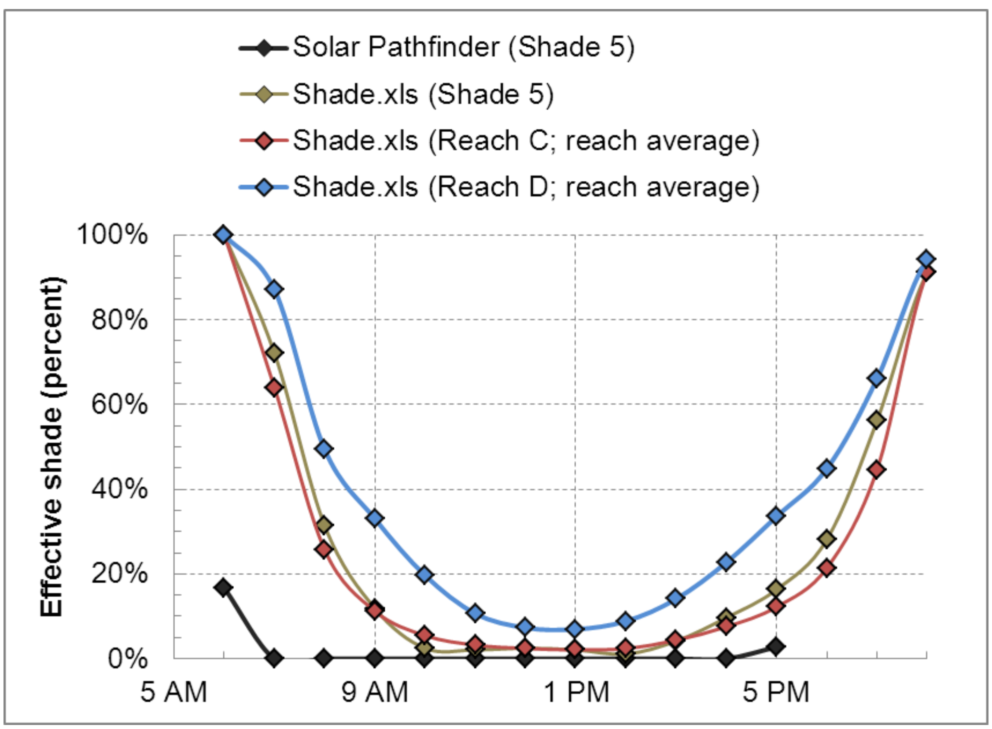

Figure IB-2. Shade analysis in reaches C and D.

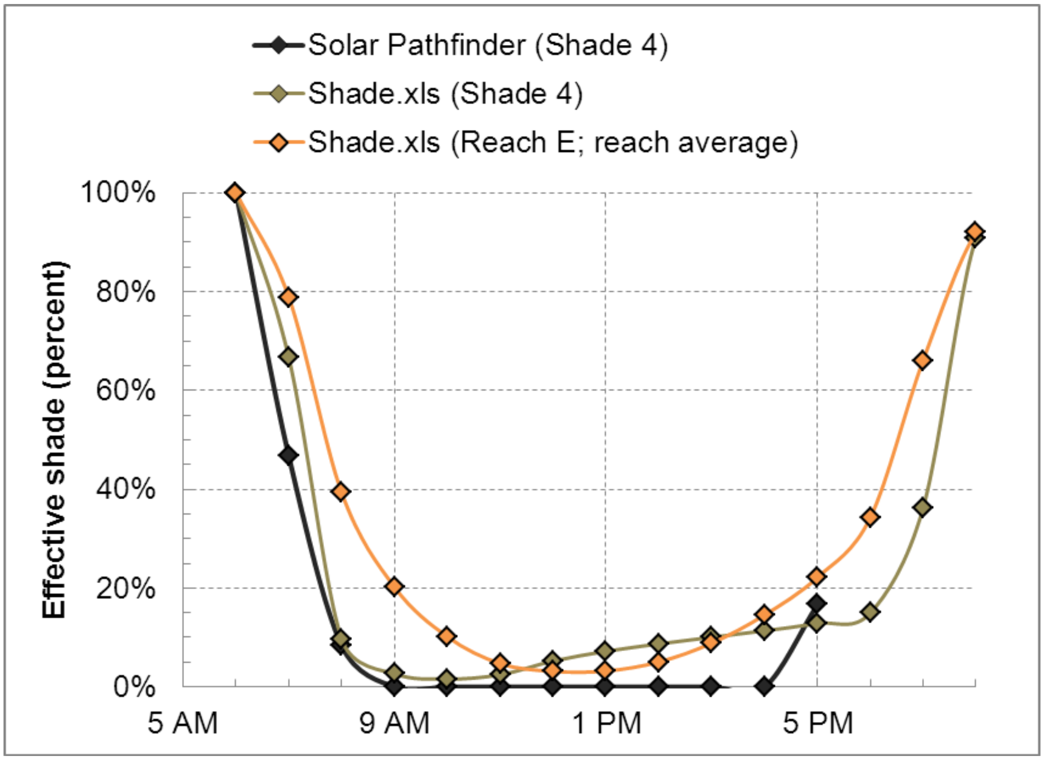

Figure IB-3. Shade analysis in reach E.

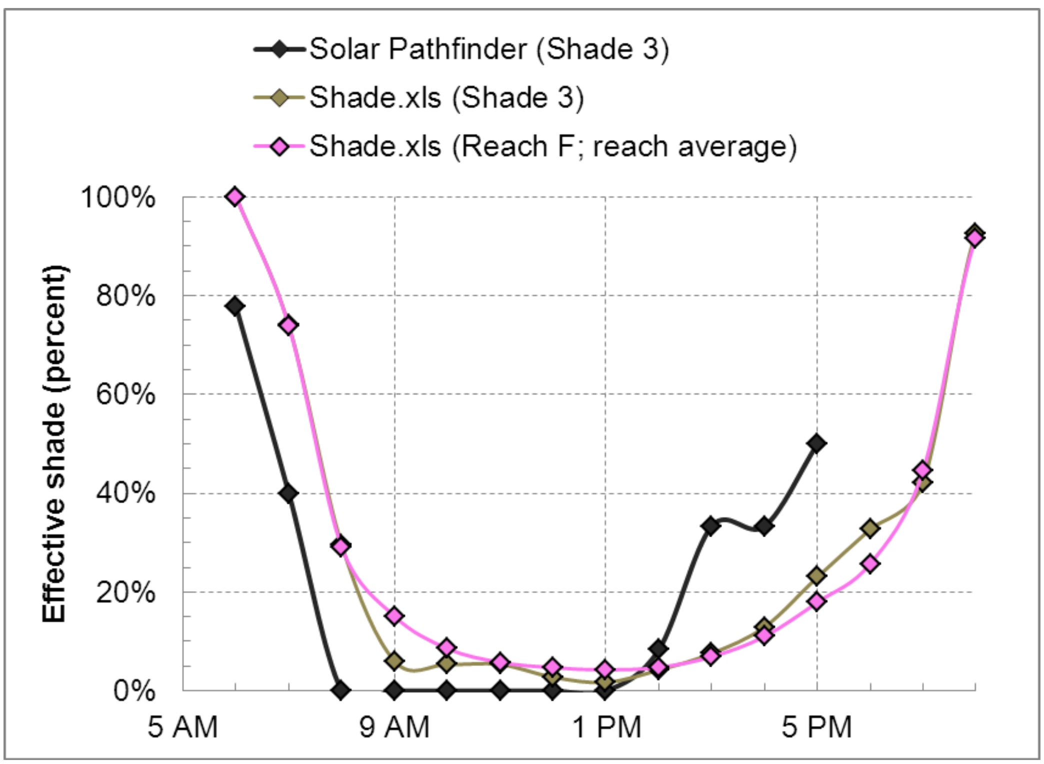

Figure IB-4. Shade analysis in reach F.

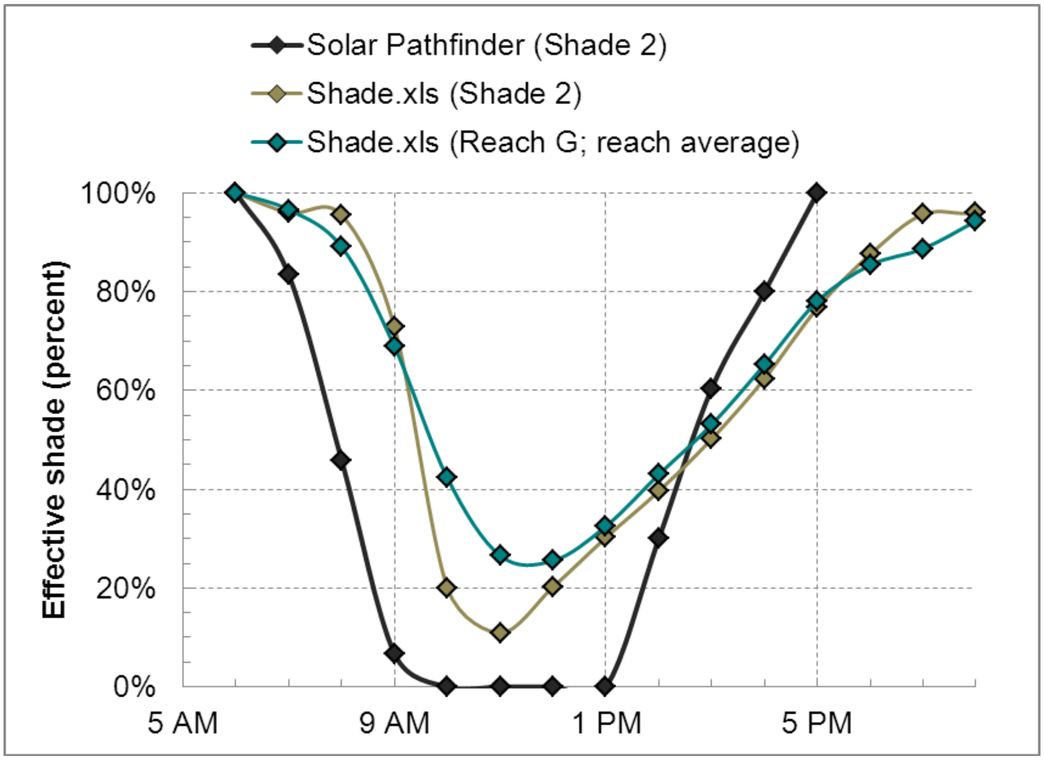

Figure IB-5. Shade analysis in reach G.

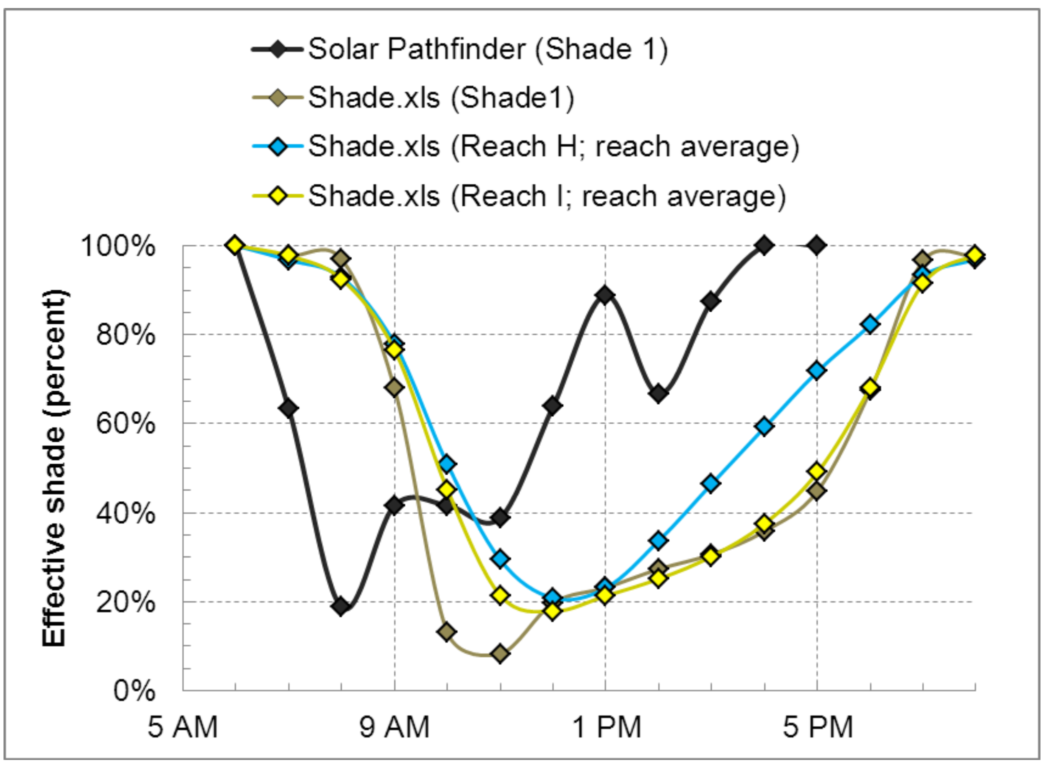

Figure IB-6. Shade analysis in reaches H and I.

APPENDIX IC. QUAL2K MODEL DEVELOPMENT

IC-1. SUMMARY OF THE ASSUMPTIONS AND SOURCES OF INPUT DATA

Table IC-1. Model input parameters

Model parameter	Source of input
Month	July 29, 2010. Warm day without rain during DEQ temperature logger deployment when synoptic flows were monitored.
Day	
Year	
Local time hours to UTC	Calculated using time zone of sample locations
Daylight savings time	Enabled
Calculation step	Estimated according to monitored instream velocities
Final time	

Table IC-2. Headwaters input parameters

Model parameter	Source of input
Flow rate	Observed at C02ROCEF05 on July, 29, 2010
Elevation	Calculated with GIS
Channel slope	
Manning roughness coefficient (n)	Estimated (Water & Environmental Technologies, 2011)
Bottom width	Estimated from observed flow-interval data that was collected when flow was measured at C02ROCEF20 on July 29, 2010.
Side slope 1	
Side slope 2	
Hourly water temperatures	Estimated from C02ROCEF05 on July 30, 2010. Logger was deployed on July 29, 2010; subsequent days were evaluated.

Table IC-3. Model segment input parameters

Model parameter	Source of input
Location	
Upstream location	Calculated with GIS
Downstream location	
Upstream elevation	
Downstream elevation	
Downstream latitude	
Downstream longitude	
Weather	
Hourly air temperatures	Estimated from observations at Philipsburg RAWS, corrected for elevation
Hourly dew point temperatures	
Hourly wind speed	Estimated from observations at Philipsburg RAWS, corrected for sensor height
Hourly cloud cover	Estimated from observations at Butte municipal airport
Hourly effective shade	Calculated with Shade3.0.xls
Manning	
Location	Calculated with GIS
Manning roughness coefficient (n)	Estimated (Water & Environmental Technologies, 2011)
Bottom width	Estimated from flow-interval data collected in late July 2010 at sites C02ROCEF20, C02ROCEF04, C02ROCEF03, C02ROCEF10, and C02ROCEF02.
Side slope 1	
Side slope 2	

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

Model parameter	Source of input
Groundwater inflow and outflow	
Upstream location	Calculated with GIS
Downstream location	
Diffuse abstraction (outflow)	Estimated from water balance
Diffuse inflow	
Temperature (for inflows)	Estimated (Water & Environmental Technologies, 2011)
Point sources and tributaries	
Location	Calculated with GIS
Abstraction (withdrawal)	Diversion: Estimated from DNRC continuous flow and temperature data Elk Creek: Estimated using DNRC above reservoir continuous flow and temperature data as surrogate Meadow Creek: Estimated using DEQ instantaneous flow and continuous temperature data
Inflow	
Mean daily temperature	
One-half range	
Time of daily maximum	

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

Model parameter	Source of input
Solar Shortwave Radiation Model	
Atmospheric attenuation model for solar	Best professional judgment
Bras solar parameter (used if Bras solar model is selected)	
Atmospheric turbidity coefficient	Default
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient	Default
Downwelling atmospheric longwave infrared radiation	
Atmospheric longwave emissivity model	Default
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	Default
Sediment heat parameters	
Sediment thermal thickness	Default
Sediment thermal diffusivity	Default
Sediment density	Default
Water density	Default
Sediment heat capacity	Default
Water heat capacity	Default

IC-2. Model Parameter Input Data

Table IC-6. Channel Geometry Inputs

Segment	Channel slope	Manning's n	Stream bottom width (meter/feet)	Side 1[a]	Side 2[a]
I	0.033	0.048	0.61 / 2.00	4.71	2.94
H	0.015	0.048	0.97 / 3.17	5.32	3.08
G	0.019	0.048	1.93 / 6.33	6.96	3.45
F	0.014	0.048	3.05 / 10.00	0.53	2.00
E	0.013	0.048	3.20 / 10.50	1.45	6.36
D	0.009	0.048	3.28 / 10.77	3.61	4.12
C	0.009	0.048	3.35 / 11.00	5.44	2.22
B	0.011	0.048	4.52 / 14.84	2.12	1.37
A	0.010	0.048	4.88 / 16.00	1.11	1.11

Notes: Segments are listed from top to bottom of the column as headwaters to mouth
[a] Adjacent side ratio (relative to one) based on the trapezoidal cross section

Table IC-7. Instream flow data used for modeling

Location	Flow (cubic meters per second)	Flow (cubic feet per second)
East Fork Rock Creek		
C02ROCEF05	3.248	114.7
C02ROCEF20	0.175	6.2
C02ROCEF04	0.730	25.8
C02ROCEF03	1.175	41.5
C02ROCEF10	1.079	38.1
C02ROCEF02	1.077	38.0
Elk Creek		
--	0.23	8.1
Meadow Creek		
C02MEDOC01	0.35	12.4

Table IC-8. Estimated diffuse flow for each reach

Segment	Direction	Diffuse flow (cubic meter per second)	Diffuse flow (cubic feet per second)
Reach I	Inflow	0.050	1.766
Reach H	Inflow	0.050	1.766
Reach G	Inflow	0.230	8.122
Reach F	Inflow	0.100	3.531
Reach E	Outflow	0.040	1.413
Reach D	Outflow	0.056	1.978
Reach C	Outflow	0.001	0.035
Reach B	Outflow	0.001	0.035
Reach A	Outflow	0.040	1.413

Table IC-9. Hourly weather data for East Fork Rock Creek on July 29, 2010

Time	Air temperature (°C)									Wind speed (meters/second)
Reach	I	H	G	F	E	D	C	B	A	All
12:00 AM	10.78	10.86	11.07	11.27	11.51	11.67	11.82	11.93	11.97	1.37
1:00 AM	9.67	9.75	9.96	10.15	10.40	10.55	10.71	10.81	10.86	0.91
2:00 AM	9.11	9.20	9.40	9.60	9.84	10.00	10.15	10.26	10.31	0.91
3:00 AM	8.56	8.64	8.85	9.04	9.29	9.44	9.60	9.70	9.75	2.74
4:00 AM	8.00	8.09	8.29	8.49	8.73	8.89	9.04	9.15	9.20	0.00
5:00 AM	7.45	7.53	7.74	7.93	8.18	8.33	8.49	8.59	8.64	0.46
6:00 AM	6.89	6.98	7.18	7.38	7.62	7.78	7.93	8.04	8.09	0.91
7:00 AM	10.78	10.86	11.07	11.27	11.51	11.67	11.82	11.93	11.97	0.91
8:00 AM	16.33	16.42	16.63	16.82	17.07	17.22	17.37	17.48	17.53	0.46
9:00 AM	21.33	21.42	21.63	21.82	22.07	22.22	22.37	22.48	22.53	2.28
10:00 AM	22.45	22.53	22.74	22.93	23.18	23.33	23.49	23.59	23.64	3.65
11:00 AM	23.56	23.64	23.85	24.04	24.29	24.44	24.60	24.70	24.75	5.02
12:00 PM	24.67	24.75	24.96	25.15	25.40	25.55	25.71	25.81	25.86	5.48
1:00 PM	25.22	25.31	25.51	25.71	25.96	26.11	26.26	26.37	26.42	4.11
2:00 PM	26.33	26.42	26.63	26.82	27.07	27.22	27.37	27.48	27.53	3.65
3:00 PM	26.33	26.42	26.63	26.82	27.07	27.22	27.37	27.48	27.53	4.56
4:00 PM	26.33	26.42	26.63	26.82	27.07	27.22	27.37	27.48	27.53	5.02
5:00 PM	26.33	26.42	26.63	26.82	27.07	27.22	27.37	27.48	27.53	4.56
6:00 PM	25.78	25.86	26.07	26.27	26.51	26.67	26.82	26.93	26.97	2.74
7:00 PM	24.67	24.75	24.96	25.15	25.40	25.55	25.71	25.81	25.86	0.91
8:00 PM	18.56	18.64	18.85	19.04	19.29	19.44	19.60	19.70	19.75	0.91
9:00 PM	15.22	15.31	15.51	15.71	15.96	16.11	16.26	16.37	16.42	2.28
10:00 PM	13.56	13.64	13.85	14.04	14.29	14.44	14.60	14.70	14.75	1.37
11:00 PM	11.33	11.42	11.63	11.82	12.07	12.22	12.37	12.48	12.53	0.46

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

Table IC-10. Hourly dew point data for East Fork Rock Creek on July 29, 2010

Time	Dew point temperature (°C)								
Segment	I	H	G	F	E	D	C	B	A
12:00 AM	8.56	8.64	8.85	9.04	9.29	9.44	9.60	9.70	9.75
1:00 AM	8.00	8.09	8.29	8.49	8.73	8.89	9.04	9.15	9.20
2:00 AM	6.89	6.98	7.18	7.38	7.62	7.78	7.93	8.04	8.09
3:00 AM	7.45	7.53	7.74	7.93	8.18	8.33	8.49	8.59	8.64
4:00 AM	6.89	6.98	7.18	7.38	7.62	7.78	7.93	8.04	8.09
5:00 AM	6.33	6.42	6.63	6.82	7.07	7.22	7.37	7.48	7.53
6:00 AM	6.33	6.42	6.63	6.82	7.07	7.22	7.37	7.48	7.53
7:00 AM	8.56	8.64	8.85	9.04	9.29	9.44	9.60	9.70	9.75
8:00 AM	11.89	11.98	12.18	12.38	12.62	12.78	12.93	13.04	13.09
9:00 AM	10.78	10.86	11.07	11.27	11.51	11.67	11.82	11.93	11.97
10:00 AM	6.33	6.42	6.63	6.82	7.07	7.22	7.37	7.48	7.53
11:00 AM	4.67	4.75	4.96	5.15	5.40	5.55	5.71	5.81	5.86
12:00 PM	3.56	3.64	3.85	4.04	4.29	4.44	4.60	4.70	4.75
1:00 PM	2.45	2.53	2.74	2.93	3.18	3.33	3.49	3.59	3.64

Table IC-10. Hourly dew point data for East Fork Rock Creek on July 29, 2010

Time	Dew point temperature (°C)								
Segment	I	H	G	F	E	D	C	B	A
2:00 PM	1.89	1.98	2.18	2.38	2.62	2.78	2.93	3.04	3.09
3:00 PM	1.33	1.42	1.63	1.82	2.07	2.22	2.37	2.48	2.53
4:00 PM	-0.33	-0.25	-0.04	0.15	0.40	0.55	0.71	0.81	0.86
5:00 PM	-2.00	-1.91	-1.71	-1.51	-1.27	-1.11	-0.96	-0.85	-0.80
6:00 PM	-1.44	-1.36	-1.15	-0.96	-0.71	-0.56	-0.40	-0.30	-0.25
7:00 PM	0.78	0.86	1.07	1.27	1.51	1.67	1.82	1.93	1.97
8:00 PM	-0.33	-0.25	-0.04	0.15	0.40	0.55	0.71	0.81	0.86
9:00 PM	2.45	2.53	2.74	2.93	3.18	3.33	3.49	3.59	3.64
10:00 PM	1.33	1.42	1.63	1.82	2.07	2.22	2.37	2.48	2.53
11:00 PM	2.45	2.53	2.74	2.93	3.18	3.33	3.49	3.59	3.64

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

Table IC-11. Hourly shade results (averaged along model segments)

Time	Shade (percent)								
Model reach	A	B	C	D	E	F	G	H	I
Up RM	0.55	1.1	2.9	4.1	5.5	7.2	8.2	9.4	9.7
Down RM	0	0.56	1.1	2.9	4.1	5.5	7.2	8.2	9.4
12:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
1:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
2:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
3:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
4:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
5:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
6:00 AM	100%	100%	100%	100%	100%	100%	100%	100%	100%
7:00 AM	87.99%	78.60%	63.95%	87.12%	78.85%	73.82%	96.58%	96.77%	97.71%
8:00 AM	54.64%	21.82%	25.68%	49.38%	39.28%	29.11%	89.05%	92.82%	92.46%
9:00 AM	34.89%	9.39%	11.25%	33.04%	20.18%	15.11%	68.86%	77.95%	76.57%
10:00 AM	23.75%	5.11%	5.47%	19.66%	10.15%	8.56%	42.25%	50.90%	45.18%
11:00 AM	17.32%	4.99%	3.24%	10.66%	4.72%	5.78%	26.55%	29.40%	21.43%
12:00 PM	14.72%	6.16%	2.44%	7.32%	3.14%	4.70%	25.54%	20.85%	17.86%
1:00 PM	15.30%	7.24%	2.09%	6.96%	3.20%	4.24%	32.53%	23.13%	21.36%
2:00 PM	18.32%	8.58%	2.42%	8.87%	5.06%	4.77%	42.99%	33.73%	25.16%
3:00 PM	22.88%	10.46%	4.38%	14.11%	8.85%	6.90%	53.09%	46.49%	30.20%
4:00 PM	29.15%	12.68%	7.56%	22.74%	14.55%	11.02%	65.23%	59.17%	37.54%
5:00 PM	37.62%	15.76%	12.23%	33.61%	22.17%	17.92%	78.06%	71.71%	49.06%
6:00 PM	48.82%	21.56%	21.41%	44.84%	34.26%	25.74%	85.37%	82.17%	68.09%
7:00 PM	81.76%	38.94%	44.61%	66.06%	66.09%	44.58%	88.70%	93.29%	91.49%
8:00 PM	94.36%	91.11%	91.10%	94.22%	91.96%	91.61%	94.28%	96.88%	97.76%
9:00 PM	100%	100%	100%	100%	100%	100%	100%	100%	100%
10:00 PM	100%	100%	100%	100%	100%	100%	100%	100%	100%
11:00 PM	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table IC-12. Heat parameters and transfer models

Parameter	Value
Solar Shortwave Radiation Model	
Atmospheric attenuation model for solar	Ryan-Stolzenbach
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient[a]	0.75
Downwelling atmospheric longwave infrared radiation	
Atmospheric longwave emissivity model	Brunt
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	Brady-Graves-Geyer
Sediment heat parameters	
Sediment thermal thickness (centimeter)[b]	10
Sediment thermal diffusivity (square centimeter per second)[c]	0.005
Sediment density (gram per cubic centimeter)[d]	1.6
Water density (gram per cubic centimeter)[d]	1
Sediment heat capacity (calorie per [gram by degree Celsius])[d]	0.4
Water heat capacity[d]	1

Notes:
[a] Atmospheric transmission coefficient default is 0.8; typical range is 0.70 to 0.91.
[b] Sediment thermal thickness default is 10 centimeters.
[c] Sediment thermal diffusivity default is 0.005 square centimeter per second
[d] These values are the model defaults.

IC-3. Calibration and Validation Results

Table IC-13. Model calibration results for July 29, 2010 in Celsius

Daily temperature	Source	C02ROCEF*					
		*05	*20	*04	*03	*10	*02
Maximum	QUAL2K	9.7	10.4	14.9	16.0	18.7	19.1
	Observed	9.4	9.9	16.1	17.3	18.3	17.6
	Abs. Error[a]	***0.4***	***0.5***	***-1.1***	***-1.3***	***0.7***	***1.5***
	Rel. Error[b]	***4%***	***5%***	***7%***	***7%***	***4%***	***8%***
Mean	QUAL2K	8.5	8.8	10.8	11.2	12.2	12.4
	Observed	8.7	8.5	11.6	12.2	12.7	12.6
	Abs. Error[a]	***-0.1***	***0.2***	***-0.8***	***-1.0***	***-0.5***	***-0.3***
	Rel. Error[b]	***1%***	***3%***	***7%***	***9%***	***4%***	***2%***
Minimum	QUAL2K	7.9	7.8	7.4	7.3	7.1	7.1
	Observed	7.7	7.9	8.1	8.1	8.4	8.0
	Abs. Error[a]	***0.2***	***0.0***	***-0.8***	***-0.8***	***-1.3***	***-0.9***
	Rel. Error[b]	***3%***	***0%***	***9%***	***9%***	15%	11%

Notes: Results are reported in degrees Celsius and rounded to the nearest one-tenth of a degree.
Calibration results that meet the acceptance criteria are presented in ***bolded italics***; results that do not meet the acceptance criteria are presented in shaded cells.
[a] Absolute error is calculated as QUAL2K minus observed.
[b] Relative error is calculated as the absolute value of QUAL2K minus observed and then divided by observed.

Table IC-14. Model validation results for August 21, 2010 in Celsius

Daily temperature	Source	blw Res	abv Elk Ck	Walden Br	abv Meadow	abv MF
Maximum	QUAL2K	11.8	12.0	13.3	15.5	16.8
	Observed	11.4	13.4	14.4	15.6	16.8
	Abs. Error[a]	***0.3***	***-1.5***	***-1.1***	***0.1***	***0.0***
	Rel. Error[b]	***3%***	11%	***7%***	***0%***	***0%***
Mean	QUAL2K	10.2	9.6	9.8	10.3	11.1
	Observed	10.3	10.3	10.5	11.1	11.8
	Abs. Error[a]	***-0.1***	***-0.8***	***-0.8***	***-0.8***	***-0.7***
	Rel. Error[b]	***1%***	***7%***	***7%***	***7%***	***6%***
Minimum	QUAL2K	9.5	8.3	8.0	7.5	7.3
	Observed	9.6	8.6	8.2	8.3	7.6
	Abs. Error[a]	***-0.2***	***-0.3***	***-0.3***	***-0.8***	***-0.2***
	Rel. Error[b]	***2%***	***3%***	***3%***	***9%***	***3%***

Notes: Results are reported in degrees Celsius and rounded to the nearest one-tenth of a degree.
Calibration results that meet the acceptance criteria are presented in ***bolded italics***; results that do not meet the acceptance criteria are presented in shaded cells.
[a] Absolute error is calculated as QUAL2K minus observed.
[b] Relative error is calculated as the absolute value of QUAL2K minus observed and then divided by observed.

APPENDIX ID. THERMOGRAPHS OF CALIBRATION AND VALIDATION TIME PERIODS

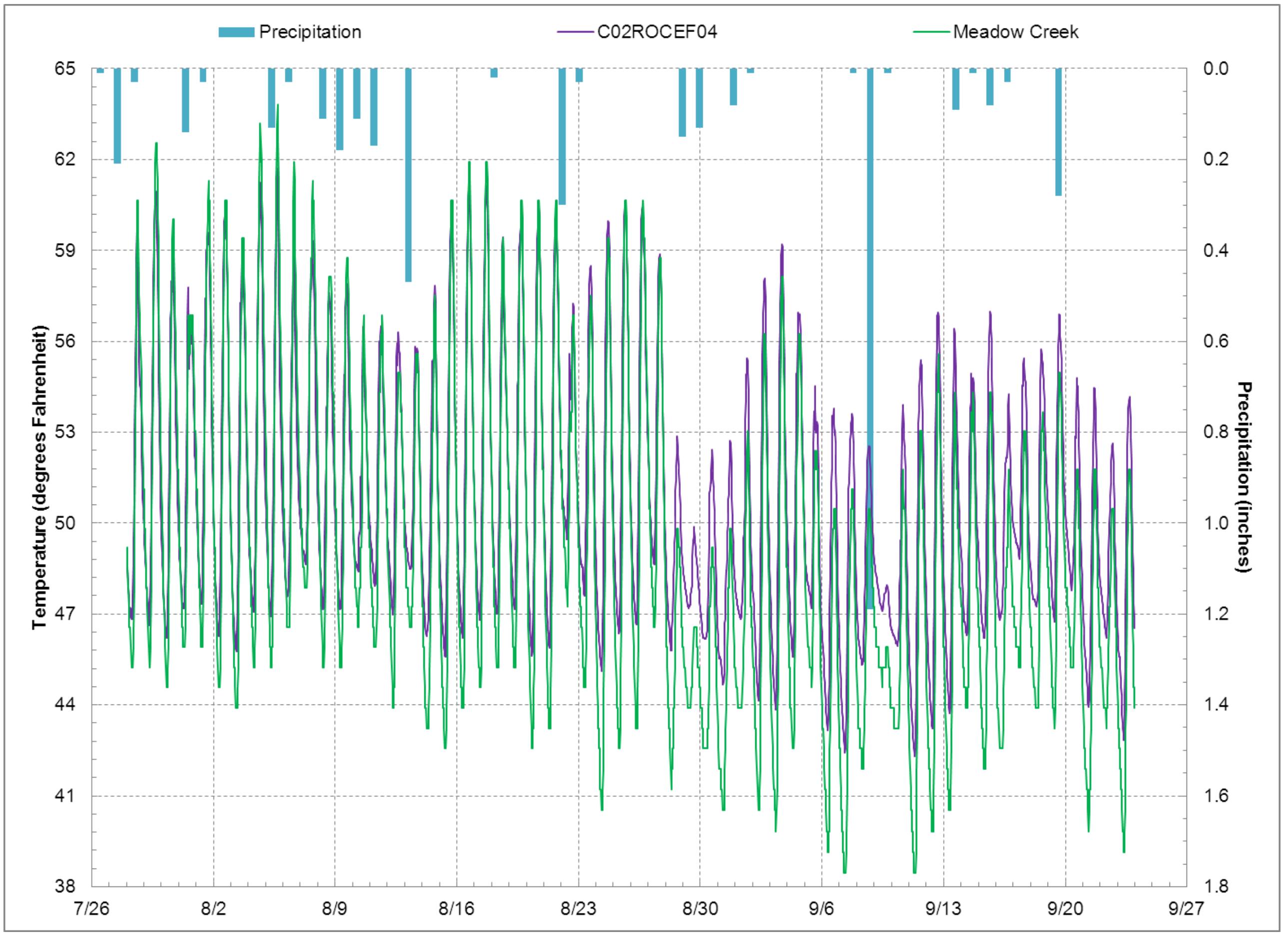

Figure ID-1. East Fork Rock Creek (above the confluence of Meadow Creek) and Meadow Creek in 2010 (DEQ temperature data).

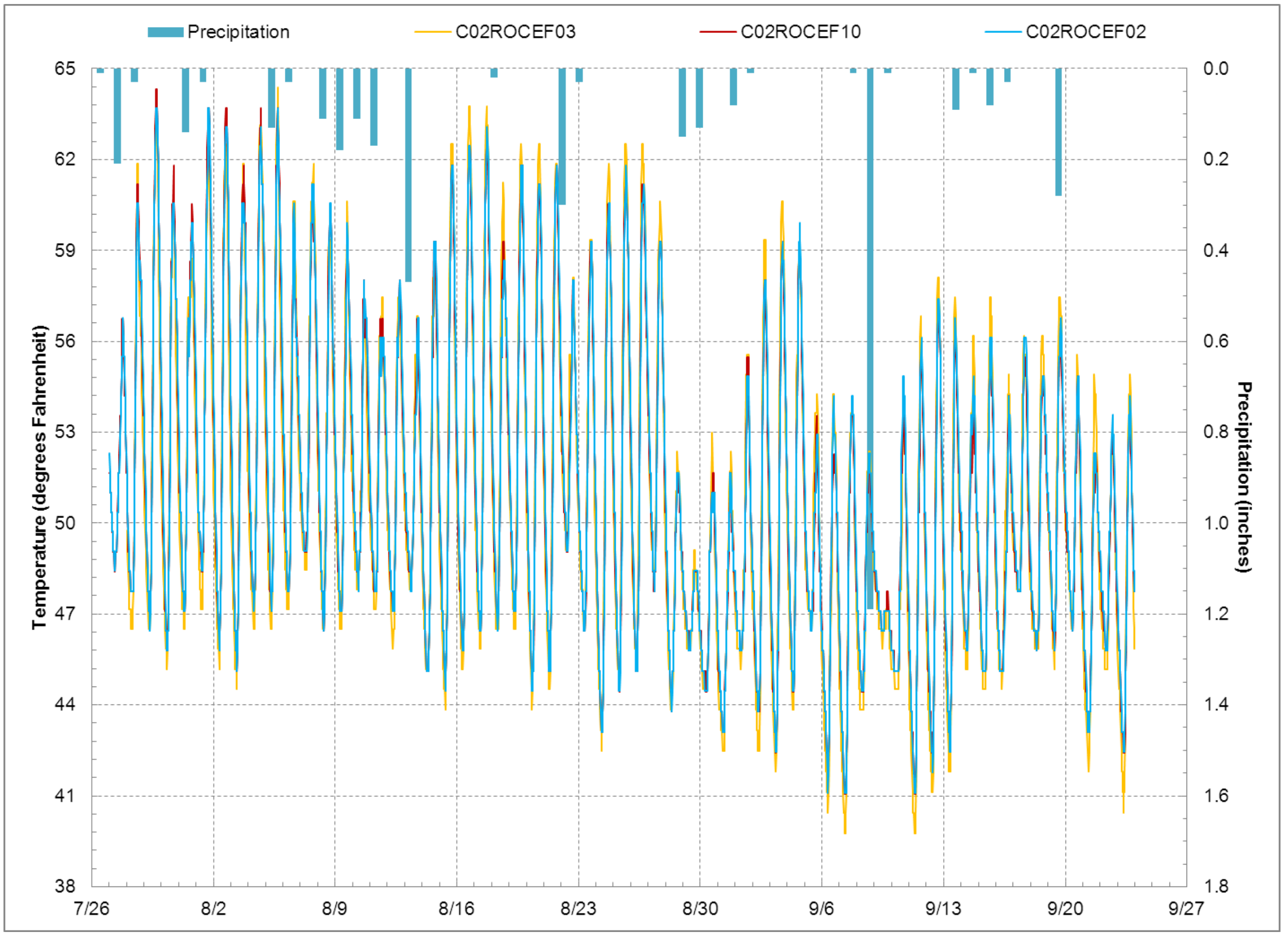

Figure ID-2. Lower East Fork Rock Creek in 2010 (DEQ temperature data).

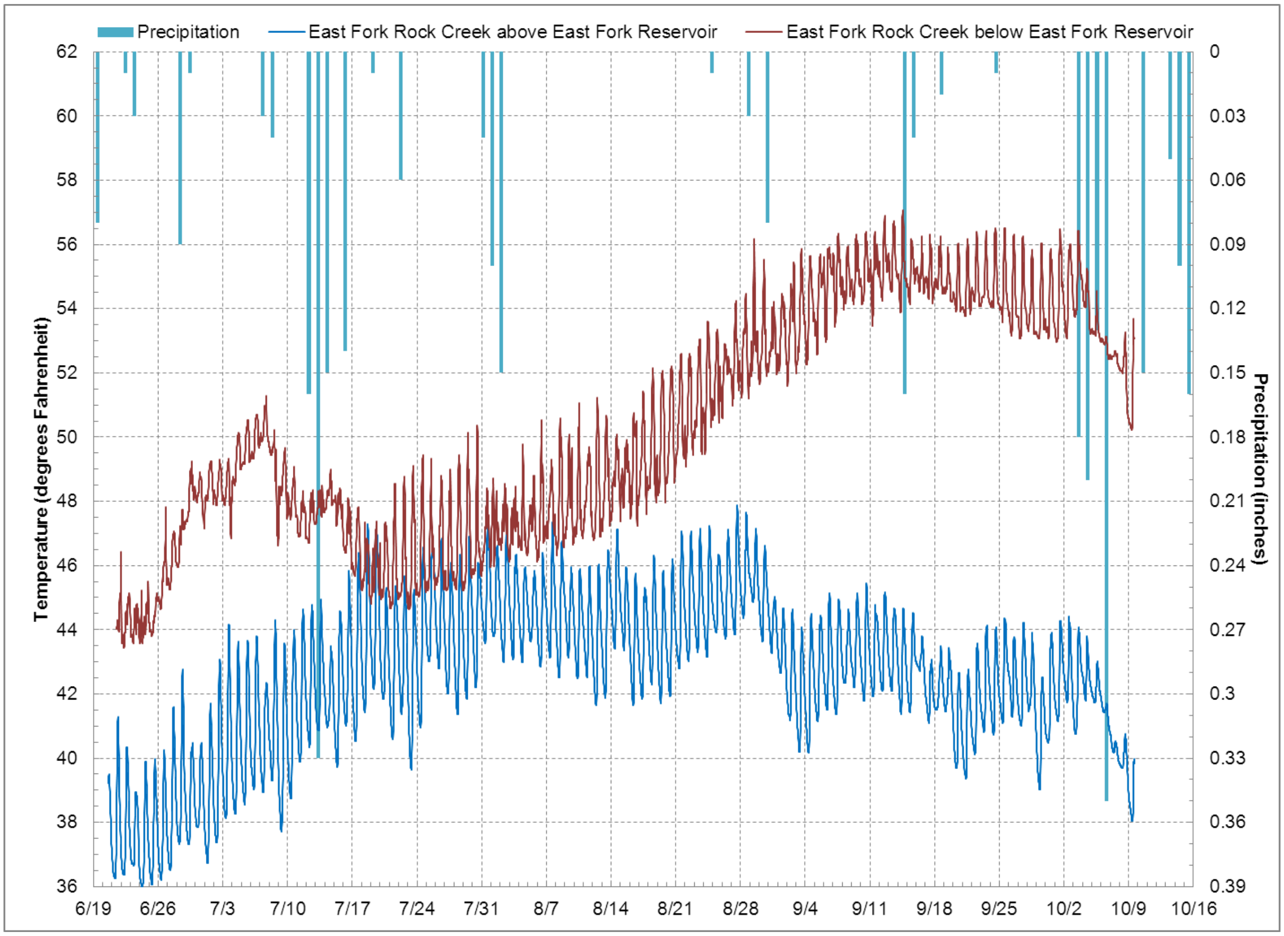

Figure ID-3. Above and below East Fork Reservoir in 2011 (DNRC temperature data).

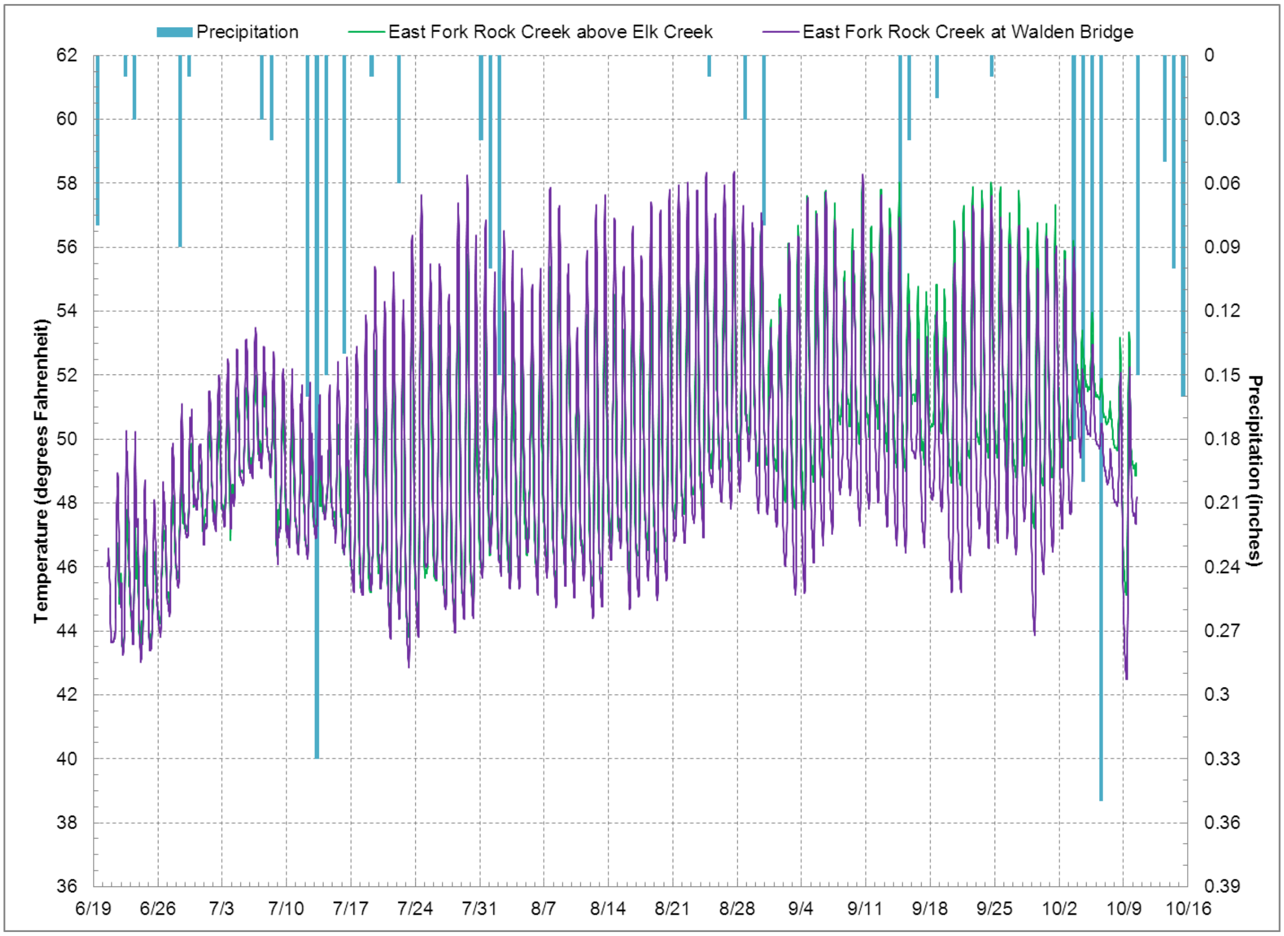

Figure ID-4. East Fork Rock Creek in 2011 (DNRC temperature data).

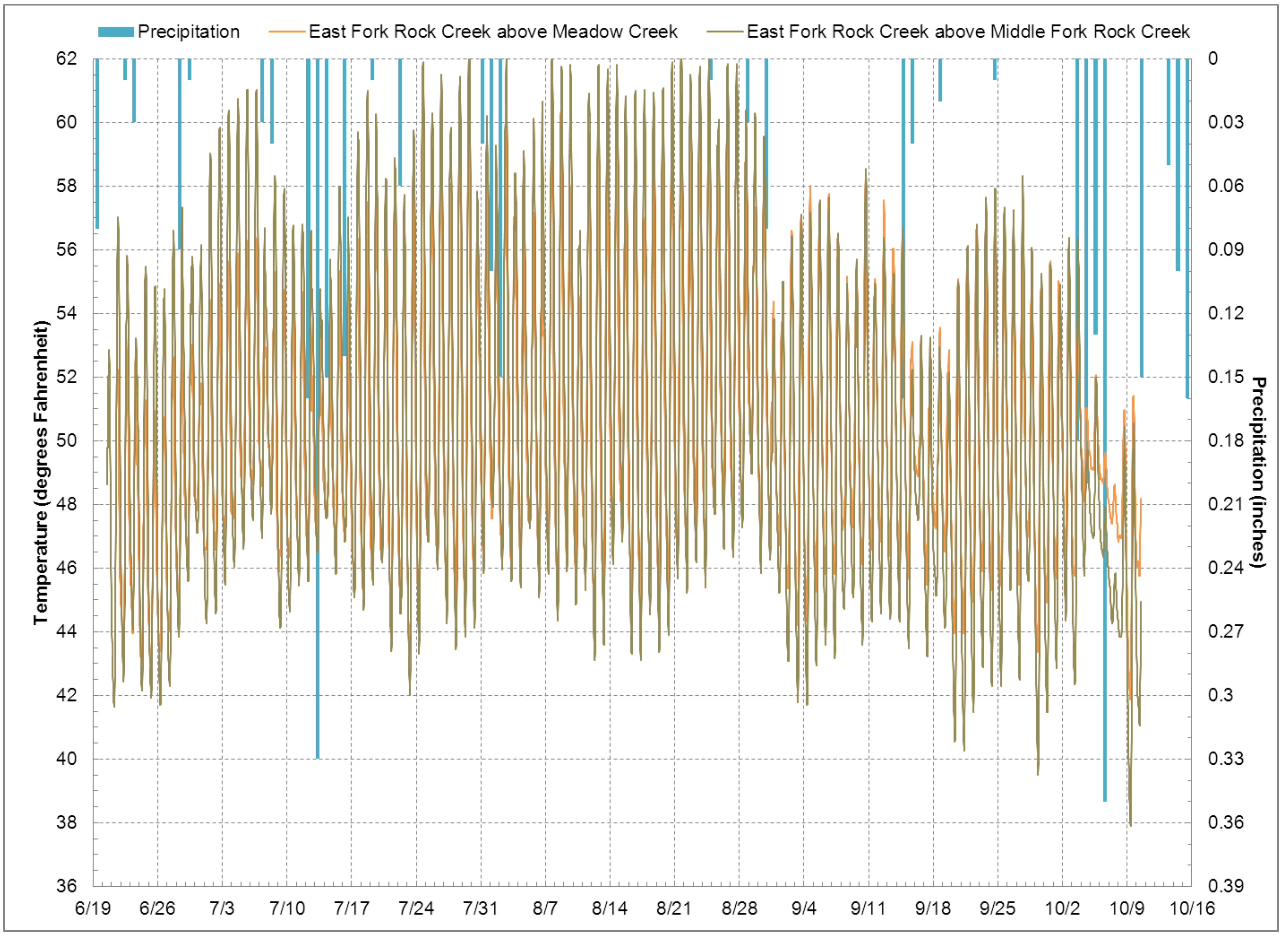

Figure ID-5. Lower East Fork Rock Creek in 2011 (DNRC temperature data).

APPENDIX J – SOUTH FORK ANTELOPE CREEK TEMPERATURE MODELING REPORT

Appendix J is based on a report prepared for the DEQ by Tetra Tech, September 2012.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

DEM	digital elevation model
EPA	U.S. Environmental Protection Agency
HUC	hydrologic unit code
DEQ	Montana Department of Environmental Quality
ODEQ	Oregon Department of Environmental Quality
QAPP	quality assurance project plan
TMDL	total maximum daily load
TPA	TMDL Planning Area
WET	Water & Environmental Technologies, PC

UNITS OF MEASURE

cfs	cubic feet per second
°C	degrees Celsius
°F	degrees Fahrenheit

EXECUTIVE SUMMARY

South Fork Antelope Creek, a small mountain stream in the Rocky Mountains of western Montana, is impaired by elevated water temperatures and is on Montana's Clean Water Act section 303(d) list. A QUAL2K model was developed to evaluate the instream water temperature response to various model scenarios. The existing conditions scenario was evaluated with natural low-flow conditions and increased shading conditions. Data for model setup and calibration are limited upstream of the monitoring station that is most upstream; available field data are not sufficient to determine how far upstream a channel might exist. These model scenarios were evaluated to assess a potential worst-case scenario.

Natural low-flow conditions scenarios resulted in increased daily maximum and mean temperatures as compared to the existing condition scenario. Increasing to full potential shade had little effect on instream water temperatures in comparison to both the existing condition and natural low-flow conditions scenarios.

J1.0 BACKGROUND

This section presents background information including a brief description of the water quality problem, the applicable water quality standards, project history, and study area.

J1.2 PROBLEM STATEMENT

South Fork Antelope Creek has a B-1 use class. It is not supporting its Aquatic Life or Primary Contact Recreation designated uses (Montana Department of Environmental Quality, 2012). Five potential causes of impairment are identified in the assessment record, including alteration in streamside or littoral vegetative covers and water temperature (Montana Department of Environmental Quality, 2012). The potential sources of the water temperature impairment are unknown. In a 2004 assessment, DEQ found that the stream temperature at the mouth was approximately 54 degrees Fahrenheit (°F), which is sufficiently cold for westslope cutthroat trout. However, it was thought that this temperature measurement may not represent the most problematic time period for temperature stress (Montana Department of Environmental Quality, 2012, p.16).

J1.3 MONTANA TEMPERATURE STANDARD

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

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

[1] ARM 17.30.623 (2)(e).

The model results will ultimately be compared to these criteria.

J1.4 Project History

Temperature and flow data were collected in South Fork Antelope Creek in 2010 by DEQ. Water & Environmental Technologies, PC (WET), under contract with DEQ, prepared a Quality Assurance Project Plan (QAPP) for temperature monitoring and modeling in the Rock TPA in 2011. A field team from WET and DEQ collected measurements on August 24th, 25th, 30th, and 31st in 2011 to characterize meteorology (i.e., air temperature, dew point, wind speed, and cloud cover), channel geometry, flow, and shade in support of the modeling effort. Tetra Tech was contracted by EPA in February 2012 to develop the QUAL2K temperature model based on the data and information compiled by WET and DEQ.

J1.5 Study Area

South Fork Antelope Creek (MT76E002_060) is in the Rocky Mountains of western Montana and is part of the Rock Creek TPA (**Figure J1**). The creek is in the Rock Creek–Mallard Creek 12-digit hydrologic unit code (HUC) (17010202 12 01), in the Flint-Rock 8-digit HUC (17010202). The impaired segment is 2.9 miles long and extends from the headwaters to the mouth. Roughly half of the South Fork Antelope Creek watershed is forested (**Figure J2** and **Figure J3**). The remaining area is either shrub or grassland, exhibiting various stages of regrowth from timber harvesting as visible on the aerial image in **Figure J3.** Approximately two-thirds of the watershed is privately owned (**Figure J4**). The remainder is owned by the U.S. Bureau of Land Management.

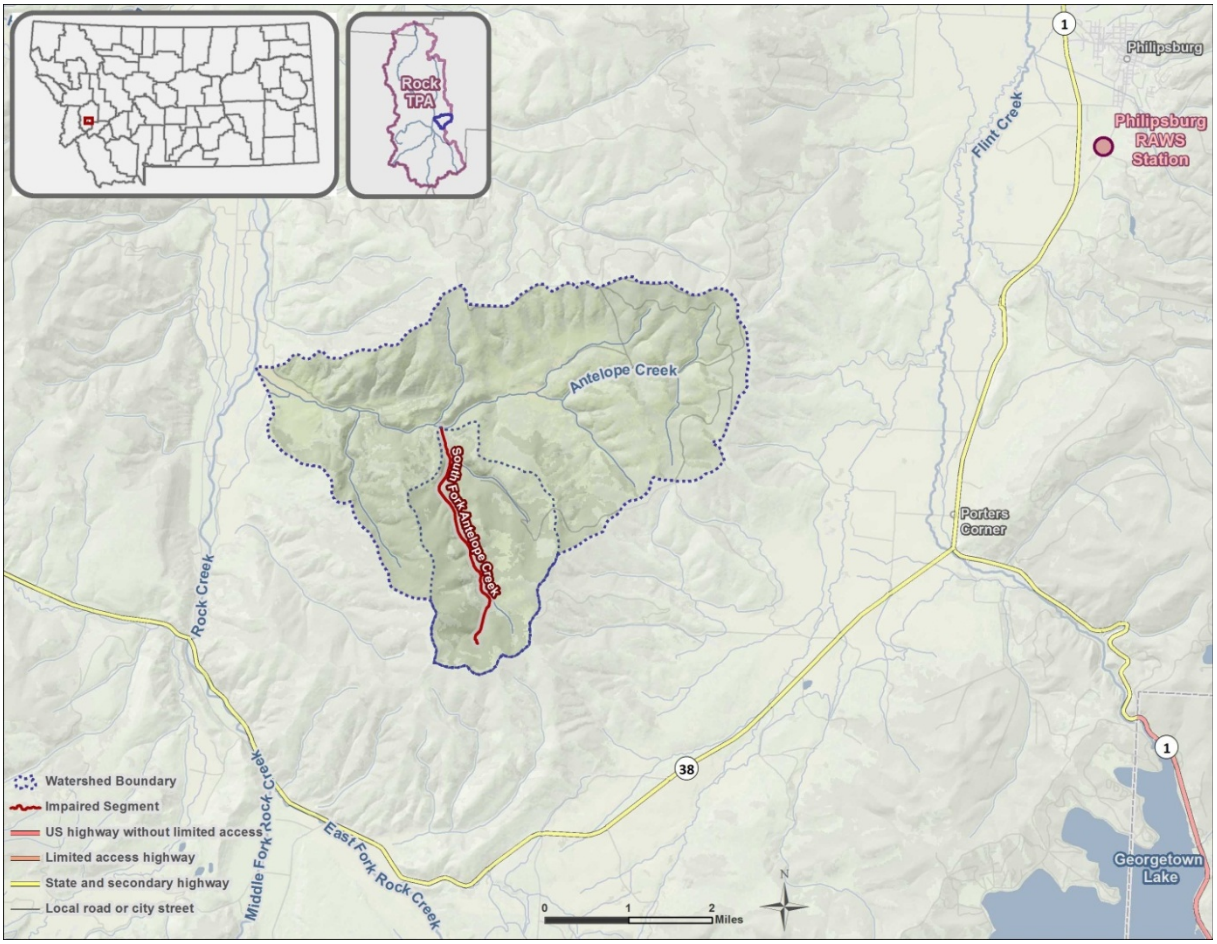

Figure J-1. South Fork Antelope Creek watershed.

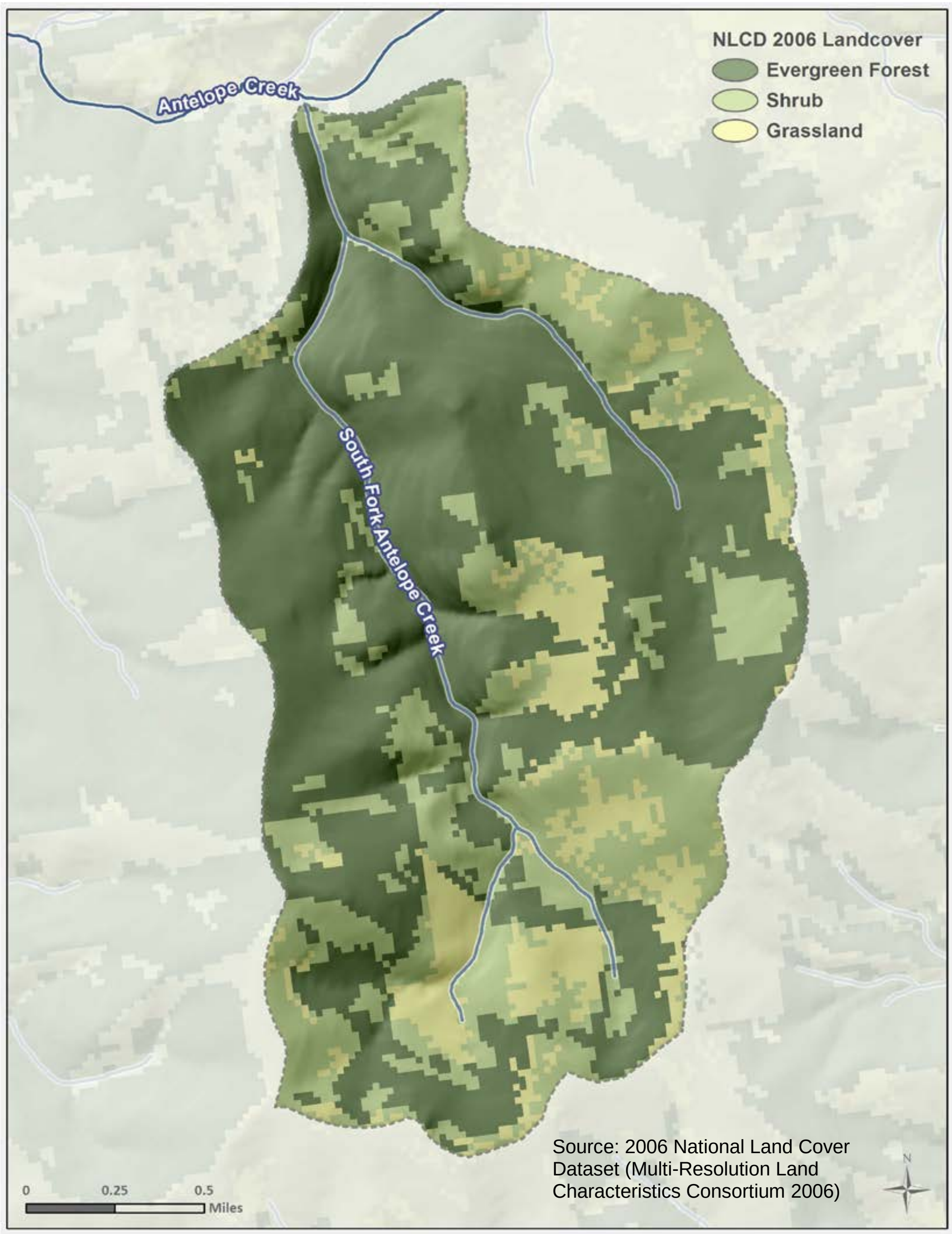

Figure J-2. Land cover in the South Fork Antelope Creek watershed.

Figure J-3. Aerial view of the South Fork Antelope Creek watershed.

Source: NRIS 2012

Figure J-4. Land ownership in the South Fork Antelope Creek watershed.

J2.0 Factors Potentially Influencing Stream Temperature

Interactions between external drivers of stream temperature and the internal integrated stream system (i.e., the channel, riparian zone, and alluvial aquifer) ultimately determine stream temperature (Pool and Berman, 2001). The external drivers include climate (e.g., solar radiation, air temperature, and near-stream wind speed), stream morphology, groundwater influences, and riparian canopy condition (Pool and Berman, 2001). External drivers could also be point source discharges, dams, and irrigation withdrawals and returns.

This section provides a summary of the external and internal factors that could influence stream temperature in South Fork Antelope Creek. It is necessary to understand these watershed characteristics to adequately simulate the existing conditions and model scenarios that might be needed for TMDL development.

J2.1 Climate

The nearest weather station to the South Fork Antelope Creek watershed is 9 miles to the northeast, in Philipsburg, Montana. Average annual precipitation is 15.02 inches with the greatest amounts falling in May and June (**Figure J5**); Western Regional Climate Center 2012). Average maximum air temperatures occur in July and August and are 80.9 and 79.2 °F, respectively. Most cloud-free days occur between June and September.

Note that the Philipsburg weather station's elevation is 5,280 feet above mean sea level, compared to the impaired reach of South Fork Antelope Creek, which ranges in elevation from approximately 5,500 to 6,600 feet above mean sea level.

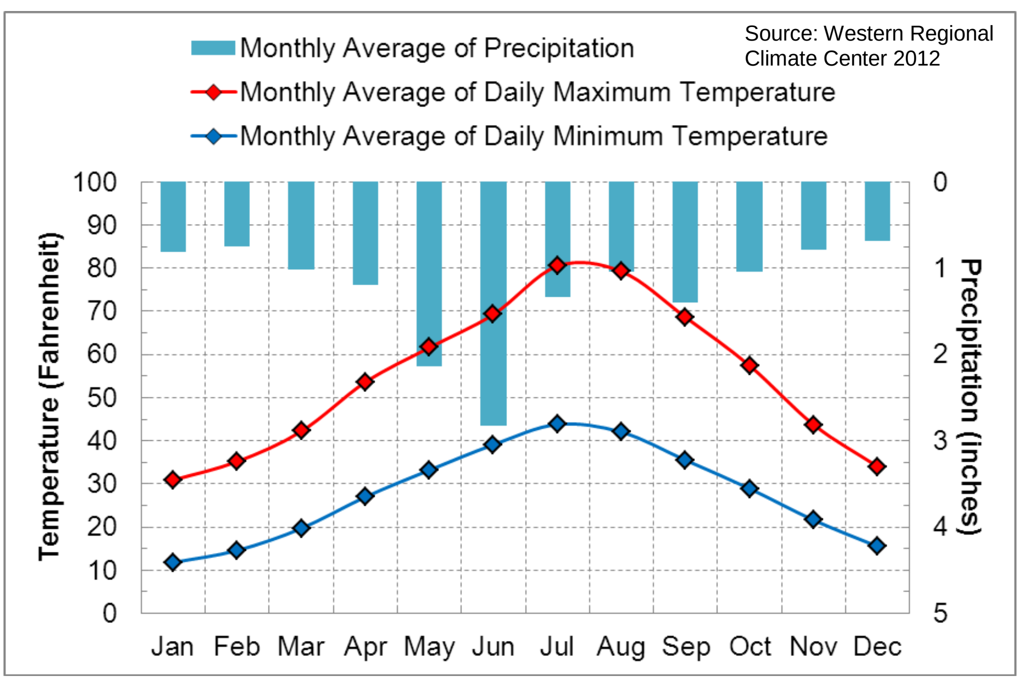

Figure J-5. Monthly average air temperatures and precipitation at Philipsburg, Montana.

J2.2 Riparian Vegetation

Riparian vegetation data along the mainstem of South Fork Antelope Creek were collected in 2011 to support shade characterization, ultimately for model development (Water & Environmental Technologies, 2011). DEQ collected vegetation/canopy height, canopy density, vegetative cover percent, and channel overhang at three transects each at all four of their sampling locations. These data are presented in **Appendix JA.** The vegetative community types occurring in the riparian corridor, as identified in aerial imagery, are shown in **Figure J6** (Water & Environmental Technologies, 2011).

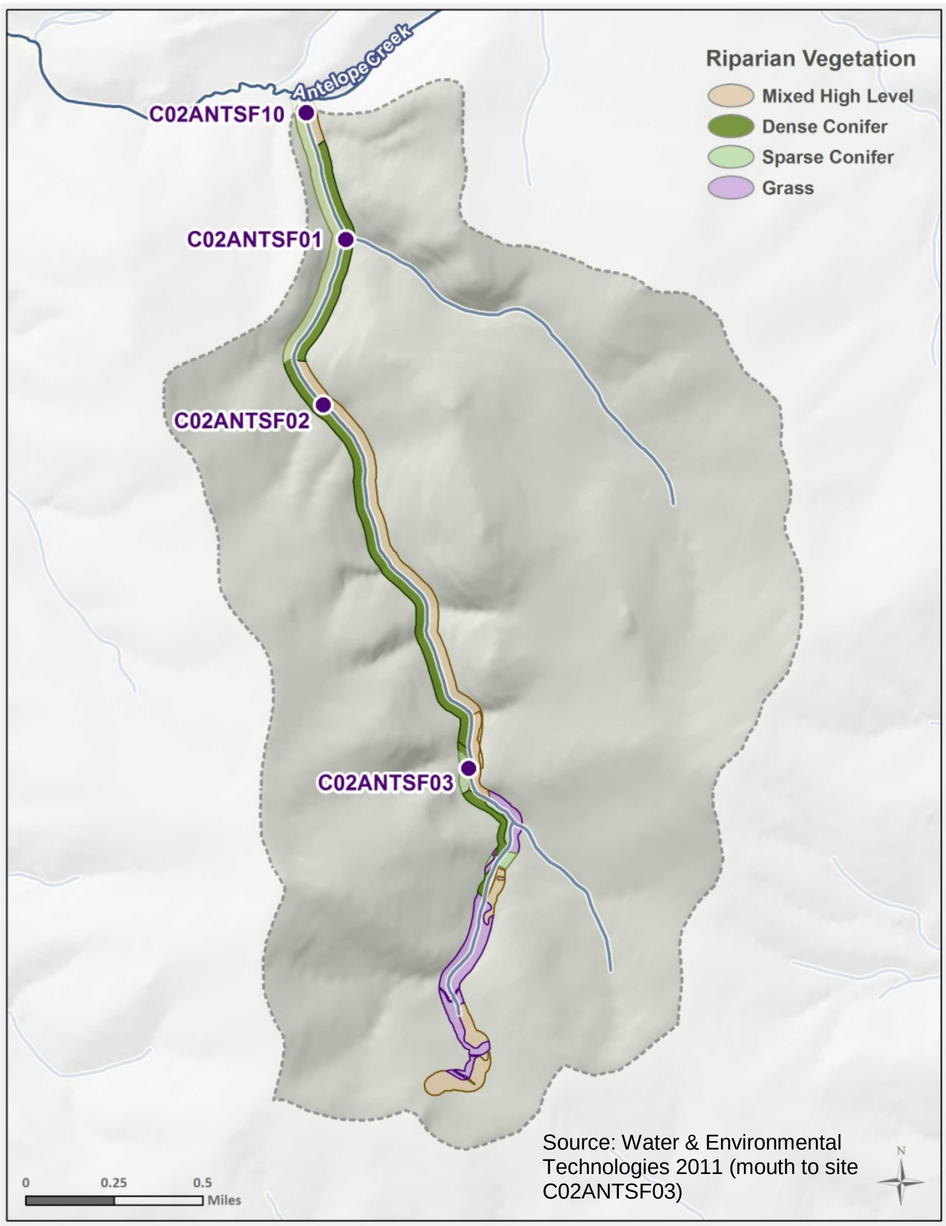

Figure J-6. Riparian vegetation along the mainstem of South Fork Antelope Creek.

J2.3 SHADE

Shade is a key input to the QUAL2K model. Shade is defined as the fraction of potential solar radiation that is blocked by topography and vegetation. DEQ used a Solar Pathfinder™ to collect shade data at three sites along South Fork Antelope Creek: C02ANTSF10, C02ANTSF01, and C02ANTSF02. Three sets of measurements were recorded at each site; only vegetative shade was observed at these sites.

An analysis of aerial imagery showed that shading along South Fork Antelope Creek was highly variable because of timber harvest and changes in elevation along the stream. Therefore, shade data were also collected at three sites (C02ANTSF10, C02ANTSF01, andC02ANTSF02) and evaluated using the spreadsheet Shadev3.0.xls[2] (referred to throughout as the Shade Model). DEQ collected data to support development of the Shade Model (**Appendix JA**, Water & Environmental Technologies, 2011); these data are discussed throughout the remainder of this section. The riparian vegetation information (i.e., height, density, and overhang that are displayed in **Appendix JA**) were calculated as the typical values for each category of vegetation on the basis of field work conducted in 2011, except where noted in the following paragraph (Water & Environmental Technologies, 2011).

The Shade Model uses these data with the spatial riparian cover and hydrography data to calculate vegetative shade (Water & Environmental Technologies, 2011). The topographic shade component was calculated using both TTools[3] and field data (Water & Environmental Technologies, 2011). Elevation, aspect, and the directional topographic shades were calculated in TTools using a digital elevation model (DEM) and the previously mentioned digitized hydrography (for the TTools results, see **Appendix JC: Table JC-1**). Wetted width, near shore zone width and center to left, and channel incision were measured during field work conducted in 2011 (Water & Environmental Technologies, 2011). The Shade Model yielded shade estimates at a finer scale than the available Solar Pathfinder data (i.e., every 15 meters along the creek compared to three sites along the creek)

Figure J7 presents shade estimates from both the Solar Pathfinder and Shade Model. As estimated by the Shade Model, shade varied over a large range above river mile 2.0, varied over a constant range from river mile 2.0 to river mile 0.2, and decreased considerably from river mile 0.2 to the mouth. The effective shade derived using the spreadsheet tool Shadev3.0.xls was compared to the field measurements from the Solar Pathfinder, aerial imagery, and site photographs. The Shadev3.0.xls output was found to be reasonably accurate (i.e., within 10 percent or less at all sites with Solar Pathfinder data; see **Figure J7**). Additional plots of these data sets are presented in **Appendix JB**.

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[2] Shadev3.0.xls contains visual basic for applications routines adapted from the Oregon Department of Environmental Quality (ODEQ) by Washington State Department of Ecology (http://www.ecy.wa.gov/programs/eap/models.html) to calculate topographic and canopy shade using solar time and position relative to the earth, and the solar position relative to the stream position, topographic, and vegetative canopy.

[3] A GIS analysis was performed using TTools (version 7.5.6), developed by the ODEQ in 2009, which is an ArcGIS template, to generate input values for Shadev3.0.xls. TTools requires hydrography that is accurate to a very fine scale (1:5,000 or finer; (Oregon Department of Environmental Quality, 2001)). Aerial imagery from 2009 and a digital elevation model were used to digitize the centerline and shores of South Fork Antelope Creek. The one-third arc second (approximately 33 feet) digital elevation map was obtained from USGS's National Elevation Dataset. Land cover along the approximately 164-foot-wide riparian corridor was digitized in GIS (Water & Environmental Technologies, 2011).

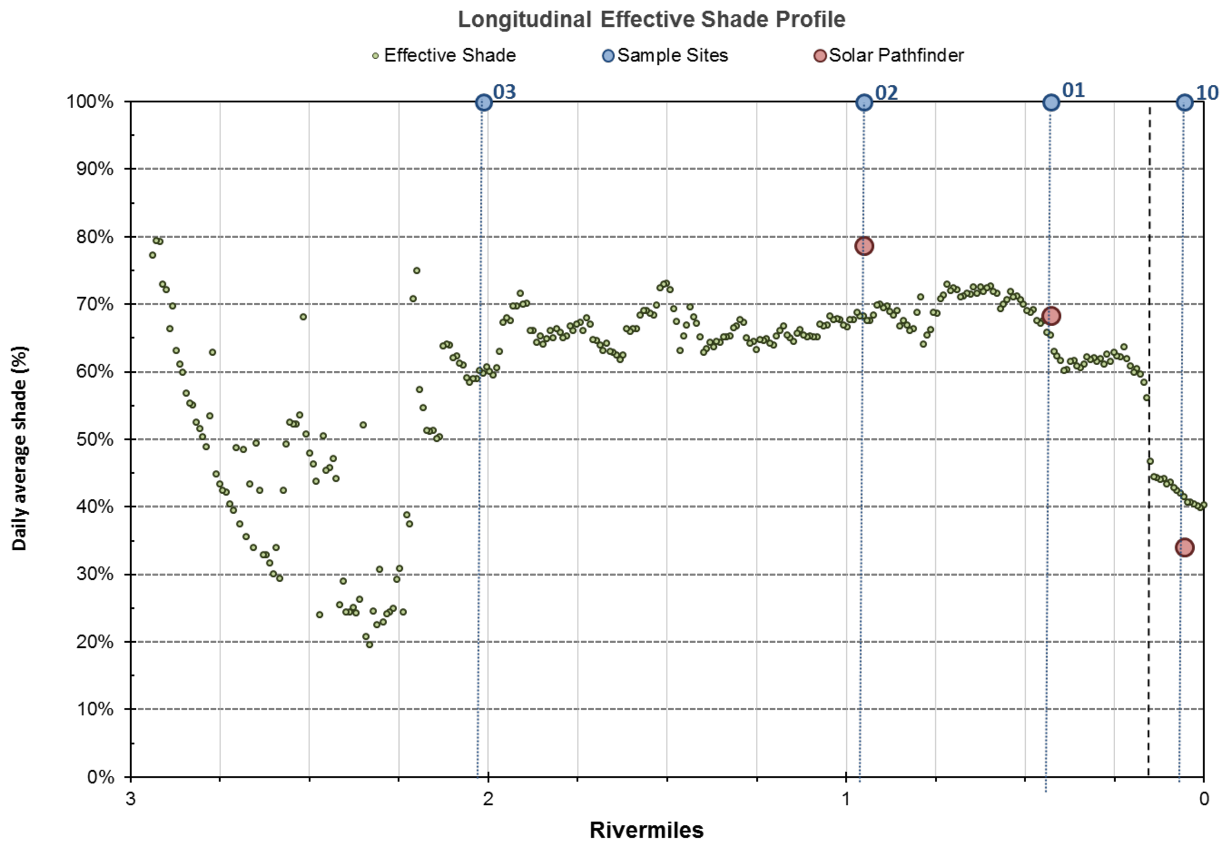


Figure J-7. Effective shade output from Shadev3.0.xls and Solar Pathfinder data.

J2.4 HYDROLOGY

Flow data for the South Fork Antelope Creek are limited to 16 instantaneous measurements. DEQ measured streamflow on three dates in South Fork Antelope Creek in 2010 (July 15, August 26/27, and September 24) and two dates in 2011 (August 1 and August 31/September 1). Monitoring locations are shown in **Figure J8** along with the locations of two springs that DEQ identified (Water & Environmental Technologies, 2011). Measured flows ranged from approximately 0.1 to 0.6 cubic feet per second (cfs) in 2010 and from 0.3 to 3.5 cfs in 2011 (**Figure J9**).

On the basis of a review of online water rights data (ftp://nris.mt.gov/dnrc), two surface diversions are in the South Fork Antelope Creek watershed. *Points of diversion* and *places of use* spatial data were obtained from the Montana Natural Resource Information System. Of the two diversions in the South Fork Antelope Creek watershed, one is directly from South Fork Antelope Creek and is used for livestock. No data are available defining the quantity of water diverted. For the purposes of this modeling study, it is assumed that the quantity is very small because it is for livestock watering.

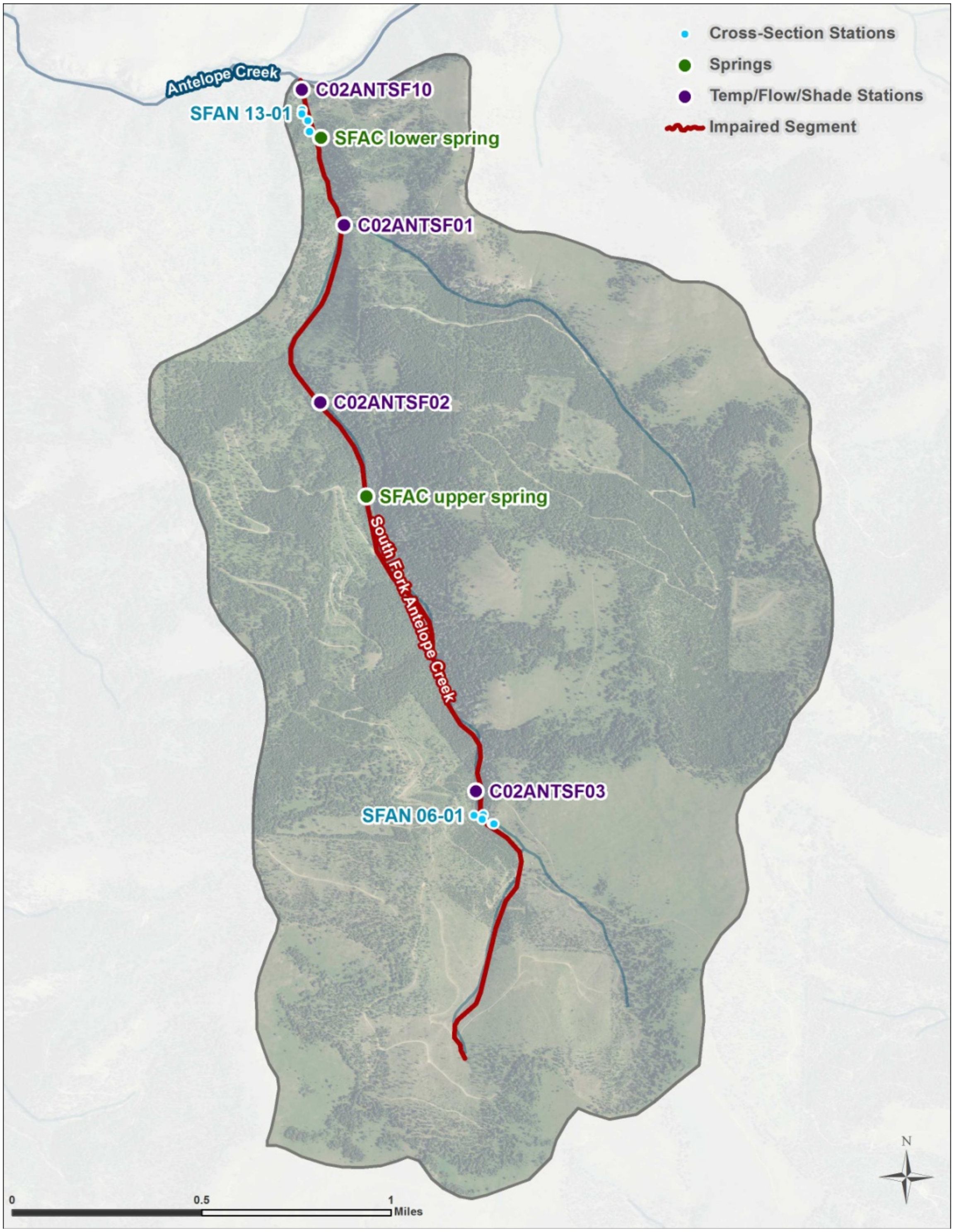
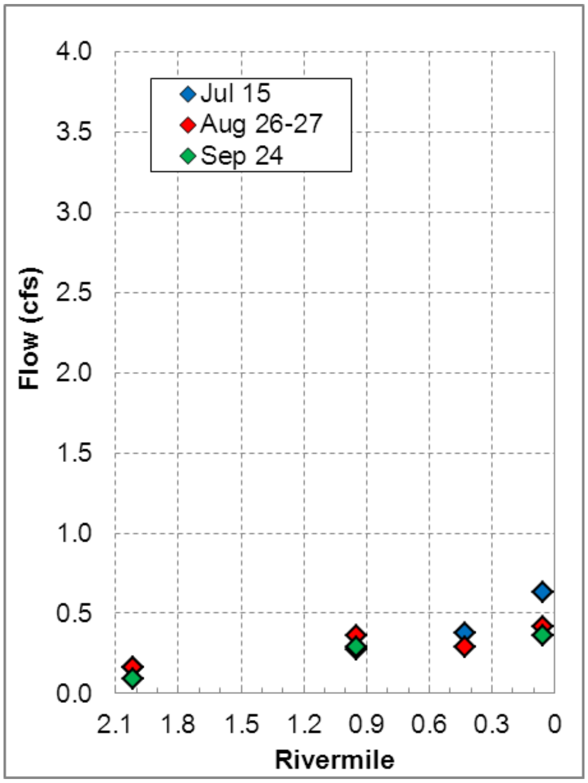


Figure J-8. Flow and temperature monitoring locations.



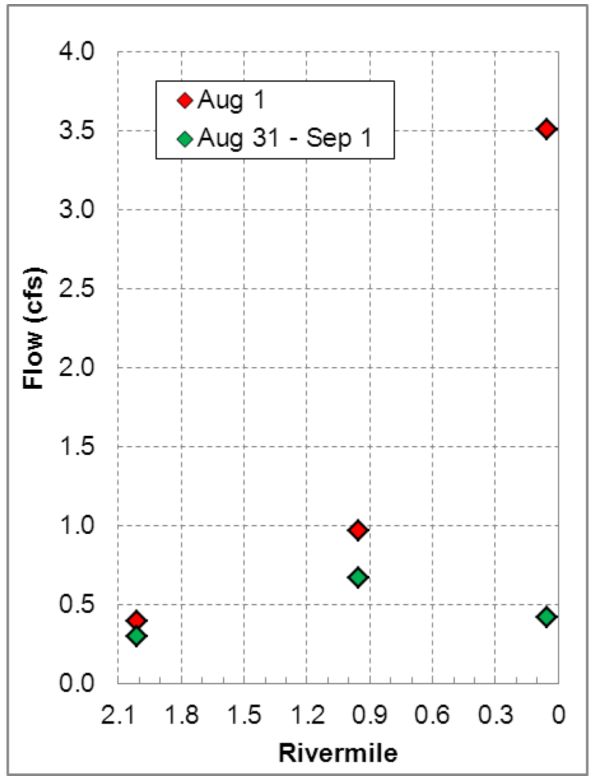


Figure J-9. DEQ flow measurements in South Fork Antelope Creek in 2010 (left) and 2011 (right).

J3.0 Stream Temperature

DEQ collected stream temperature data in 2010. Monitoring locations are shown in **Figure J8**. A brief discussion of all the available temperature data and factors that could be influencing stream temperature follows.

J3.1 Stream Temperature Data

DEQ collected continuous temperature data at four locations along South Fork Antelope Creek in 2010 (i.e., sites C02ANTSF10, C02ANTSF01, C02ANTSF02, and C02ANTSF03 shown on **Figure J8**). Loggers recorded temperatures every half hour for 2 months between July 15 and 16, 2010, and September 23 and 24, 2010 (i.e., 70 days); these data are summarized in **Figure J10**. Daily maximum temperatures were the coolest and varied the least (between approximately 44.0 and 55.0 °F) at the site that is most downstream (C02ANTSF10). The highest maximum temperatures were at the site that is most upstream (C02ANTSF03) and ranged from approximately 44.0 to 61.0 °F. The largest range of maximum daily temperatures was also observed at the site that is most upstream (C02ANTSF03).

Additionally, temperature grab samples were collected from two springs along Antelope Creek in 2011. DEQ also collected instantaneous water temperatures during water quality monitoring in 2004, 2010, and 2011. These data are summarized in **Table J-1**.

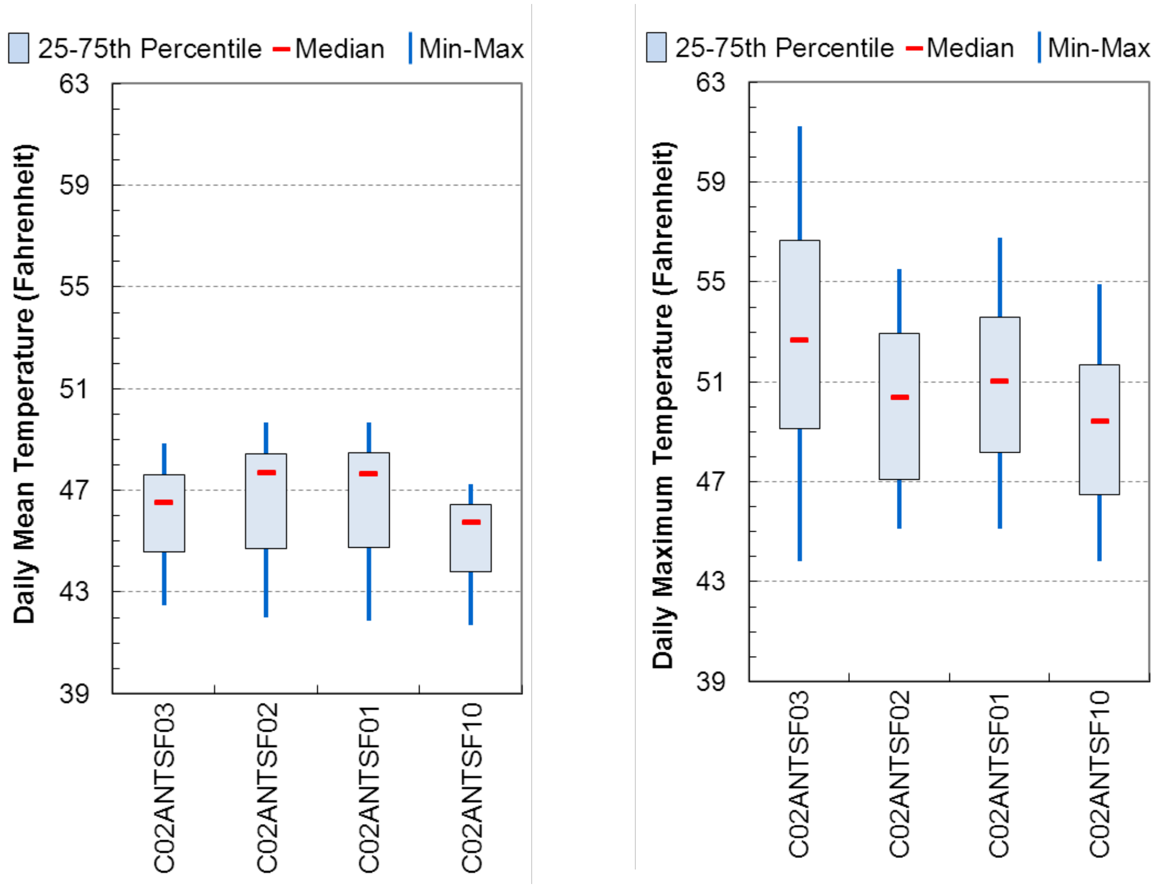


Figure J-10. Daily mean (left) and maximum (right) temperatures calculated at loggers along South Fork Antelope Creek in 2010.

Table J-1. Instantaneous water temperature measurements (°F)

Location	7/24/2004	7/15/2010	8/26/2010	9/24/2010	8/1/2011	8/31/2011
C02ANTSF10	54.3	--	--	--	--	--
C02ANTSF01	--	50.2	42.4	--	--	--
C02ANTSF02	--	53.8	51.6	43.9	48.7	45.3
C02ANTSF03	--	52.0	44.8	50.4	50.7	45.5
Upper Spring	--	--	--	--	--	43.5
Lower Spring	--	--	--	--	--	44.1

Note: Temperatures were originally reported in degrees Celsius and were converted to degrees Fahrenheit.

J3.2 Stream Temperature Data Analysis

South Fork of Antelope Creek is a small, shallow mountain stream. The coolest recorded stream temperatures were observed at the station that is most downstream, which corresponds to the lowest effective shade (**Figure J7**). The warmest recorded maximum temperatures were observed at the most upstream station where effective shade values are among the highest (**Figure J7**). This suggests that shade might not be the most important factor in moderating stream temperatures in South Fork Antelope Creek. It appears that the dominant factor affecting instream temperatures is the ambient air temperature.

Figure J-11 and **Figure J-12** show the instream temperature response to the cooler air temperatures and addition of rainwater. The headwaters of the creek (site C02ANSF03) are very shallow, and instream temperatures directly correspond to the ambient air temperature. Temperatures logged in the lower segments of the South Fork of Antelope Creek also typically vary with temperature but are generally cooler than the headwaters segments during the day and warmer than the headwaters during the night.

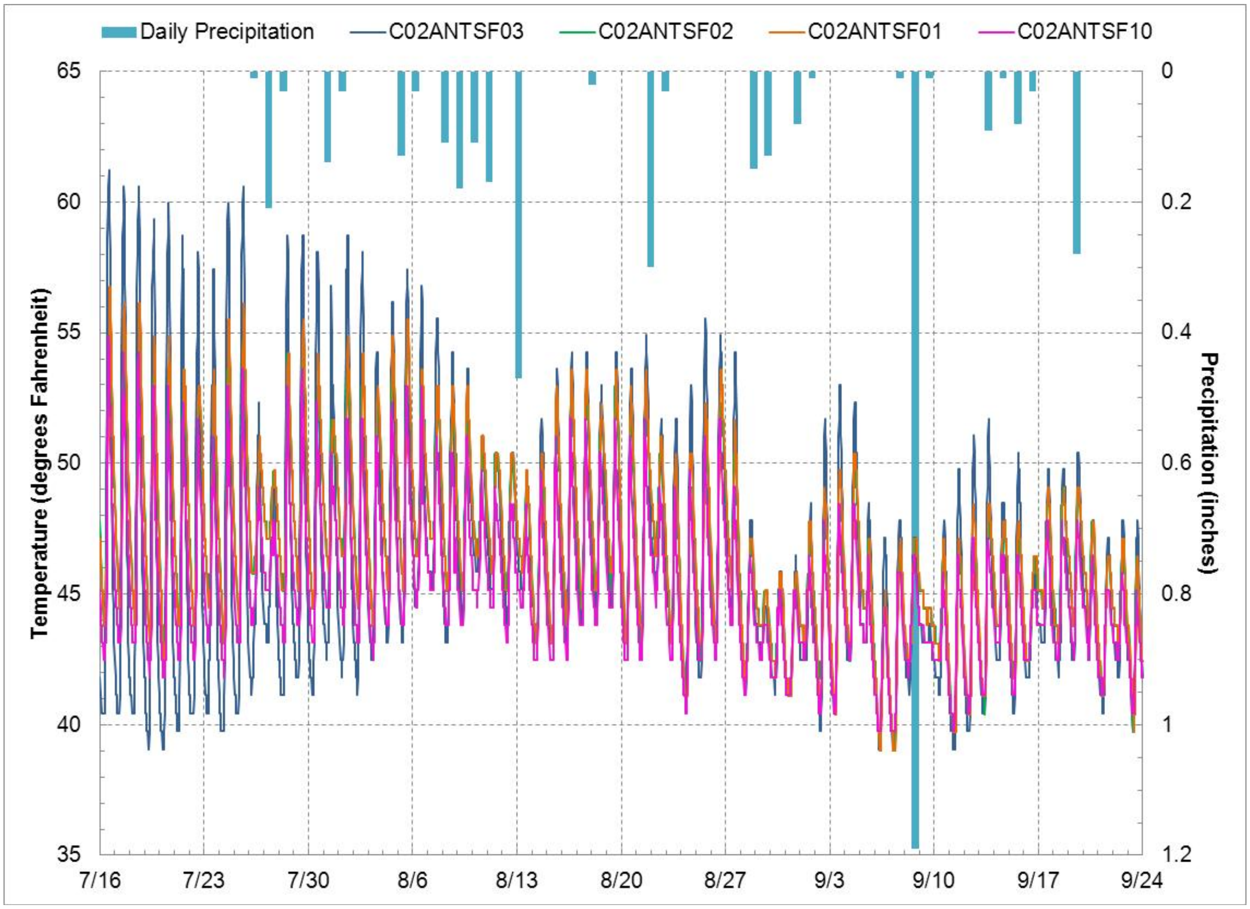
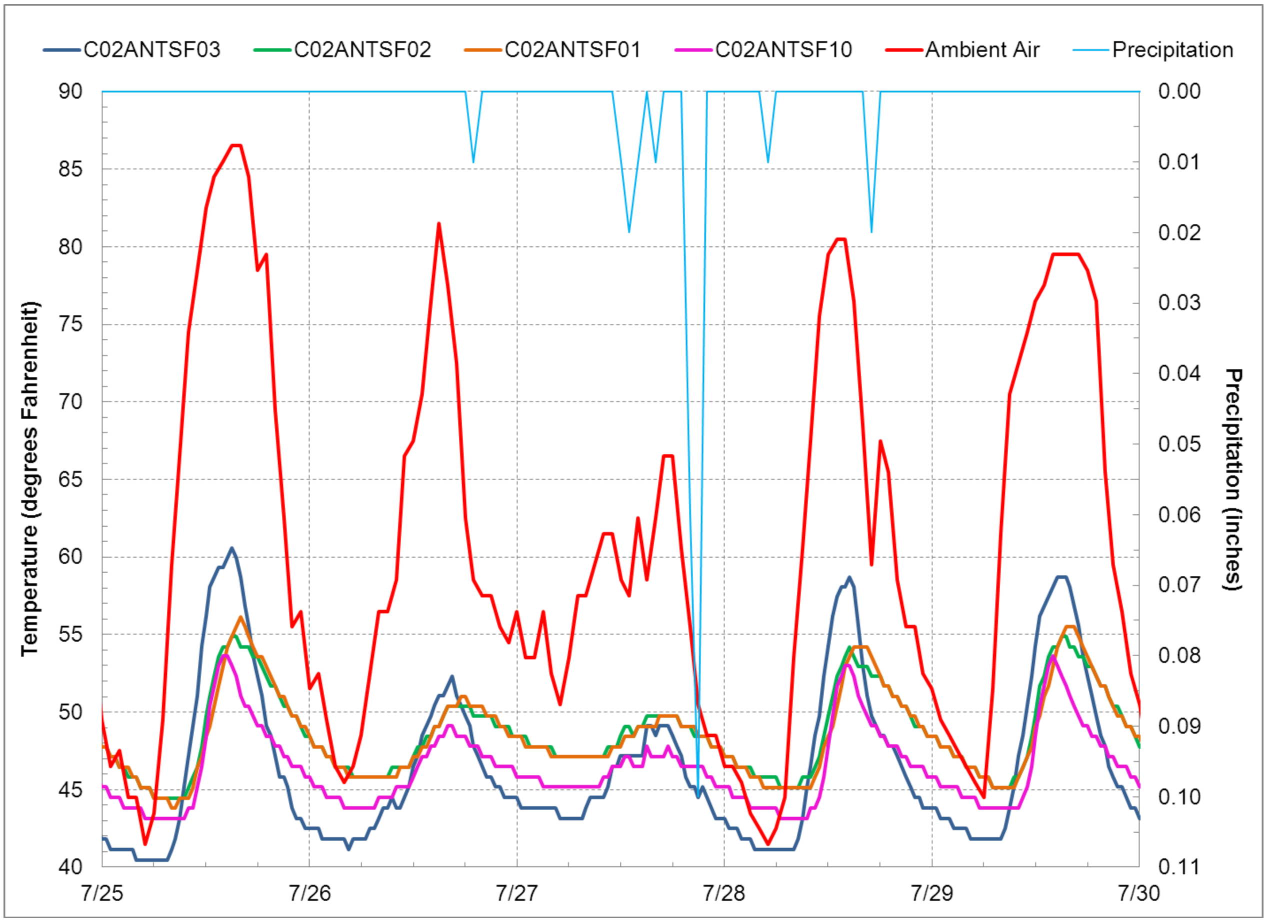


Figure J-11. Hourly water temperatures at the four loggers and daily precipitation at the Philipsburg RAWS (July 16 to September 24, 2010).



Notes: Hourly ambient air temperature data were acquired from the Philipsburg RAWS and were elevation-corrected. Hourly precipitation data were acquired from the Philipsburg RAWS.

Figure J-12. Hourly water and ambient air temperatures and precipitation (July 25-30, 2010).

J4.0 MODEL SETUP

The QUAL2K model was selected to simulate temperatures in South Fork Antelope Creek. QUAL2K is supported by EPA and has been used extensively for TMDL development and point source permitting across the country. The QUAL2K model is suitable for simulating hydraulics and water quality conditions of small rivers and creeks. It is a one-dimensional, uniform flow model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, nonpoint source loading, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K can address nutrient cycles, algal growth, and dissolved oxygen dynamics. QUAL2K also simulates instream temperatures via a heat balance that accounts "for heat transfers from adjacent elements, loads, withdrawals, the atmosphere, and the sediments" (Chapra, 2008, p. 19).

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

The following describes the process that was used to setup the QUAL2K models for South Fork Antelope Creek.

J4.1 Channel Flow Path

South Fork Antelope Creek, as delineated in the National Hydrography Dataset, is a 2.9-mile perennial stream. DEQ evaluated multiple locations along the creek from its mouth upstream to river mile 2.01, which is site C02ANTSF03. The upper 0.9 mile has not been visited, and it is not known how far upstream of river mile 2.0 that the defined channel persists. Therefore, the QUAL2K model for South Fork Antelope Creek was developed for the 2.01-mile portion of the creek (i.e., from the mouth on Antelope Creek to DEQ sample site C02ANTSF03).

Two unnamed tributaries to South Fork Antelope Creek were delineated by the U.S. Geological Survey (USGS) in the National Hydrography Dataset. The confluences of the tributaries are at approximately river miles 0.4 and 2.3 along South Fork Antelope Creek. The unnamed tributary at river mile 0.4 was modeled implicitly as diffuse flow because it was assumed to contribute minimal flow. The tributary at river mile 2.3 was not directly addressed but is included in the headwaters boundary conditions.

Finally, two springs were identified by DEQ during the 2011 field visit (Water & Environmental Technologies, 2011). The springs were modeled as point inputs at river miles 0.19 and 1.24. The modeled flow path is shown graphically in **Figure J-13**.

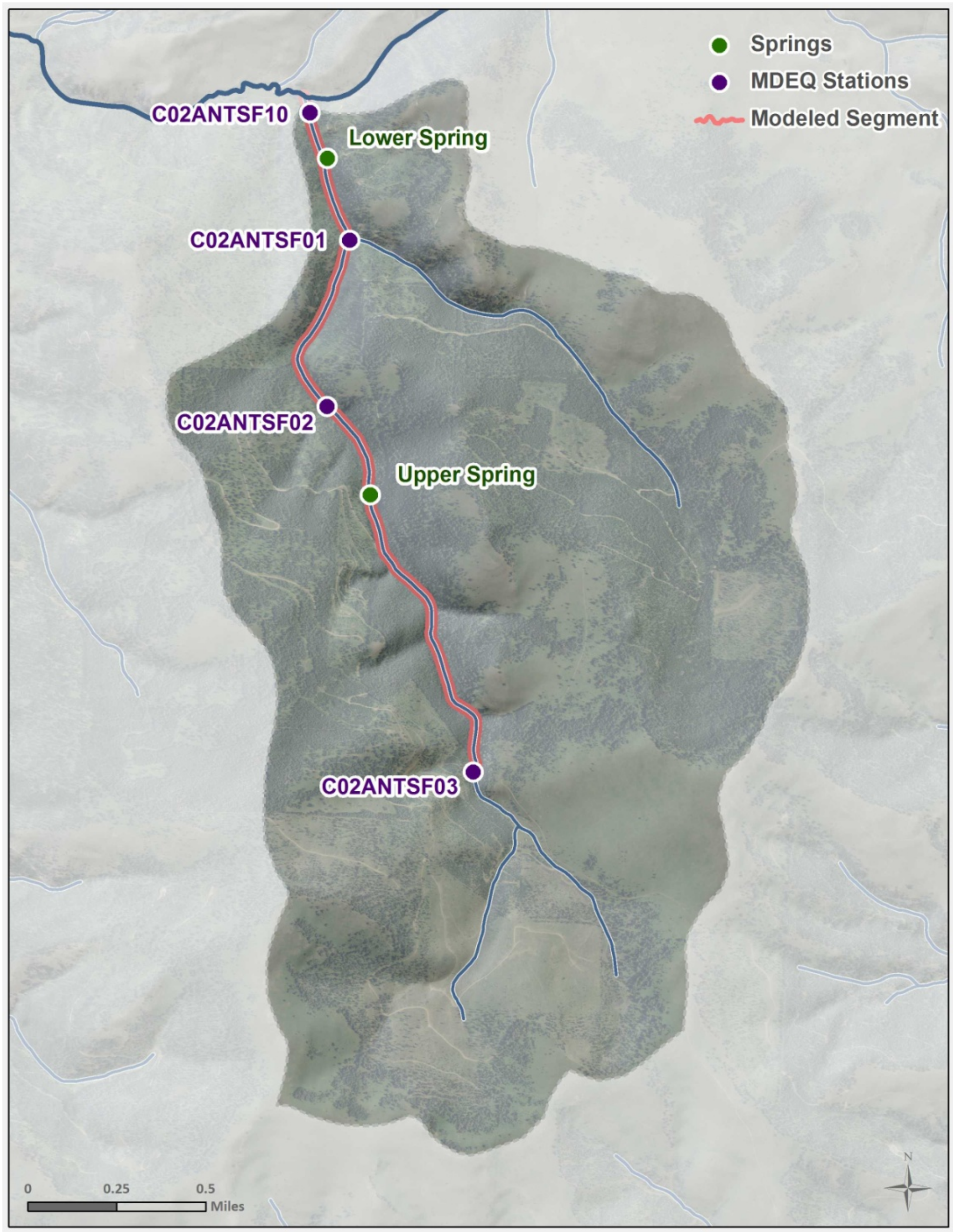


Figure J-13. Schematic of the surface hydrography of South Fork Antelope Creek.

J4.2 Stream Segmentation

South Fork Antelope Creek was divided into four linked segments (**Figure J-14)**; identified as D, C, B, and A [headwaters to mouth]). The segment locations were selected on the basis of available diurnal temperature and flow data (available at the four sample sites), changes in vegetation, and changes in effective shade. The existing conditions scenario is defined as segments D, C, B, and A; DEQ collected data along these segments that were used to develop the model.

Each of the linked segments is further subdivided into five equally spaced elements or computational units. The number of computational units was determined on the basis of the estimated velocity and computational time-step to ensure the containment of the heat load calculation in each element per time-step. The element length was selected to be short enough to increase the spatial resolution and long enough to support model stability.

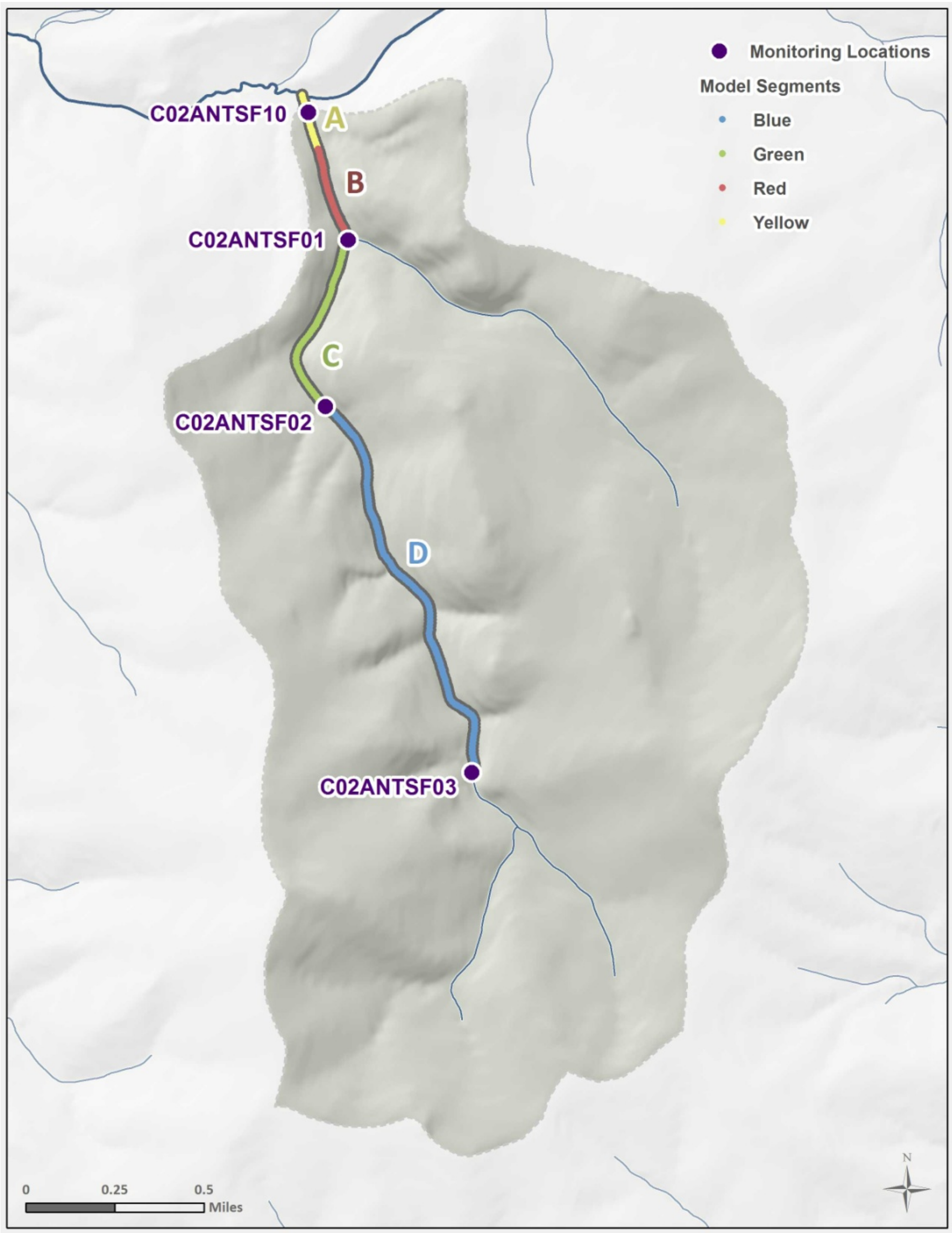
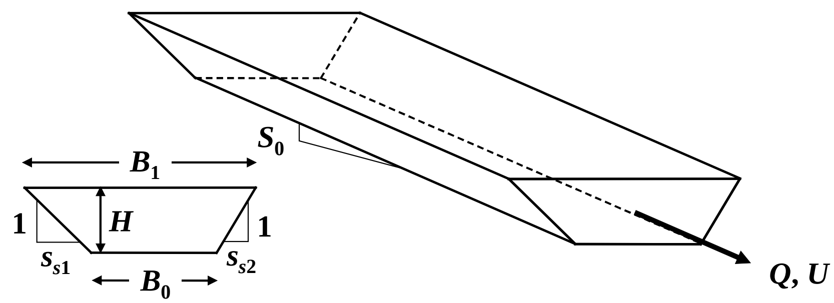


Figure J-14. Model segmentation along South Fork Antelope Creek.

J4.3 Channel Geometry

Channel geometry inputs for QUAL2K for reaches A, B, C, and D were derived using field-measured data and DEQ's cross-sections (Water & Environmental Technologies, 2011) (for the original data, see **Appendix JA** and for the model inputs, see **Appendix JC**). No channel geometry data were available upstream of sample site C02ANTSF03.

Manning's roughness coefficient (n) was estimated during a field visit (Water & Environmental Technologies, 2011). Channel slope was calculated using field-collected elevation data (Water & Environmental Technologies, 2011). Stream bottom width and the sides of the trapezoidal cross-section assumed for modeling (**Figure J-15**) were estimated using cross-sectional profile data collected during field work (Water & Environmental Technologies, 2011).



Source: (Chapra, 2008)

Note: B_0 is stream bottom width, S_{s1} and S_{s2} are side lengths relative to one, and S_0 is channel slope.

Figure J-15. Idealized trapezoidal channel assumed in QUAL2K.

J4.4 HYDROLOGIC SIMULATION

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

The observed data collected at four locations along the mainstem on July 15, 2010, were used to derive all the flow inputs required to run the QUAL2K model for the calibration day of July 16, 2010 (**Appendix JC, Table JC-3).** The difference in flow between each observation was assumed to be diffuse flow (**Appendix JC, Table JC-4**). The headwaters inflow was assumed to be 1.7 cfs and was calculated on the basis of an area ratio with the flow monitored at C02ANTSF03. Note that the tributary at river mile 0.43 was not explicitly modeled and is represented in the diffuse flow to reach B.

Two springs were observed during field work (Water & Environmental Technologies, 2011). The flow rates for input into the QUAL2K model were based on qualitative observations during field work. The upper spring was calculated as 8 percent of the mainstem flow; during field work, the contribution was estimated to be 6 to 10 percent of the mainstem flow. The lower spring was observed to discharge very small flow; the spring was calculated as 1 percent of the mainstem flow (**Appendix JC**, **Table JC-5**).

Diffuse inflow (i.e., groundwater) temperatures were estimated on the basis of available groundwater temperature data in the Ground Water Information Center database (Water & Environmental Technologies, 2011). An average temperature of 8.13 °C was assigned equally to all diffuse inflows. The spring temperatures (both the upper and lower springs) were estimated by averaging the two field-collected instantaneous temperatures.

Figure J-16 is a graphical summary of the hydrologic inputs.

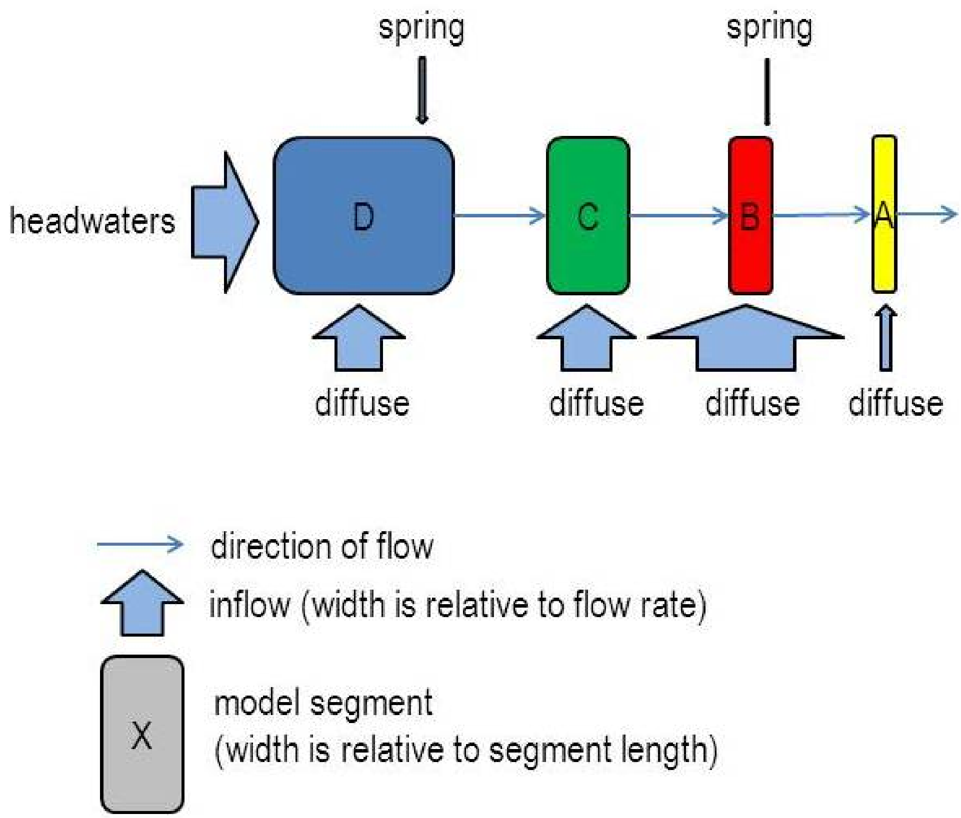


Figure J-16. Schematic representation of inflows to South Fork Antelope Creek.

J4.5 Weather

Weather inputs were compiled from the closest station recording the necessary data (**Appendix JC**, **Table JC-6**and **Table JC-7**). These data were used as model input for the July 16, 2010, critical date. Air temperature, wind speed, relative humidity, and solar radiation data were obtained from the Philipsburg RAWS, which is at an elevation of 5,280 feet. Air temperature and dew point temperature data from this station were corrected to account for the elevation difference between the station and the impaired stream. Wind speed was corrected for the height differences of the sensor at Philipsburg RAWS (reported as 20 feet) and the assumed height in QUAL2K (approximately 23 feet). Cloud cover was estimated on the basis of available hourly data at the Butte municipal airport (WBAN 24135) weather station that is operated by the National Weather Service, which is the closest weather station that measures cloud cover. Zero percent cloud cover was observed at the Butte municipal airport on July 16, 2010; therefore, zero percent was input for all 24 hours in the QUAL2K model.

J4.6 Shade

Riparian shade was estimated using a geographical information system and the Shadev3.0.xls (for a discussion of how shade was estimated, see **Section J2.3**. The hourly shade inputs per reach for the proposed QUAL2K model segments are summarized in **Figure J-17** (for the inputs for QUAL2K, see **Appendix JC Table JC-8**).

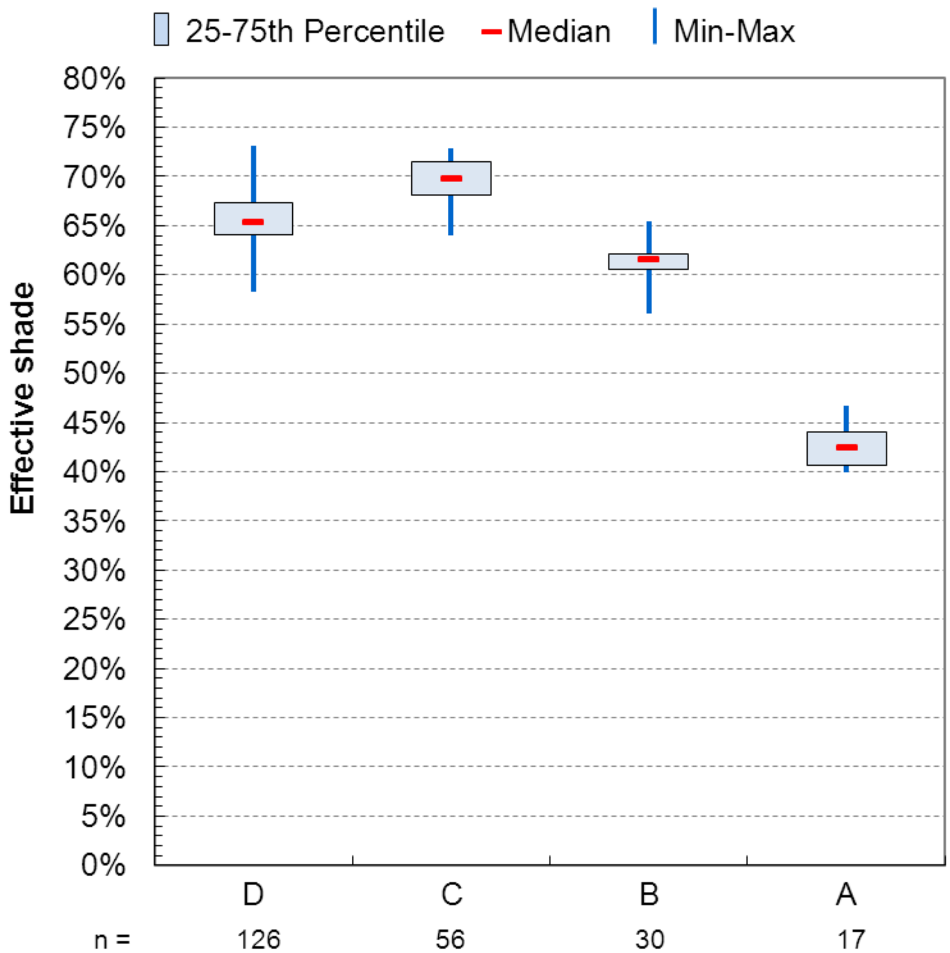


Figure J-17. Box and whisker plot evaluation of effective shade output.

J4.7 HEAT

QUAL2K users can select various heat transfer model input parameters. For this project, default values recommended by Chapra et al. (2008) were used; the inputs are presented in **Table JC-9** in **Appendix JC**.

J5.0 CALIBRATION AND VALIDATION

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

Discussions of calibration and validation are in the *Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling* (Tetra Tech, 2012).

J5.1 Error Analysis

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

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

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

J5.2 Calibration and Validation Periods

The period for calibration and validation for developing the temperature QUAL2K model were selected on the basis of the available data. The available flow and stream geometry data suggest that travel times in the stream, from headwaters to mouth, is less than one day. Average velocities were calculated from depth-velocity interval data recorded when flow was monitored on 11 occasions. Average velocity ranged from 0.21 to 1.4 feet per second, with an average of 0.67 foot per second. Such velocities yield travel times of 3.5 to 22 hours, with an average of 7.2 hours.

Available precipitation data were also considered when selecting calibration and validation periods (**Figure J-18**). The warmest stream temperatures occurred in July when there was no precipitation (**Figure J-18**). Precipitation events resulted in cooling, rather than warming, the stream, likely because of cooler ambient air temperatures.

Therefore, a single day each was selected for the calibration period and the validation period. The calibration period (July 16, 2010) and validation period (August 26, 2010) consisted of a warm day without precipitation on that day or preceding days during summer low flows, which allows for calibration to conditions that would be similar to that of critical conditions (i.e., warm water with low flows).

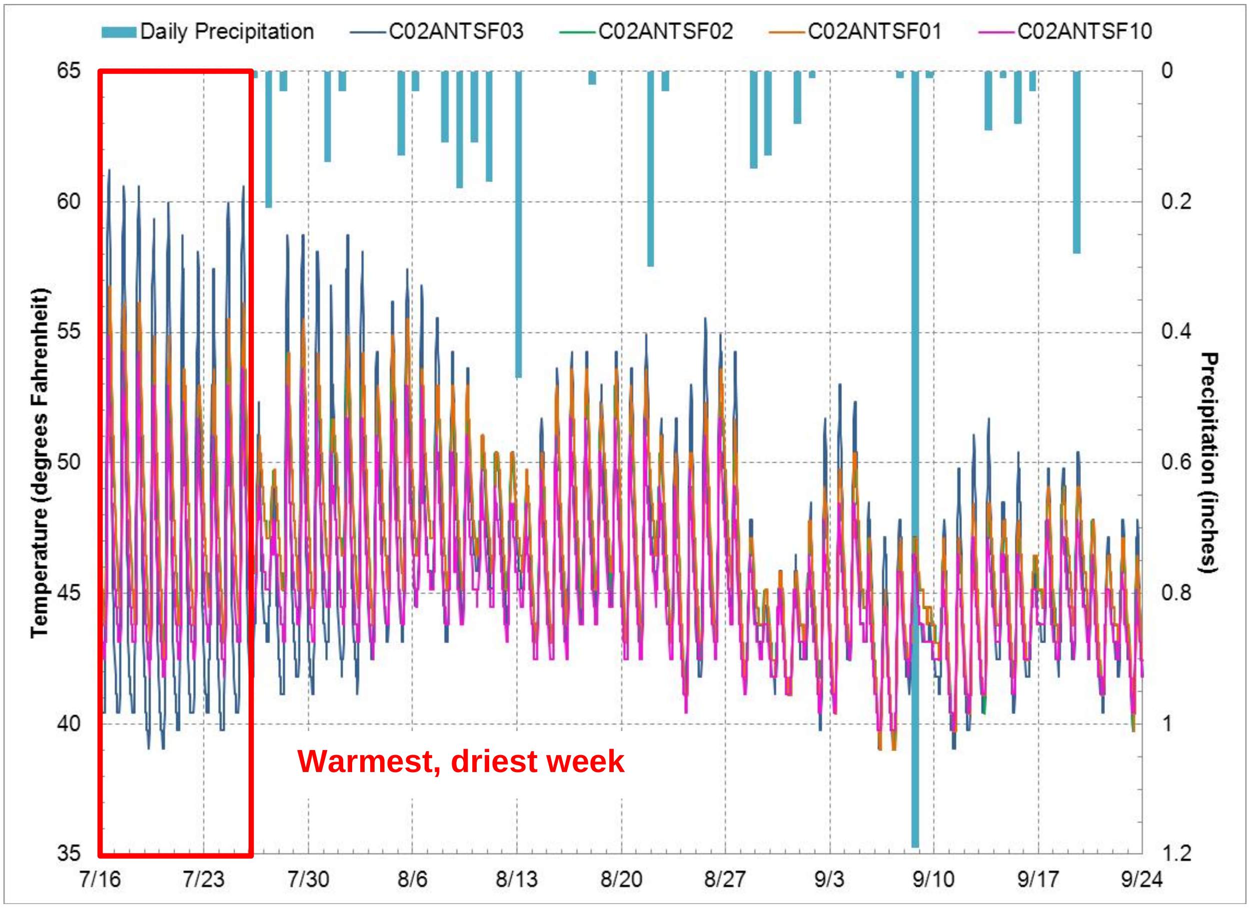


Figure J18. Daily precipitation and instream temperature along South Fork Antelope Creek.

J5.3 Calibration Results

Temperature calibration for the South Fork Antelope Creek QUAL2K model relied on a comparison of model predictions to observations at the four temperature loggers in the temperature-impaired segment (C02ANTSF03, C02ANTSF02, C02ANTSF01, and C02ANTSF10).

All the modeled minima, means, and maxima are within 2 °C of the corresponding observed minima, means, and maxima (**Table JC-10**). All but two of the relative differences are less than 10 percent. Therefore, in accordance with the QAPP (Tetra Tech, 2012), the calibration is acceptable.

The calibration results are displayed in **Table J-2** and **Figure J-19** in Fahrenheit to facilitate comparisons with model scenarios that are discussed in **Section J6.0.**

Table J-2. Model calibration results for July 16, 2010 (°F)

Daily temperature	Source	Fahrenheit			
		C02ANTSF03	C02ANTSF02	C02ANTSF01	C02ANTSF10
Maximum	QUAL2K	60.3	57.1	55.1	53.3
	Observed	61.2	55.5	56.8	54.9
	Difference	-1.0	+1.6	-1.7	-1.6
Mean	QUAL2K	47.9	47.7	47.6	47.4
	Observed	47.9	49.0	49.0	46.9
	Difference	-0	-1.3	-1.5	+0.5
Minimum	QUAL2K	40.5	41.5	42.7	43.7
	Observed	40.4	43.8	43.8	42.5
	Difference	-0	-2.3	-1.1	+1.2

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree. The difference is calculated as the QUAL2K minus observed.

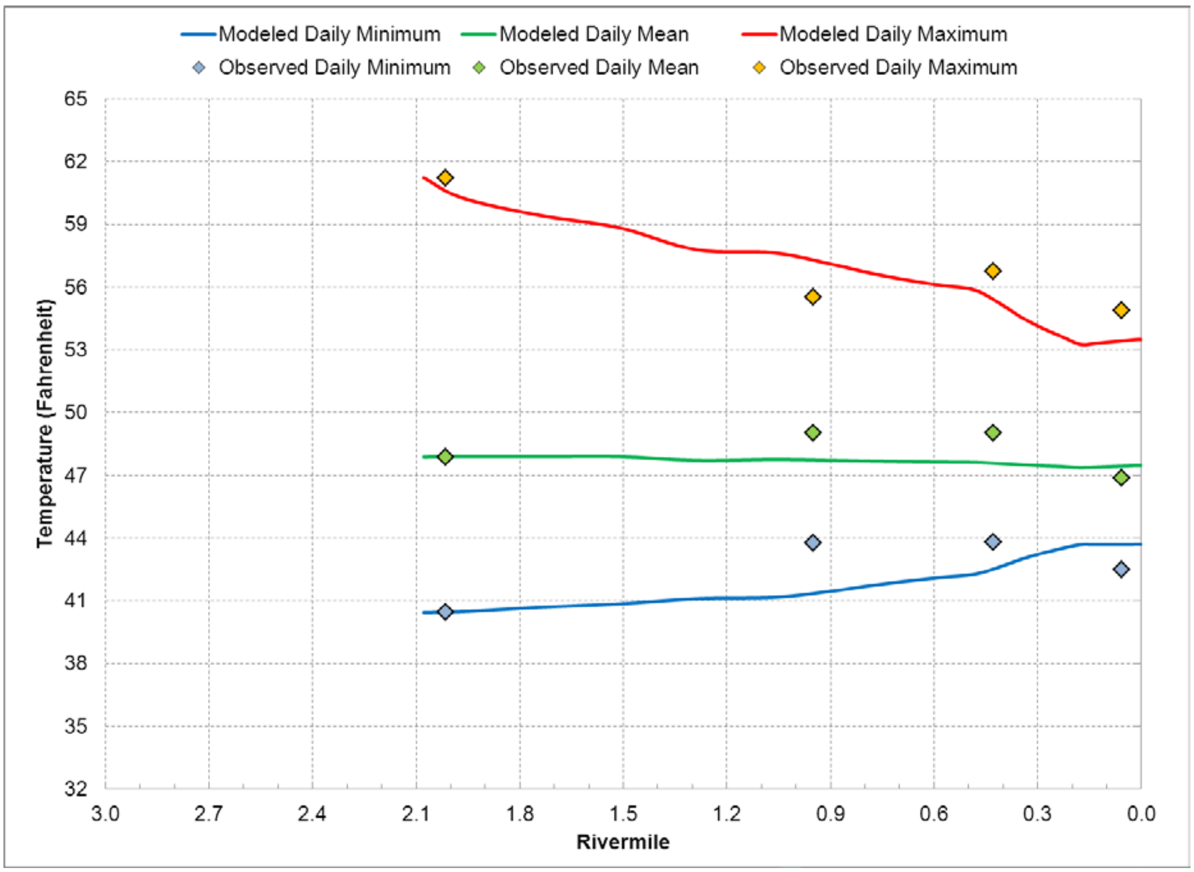


Figure J-19. Calibration period (July 16, 2010).

J5.4 Validation Results

Model validation was determined by a second model run that was conducted under different hydrological and weather conditions (August 26, 2010). Instantaneous flow measurements were collected at three of the four DEQ sites on August 26, 2010. Flow was not monitored at C02ANTSF02 nor was flow monitored at the springs. Flow at these un-gaged sites was estimated using the relationship between flows at the un-gaged sites from July 16, 2010, and the other monitored sites from July 16, 2010, and the flows monitored on August 26, 2010. Weather data for August 26, 2010, were obtained from the same weather stations as for July 16, 2010.

All the modeled minima, means, and maxima are within 2 °C of the corresponding observed minima, means, and maxima (**Table JC-11**). All but one of the relative differences is less than 10 percent. Therefore, in accordance with the QAPP (Council for Regulatory Environmental Modeling, 2009), the validation is acceptable.

The calibration results are displayed in **Table J-3** and **Figure J-20** in Fahrenheit to facilitate comparisons with model scenarios that are discussed in **Section J6**.

Table J-3. Model validation results for August 26, 2010 (°F)

Daily temperature	Source	Fahrenheit			
		C02ANTSF03	C02ANTSF02	C02ANTSF01	C02ANTSF10
Maximum	QUAL2K	54.2	53.8	54.5	53.1
	Observed	54.9	52.3	53.6	51.7
	Difference	-0.7	+1.5	+1.0	+1.4
Mean	QUAL2K	47.6	47.7	47.8	47.6
	Observed	48.1	47.8	48.1	46.6
	Difference	+0.5	-0.1	-0.4	+0.9
Minimum	QUAL2K	43.0	42.9	42.7	43.6
	Observed	43.1	43.1	43.1	42.5
	Difference	+0.1	-0.2	-0.5	+1.1

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree. The difference is calculated as the QUAL2K minus observed.

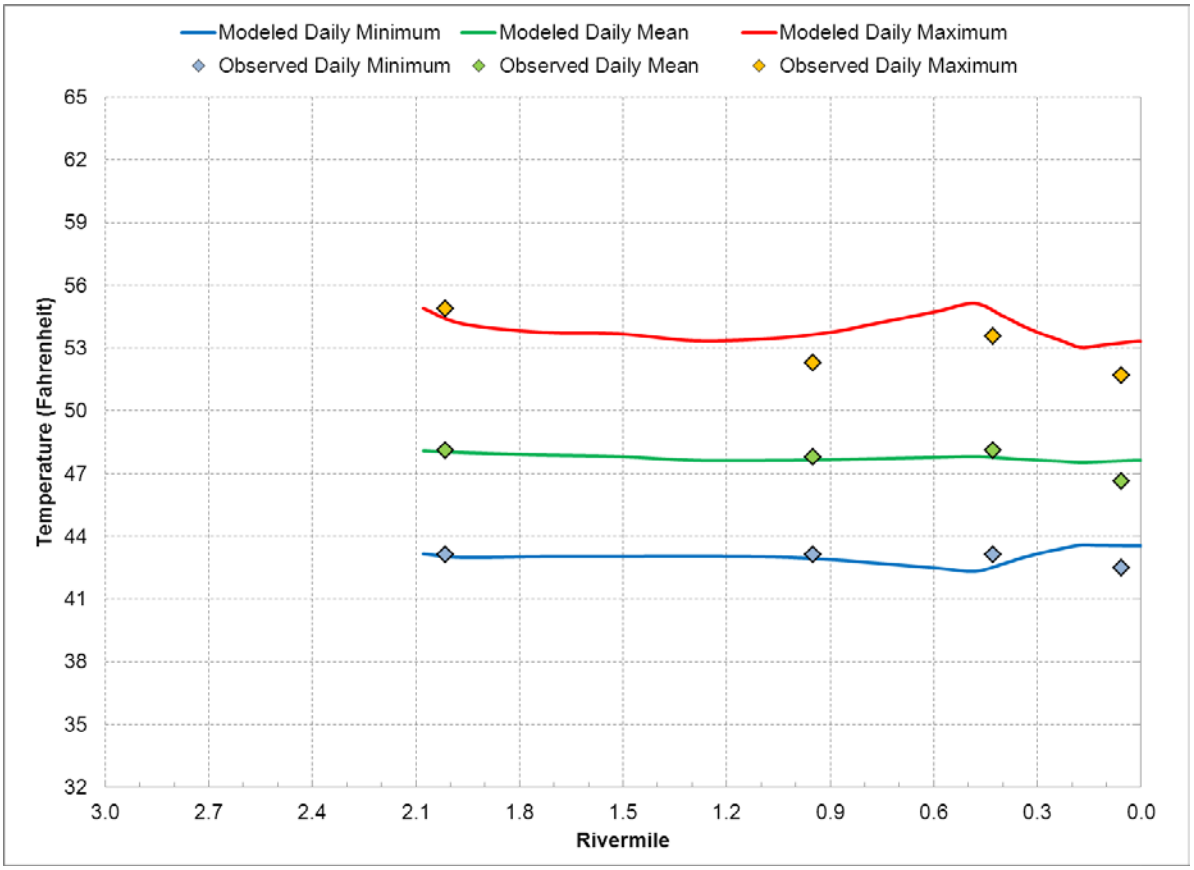


Figure J-20. Validation period (August 26, 2010).

J6.0 Model Scenarios

The South Fork Antelope Creek QUAL2K model was used to evaluate instream temperature response associated with the following scenarios:

- Existing condition
- Existing condition with low flow
- Full potential shade
- Full potential shade with low flow

Table J-4 summarizes the alterations to input parameters for each model scenario. The following sections present a discussion of the modifications to the QUAL2K models and the results for each scenario.

Table J-4. Model scenarios and summary of inputs

Scenario	Inputs
Existing conditions (calibration)	As previously discussed in Section J5.3
Existing conditions with low flow	Reduce inflows by 20 and 37 percent
Full potential shade	Increase shade in all reaches to be equivalent to the reach with the most shade
Full potential shade with low flow	Reduce all inflows by 37 percent and increase shade in all reaches to be equivalent to the reach with the most shade

Throughout this section, the differences between the simulated existing conditions and scenarios are reported. The difference is calculated as the scenario results minus the existing conditions results. A negative value means that the scenario resulted in cooler temperatures than were simulated with the existing conditions; a positive value means that the scenario resulted in warmer temperatures than were simulated in the existing conditions.

J6.1 Existing Conditions

The calibration model serves as the existing conditions scenario (i.e., baseline) for which to construct the other scenarios and compare the results against. This model represents dry conditions during July. The construction of the model and its inputs are discussed in **Section J4**.

J6.2 Existing Conditions with Low Flow

In this scenario, the flow inputs to the QUAL2K model are decreased to represent critical low-flow conditions, simulating the stream dynamics during an exceptionally dry season. An evaluation of monthly flows at the USGS gage on the Middle Fork Rock Creek near Philipsburg, Montana (12332000) showed that low-flow conditions (represented by the monthly 25th percentile flow) were 37 percent smaller than the average conditions (represented by the monthly mean flow) for July; for August, 20 percent smaller. The headwaters inflow, diffuse flow (i.e., groundwater) and springs' inflow were reduced by 37 percent (July) and 20 percent (August).

These low-flow condition scenarios resulted in higher daily maximum and daily mean temperatures along the entire stream, with a greater increase in temperature corresponding to a greater decrease in flow. The uniform decrease in minimum temperatures might be related to the increased influence of cooler groundwater during low-flow conditions. **Table J-5** and **Table J-6** present the scenario results at DEQ's sample sites; **Figure J21** presents the continuous results along South Fork Antelope Creek.

Table J-5. Low-flow conditions results for 20 percent reduction in flow (August – Validation)

Daily temperature	Source	Fahrenheit			
		C02ANTSF03	**C02ANTSF02**	**C02ANTSF01**	**C02ANTSF10**
Maximum	Existing	60.3	57.1	55.1	53.3
	Scenario	60.4	57.5	55.6	53.8
	Difference	**+0.1**	**+0.4**	**+0.4**	**+0.5**
Mean	Existing	47.9	47.7	47.6	47.4
	Scenario	47.9	47.8	47.6	47.5
	Difference	**+0**	**+0.1**	**+0.1**	**+0.1**
Minimum	Existing	40.5	41.5	42.7	43.7
	Scenario	40.4	41.2	42.5	43.5
	Difference	**-0.1**	**-0.2**	**-0.2**	**-0.2**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The term "+0" represents a difference of less than +0.05 degree.

Table J-6. Low-flow conditions results for 37 percent reduction in flow (July – Calibration)

Daily temperature	Source	Fahrenheit			
		C02ANTSF03	C02ANTSF02	C02ANTSF01	C02ANTSF10
Maximum	Existing	60.3	57.1	55.1	53.3
	Scenario	60.5	58.0	56.2	54.4
	Difference	**+0.2**	**+0.8**	**+1.1**	**+1.0**
Mean	Existing	47.9	47.7	47.6	47.4
	Scenario	47.9	47.9	47.7	47.6
	Difference	**+0**	**+0.2**	**+0.2**	**+0.2**
Minimum	Existing	40.5	41.5	42.7	43.7
	Scenario	40.3	40.9	42.2	43.3
	Difference	**-0.2**	**-0.5**	**-0.5**	**-0.4**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The term "+0" represents a difference of less than +0.05 degree.

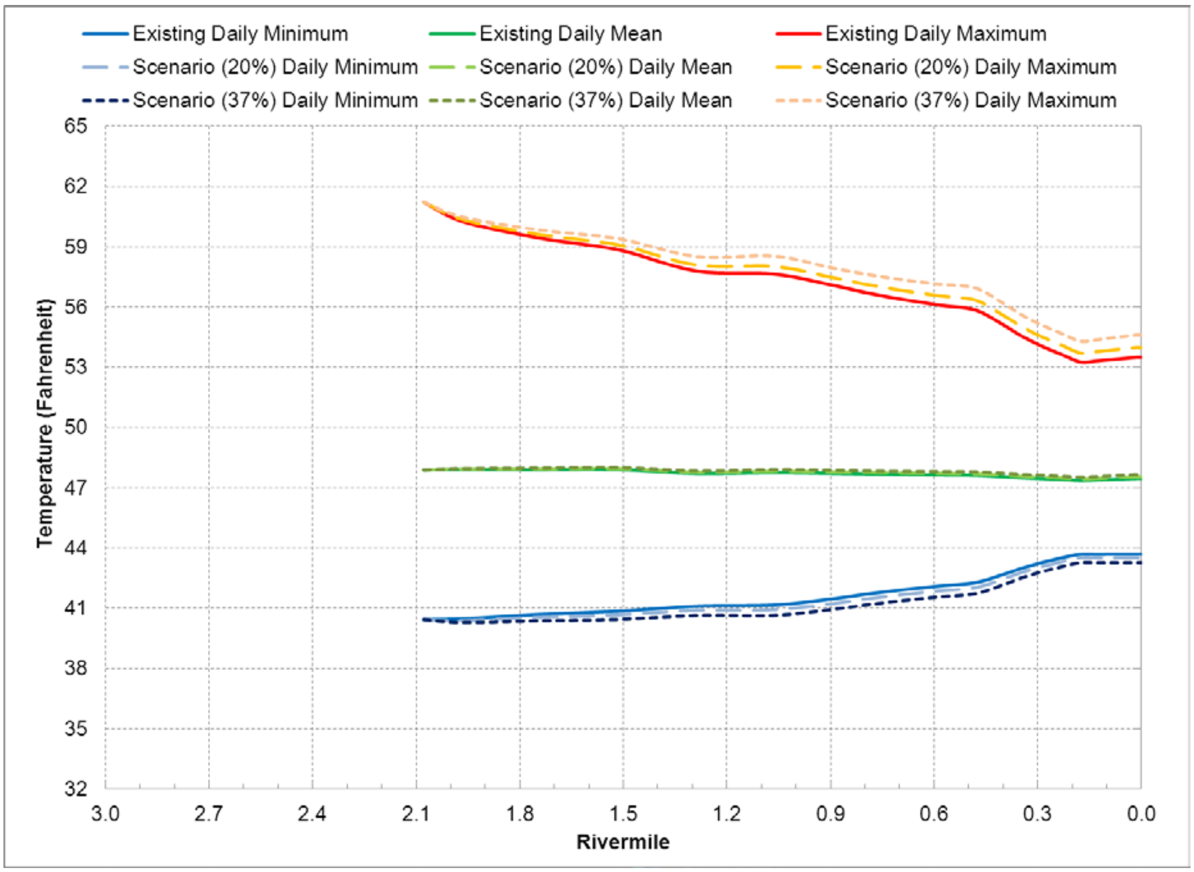


Figure J-21. Low-flow conditions results.

J6.3 Full Potential Shade

This shade scenario uses the existing conditions model and increases shading along the creek. In this scenario, the shading of all the reaches was increased to the level of shading in the reach with the highest levels of estimated shading. The 24-hour shade input for reaches A, B, and C were set to the same as the 24-hour shade input for reach D.

This full potential shade scenario had little to no effect on water temperatures along South Fork Antelope Creek. While the scenario results in small decreases of maximum daily water temperatures in the lower half of the watershed, the daily minimum and most of the daily mean water temperatures remained the same. **Table J7** presents the scenario results at DEQ's sample sites; **Figure J-22** presents the continuous results along South Fork Antelope Creek.

Table J-7. Full potential shade results

Daily temperature	Source	Fahrenheit			
		C02ANTSF03	C02ANTSF02	C02ANTSF01	C02ANTSF10
Maximum	Existing	60.3	57.1	55.1	53.3
	Scenario	60.3	57.1	54.9	53.0
	Difference	**0**	**0**	**-0.2**	**-0.3**
Mean	Existing	47.9	47.7	47.6	47.4
	Scenario	47.9	47.7	47.6	47.4
	Difference	**0**	**0**	**+0.1**	**0**
Minimum	Existing	40.5	41.5	42.7	43.7
	Scenario	40.5	41.5	42.7	43.7
	Difference	**0**	**0**	**0**	**0**

Note: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.

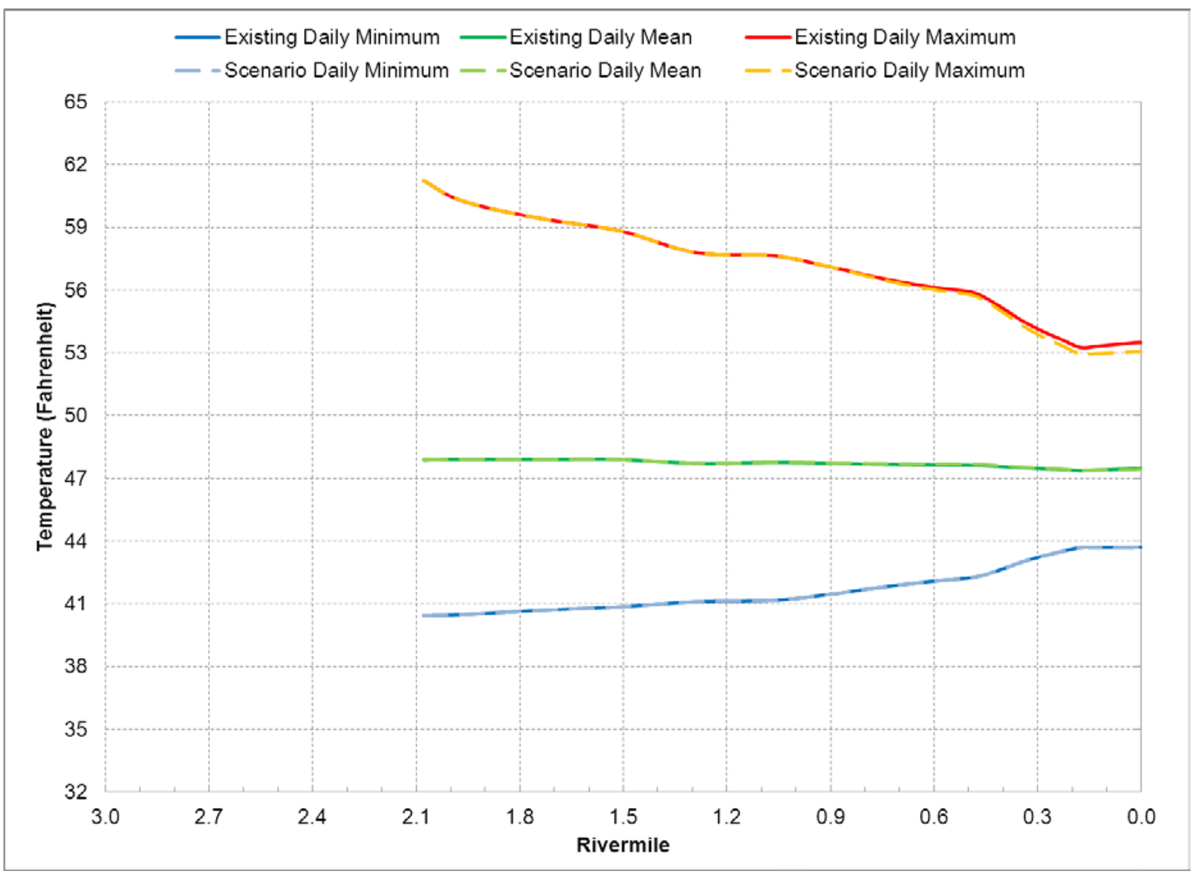


Figure J-22. Full potential shade results.

J6.4 Full Potential Shade with Low Flow

This scenario is the combination of the scenarios presented in **Sections J6.3** and **J6.2**. The 24-hour shade input for reaches A, B, and C were set to the same as the 24-hour shade input for reach D and the headwaters inflow, diffuse flow (i.e., groundwater) and springs' inflow were reduced by 37 percent.

The results of this scenario indicate a slight decrease of minimum daily temperatures and an increase in maximum daily temperatures. **Table J-8** presents the scenario results at DEQ's sample sites; **Figure J-23** presents the continuous results along South Fork Antelope Creek.

Table J8. Low-flow conditions (37 percent reduction) and full potential shade results

Daily temperature	Source	Fahrenheit			
		C02ANTSF03	**C02ANTSF02**	**C02ANTSF01**	**C02ANTSF10**
Maximum	Existing	60.3	57.1	55.1	53.3
	Scenario	60.5	58.1	56.1	54.0
	Difference	**+0.2**	**+1.0**	**+1.0**	**+0.7**
Mean	Existing	47.9	47.7	47.6	47.4
	Scenario	47.9	47.9	47.8	47.6
	Difference	**+0**	**+0.2**	**+0.2**	**+0.2**
Minimum	Existing	40.5	41.5	42.7	43.7
	Scenario	40.3	40.9	42.2	43.3
	Difference	**-0.2**	**-0.5**	**-0.5**	**-0.4**

Notes: Results are reported in degrees Fahrenheit and rounded to the nearest one-tenth of a degree.
The term "+0" represents a difference of less than +0.05 degree.

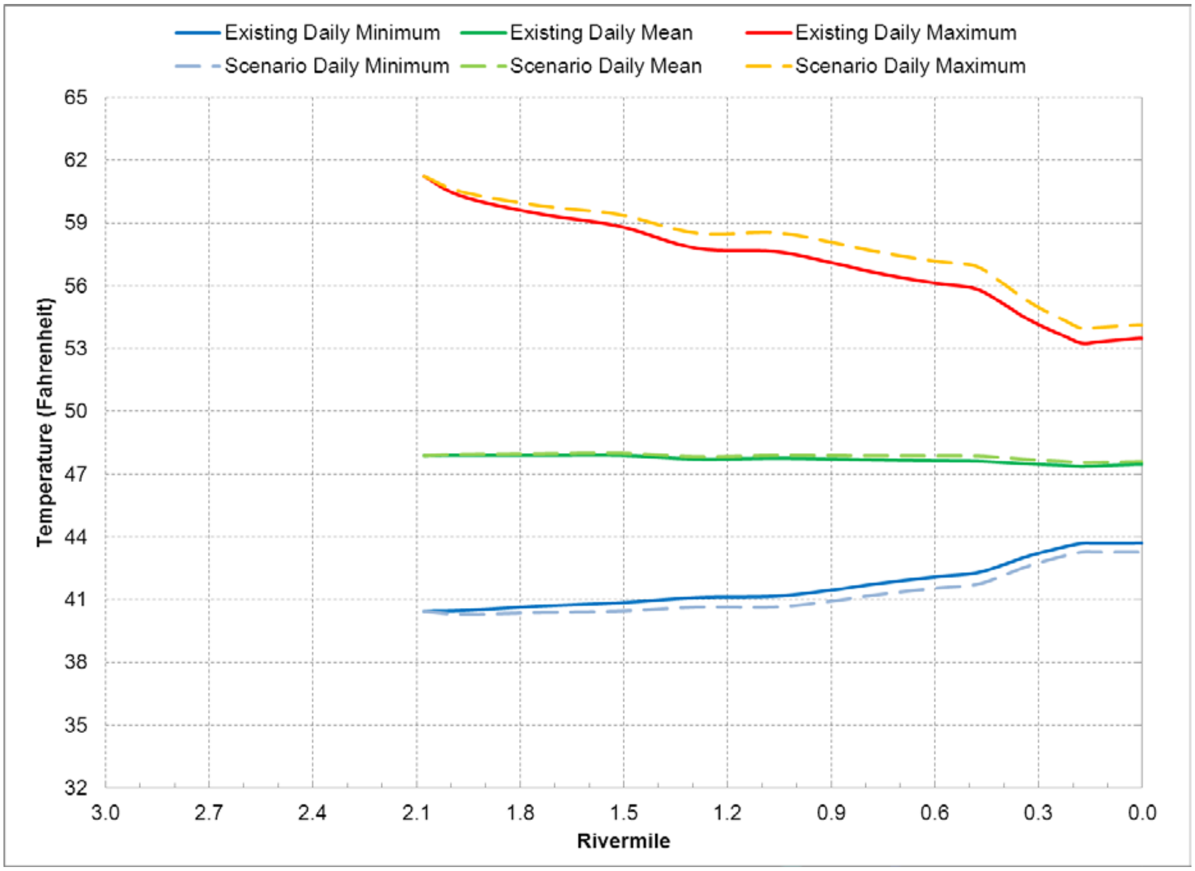


Figure J-23. Low-flow conditions (37 percent reduction) and full potential shade results.

J6.5 Scenarios Results and Discussion

Scenarios were developed in QUAL2K to evaluate the impacts of various factors that could affect instream water temperatures in South Fork Antelope Creek. Reducing flows by 20 to 37 percent to simulate natural low-flow or drought conditions resulted in increases of up to 1.1 °F. Increasing shade to replicate the effect of re-vegetation after timber harvest resulted in little change (≤ 0.4°F) when compared to both the existing condition scenario and the natural low-flow scenarios.

J7.0 References

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APPENDIX JA. FIELD DATA (WATER & ENVIRONMENTAL TECHNOLOGIES, 2011)

Table JA-1. Shade measurements (Water & Environmental Technologies, 2011)

Site ID	Location and bank	Wetted width (feet)	Vegetation	Vegetation Height (feet)	Density (percent)	Bank height (feet)	Overhang (feet)
C02ANTSSF02	A - LB	1.25	Sparse Conifer	97.8	82%	ridge 168ft	1
	A - RB	N/A	Sparse Conifer	156	88%	0.6	0
	B - LB	7.5	Sparse Conifer	89	94%	0.3	0
	B - RB	N/A	Medium Conifer	98	88%	0.8	0
	C - LB	7.2	Sparse Conifer	98	94%	0.7	0
	C - RB	N/A	Medium Conifer	112	100%	1.2	0
CO2ANTSF10	A - LB	1.8	Dense conifer	70.4	100%	1	0
	A - RB	N/A	Sparse Conifer	24.23	100%	1	0
	B - LB	0.9	Mixed High Level	51.2	88%	0	0.9
	B - RB	N/A	Mixed High Level	11.5	76%	0	0
	C - LB	2.5	Sparse Conifer	58.7	100%	2.9	0
	C - RB	N/A	Mixed High Level	32.8	71%	2.6	0
CO2ANTSF01	A - LB	2.4	Mixed High Level	48.3	100%	0.6	1
	A - RB	N/A	Mixed High Level	77	82%	0.9	0
	B - LB	7	Medium Conifer	70.8	100%	4	0
	B - RB	N/A	Sparse Conifer	78.4	94%	2.3	0
	C - LB	3.5	Sparse Conifer	15.5	94%	1.2	0
	C - RB	N/A	Sparse Conifer	96.5	94%	0.6	0
C02ANTSF03	A - LB	1.9	Dense conifer	73.6	94%	0	0
	A - RB	N/A	Dense conifer	27.9	94%	0	0
	B - LB	2	Sparse Conifer	19.8	47%	0	0
	B - RB	N/A	Dense conifer	39.7	88%	0	0
	C - LB	2.8	Dense conifer	56.3	88%	0	0
	C - RB	N/A	Dense conifer	54.5	88%	0	0

Source: (Water & Environmental Technologies, 2011)
Note: LB = left bank; n/a = not available; RB = right bank

Table JA-2. Riparian summary (Water & Environmental Technologies, 2011)

Vegetation description	Height (feet)	Density (percent)	Overhang (feet)
Dense Conifer	70.4	74%	0.0
Mixed High Level	44.2	43%	0.4
Medium Conifer	70.4	70%	0.0
Sparse Conifer	70.4	45%	0.1
Blank	0.0	0%	0.0

Source: (Water & Environmental Technologies, 2011)

Table JA-3. Channel cross section data, SFAC 06-01 (Water & Environmental Technologies, 2011)

Cell	Feature	Bankfull channel width (feet)	Cross-sectional area (sq. feet)	Bankfull mean depth (feet)	Width / depth ratio	Maximum depth (feet)	Floodprone width (feet)	Entrenchment ratio
1	Riffle	2.4	1.20	0.50	4.8	0.7	19.4	8.1
2	Riffle	4.4	1.02	0.23	18.9	0.6	13.4	3.0
3	Riffle	4.0	1.16	0.29	13.8	0.6	13.0	3.3
4	Riffle	3.5	1.33	0.38	9.2	0.7	18.5	5.3
5	Riffle	3.5	1.09	0.31	11.3	0.6	19.5	5.6

Source: (Water & Environmental Technologies, 2011)

Table JA-4. Channel cross section data, SFAC 13-01 (Water & Environmental Technologies, 2011)

Cell	Feature	Bankfull channel width (feet)	Cross-sectional area (sq. feet)	Bankfull mean depth (feet)	Width / depth ratio	Maximum depth (feet)	Floodprone width (feet)	Entrenchment ratio
1	Riffle	7.0	3.64	0.52	13.5	1.1	31.0	4.4
2	Riffle	4.0	2.60	0.65	6.2	1.1	21.0	5.3
3	Riffle	8.5	4.59	0.54	15.7	1.4	21.5	2.5
4	Riffle	5.0	2.05	0.41	12.2	1.2	18.0	3.6
5	Riffle	8.0	4.72	0.59	13.6	1.4	63.0	7.9

Source: (Water & Environmental Technologies, 2011)

APPENDIX JB. SHADE ANALYSES

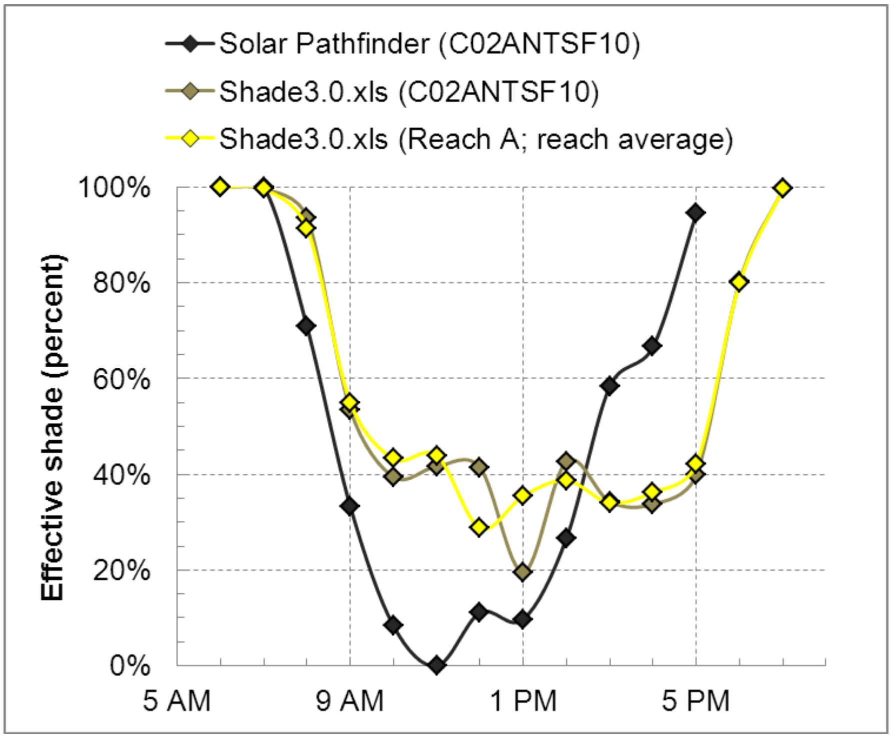

Figure JB - 1. Shade analysis in Reach A.

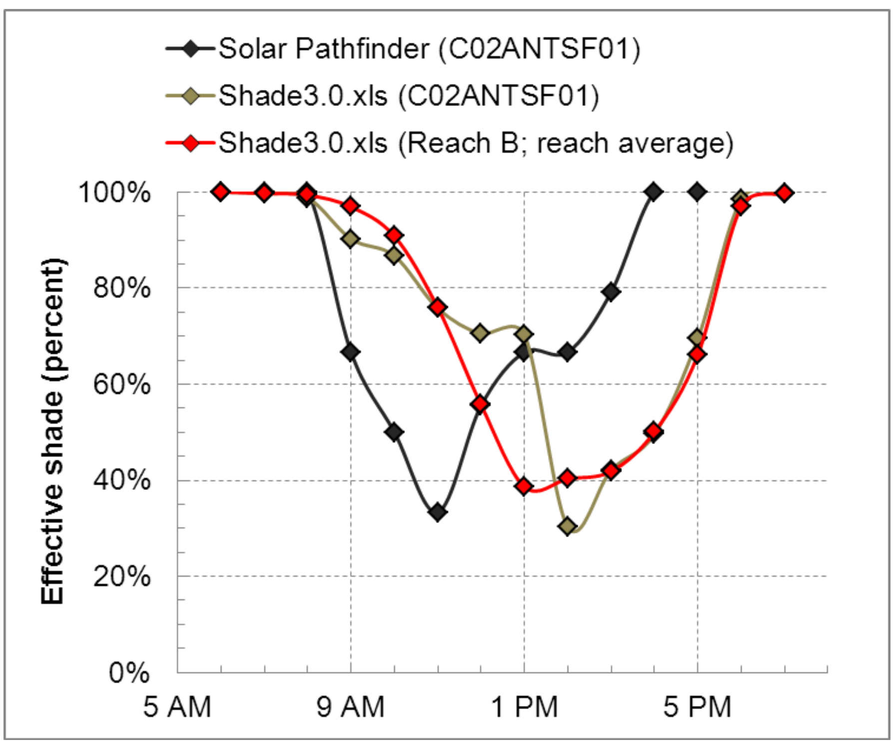

Figure JB - 2. Shade analysis in Reach B.

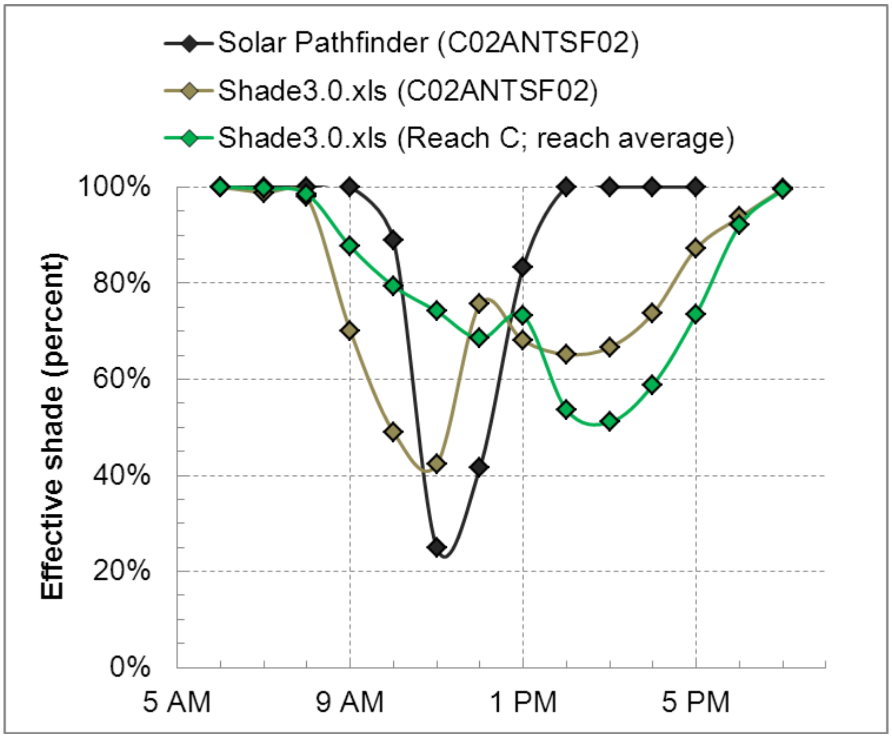

Figure JB - 3. Shade analysis in Reach C.

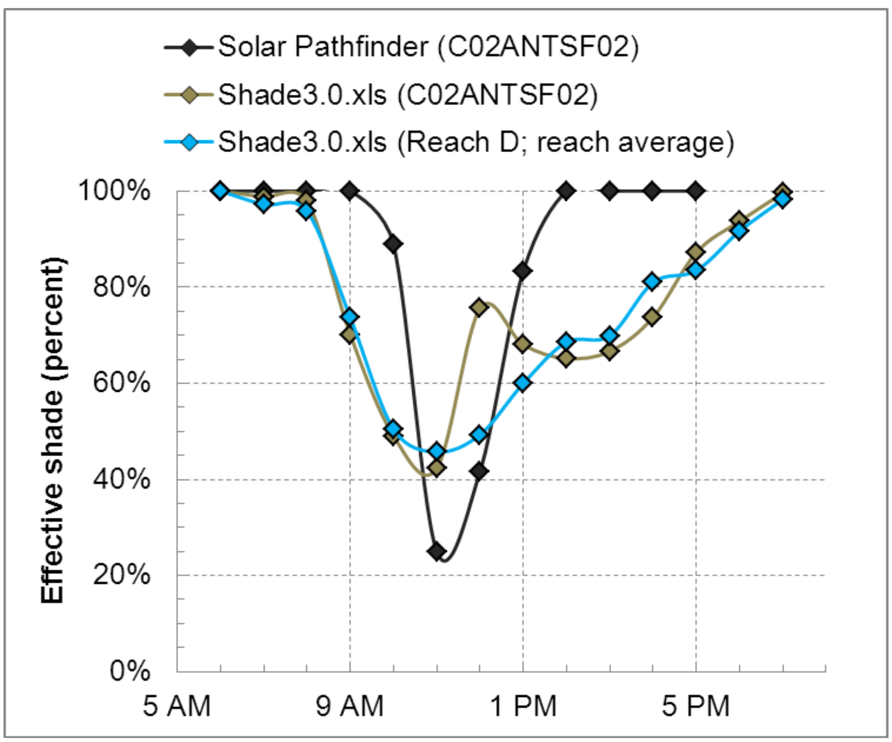

Figure JB - 4. Shade Analysis in Reach D.

APPENDIX JC. QUAL2K MODEL DEVELOPMENT

Table JC-1. Input parameters for Shadev3.0.xls (at each sampling location)

Sample station	Elevation (meters)	Aspect (degrees)	Wetted width (meters)	NSDZ width (meters)	Center to left NSDZ (meters)	Channel incision (meters)	Topographic shade West (degrees)	Topographic shade South (degrees)	Topographic shade East (degrees)
C02ANTSF 03	1,916	8	0.68	1.16	0.58	0.00	17.51	8.87	23.07
C02ANTSF 02	1,794	313	1.62	1.62	0.81	0.22	14.92	16.25	20.10
C02ANTSF 01	1,719	12	1.31	1.84	0.92	0.49	24.43	13.93	18.36
C02ANTSF 10	1,671	355	0.53	2.00	1.00	0.38	5.62	11.96	15.54

Notes: Sites are listed from top to bottom as headwaters to mouth.
NSDZ = near-shore disturbance zone

Table JC-2. Channel geometry inputs for QUAL2K

Segment	Channel slope	Manning's n	Stream bottom width (meters)	Side 1a	Side 2a
Headwaters inflow	0.073	0.0740	0.76	10.00	3.75
D	0.073	0.0740	0.76	10.00	3.75
C	0.089	0.0540	1.37	0.83	1.67
B	0.085	0.0468	1.37	0.83	1.67
A	0.058	0.0528	0.30	5.00	2.50

Notes: Segments are listed from top to bottom of the column as headwaters to the mouth
[a] Adjacent side ratio (relative to one) based on the trapezoidal cross section (**Figure J-15**).

Table JC-3. Observed instream flow data used for modeling

Location	Flow (cubic meters per second)
C02ANTSF03	0.048
C02ANTSF02	0.084
C02ANTSF01	0.117
C02ANTSF10	0.192

Table JC-4. Estimated diffuse flow for each reach for QUAL2K

Segment	Diffuse flow (cubic meter per second)
Reach D	0.0310
Reach C	0.0330
Reach B	0.0665
Reach A	0.0070

Table JC-5. Estimated springs' flow

Spring	Diffuse flow (cubic meter per second)
Upper	0.0039
Lower	0.0012

Table JC-6. Hourly weather data for South Fork Antelope Creek on July 16, 2010

Time	Air temperature (°C)				Wind speed (meters/second)
Reach	D	C	B	A	All
12:00 AM	9.39	10.17	10.56	10.69	1.37
1:00 AM	8.28	9.06	9.44	9.58	1.37
2:00 AM	7.17	7.95	8.33	8.46	0.46
3:00 AM	6.62	7.39	7.78	7.91	0.46
4:00 AM	6.62	7.39	7.78	7.91	0.00
5:00 AM	5.51	6.28	6.67	6.80	0.91
6:00 AM	7.17	7.95	8.33	8.46	1.37
7:00 AM	11.62	12.39	12.78	12.91	0.91
8:00 AM	15.51	16.28	16.67	16.80	0.91
9:00 AM	19.95	20.72	21.11	21.24	0.91
10:00 AM	24.39	25.17	25.56	25.69	1.83
11:00 AM	27.17	27.95	28.33	28.46	3.65
12:00 PM	27.73	28.50	28.89	29.02	5.93
1:00 PM	28.28	29.06	29.44	29.58	5.93
2:00 PM	29.39	30.17	30.56	30.69	5.93
3:00 PM	29.39	30.17	30.56	30.69	6.85
4:00 PM	28.84	29.61	30.00	30.13	4.56
5:00 PM	27.73	28.50	28.89	29.02	4.56
6:00 PM	26.62	27.39	27.78	27.91	4.11
7:00 PM	24.95	25.72	26.11	26.24	1.83
8:00 PM	21.06	21.84	22.22	22.35	0.46
9:00 PM	17.73	18.50	18.89	19.02	2.28
10:00 PM	15.51	16.28	16.67	16.80	1.83
11:00 PM	14.95	15.72	16.11	16.24	1.37

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

Table JC-7. Hourly dew point temperature data for South Fork Antelope Creek on July 16, 2010

Time	Dew point temperature (°C)			
Segment	D	C	B	A
12:00 AM	-2.27	-1.50	-1.11	-0.98
1:00 AM	-0.61	0.17	0.56	0.69
2:00 AM	-0.61	0.17	0.56	0.69
3:00 AM	0.51	1.28	1.67	1.80
4:00 AM	0.51	1.28	1.67	1.80
5:00 AM	2.17	2.95	3.33	3.46
6:00 AM	2.73	3.50	3.89	4.02
7:00 AM	3.84	4.61	5.00	5.13
8:00 AM	6.62	7.39	7.78	7.91
9:00 AM	7.17	7.95	8.33	8.46
10:00 AM	7.73	8.50	8.89	9.02
11:00 AM	3.28	4.06	4.44	4.58
12:00 PM	2.17	2.95	3.33	3.46
1:00 PM	2.17	2.95	3.33	3.46
2:00 PM	0.51	1.28	1.67	1.80
3:00 PM	-2.27	-1.50	-1.11	-0.98
4:00 PM	-0.61	0.17	0.56	0.69
5:00 PM	1.62	2.39	2.78	2.91
6:00 PM	1.62	2.39	2.78	2.91
7:00 PM	-0.05	0.72	1.11	1.24
8:00 PM	-0.05	0.72	1.11	1.24
9:00 PM	-0.05	0.72	1.11	1.24
10:00 PM	0.51	1.28	1.67	1.80
11:00 PM	-0.61	0.17	0.56	0.69

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

Table JC-8. Hourly shade results (averaged along proposed model segments)

Time	Shade (percent)			
Segment	D	C	B	A
12:00 AM	100%	100%	100%	100%
1:00 AM	100%	100%	100%	100%
2:00 AM	100%	100%	100%	100%
3:00 AM	100%	100%	100%	100%
4:00 AM	100%	100%	100%	100%
5:00 AM	100%	100%	100%	100%
6:00 AM	100%	100%	100%	100%
7:00 AM	97%	100%	100%	100%
8:00 AM	96%	99%	99%	91%
9:00 AM	74%	88%	97%	55%
10:00 AM	50%	79%	91%	43%
11:00 AM	46%	74%	76%	44%
12:00 PM	49%	68%	56%	29%
1:00 PM	60%	73%	39%	35%
2:00 PM	69%	54%	40%	39%
3:00 PM	70%	51%	42%	34%
4:00 PM	81%	59%	50%	36%
5:00 PM	83%	74%	66%	42%
6:00 PM	92%	92%	97%	80%
7:00 PM	98%	99%	100%	100%
8:00 PM	99%	100%	100%	100%
9:00 PM	100%	100%	100%	100%
10:00 PM	100%	100%	100%	100%
11:00 PM	100%	100%	100%	100%

Table JC-9. Heat parameters and transfer models

Parameter	Value
Solar Shortwave Radiation Model	
Atmospheric attenuation model for solar	Ryan-Stolzenbach
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient[a]	0.75
Downwelling atmospheric longwave infrared radiation	
Atmospheric longwave emissivity model	Brunt
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	Brady-Graves-Geyer
Sediment heat parameters	
Sediment thermal thickness (centimeter)[b]	10
Sediment thermal diffusivity (square centimeter per second)[c]	0.005
Sediment density (gram per cubic centimeter)[d]	1.6
Water density (gram per cubic centimeter)[d]	1
Sediment heat capacity (calorie per [gram by degree Celsius])[d]	0.4
Water heat capacity[d]	1

Notes:
[a] Atmospheric transmission coefficient default is 0.8; typical range is 0.70 to 0.91.
[b] Sediment thermal thickness default is 10 centimeters.
[c] Sediment thermal diffusivity default is 0.005 square centimeter per second
[d] These values are the model defaults.

Table JC-10. Model calibration results for July 16, 2010 in Celsius

Daily temperature	Source	Celsius			
		C02ANTSF03	C02ANTSF02	C02ANTSF01	C02ANTSF10
Maximum	QUAL2K	15.7	14.0	12.8	11.8
	Observed	16.2	13.1	13.8	12.7
	Abs. Error[a]	***-0.5***	***+0.9***	***-0.9***	***-0.9***
	Rel. Error[b]	***3%***	***7%***	***7%***	***7%***
Mean	QUAL2K	8.8	8.7	8.6	8.6
	Observed	8.8	9.5	9.5	8.3
	Abs. Error[a]	***0.0***	***-0.7***	***-0.8***	***+0.3***
	Rel. Error[b]	***0%***	***8%***	***9%***	***4%***
Minimum	QUAL2K	4.7	5.3	5.9	6.5
	Observed	4.7	6.5	6.6	5.8
	Abs. Error[a]	***0.0***	***-1.3***	***-0.6***	***+0.7***
	Rel. Error[b]	***0%***	20%	***10%***	12%

Notes:
Results are reported in degrees Celsius and rounded to the nearest one-tenth of a degree.
Calibration results that meet the acceptance criteria are presented in ***bold italics***; results that do not meet the acceptance criteria are presented in shaded cells.
[a] Absolute error is calculated as QUAL2K minus observed.
[b] Relative error is calculated as the absolute value of QUAL2K minus observed and then divided by observed.

Table JC-11. Model validation results for August 26, 2010 in Celsius

Daily temperature	Source	Celsius			
		C02ANTSF03	C02ANTSF02	C02ANTSF01	C02ANTSF10
Maximum	QUAL2K	12.3	12.1	12.5	11.7
	Observed	12.7	11.3	12.0	10.9
	Abs. Error[a]	***-0.4***	***+0.8***	***+0.5***	***+0.8***
	Rel. Error[b]	***3%***	***7%***	***4%***	***7%***
Mean	QUAL2K	8.7	8.7	8.8	8.6
	Observed	8.9	8.8	9.0	8.1
	Abs. Error[a]	***-0.3***	***-0.1***	***-0.2***	***+0.5***
	Rel. Error[b]	***3%***	***1%***	***2%***	***6%***
Minimum	QUAL2K	6.1	6.1	5.9	6.4
	Observed	6.2	6.2	6.2	5.8
	Abs. Error[a]	***-0.1***	***-0.1***	***-0.3***	***+0.6***
	Rel. Error[b]	***1%***	***2%***	***4%***	***10%***

Notes:
Results are reported in degrees Celsius and rounded to the nearest one-tenth of a degree.
Validation results that meet the acceptance criteria are presented in ***bold italics***; results that do not meet the acceptance criteria are presented in shaded cells.
[a] Absolute error is calculated as QUAL2K minus observed.
[b] Relative error is calculated as the absolute value of QUAL2K minus observed and then divided by observed.

APPENDIX K –NUTRIENT WATER QUALITY DATA

OrgID	StationNam	StationID	ActvtyDate	Flow_cfs	TPN_N	NO_2NO_3_as N	TotalP_as P	Chlorophyl-*a*	AFDW
MDEQ_WQ_WQX	Rock Creek East Fork at wilderness boundary	C02ROCEF01	7/13/2009 17:30	-	0.081	0.008	0.005	-	-
MDEQ_WQ_WQX	Rock Creek East Fork just below East Fork Reservoir	C02ROCEF05	7/28/2010 12:30	114.7(E)	-0.05	-0.01	0.006	10.2	18.33
MDEQ_WQ_WQX	Rock Creek East Fork just below East Fork Reservoir	C02ROCEF05	8/30/2010 17:24	77.6	-0.05	-0.01	0.005	-	-
MDEQ_WQ_WQX	Rock Creek East Fork just below East Fork Reservoir	C02ROCEF05	9/28/2010 17:17	4 (E)	-0.05	-0.01	0.007	-	-
MDEQ_WQ_WQX	Rock Creek East Fork Upper 1/4 mi d/s East Fork Reservoir	C02ROCEF20	7/26/2004 14:15	-	-	-0.01	0.027	-	-
MDEQ_WQ_WQX	Rock Creek East Fork Upper 1/4 mi d/s East Fork Reservoir	C02ROCEF20	7/26/2004 14:15	-	-	-0.01	0.031	-	-
MDEQ_WQ_WQX	Rock Creek East Fork upstream of Meadow Creek confluence	C02ROCEF04	7/27/2010 16:30	25.78	0.06	-0.01	0.009	17.6	125.5
MDEQ_WQ_WQX	Rock Creek East Fork upstream of Meadow Creek confluence	C02ROCEF04	8/30/2010 15:50	14.2	0.09	-0.01	0.007	-	-
MDEQ_WQ_WQX	Rock Creek East Fork upstream of Meadow Creek confluence	C02ROCEF04	9/28/2010 14:45	11.56	-0.05	-0.01	0.007	-	-
MDEQ_WQ_WQX	Rock Creek East Fork	C02ROCEF03	7/27/2010 11:00	41.51	-0.05	-0.01	0.008	15.7	72.59
MDEQ_WQ_WQX	Rock Creek East Fork	C02ROCEF03	8/30/2010 14:24	28.41	0.09	-0.01	0.007	-	-
MDEQ_WQ_WQX	Rock Creek East Fork	C02ROCEF03	9/28/2010 13:25	13.61	-0.05	-0.01	0.008	-	-
MDEQ_WQ_WQX	Rock Creek East Fork Lower abv bridge on Middle Fork Road	C02ROCEF10	7/27/2004 15:45	14.98	-	0.040	0.024	-	-
MDEQ_WQ_WQX	Rock Creek East Fork Lower abv bridge on Middle Fork Road	C02ROCEF10	7/12/2007 16:30	-	0.01	0.013	0.015	-	-
MDEQ_WQ_WQX	Rock Creek East Fork Lower abv bridge on Middle Fork Road	C02ROCEF10	7/26/2010 16:00	38.12	0.08	-0.01	0.012	15.1	70.42
MDEQ_WQ_WQX	Rock Creek East Fork Lower abv bridge on Middle Fork Road	C02ROCEF10	8/30/2010 12:15	34.62	0.06	0.01	0.015	-	-
MDEQ_WQ_WQX	Rock Creek East Fork Lower abv bridge on Middle Fork Road	C02ROCEF10	9/28/2010 11:55	30.38	0.11	-0.01	0.021	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork near headwaters	C02ANTSF03	7/15/2010 17:48	0.16	0.67	0.54	0.01	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork near headwaters	C02ANTSF03	8/27/2010 9:50	0.16	0.58	0.49	0.016	30.27	6.88
MDEQ_WQ_WQX	Antelope Creek South Fork near headwaters	C02ANTSF03	9/24/2010 13:56	0.09	0.79	0.49	0.063	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork near headwaters	C02ANTSF03	8/1/2011 15:30	0.39	0.87	0.62	0.03	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork near headwaters	C02ANTSF03	9/1/2011 10:42	0.3	1.48	0.6	0.056	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork	C02ANTSF02	7/15/2010 14:30	0.27	0.56	0.46	0.013	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork	C02ANTSF02	8/26/2010 15:05	0.36	0.54	0.48	0.013	17.57	4.4
MDEQ_WQ_WQX	Antelope Creek South Fork	C02ANTSF02	9/24/2010 11:29	0.29	0.54	0.54	0.016	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork	C02ANTSF02	8/1/2011 12:30	0.97	0.62	0.55	0.007	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork	C02ANTSF02	8/31/2011 12:45	0.67	1.08	0.56	0.013	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork 100 yards upstream from mouth	C02ANTSF10	7/27/2004 12:40	0.3 (E)	-	0.24	0.035	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork 100 yards upstream from mouth	C02ANTSF10	7/15/2010 11:20	0.63	0.43	0.36	0.01	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork 100 yards upstream from mouth	C02ANTSF10	8/26/2010 12:00	0.42	0.38	0.36	0.015	7	-
MDEQ_WQ_WQX	Antelope Creek South Fork 100 yards upstream from mouth	C02ANTSF10	9/24/2010 9:47	0.26	0.47	0.43	0.011	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork 100 yards upstream from mouth	C02ANTSF10	8/1/2011 11:40	1.55*	0.42	0.39	-0.005	-	-
MDEQ_WQ_WQX	Antelope Creek South Fork 100 yards upstream from mouth	C02ANTSF10	8/31/2011 10:30	0.42	0.45	0.42	0.012	-	-
MDEQ_WQ_WQX	Sluice Gulch	C02SLUCG03	7/14/2010 17:23	1.41	0.67	0.41	0.014	-	-
MDEQ_WQ_WQX	Sluice Gulch	C02SLUCG03	8/24/2010 15:40	1.64	0.55	0.5	0.019	-	-
MDEQ_WQ_WQX	Sluice Gulch	C02SLUCG04	8/25/2010 0:00	-	-	-	-	24.4	8.43
MDEQ_WQ_WQX	Sluice Gulch	C02SLUCG03	9/23/2010 16:26	1.43	0.52	0.49	0.013	-	-
MDEQ_WQ_WQX	Sluice Gulch	C02SLUCG03	8/2/2011 15:18	1.44	0.42	0.36	0.01	-	-
MDEQ_WQ_WQX	Sluice Gulch	C02SLUCG03	9/1/2011 15:18	1.56	0.56	0.49	0.014	-	-
MDEQ_WQ_WQX	Sluice Gulch about 1/4 mile upstream from Silver King Mine	C02SLUCG02	7/14/2010 15:50	1.26	0.41	0.25	0.015	-	-
MDEQ_WQ_WQX	Sluice Gulch about 1/4 mile upstream from Silver King Mine	C02SLUCG02	8/24/2010 10:00	1.33	0.41	0.45	0.014	34.22	12.69
MDEQ_WQ_WQX	Sluice Gulch about 1/4 mile upstream from Silver King Mine	C02SLUCG02	9/23/2010 14:05	1.42	0.41	0.37	0.011	-	-

OrgID	StationNam	StationID	ActvtyDate	Flow_cfs	TPN_N	NO_2NO_3_as N	TotalP_as P	Chlorophyl-*a*	AFDW
MDEQ_WQ_WQX	Sluice Gulch about 1/4 mile upstream from Silver King Mine	C02SLUCG02	8/2/2011 13:11	1.06	0.33	0.28	0.01	-	-
MDEQ_WQ_WQX	Sluice Gulch about 1/4 mile upstream from Silver King Mine	C02SLUCG02	9/1/2011 14:35	1.31	0.5	0.43	0.018	-	-
MDEQ_WQ_WQX	Sluice Gulch Lower 1/4 mile upstream from mouth	C02SLUCG10	7/28/2004 10:00	1.2 (E)	-	0.06	0.011	-	-
MDEQ_WQ_WQX	Sluice Gulch near mouth (Rock Creek)	C02SLUCG01	7/14/2010 14:12	1.12	0.27	0.09	0.012	-	-
MDEQ_WQ_WQX	Sluice Gulch near mouth (Rock Creek)	C02SLUCG01	8/23/2010 14:20	1.18	0.33	0.29	0.019	20.7	-
MDEQ_WQ_WQX	Sluice Gulch near mouth (Rock Creek)	C02SLUCG01	9/23/2010 11:53	0.9	0.45	0.31	0.013	-	-
MDEQ_WQ_WQX	Sluice Gulch near mouth (Rock Creek)	C02SLUCG01	8/2/2011 10:54	1.23	0.34	0.24	0.01	-	-
MDEQ_WQ_WQX	Sluice Gulch near mouth (Rock Creek)	C02SLUCG01	9/1/2011 13:46	1.42	0.46	0.38	0.017	-	-
MDEQ_WQ_WQX	Scotchman Gulch near headwaters	C02SCTMG01	8/5/2009 12:00	0.22	0.228	0.01	0.036	7.15	-
MDEQ_WQ_WQX	Scotchman Gulch near headwaters	C02SCTMG01	9/15/2009 10:15	0.11	0.104	0.014	0.031	2.29	-
MDEQ_WQ_WQX	Scotchman Gulch near headwaters	C02SCTMG01	7/7/2010 13:35	0.53	0.188	0.006	0.028	-	-
MDEQ_WQ_WQX	Scotchman Gulch near headwaters	C02SCTMG01	8/5/2010 12:17	0.19	0.2	-0.01	0.032	-	-
MDEQ_WQ_WQX	Scotchman Gulch near headwaters	C02SCTMG01	9/10/2010 11:43	0.58	0.38	0.006	0.046	-	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	8/1/2004	0.2 (E)	-	0.015	0.063	-	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	8/4/2009 17:00	0.21	0.315	0.025	0.061	6	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	9/14/2009 11:16	0.16	0.152	0.011	0.047	5.82	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	7/7/2010 10:20	0.65	0.223	0.014	0.036	-	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	8/5/2010 10:24	0.24	0.23	0.009	0.039	-	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	9/10/2010 10:02	0.79	0.412	0.027	0.064	-	-
MDEQ_WQ_WQX	Scotchman Gulch Upper 50 yards upstream from road crossing	C02SCTMG10	8/16/2011 9:46	0.12	0.246	-	0.046	14.29	13.82
MDEQ_WQ_WQX	Scotchman Gulch about 1 mile downstream of National Forest Boundary	C02SCTMG02	8/5/2009 17:20	0.29	0.285	0.009	0.064	3.28	-
MDEQ_WQ_WQX	Scotchman Gulch about 1 mile downstream of National Forest Boundary	C02SCTMG02	9/13/2009 11:15	0.2	0.156	0.016	0.047	3.79	-
MDEQ_WQ_WQX	Scotchman Gulch about 1 mile downstream of National Forest Boundary	C02SCTMG02	7/7/2010 8:19	0.68	0.222	0.01	0.045	-	-
MDEQ_WQ_WQX	Scotchman Gulch about 1 mile downstream of National Forest Boundary	C02SCTMG02	8/5/2010 9:24	0.26	0.248	0.005	0.048	-	-
MDEQ_WQ_WQX	Scotchman Gulch about 1 mile downstream of National Forest Boundary	C02SCTMG02	9/10/2010 8:39	1.02	0.431	0.009	0.074	-	-
MDEQ_WQ_WQX	Scotchman Gulch about 1 mile downstream of National Forest Boundary	C02SCTMG02	8/15/2011 17:25	0.16	0.268	0.005	0.06	3.67	4.16
MDEQ_WQ_WQX	Scotchman Gulch Lower 1/2 mile upstream from mouth	C02SCTMG20	8/2/2004 11:29	0.3 (E)	-	-	0.082	-	-
MDEQ_WQ_WQX	Scotchman Gulch Lower 1/2 mile upstream from mouth	C02SCTMG20	7/12/2007 14:00	-	0.15	-	0.058	-	-
MDEQ_WQ_WQX	Scotchman Gulch between mouth and first road crossing	C02SCTMG03	8/6/2009 11:30	0.64	0.388	0.019	-0.001	3.6	-
MDEQ_WQ_WQX	Scotchman Gulch between mouth and first road crossing	C02SCTMG03	9/12/2009 14:05	0.21	0.154	0.01	0.045	4.25	-
MDEQ_WQ_WQX	Scotchman Gulch between mouth and first road crossing	C02SCTMG03	7/6/2010 19:30	-	0.707	0.095	0.102	-	-
MDEQ_WQ_WQX	Scotchman Gulch between mouth and first road crossing	C02SCTMG03	8/5/2010 7:47	0.24	0.313	0.032	0.056	-	-
MDEQ_WQ_WQX	Scotchman Gulch between mouth and first road crossing	C02SCTMG03	9/9/2010 15:28	0.67	0.418	0.006	0.115	-	-
MDEQ_WQ_WQX	Scotchman Gulch between mouth and first road crossing	C02SCTMG03	8/14/2011 9:14	0.17	0.297	0.02	0.056	12.59	3.98
MDEQ_WQ_WQX	Flat Gulch	C02FLATG04	8/15/2011 15:01	0.03	0.384	-	0.095	15.23	2.61
MDEQ_WQ_WQX	Flat Gulch near headwaters	C02FLATG01	8/7/2009 14:30	0.06	0.333	-	0.089	25.2	-
MDEQ_WQ_WQX	Flat Gulch near headwaters	C02FLATG01	9/11/2009 9:42	0.03	0.488	-	0.078	8.61	-
MDEQ_WQ_WQX	Flat Gulch near headwaters	C02FLATG01	7/6/2010 17:00	0.03	0.397	-	0.16	-	-
MDEQ_WQ_WQX	Flat Gulch near headwaters	C02FLATG01	8/4/2010 12:30	0.174	0.33	-	0.088	-	-
MDEQ_WQ_WQX	Flat Gulch near headwaters	C02FLATG01	9/9/2010 12:37	0.25	0.984	-	0.182	-	-
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	7/30/2004 12:00	0.3 (E)	-	-0.01	0.213	25.1	-
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	8/7/2009 9:30	0.1	1.04	-	0.322	13.72	-
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	9/12/2009 9:15	0.02	1.09	-	0.295	5.54	-
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	7/6/2010 14:06	0.01	0.429	-	0.211	-	-
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	8/4/2010 10:14	0.248	0.508	-	0.319	-	-

OrgID	StationNam	StationID	ActvtyDate	Flow_cfs	TPN_N	NO_2NO_3_as N	TotalP_as P	Chlorophyl-*a*	AFDW
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	9/9/2010 10:20	0.36	1.23	-	0.402	-	-
MDEQ_WQ_WQX	Flat Gulch about 2 miles from mouth	C02FLATG10	8/13/2011 14:03	0.02	0.439	-	0.174	7.59	2.97
MDEQ_WQ_WQX	Flat Gulch near mouth	C02FLATG02	8/6/2009 15:25	0.03	0.745	-	0.324	8.55	-
MDEQ_WQ_WQX	Flat Gulch near mouth	C02FLATG02	9/10/2009 10:02	0.4	1.11	-	0.308	12.8	-
MDEQ_WQ_WQX	Flat Gulch near mouth	C02FLATG02	7/6/2010 11:25	0.018	0.229	-	0.115	-	-

*The flow reported on 8/31/2011 was reported as 3.51 CFS. A flow of 1.55 was used. 1.55 CFS was recalculated by DEQ Monitoring and Assessment staff and is a more accurate representation of flow on that date.

APPENDIX L – SURFACE WATER AND SEDIMENT METALS DATA, ROCK CREEK TMDL PLANNING AREA

This appendix contains two data tables. **Table L-1** contains surface water flow and water column metals concentration data for stream sampling locations in the Rock Creek TPA. **Table L-2** contains stream channel sediment metals concentration data and the corresponding ratio of each measured concentration to the recommended PEL concentration.

Table L-1. Surface Water Metals Concentration Data for the Rock Creek TMDL Planning Area

Waterbody Segment	Site Description	Station ID	Sample Date	Hardness (mg/L)	Flow (cfs)	Field pH (su)	AL (Dis) (µg/L)	As (TR) (µg/L)	Cd (TR) (µg/l)	Cu (TR) (µg/l)	Fe (TR) (mg/L)	Hg (TR) (µg/L)	Pb (TR) (µg/l)	Ag (TR) (µg/l)	Zn (TR) (µg/l)
Basin Gulch	Lowest road Xing	C02BASNG10	06/03/10	196	0.1	--	< 30	14	<0.08	<1	<50	--	<0.5	<0.5	<10
Basin Gulch	Lowest road Xing	C02BASNG10	07/29/10	219	0.1	8.4	< 30	14	<0.08	<1	<50	<0.005	<0.5	<0.5	<10
Basin Gulch	Lowest road Xing	C02BASNG10	08/25/10	228	0.1	8.3	< 30	15	<0.08	<1	<50	<0.005	<0.5	<0.5	<10
Basin Gulch	Lowest road Xing	C02BASNG10	10/05/10	225	0.1	8.0	< 30	14	<0.08	<1	<50	<0.005	<0.5	<0.5	<10
Basin Gulch	Lowest road Xing	C02BASNG10	06/15/11	175	1.0	8.0	< 30	15	<0.08	<1	<50	--	<0.5	<0.5	<10
Basin Gulch	Lowest road Xing	C02BASNG10	06/30/11	166	0.1	8.3	< 30	15	<0.08	<1	<50	--	<0.5	<0.5	<10
Eureka Gulch	200 yds. D/S** of Basin Gulch mouth	C02EURKG10	07/29/04	156	0.3	6.6	<100	16	<0.1	<1	<10	--	<0.5	<3	<10
Flat Gulch	Near headwaters	C02FLATG01	08/07/09	48.3	--	--	--	--	--	--	--	--	--	--	--
Flat Gulch	Near headwaters	C02FLATG01	09/11/09	45.5	--	--	120	2	<0.08	1	290	--	<0.5	<0.5	<1
Flat Gulch	Near headwaters	C02FLATG01	07/06/10	46.1	0.03	--	60	3	<0.08	<1	--	--	<0.5	<0.5	<5
Flat Gulch	Near headwaters	C02FLATG01	08/04/10	47.8	0.174	8.3	50	2	<0.08	1	--	--	<0.5	<0.5	<5
Flat Gulch	Near headwaters	C02FLATG01	09/09/10	--	0.25	8.2	--	--	--	--	--	--	--	--	--
Flat Gulch	Near headwaters	C02FLATG02	08/06/09	67.6	0.03	--	--	--	--	--	--	--	--	--	--
Flat Gulch	Near mouth	C02FLATG02	09/10/09	64.7	0.174		120	4	<0.08	3	1,140	--	1	<0.5	5
Flat Gulch	Near mouth	C02FLATG02	07/06/10	66.5	0.25		70	3	<0.08	<1	--	--	<0.5	<0.5	<5
Flat Gulch	Near mouth	C02FLATG02	08/13/11	62.2	0.03	8	50	4	<0.08	1	380	--	<0.5	<0.5	<5
Flat Gulch	0.2 mi. U/S*** of C02FLATG01	C02FLATG04	08/15/11	46.2	0.03	7.8	100	3	<0.08	<1	380	--	<0.5	<0.3	<5
Flat Gulch	0.2 mi. U/S of C02FLATG01	C02FLATG04	06/20/2012	48	0.07	7	50	<3	<0.08	<1	170	--	<0.5	<0.5	<5
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	08/07/09	63.1	--	--	--	--	--	--	--	--	--	--	--
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	09/12/09	58.7	--	--	130	4	<0.08	3	1,370	--	1	<0.5	5
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	07/06/10	69	0.01		60	5	<0.08	1	--	--	<0.5	<0.5	<5
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	08/04/10	75.7	0.25	8.3	70	4	<0.08	1	--	--	<0.5	<0.5	<5
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	09/09/10	--	0.36	8.2	--	--	--	--	--	--	--	--	--
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	08/13/11	55	0.02	7.6	60	4	<0.08		440	--	--	<0.3	<5
Flat Gulch	2 mi. U/S of mouth	C02FLATG10	07/30/04	62	0.3	7.4	<100	<3	<0.1	2	450	--	<0.5	<0.3	<10
Miners Gulch	near headwaters	C02MNRSG01*	07/08/10	15.6	--	--	50	1	< 0.08	< 1	60	--	< 0.5	<0.5	<5
Miners Gulch	near headwaters	C02MNRSG01*	08/06/10	18	--	--	40	< 1	< 0.08	< 1	40	--	< 0.5	<0.5	<5
Miners Gulch	near headwaters	C02MNRSG01*	09/11/10	18.3	--	--	50	< 1	< 0.08	< 1	80	--	< 0.5	<0.5	<5
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	06/04/10	34	0.37	--	50	<3	--	1	120	--	<0.5	<0.5	<10
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	07/29/10	52	0.07	8.1	<30	4	<0.08	<1	110	< 0.005	<0.5	<0.5	<10
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	08/25/10	63	0.03	8	<30	3	<0.08	<1	100	< 0.005	<0.5	<0.5	<10
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	10/05/10	68	0.06	7.8	<30	4	<0.08	<1	170	< 0.005	<0.5	<0.5	<10
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	06/15/11	21	1.8	7.9	460	6	<0.08	1	480	--	<0.5	<0.5	<10
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	06/29/11	26	0.36	8.2	160	5	<0.08	1	290	--	<0.5	<0.5	<10
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	07/21/11	36	0.16	7.8	<30	5	<0.08	<1	140	0.0067	<0.5	<0.5	
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	08/09/11	--	--	7.54	--	--	--	--	--	--	--	--	--
Quartz Gulch	1.4 miles U/S of mouth	C02QRTZG01	09/14/11	57	0.03	8.7	<30	4	<0.08	<1	130	--	<0.5	<0.5	<10
Scotchman Gulch	headwaters	C02SCTMG01*	08/05/09	32.3	--	--	--	--	--	--	--	--	--	--	--
Scotchman Gulch	headwaters	C02SCTMG01*	09/15/09	32.3	--	--	30	1	<0.08	<1	150	--	<0.5	<0.5	<1
Scotchman Gulch	headwaters	C02SCTMG01*	07/07/10	25	0.53	--	130	1	<0.08	<1	--	--	<0.5	<0.5	<5
Scotchman Gulch	headwaters	C02SCTMG01*	08/05/10	--	0.19	7.9	--	--	--	--	--	--	--	--	--

Table L-1. Surface Water Metals Concentration Data for the Rock Creek TMDL Planning Area

Waterbody Segment	Site Description	Station ID	Sample Date	Hardness (mg/L)	Flow (cfs)	Field pH (su)	AL (Dis) (µg/L)	As (TR) (µg/L)	Cd (TR) (µg/l)	Cu (TR) (µg/l)	Fe (TR) (mg/L)	Hg (TR) (µg/L)	Pb (TR) (µg/l)	Ag (TR) (µg/l)	Zn (TR) (µg/l)
Scotchman Gulch	1 mi. D/S of Nat'l Forest Boundary	C02SCTMG02	08/05/09	36.4	--	--	--	--	--	--	--	--	--	--	--
Scotchman Gulch	1 mi. D/S of Nat'l Forest Boundary	C02SCTMG02	09/13/09	39.9	--	--	20	1	<0.08	<1	480	--	<0.5	<0.5	1
Scotchman Gulch	1 mi. D/S of Nat'l Forest Boundary	C02SCTMG02	07/07/10	29.8	0.68	--	100	1	<0.08	<1	--	--	<0.5	<0.5	<5
Scotchman Gulch	1 mi. D/S of Nat'l Forest Boundary	C02SCTMG02	08/05/10	--	0.26	8	--	--	--	--	--	--	--	--	--
Scotchman Gulch	1 mi. D/S of Nat'l Forest Boundary	C02SCTMG02	09/10/10	--	1.02	8.3	--	--	--	--	--	--	--	--	--
Scotchman Gulch	1 mi. D/S of Nat'l Forest Boundary	C02SCTMG02	08/15/11	35.1	0.16	8.1	30	1	<0.08	<1	570	--	<0.5	<0.3	<5
Scotchman Gulch	0.4 mi. U/S of mouth	C02SCTMG03	08/06/09	48.7	0.64	8.7	--	--	--	--	--	--	--	--	--
Scotchman Gulch	0.4 mi. U/S of mouth	C02SCTMG03	09/12/09	48.4	0.21	7.8	10	2	<0.08	<1	190	--	<0.5	<0.5	1
Scotchman Gulch	0.4 mi. U/S of mouth	C02SCTMG03	07/06/10	35.6	0		120	2	<0.08	1		--	<0.5	<0.5	6
Scotchman Gulch	0.4 mi. U/S of mouth	C02SCTMG03	08/05/10	--	0.24	8.3	--	--	--	--	--	--	--	--	--
Scotchman Gulch	0.4 mi. U/S of mouth	C02SCTMG03	09/09/10	--	0.67	8.2	--	--	--	--	--	--	--	--	--
Scotchman Gulch	0.4 mi. U/S of mouth	C02SCTMG03	08/14/11	42.8	0.17	8.2	20	1	<0.08	<1	350	--	<0.5	<0.3	<5
Scotchman Gulch	headwaters	C02SCTMG04[*]	06/20/12	25	--	--	140	<3	<0.08	<1	310	--	<0.5	<0.5	<10
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	08/01/04	45	0.2	5.2	<100	<3	<0.1	<1	240	--	<0.5	<0.3	<10
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	08/04/09	34.8	0.21	8.1	--	--	--	--	--	--	--	--	--
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	09/14/09	37.1	--	--	20	1	<0.08	<1	420	--	<0.5	<0.5	<1
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	07/07/10	27.5	0.65	--	160	1	<0.08	<1		--	<0.5	<0.5	<5
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	09/10/10	--	0.79	8.1	--	--	--	--	--	--	--	--	--
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	08/16/11	34.1	0.12	8	40	1	<0.08	<1	440	--	<0.5	<0.5	<5
Scotchman Gulch	50 yds U/S of Scotchmn Gul Rd.	C02SCTMG10	06/20/12	28	0.59	8.5	110	<3	<0.08	<1	470	--	<0.5	<0.5	<10
Scotchman Gulch	½ mi. U/S of mouth	C02SCTMG20	08/02/04	60	0.3	5.9	<100	<3	<0.1	<1	170	--	<0.5	<0.3	<10
Scotchman Gulch	½ mi. U/S of mouth	C02SCTMG20	06/20/12	35	0.11	7.6	70	<3	<0.08	<1	550	--	<0.5	<0.3	<10
Sluice Gulch	near mouth	C02SLUCG01	06/03/10	146			<30	12	<0.08	1	200	--	<0.5	<0.5	<10
Sluice Gulch	near mouth	C02SLUCG01	09/23/10	147	1.11		<30	11	<0.08	<1	70	--	<0.5	<0.5	<10
Sluice Gulch	near mouth	C02SLUCG01	07/14/10	--	1.12		--	--	--	--	--	--	--	--	--
Sluice Gulch	near mouth	C02SLUCG01	08/23/10	--	1.18	8.8	--	--	--	--	--	--	--	--	--
Sluice Gulch	near mouth	C02SLUCG01	09/23/10	--	0.9	8.7	--	--	--	--	--	--	--	--	--
Sluice Gulch	near mouth	C02SLUCG01	08/02/11	--	1.23	9.2	--	--	--	--	--	--	--	--	--
Sluice Gulch	near mouth	C02SLUCG01	09/01/11	--	1.42	--	--	--	--	--	--	--	--	--	--
Sluice Gulch	¼ mi. U/S of Silver King	C02SLUCG02	06/03/10	144	1.27	--	<30	12	<0.08	<1	90	--	<0.5	<0.5	<10
Sluice Gulch	¼ mi. U/S of Silver King	C02SLUCG02	07/14/10	--	1.26	--	--	--	--	--	--	--	--	--	--
Sluice Gulch	¼ mi. U/S of Silver King	C02SLUCG02	08/24/10	--	1.33	8.8	--	--	--	--	--	--	--	--	--
Sluice Gulch	¼ mile U/S of Silver King	C02SLUCG02	09/23/10	148	1.42	8.9	<30	11	<0.08	<1	60	--	<0.5	<0.5	<10
Sluice Gulch	¼ mi. U/S of Silver King	C02SLUCG02	08/02/11	--	1.06	8.9	--	--	--	--	--	--	--	--	--
Sluice Gulch	¼ mi. U/S of Silver King	C02SLUCG02	09/01/11	--	1.31		--	--	--	--	--	--	--	--	--
Sluice Gulch	1.7 mi. U/S of mouth	C02SLUCG03	06/03/10	141	--	--	<30	11	<0.08	<1	<50	--	<0.5	<0.5	<10
Sluice Gulch	1.7 mi. U/S of mouth	C02SLUCG03	09/23/10	150	--	--	<30	11	<0.08	<1	<50	--	<0.5	<0.5	<10
Sluice Gulch	3.4 mi. U/S of mouth	C02SLUCG04	06/03/10	34	--	--	100	11	<0.08	4	200	--	<0.5	<0.5	<10
Sluice Gulch	¼ mile U/S of mouth	C02SLUCG10	07/28/04	139	--	--	<100	11	<0.1	<1	30	--	<0.5	<0.3	<10
West Fork Rock Creek	½ mi. D/S of Bowles Cr.	C02ROCWF01	08/25/09	11	--	7.2	--	--	--	--	--	--	--	--	--
West Fork Rock Creek	½ mi. D/S of Bowles Cr.	C02ROCWF01	09/22/09	12	--	7.8	<30	<3	<0.08	<1	60	<0.005	<0.5	<0.5	<10
West Fork Rock Creek	½ mi. D/S of Bowles Cr.	C02ROCWF01	06/11/10	7	117.75		70	<3	<0.08	<1	100	--	<0.5	<0.5	<10
West Fork Rock Creek	½ mi. D/S of Bowles Cr.	C02ROCWF01	10/04/10	12	6.22	8	<30	<3	<0.08	<1	60	--	<0.5	<0.5	<10
West Fork Rock Creek	0.4 mi. D/S Sand Basin Cr.	C02ROCWF02	08/25/09	10	--	7.8	--	--	--	--	--	--	--	--	--
West Fork Rock Creek	0.4 mi. D/S Sand Basin Cr.	C02ROCWF02	09/22/09	10	--	7.7	<30	<3	<0.08	<1	70	<0.005	<0.5	<0.5	<10
West Fork Rock Creek	0.4 mi. D/S Sand Basin Cr.	C02ROCWF02	06/11/10	6	491.4	--	80	<3	<0.08	<1	100	--	<0.5	<0.5	<10
West Fork Rock Creek	0.4 mi. D/S Sand Basin Cr.	C02ROCWF02	10/04/10	11	7.04	8.2	<30	<3	<0.08	<1	70	--	<0.5	<0.5	<10

Table L-1. Surface Water Metals Concentration Data for the Rock Creek TMDL Planning Area

Waterbody Segment	Site Description	Station ID	Sample Date	Hardness (mg/L)	Flow (cfs)	Field pH (su)	AL (Dis) (µg/L)	As (TR) (µg/L)	Cd (TR) (µg/l)	Cu (TR) (µg/l)	Fe (TR) (mg/L)	Hg (TR) (µg/L)	Pb (TR) (µg/l)	Ag (TR) (µg/l)	Zn (TR) (µg/l)
West Fork Rock Creek	4 mi. U/S of mouth	C02ROCWF03	08/25/09	8	--	6.9	--	--	--	--	--	--	--	--	--
West Fork Rock Creek	4 mi. U/S of mouth	C02ROCWF03	09/21/09	8	--	7.6	<30	<3	<0.08	<1	40	--	<0.5	<0.5	<10
West Fork Rock Creek	4 mi. U/S of mouth	C02ROCWF03	06/11/10	6	543.99	--	90	<3	<0.08	<1	100	--	<0.5	<0.5	<10
West Fork Rock Creek	4 mi. U/S of mouth	C02ROCWF03	10/04/10	8	18.58	8.2	<30	<3	<0.08	<1	<50	--	<0.5	<0.5	<10
West Fork Rock Creek	0.8 mi. U/S of mouth	C02ROCWF04	08/24/09	11	--	7.2	--	--	--	--	--	--	--	--	--
West Fork Rock Creek	0.8 mi. U/S of mouth	C02ROCWF04	09/21/09	11	--	7.2	<30	<3	<0.08	<1	120	--	<0.5	<0.5	<10
West Fork Rock Creek	at mouth	C02ROCWF05	06/11/10	7	940.34		90	<3	<0.08	<1	130	--	<0.5	<0.5	<10
West Fork Rock Creek	at mouth	C02ROCWF05	10/04/10	17	32.6	8.6	<30	<3	<0.08	<1	110	--	<0.5	<0.5	<10
West Fork Rock Creek	2 mi. U/S of Coal Gulch	C02ROCWF06	06/11/10	5	961.54		80	<3	<0.08	<1	90	--	<0.5	<0.5	<10
West Fork Rock Creek	2 mi. U/S of Coal Gulch	C02ROCWF06	10/04/10	7	21.37	8.1	<30	<3	<0.08	<1	<50	--	<0.5	<0.5	<10
West Fork Rock Creek	Off Jeep Trail	C02ROCWF07	06/11/10	6	42.02		90	<3	<0.08	<1	140	<0.005	<0.5	<0.5	<10

Table L-2. Metal concentrations in sediment and corresponding ratios of measured concentration to metal PEL concentrations recommended for fresh water sediment.

SEGMENT NAME	SITE ID	Sample Date	Site Description	As Conc. (ug/kg)	As Conc/ PEL Ratio	Cd Conc. (ug/kg)	Cd Conc/ PEL Ratio	Cu Conc. (ug/kg)	Cu Conc/ PEL Ratio	Pb Conc. (ug/kg)	Pb Conc/ PEL Ratio	Hg Conc. (ug/kg)	Hg Conc/ PEL Ratio	Zn Conc. (ug/kg)	Zn Conc/ PEL Ratio
Flat Gulch	C02FLATG01	09/11/09	headwaters	4.85	0.3	<0.25	<0.01	14.3	0.07	6.42	0.07	0.08	0.16	27.8	0.09
Flat Gulch	C02FLATG02	09/10/09	near mouth	3.82	0.2	<0.25	<0.01	20.5	0.10	7.56	0.08	0.08	0.16	41.2	0.13
Flat Gulch	C02FLATG10	09/12/09	2 mi. U/S of mouth	4.07	0.2	<0.25	<0.01	18	0.09	7.21	0.08	0.07	0.14	36.9	0.12
Quartz Gulch	C02QRTZG01	09/14/11	1.4 mi. U/S of mouth	1050	62	1.1	0.31	38	0.19	31	0.34	1	2.06	871	2.77
Scotchman Gulch	C02SCTMG01	9/15/09	headwaters	3.53	0.2	< 0.25	<0.1	9.36	0.05	6.43	0.07			22.8	0.07
Scotchman Gulch	C02SCTMG01	7/7/10	headwaters	6.43	0.4	< 0.2	<0.1	8.98	0.05	5.94	0.07	0.09	0.19	26.7	0.08
Scotchman Gulch	C02SCTMG10	9/14/09	50 yds U/S of Scotchmn Gul Rd.	16.5	1.0	< 0.25	<0.1	10.6	0.05	7.22	0.08			48.6	0.15
Scotchman Gulch	C02SCTMG10	7/7/10	50 yds. U/S of Scotchman Gulch Rd.	10.4	0.6	<0.2	<0.1	10.1	0.05	6.65	0.07	0.12	0.25	38.1	0.12
Scotchman Gulch	C02SCTMG02	9/13/09	1 mi. D/S of Nat'l Forest Boundary	5.2	0.3	<0.25	<0.1	13.8	0.07	7.72	0.08	0.09	0.19	36.9	0.12
Scotchman Gulch	C02SCTMG02	7/7/10	1 mi. D/S of Nat'l Forest Boundary	6.18	0.4	<0.2	<0.1	12.9	0.07	7.36	0.08	0.08	0.16	35.3	0.11
Scotchman Gulch	C02SCTMG03	9/12/09	0.4 mi. U/S of mouth	4.32	0.3	<0.25	<0.1	10.4	0.05	6.96	0.08	0.06	0.12	37.8	0.12
Scotchman Gulch	C02SCTMG03	7/6/10	0.4 mi. U/S of mouth	4.41	0.3	<0.2	<0.1	12.8	0.06	7.3	0.08	0.05	0.10	43.8	0.14
Sluice Gulch	C02SLUCG01	09/23/10	near mouth	18	1.1	0.3	0.1	26	0.1	17	0.2	<0.05	<0.10	66	0.2
Sluice Gulch	C02SLUCG10	07/28/04	¼ mile U/S of mouth	10	0.6	<0.5	<0.1	10.3	0.1	6.9	0.1	<1	<0.002	26	0.1
Sluice Gulch	C02SLUCG02	09/23/10	¼ mi. U/S of Silver King	22	1.3	0.2	0.1	20	0.1	14	0.2	<0.05	<0.10	61	0.2
Sluice Gulch	C02SLUCG03	09/23/10	1.7 mi. U/S of mouth	30	1.8	0.2	0.1	20	0.1	14	0.2	<0.05	<0.10	63	0.2
West Fork Rock Creek	C02ROCWF01*	08/25/09	½ mi. D/S of Bowles Cr.	2	0.12	<0.2	<0.3	<20	<0.1	9	0.1	0.071	0.14	23	0.07
West Fork Rock Creek	C02ROCWF01*	09/22/09	½ mi. D/S of Bowles Cr.	<8	<0.5	<0.2	<0.3	<20	<0.1	<5	<0.05	<0.05	<0.1	<20	<0.06
West Fork Rock Creek	C02ROCWF02	08/25/09	0.4 mi. D/S Sand Basin Cr.	5	0.29	0.2	0.06	<20	<0.1	11	0.12	0.13	0.27	32	0.10
West Fork Rock Creek	C02ROCWF02	09/22/09	0.4 mi. D/S Sand Basin Cr.	<8	<0.5	<0.2	<0.3	<20	<0.1	<5	<0.05	<0.05	<0.1	24	0.08
West Fork Rock Creek	C02ROCWF03	08/25/09	4 mi. U/S of mouth	7	0.41	0.2	0.06	<20	<0.1	11	0.12	0.091	0.19	33	0.10
West Fork Rock Creek	C02ROCWF03	09/21/09	4 mi. U/S of mouth	<8	<0.5	<0.2	<0.3	<20	<0.1	<5	<0.05	<0.05	<0.1	<20	<0.06
West Fork Rock Creek	C02ROCWF04	08/24/09	0.8 mi. U/S of mouth	4	0.24	<0.2	<0.3	<20	<0.1	9	0.1	0.085	0.17	25	0.08
West Fork Rock Creek	C02ROCWF04	09/21/09	0.8 mi. U/S of mouth	<8	<0.5	<0.2	<0.3	<20	<0.1	<5	<0.05	<0.05	<0.1	<20	<0.06

*Natural background site; **D/S = Downstream; *** U/S = Upstream;

APPENDIX M – SOURCE ASSESSMENT AND TARGET DEPARTURE ANALYSIS

TABLE OF CONTENTS

List of Tables

List of Figures

M1.0 INTRODUCTION

This appendix summarizes the sources assessment and target departures for the metals impaired streams of the Rock Creek TMDL planning area (TPA). The target departure is the difference between water quality and stream sediment data from impaired streams and water quality and steam sediment targets for metals (**Section 8.4** of main document). The water quality targets are the numeric criteria for chronic aquatic life (CAL), acute aquatic life (AAL) and human health (HH), contained in DEQ-7 (Montana Department of Environmental Quality, 2010) for metal parameters. The numeric probable effects levels (PELs) for metals in fresh water stream sediment are supplemental indicators of metals impairment (**Table 8-4 of the TMDL Document**). Loading sources are described for each stream segment and watershed maps are included to show the stream extent, the locations of monitoring sites, and locations of potential metals sources.

The differences between numeric targets and metal concentrations measured in stream samples are interpreted to determine whether water uses are impaired. The target departures and impairment determinations are summarized in a table for each stream segment. Regardless of the metal impairment causes in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012), the departure analysis is based on data for a core list of nine metals parameters that include aluminum, arsenic, cadmium, copper, iron, lead, mercury, silver, and zinc. The departure analysis for hardness-dependent metals includes only results with corresponding hardness values. The number and timing of available water quality analyses vary by stream. The raw data used in the departure analysis is contained in **Appendix L**.

Placer mining has affected many streams in the planning area. However, a number of sites on selected stream segments are sufficiently remote enough from mining disturbances to represent the natural background metals loading condition. Water quality from these sites is assumed to have minimal influence from mining and other human-caused sources. The analytical results from these “background” sites are used to quantify background loading and estimate the magnitude of human-caused sources.

M2.0 SOURCE ASSESSMENT AND TARGET DEPARTURES BY STREAM

Assessment of existing metals sources is needed to develop load allocations to specific source categories. DEQ’s monitoring and assessment record (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) is the principal basis for stream impairment listings. Most of the metals impairments are based on water column chemistry data collected by DEQ or its contractors during 2004 and from 2009 through 2012. Sediment chemistry data, collected by DEQ monitoring and assessment field crews from 2009 through 2012, is available from samples collected under both high- and low-flow conditions from streams or their tributaries with metals impairment causes. DEQ assessment data was supplemented by STORET and NWIS data collected between 2001 and 2011.

The below sections describe the most significant natural and human-caused sources in more detail, provide nutrient loading estimates for natural and human-caused source categories to nutrient-impaired stream segments, and establish TMDLs and load allocations to specific source categories for the following streams.

Departures from target values are summarized below for 7 streams in the Rock Creek TPA. Each of the following sections describes the metals loading sources, the current condition data set, and the metals target departures for a single stream segment. The need for TMDLs is based on the outcomes for several data-related and source-related decision factors. These factors, explained in **Section 8.4.3** of the main documen**t**, are column headings in each of the target departure tables presented below. TMDL conclusions for each metal parameter are drawn from the entries in the tables for each factor. An entry of "NA" indicates a factor for a specific metal does not apply. For example, since there is no human health criterion for aluminum, an "NA" is entered in the corresponding cell in each table.

The order of stream discussions is northward from the West Fork of Rock Creek, to Eureka Creek and its Basin Gulch and Quartz Gulch tributaries, followed by Sluice Creek and Flat, Scotchmen, and Miners Gulches. The relationship between sources and target departures is clearer when the sections of this appendix are reviewed with the corresponding, segment-specific discussions in **Section 8.4** of the main document.

M2.1 West Fork Rock Creek (MT76E002_030)

The West Fork of Rock Creek is listed as impaired by mercury in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012). The stream extends for 25.2 miles from its headwaters in the Sapphire Mountains to its confluence with Rock Creek. **Figure M-1** shows the West Fork Rock Creek watershed, recent surface water sample sites, and locations of mine-related sources of metals loading.

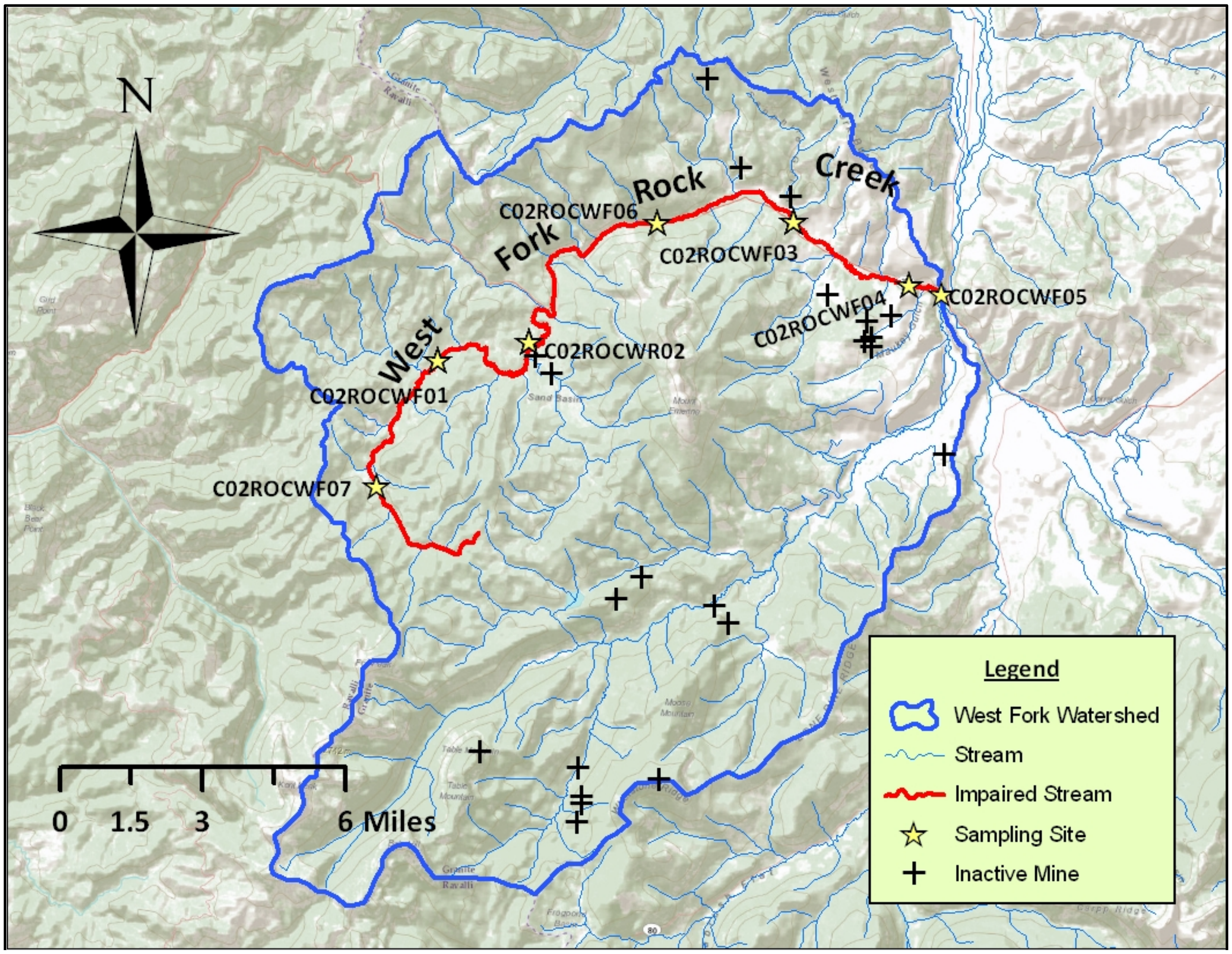

Figure M-1. West Fork Rock Creek watershed, monitoring sites, and mining sources

The West Fork is a fourth order Rock Creek tributary that drains about 178 square miles in the southern Sapphire Mountain Range. The geology of the drainage consists of a thick sequence of Precambrian sedimentary rocks that were thrust-faulted eastward and later intruded by a large granitic mass in the upper watershed and smaller volcanic outcrops to the north and east.

M2.1.1 West Fork Rock Creek Sources

The MBMG database lists 21 inactive and abandoned mines in the West Fork watershed. Most of these are past placer gold mines in stream sediments. Placer mining for gold that began in the 1860s led to the discovery of placer deposits of sapphires along the lower West Fork and a number of gulches draining the northeastern portion of the watershed. Placer mining for sapphires peaked during the early 1900s and continues as a tourist attraction along the lower West Fork.

A number of placer quarries in the Anaconda and Sapphire gulch drainages supply screened gravel for a tourism-based gem washing operation located off of Skalkaho Road on Sapphire Gulch Lane near the confluence of Sapphire Gulch and West Fork Rock Creek. The operation is open 7 days per week from June through October. A quarry area on Anaconda Gulch, owned by C^3 LLC, holds an exploration license (#628) and a small miners exclusion (#119). An operating permit for a placer operation for gemstones recovery on the West Fork Rock Creek floodplain near the confluence of Anaconda Gulch is held by

Skalkaho Grazing, Inc. The permit (#44) is currently suspended by the DEQ, Environmental Management Bureau due to a reclamation bonding shortfall.

A couple of small lode deposits for gold recovery are located in the Maukey Gulch tributary of the lower West Fork. Current conditions at these properties consist of small, mine-related hillslope disturbances, associated access roads, and areas of timber harvest in the gulch headwaters. Two inactive mines in the Sand Basin area of the West Fork are described as titanium and columbium rare earth prospects. No related surface disturbances are apparent in the area.

The West Fork Rock Creek water quality dataset includes between 18 records from each of 7 monitoring sites (**Figure M-1**). All sites were established by DEQ monitoring and assessment efforts. Water samples were collected during high- and low-flow periods during 2009 and 2010. The sediment metals analysis record consists of 8 samples; there are two samples each for sites C02ROCWF01, C02ROCWF02, C02ROCWF03, and C02ROCWF04.

M2.1.2 West Fork Rock Creek Target Departures

Surface water column chemistry results are compared with Circular DEQ 7 numeric criteria for human health (HH), acute aquatic life (AAL), and chronic aquatic life (CAL). The water quality and sediment chemistry data are assessed against TMDL decision factors for metals. **Table M-1** summarizes the results of the target departure analysis in terms of critical TMDL decision factors. The far right column in the table contains TMDL development conclusions.

Table M-1. West Fork Rock Creek TMDL Decision Factors and TMDL Conclusion

Pollutant Parameter	Sample Size	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Sediment PEL Exceeded	Human-Caused Sources Present	2012 Listing Status	TMDL Decision
Aluminum	15	Y	N	NA	NA	Y	Unlisted	TMDL
Arsenic	15	N	N	N	N	Y	Unlisted	No TMDL
Cadmium	15	N	N	N	N	Y	Unlisted	No TMDL
Copper	15	N	N	N	N	Y	Unlisted	No TMDL
Iron	15	N	NA	NA	NA	Y	Unlisted	No TMDL
Lead	15	N	N	N	N	Y	Unlisted	No TMDL
Mercury	3	N	N	N	N	Y	Listed	No TMDL
Silver	15	NA	N	N	NA	Y	Unlisted	No TMDL
Zinc	15	N	N	N	N	Y	Unlisted	No TMDL

There are no human health criteria or aquatic life criteria exceedances for any of the 9 metal parameters among the recent surface water samples collected the West Fork Rock Creek. There was three water column target exceedance for aluminum. Aluminum was reported as 90 ug/L at three locations which is slightly above the CAL of 87 ug/L. Three exceedances in a sample set of 15 samples yields a chronic exceedance rate of %20, which is above the %10 exceedance requiring TMDL development.

Table M-2 summarizes the sediment chemistry data as the ratios of the metal concentrations measured in 8 sediment samples, to the PEL concentration recommended of metals parameters in fresh water stream sediment. For example, the value of 0.12 for arsenic at site C02ROCWF01 in the first row of the table is obtained by dividing the measured arsenic value of 2 micrograms per gram, (µg/g) by the arsenic PEL of 17 µg/g (2 µg/g/ 17 µg/g = 0.12). If the measured value is equal to the PEL, the ratio of the two values equals 1. Where values in the sediment chemistry tables are less than or equal to 1, the measured metal concentration is less than the corresponding PEL. Where the table values are greater than one, the metal concentration in the sample exceeds the PEL. The monitoring site identification numbers, site locations, and sediment metals ratios are arranged in upstream to downstream order in the table. Sediment chemistry data are given by stream segment in **Appendix L**.

Table M-2. Ratios of measured sediment metals concentrations to PELs for sediment samples from four West Fork Rock Creek sampling sites.

SITE ID	Site Location	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
C02ROCWF01	0.5 mile below Bowles Creek	0.12	< 0.3	< 0.1	0.10	<0.5	0.07
C02ROCWF01		< 0.50	< 0.3	< 0.1	< 0.05	< 0.1	< 0.06
C02ROCWF02	0.4 mile below Sand Basin Creek	0.29	0.06	< 0.1	0.12	0.27	0.10
C02ROCWF02		< 0.50	< 0.3	< 0.1	< 0.05	< 0.1	0.08
C02ROCWF03	0.1 mile below Sapphire Gulch	0.41	0.06	< 0.1	0.12	0.19	0.10
C02ROCWF03		< 0.50	< 0.3	< 0.1	< 0.05	< 0.1	< 0.06
C02ROCWF04	0.4 mile upstream of Maukey Gulch	0.24	< 0.3	< 0.1	0.10	0.17	0.08
C02ROCWF04		< 0.50	< 0.3	< 0.1	< 0.05	< 0.1	< 0.06

Since all ratios in the table are less than 1, all sediment metals concentrations at all 4 sampling sites are less than the PELs. Sediment metals concentrations do not indicate the presence of elevated metals in West Fork Rock Creek stream sediment.

M2.1.3 West Fork Rock Creek TMDL Summary

The listing status and TMDL conclusions for metals in the West Fork Rock Creek are summarized in **Table M-3.**

Table M-3. Metals listing status and TMDL conclusions for West Fork Rock Creek

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	New Listing	Y
Arsenic	Not a Cause	N
Cadmium	Not a Cause	N
Copper	Not a Cause	N
Iron	Not a Cause	N
Lead	Not a Cause	N
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Remove Current Listing	N
Number of Metals TMDLs Required		1

M2.2 Basin Gulch (MT76E002_080)

Basin Gulch, and an adjacent drainage, Quartz Gulch, are first order headwater tributaries of Eureka Gulch. Each of the three stream segments is a separate water quality assessment unit described in this and subsequent sections. Basin Gulch extends from its headwaters for about 1.5 miles to its confluence with Quartz Gulch. The Basin Gulch watershed area is approximately 500 acres; Quartz Gulch is about 1,600 acres. Eureka Gulch below the Quartz Gulch-Basin Gulch confluence drains about 200 acres, making the entire Eureka Gulch watershed area about 2,300-acres. **Figure M-2** shows the watershed areas, section boundaries, recent sample sites, and locations of mine-related sources in Basin, Quartz, and Eureka gulches.

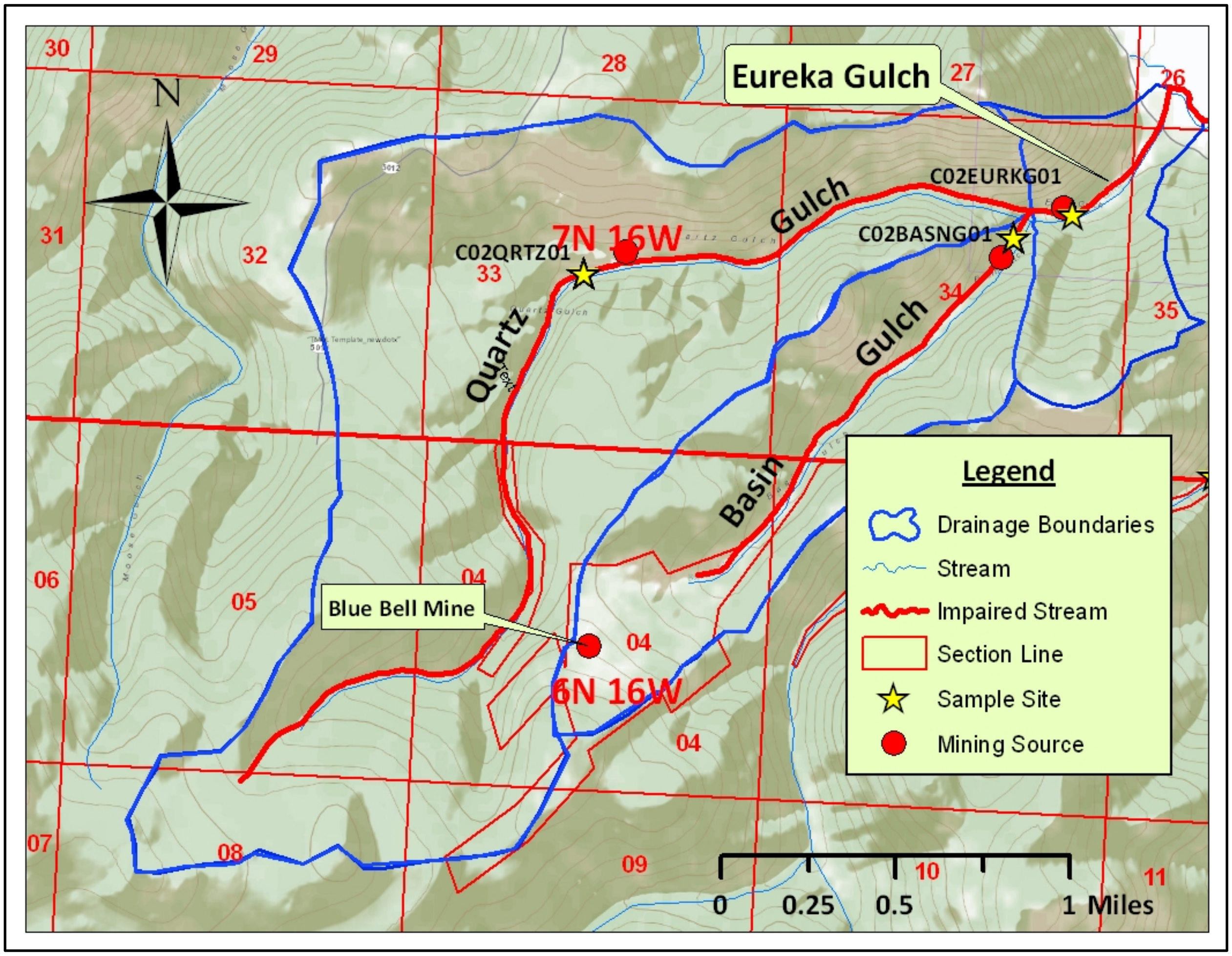

Figure M-2. Eureka Gulch, Quartz Gulch, and Basin Gulch watersheds, section boundaries, monitoring sites, and mining sources.

M2.2.1 Basin Gulch Sources

The MBMG database lists 4 inactive mines in the Eureka Gulch watershed. Two of these properties, the Blue Bell Mine and a downstream mill tailings site are in Basin Gulch. The Blue Bell Mine (**Figure M-2**) is a former underground silver mine consisting of two shallow hillside drifts. Marvin et al, (1995) describe an abandoned mine property referred to as the "Basin/Quartz Gulch Placer and Mill Tailings." Though not described in detail, the site contained a breached tailings impoundment, streamside tailings deposits, and other mining wastes. The Gold Hill Placer & Quartz Hill Placer is listed as an active placer mine operating for gold recovery in upper Basin Gulch under a small miner exclusion statement (SMES) provided by DEQ (#46-139).

A DEQ field assessment conducted on July 28, 2004, described most of the drainage bottom as consisting of a re-graded placer mine with sparse vegetation cover and no discernible stream channel. An existing road crossing serves as a check dam across the drainage bottom with an additional check dam farther downstream. Both impoundments are described in the assessment summary as potential sources of large sediment loads during high-flow events. The most recent entry in the SMES file is a past-due notice of the required annual report. A letter from the mine operator dated May 25, 2011, stated a desire not to renew the SMES.

M2.2.2 Basin Gulch Target Departures

Basin Gulch has no current metals impairment causes listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012). Current impairment is due to alteration in streamside or littoral vegetative covers. The recent water quality dataset for Basin Gulch includes 6 records containing metals and low level mercury analysis results for samples collected in 2010 and 2011. All samples were collected at site C02BASNG10 located 500 feet upstream of the Basin Gulch mouth. **Table M-4** summarizes the results of the target departure analysis in terms of TMDL decision factors. The far right column in **Table M-4** specifies a TMDL development conclusion based on the decision factors for each of nine metal parameters.

Table M-4. Basin Gulch TMDL Decision Factors and TMDL Conclusions

Pollutant Parameter	Sample Size	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Sediment PEL Exceeded	Human-Caused Sources Present	2012 303(d) Listing Status	TMDL Decision
Aluminum	6	N	N	NA	NA	Y	Unlisted	No TMDL
Arsenic	6	N	N	Y	NA	Y	Unlisted	As TMDL
Cadmium	6	N	N	N	NA	Y	Unlisted	No TMDL
Copper	6	N	N	N	NA	Y	Unlisted	No TMDL
Iron	6	N	NA	NA	NA	Y	Unlisted	No TMDL
Lead	6	N	N	N	NA	Y	Unlisted	No TMDL
Mercury	6	N	N	N	NA	Y	Unlisted	No TMDL
Silver	6	NA	N	N	NA	Y	Unlisted	No TMDL
Zinc	6	N	N	N	NA	Y	Unlisted	No TMDL

All 6 of the arsenic results exceeded the human health criterion of 10 µg/L, indicating the need for an arsenic TMDL. Although there are human-caused sources present, the 6 samples contained less than detectable amounts of the remaining 8 metal parameters. Sediment chemistry data are not available for Basin Gulch.

M2.2.3 Basin Gulch TMDL Summary

The listing status and TMDL conclusions for metals in Basin Gulch are summarized in Ta**ble M-5.** An arsenic TMDL is required in Basin Gulch.

Table M-5. Metals listing status and TMDL conclusions for Basin Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	Not a Cause	N
Arsenic	New Listing	Y
Cadmium	Not a Cause	N
Copper	Not a Cause	N
Iron	Not a Cause	N
Lead	Not a Cause	N
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Not a Cause	N
Number of metals TMDLs Required		1

M2.3 QUARTZ GULCH (MT76E002_070)

Quartz Gulch is a headwater tributary of Eureka Gulch (**Figure M-2**). Quartz Gulch extends for 3.4 miles from its headwaters in the Sapphire Mountains to its confluence with Basin Gulch. This confluence is the beginning of Eureka Gulch. Quartz Gulch is listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) as being impaired by elevated mercury, sediment, and alteration in streamside vegetative covers.

M2.3.1 Quartz Gulch Sources

The MBMG abandoned mines database lists the "American Eagle Co. Placer Claims" as the only inactive mine property in Quartz Gulch. No distinguishing features of the property can be identified from 2011 aerial imagery. The Gold Hill Placer & Quartz Hill Placer is listed as an active mine operating in Section 4, Township 7 North, Range 16 East under a SMES (#46-139). Section 4 occurs in the upper reaches of both Basin Gulch and Quartz Gulch and the placer operation for gold recovery could be active in both drainages.

A DEQ field assessment of the ephemeral stream dated July 29, 2004, describes a placer mined drainage bottom with no discernible channel in the upper reaches and a constructed channel farther downstream that has been relocated to the edge of the drainage bottom. The drainage is a potential sediment source during high flow flows until the channel is reestablished.

M2.3.2 Quartz Gulch Target Departures

Quartz Gulch is listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) as being impaired due to mercury, sediment, and alteration in streamside or littoral vegetative covers. The recent water quality dataset for Quartz Gulch includes 12 records containing metals and low level mercury analysis results for samples collected in 2010 and 2011. All samples were collected at site C02QRTZG01 located about 1.4 miles upstream of the mouth. **Table M-6** summarizes the results of the target departure analysis in terms of TMDL decision factors, with TMDL development conclusions in the far right column of the table.

Table M-6. Quartz Gulch TMDL Decision Factors and TMDL Conclusions

Pollutant Parameter	Sample Size	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Sediment PEL Exceeded	Human-Caused Sources Present	2012 303(d) Listing Status	TMDL Decision
Aluminum	8	Y	N	NA	NA	Y	Unlisted	Al TMDL
Arsenic	8	N	N	N	Y	Y	Unlisted	No TMDL
Cadmium	8	N	N	N	N	Y	Unlisted	No TMDL
Copper	8	N	N	N	N	Y	Unlisted	No TMDL
Iron	8	N	NA	NA	NA	Y	Unlisted	No TMDL
Lead	8	Y	N	N	N	Y	Unlisted	Pb TMDL
Mercury	8	N	N	N	Y	Y	Listed	No TMDL
Silver	8	NA	N	N	NA	Y	Unlisted	No TMDL
Zinc	8	N	N	N	Y	Y	Unlisted	No TMDL

Two samples in 8 (25%) exceed the CAL criterion of 87 µg/L for aluminum. One sample in 8 (12%) exceed the CAL criterion of 0.57 for lead, based on a hardness value of 26 mg/L. Other water column metals concentrations are either less than detectable concentrations, or at or below metals target values.

A single sediment sample is available from site C02QRTZG01. **Table M-7** summarizes the sediment chemistry data as the ratios of the metal concentrations measured in sediment samples, to the PEL concentration recommended of metals parameters in stream sediment.

Table M-7. Ratios of measured sediment metals concentrations to PELs for a sediment sample from Quartz Gulch.

SITE ID	Site Location	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
C02ROCWF01	1.4 miles U/S of mouth	61.80	0.31	0.19	0.34	2.06	2.80

The sediment sample contains an extremely high concentration of arsenic (1,050 µg/g) compared with the sediment arsenic PEL of 17 µg/g. Though not as extreme as the arsenic level, the mercury and zinc concentrations in the sediment also exceeded the PEL values. Despite the elevated sediment concentrations of arsenic, mercury, and zinc, the water column concentrations of these metals are less than the most restrictive target values.

M2.3.3 Quartz Gulch TMDL Summary

The listing status and TMDL conclusions for metals in Quartz Gulch are summarized in Ta**ble M-8.** TMDLs are required for aluminum and lead in Quartz Gulch.

Table M-8. Metals listing status and TMDL conclusions for Quartz Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	New Listing	Y
Arsenic	Not a Cause	N
Cadmium	Not a Cause	N
Copper	Not a Cause	N
Iron	Not a Cause	N
Lead	Not a Cause	Y
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Listed	N
Number of metals TMDLs Required		2

The data record for mercury should be reevaluated to determine whether this metal persists as an actual impairment cause in Quartz Creek.

M2.4 EUREKA GULCH (MT76E002_090)

Eureka Gulch is a second order tributary of Rock Creek. The stream extends for 1.9 miles from the confluence of Basin and Quartz gulches to Rock Creek (**Figure M-2**). Eureka Gulch is listed as impaired in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) because of drinking water impairments caused by elevated arsenic and mercury. Non-metal impairments of Eureka Gulch in 2012 include sediment and alteration of streamside vegetative covers.

The Eureka Gulch data set consists of a single sample collected at site C02EURKG01 during July of 2004. Water quality monitoring since 2004 has recorded no flow in Eureka Gulch. The streambed and floodplain are altered by placer mining that has partially diverted surface flow into excavated pits.

M2.4.1 Eureka Gulch Sources

The MBMG abandoned mines database lists the "Basin and Quartz Creek Placers" as the single inactive mine in Eureka Gulch. Potentate Mining, LLC, started work under Exploration License #00739 to test for placer gold in Eureka gulch. They are currently placer mining under SMES #46-144. The operation is approved to disturbed 2.6 acres. Potentate holds an amount of unobligated bond for potential expansion of the disturbance. The Braach Placer is operating in lower Eureka Gulch (S35 T7N R16W) for gold, sapphires, and garnets under a SMES (#46-139) from DEQ. An exploration license (#00709) for the same commodities at the same location was issued by DEQ on 11/30/2009 and has not been renewed. The entire bottom of Eureka Gulch is described in a July 29, 2004, inspection by DEQ as a regraded and poorly vegetated placer mine disturbance with two excavated mine pits connected by a constructed channel. Standing water is retained in the pits and no flow was observed in the connecting channel.

M2.4.2 Eureka Gulch Target Departures

Eureka Gulch is listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) as being impaired by elevated arsenic, mercury, sediment, and alteration in streamside or littoral vegetative covers. The recent water quality dataset for Eureka Gulch consists of a single record for a sample collected at site C02EURKG10 (on July 29th, 2004. Site C02QRTZG01 is located about 200 meters downstream of the mouth of Basin Gulch **(Figure M-2**).**Table M-9** contains the hardness, pH and metal analysis results for the Eureka Gulch sample.

Table M-9. Hardness (mg/L), pH, dissolved aluminum, and total recoverable metal analysis results (µg/L) for the July, 2004, Eureka Gulch sample.

Station ID	Hardness	pH	Aluminum (Diss)	Arsenic	Cadmium	Copper	Lead	Iron	Zinc
C02EURKG10	156	6.57	<100	16	<0.1	1.0	<0.5	<10	<10

Since the method detection limit for aluminum (100 µg/L) is higher than the 87 µg/L chronic criterion, the aluminum result cannot be used to assess aquatic life support. The arsenic result exceeds the human health criterion of 10 µg/L. All other metal concentrations in the sample are less than targets. Sediment chemistry data are not available for Eureka Gulch.

The listing of mercury as an impairment causes stems from samples collected on May 20th, 1997, that contained 200 and 400 µg/L at separate sample locations. Mercury analysis was not performed on a sample collected during the 2004 inspection.

M2.4.3 Eureka Gulch TMDL Summary

The human health criterion exceedance for arsenic requires development of an arsenic TMDL. Since more recent data for mercury are not available, a mercury TMDL will be developed to addressed the current mercury impairment listing. The listing status and TMDL conclusions for metals in Eureka Gulch are summarized in **Table M-10.**

Table M-10. Metals listing status and TMDL conclusions for Eureka Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	Not a Cause	N
Arsenic	Listed	Y
Cadmium	Not a Cause	N
Copper	Not a Cause	N
Iron	Not a Cause	N
Lead	Not a Cause	N
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Listed	Y
Number of metals TMDLs Required		2

M2.5 Sluice Gulch (MT76E002_110)

Sluice Gulch is a second order tributary of Rock Creek. The stream extends for 6.3 miles from its headwaters in the John Long Mountains to its mouth. The drainage area is just under 7 square miles. Sluice Gulch is listed as impaired in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) because of elevated arsenic. Non-metal impairments of Sluice Gulch in 2012 include sediment, nitrate plus nitrite nitrogen, and alteration of streamside vegetative covers. The Sluice Gulch metals data set consists of 8 samples collected at 5 sites (**Figure M-3**) during July of 2004 and during June and September of 2010.

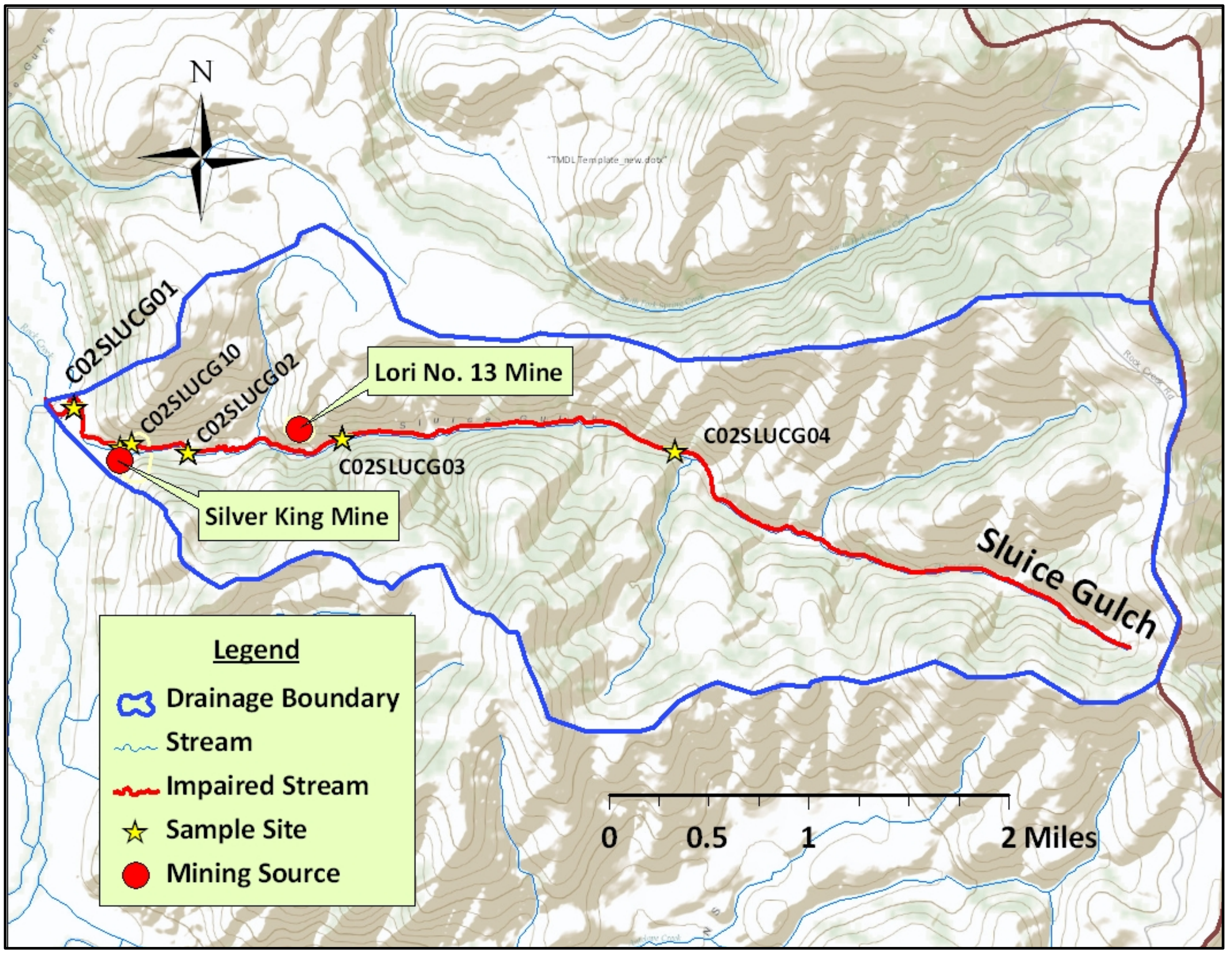

Figure M-3. Sluice Gulch watershed, monitoring sites, and mining sources.

M2.5.1 Sluice Gulch Sources

The MBMG abandoned mines database lists two inactive mines in the Sluice Gulch drainage: the Silver King Mine and the Lori No. 13. The Silver King is a former gold and silver lode mine occupying about 18 acres on the south flank of Sluice Gulch where the drainage enters the Upper Willow Creek valley. The mine consists of access roads, operating benches, 5 adit openings, and 30,000 cubic yards of waste rock in several dumps. A 1993 field assessment reported one of the adits discharging at about 50 gallons per minute. Analysis of the adit water indicated elevated copper (Pioneer Technical Services, Inc., 1995). Sluice Gulch water samples collected in 1993 both above and below the mine exceeded the 10 µg/L human health criterion for arsenic. Other metal concentrations were within water quality standards.

Approximately one mile upstream of the Silver King Mine is the Lori No. 13 that consists of a single dry adit and a re-vegetated waste rock dump containing about 700 cubic yards (Pioneer Technical Services, Inc., 1995). The mine disturbs about 9 acres on the north side of the gulch and is about 800 feet from Sluice Gulch surface water. Both the Silver King and Lori N. 13 are ranked as priority mine sites that have potential human health and safety hazards.

M2.5.2 Sluice Gulch Target Departures

Sluice Gulch is listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) as being impaired due to arsenic, sediment, nitrite plus nitrate nitrogen, and alteration in streamside vegetative covers. The recent water quality dataset for Sluice Gulch contains 8 metals analysis records for samples collected in 2004 and 2010. All samples were collected at the 5 sites shown in **Figure M-3**. **Table M-9** summarizes the results of the target departure analysis in terms of TMDL decision factors.

Table M-9. Sluice Gulch TMDL Decision Factors and TMDL Conclusions

Pollutant Parameter	Sample Size	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Sediment PEL Exceeded	Human-Caused Sources Present	2012 303(d) Listing Status	TMDL Decision
Aluminum	8	N	N	NA	NA	Y	Unlisted	No TMDL
Arsenic	8	N	N	Y	Y	Y	Listed	As TMDL
Cadmium	8	N	N	N	N	Y	Unlisted	No TMDL
Copper	8	Y	N	N	N	Y	Unlisted	Cu TMDL
Iron	8	N	NA	NA	NA	Y	Unlisted	No TMDL
Lead	8	N	N	N	N	Y	Unlisted	No TMDL
Mercury	8	N	N	N	N	Y	Unlisted	No TMDL
Silver	8	NA	N	N	NA	Y	Unlisted	No TMDL
Zinc	8	N	N	N	N	Y	Unlisted	No TMDL

All 8 results for arsenic exceeded the human health criterion of 10 µg/L. One in 8 results copper exceeded the chronic aquatic life criterion. Other water column metals concentrations are either less than detectable concentrations, or at or below metals target values.

Sediment chemistry results are available for 4 samples from the sites listed in **Table M-10**. The values in the table express the sediment chemistry data as the ratios of the metal concentrations measured in the samples, to the PEL concentration recommended of metals parameters in fresh water stream sediment.

Table M-10. Ratios of measured sediment metals concentrations to PELs for sediment samples from Sluice Gulch.

SITE ID	Site Location	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
C02SLUCG01	near mouth	1.1	0.1	0.1	0.2	< 0.10	0.2
C02SLUCG10	¼ mile upstream from mouth	0.6	< 0.1	0.1	0.1	--	0.1
C02SLUCG02	¼ mile upstream from Silver King Mine	1.3	0.1	0.1	0.2	< 0.10	0.2
C02SLUCG03	1.7 miles above mouth	1.8	0.1	0.1	0.2	< 0.10	0.2

Sediment chemistry samples from 3 of 4 sites exceeded the PEL values for arsenic in fresh water stream sediment. The magnitude of the arsenic exceedances increases downstream. Three of 4 mercury values are less than PELs; the mercury value from site C02SLUCG10 is not used due to a high method detection limit applied to the 2004 sample.

M2.5.3 Sluice Gulch TMDL Summary

The human health criterion exceedance for arsenic and chronic aquatic life criteria exceedances for copper require development of TMDLs for these 2 metal parameters. The listing status and TMDL conclusions for metals in Sluice Gulch are summarized in **Table M-11.**

Table M-11. Metals listing status and TMDL conclusions for Sluice Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	Not a Cause	N
Arsenic	Listed	Y
Cadmium	Not a Cause	N
Copper	New Listing	Y
Iron	Not a Cause	N
Lead	Not a Cause	N
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Listed	N
Number of metals TMDLs Required		2

M2.6 Flat Gulch (MT76E002_120)

Flat Gulch is a first order tributary of Rock Creek. The stream extends for 3 miles from its headwaters on the east flank of Ram Mountain to its mouth on Rock Creek. The drainage area is approximately 3 square miles. Flat Gulch is listed as impaired in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) because of nutrients (nitrogen and phosphorus) and sediment. The Flat Gulch metals data set consists of 13 samples collected at 4 sites during July of 2004 and during low-flow periods of 2009, 2010, and 2011. **Figure M-4** shows the Flat Gulch drainage area, stream extent, and sampling locations.

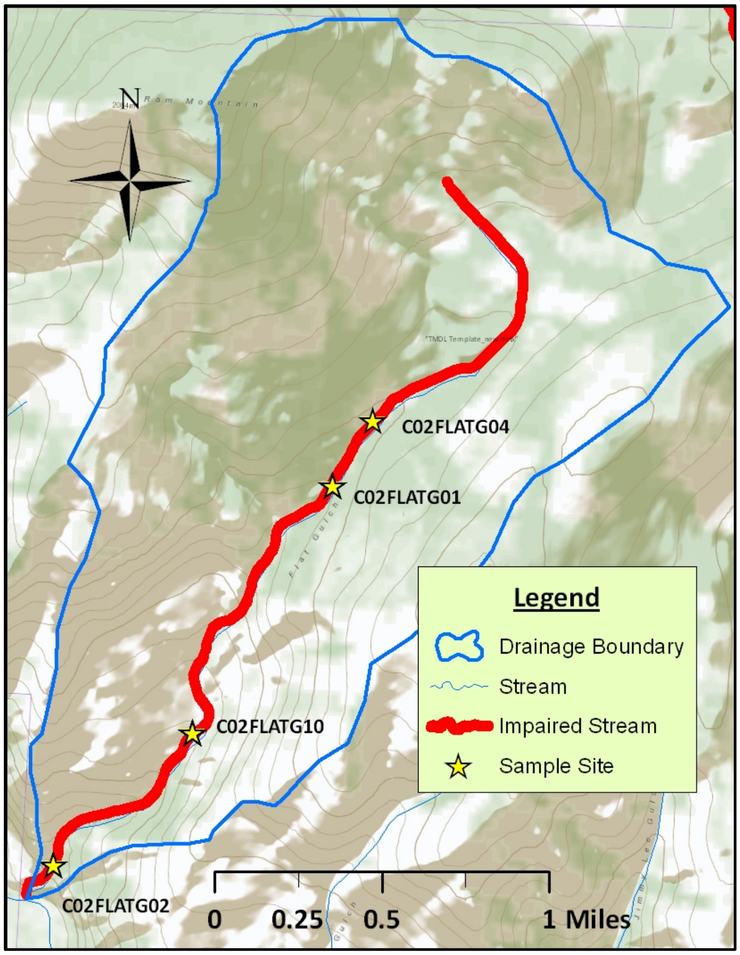

Figure M-4. Flat Gulch watershed, stream extent, and monitoring sites.

M2.6.1 Flat Gulch Sources

There are no abandoned mines described in the Flat Gulch drainage in either the MBMG or DEQ abandoned mine databases. Aluminum exceedances were reported during high flow conditions, suggesting that aluminum is bound in the sediment and only becomes mobile when there is a significant disturbance (high flow events). Therefore, metals loading (Fe and Hg) is likely to be associated with local sources of sediment. The analysis report of stream base parameters and bank erosion conditions in Flat Gulch (Water & Environmental Technologies, 2012) describes extensive streambank trampling by domestic livestock in both the upper and lower drainage. Timber harvesting and the associated road network are also a common upper basin land use. The density of discernible forest access and logging roads on 2011 aerial imagery of the drainage is approximately 3.5 miles per square mile. Timber harvest, livestock grazing, and limited past placer mining are described as potential sediment sources in the lower assessment reach.

M2.6.2 Flat Gulch Target Departures

Flat Gulch is listed in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) as being impaired due to sediment, total Kjeldahl nitrogen, and total phosphorus. The recent water quality dataset for Flat Gulch contains 13 metals analysis records for samples collected in 2004 and 2009-2011. All samples were collected at the 4 sites shown in **Figure M-4**. **Table M-12** summarizes the results of the target departure analysis in terms of TMDL decision factors.

Table M-12. Flat Gulch TMDL Decision Factors and TMDL Conclusions

Pollutant Parameter	Sample Size	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Sediment PEL Exceeded	Human-Caused (Sediment related) Sources Present	2012 303(d) Listing Status	TMDL Decision
Aluminum	13	Y	N	NA	NA	Y	Unlisted	Al TMDL
Arsenic	13	N	N	N	N	N	Unlisted	No TMDL
Cadmium	13	N	N	N	N	N	Unlisted	No TMDL
Copper	13	N	N	N	N	N	Unlisted	No TMDL
Iron	8	Y	NA	NA	NA	Y	Unlisted	Fe TMDL
Lead	13	N	N	N	N	N	Unlisted	No TMDL
Mercury	0	N	N	N	N	Y	Unlisted	No TMDL
Silver	13	NA	N	N	NA	N	Unlisted	No TMDL
Zinc	13	N	N	N	N	N	Unlisted	No TMDL

Twelve of the 13 results for dissolved aluminum have method detection limits low enough to determine compliance with the chronic aquatic life criterion (87 µg/L). Four of these12 results (30%) exceed the chronic aquatic life target. All 13 results for arsenic are less than the human health criterion of 10 µg/L. Two of 7 results for iron exceed the chronic aquatic life criterion of 1,000 µg/L. Other water column metals concentrations are either less than detectable concentrations, or at or below metals target values.

Sediment chemistry results are available for three samples from the sites listed in **Table M-13**. The values in the table express the sediment chemistry data as the ratios of the metal concentrations measured in the samples, to the PEL concentration recommended of metals parameters in fresh water stream sediment. Since all values in the table are less than 1, sediment chemistry concentrations are all less than the corresponding PEL indicator.

Table M-13. Ratios of measured sediment metals concentrations to PELs for sediment samples from Flat Gulch.

SITE ID	Site Location	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
C02FLATG01	2 miles above mouth	0.3	< 0.015	0.1	0.1	0.16	0.1
C02FLATG10	1 mile above mouth	0.2	< 0.015	0.1	0.1	0.16	0.1
C02FLATG02	near mouth	0.2	< 0.015	0.1	0.1	0.14	0.1

M2.6.3 Flat Gulch TMDL Summary

The chronic aquatic life criteria exceedances for aluminum and iron require development of TMDLs for these two metals. The listing status and TMDL conclusions for metals in Flat Gulch are summarized in Ta**ble M-14.**

Table M-14. Metals listing status and TMDL conclusions for Flat Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	New Listing	Y
Arsenic	Not a Cause	N
Cadmium	Not a Cause	N
Copper	New Listing	N

Table M-14. Metals listing status and TMDL conclusions for Flat Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Iron	New Listing	Y
Lead	Not a Cause	N
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Remove Current Listing	N
Number of metals TMDLs Required		2

M2.7 Scotchman Gulch (MT76E002_100)

Scotchman Gulch is a first order tributary of Upper Willow Creek. The stream extends for 6.9 miles from its headwaters in the Sapphire Mountains. The drainage is predominantly a forested watershed with mixed forest and grassland and hay production acreage in the lower watershed. The Scotchman Gulch drainage area is approximately 5.7 square miles. Scotchman Gulch is listed as impaired in the 2012 Integrated Report (Montana Department of Environmental Quality, 2012) because of nutrients (phosphorus) and sediment. **Figure M-5** shows the Scotchman Gulch drainage area, stream extent, sampling locations, and potential mining sources of metals loading.

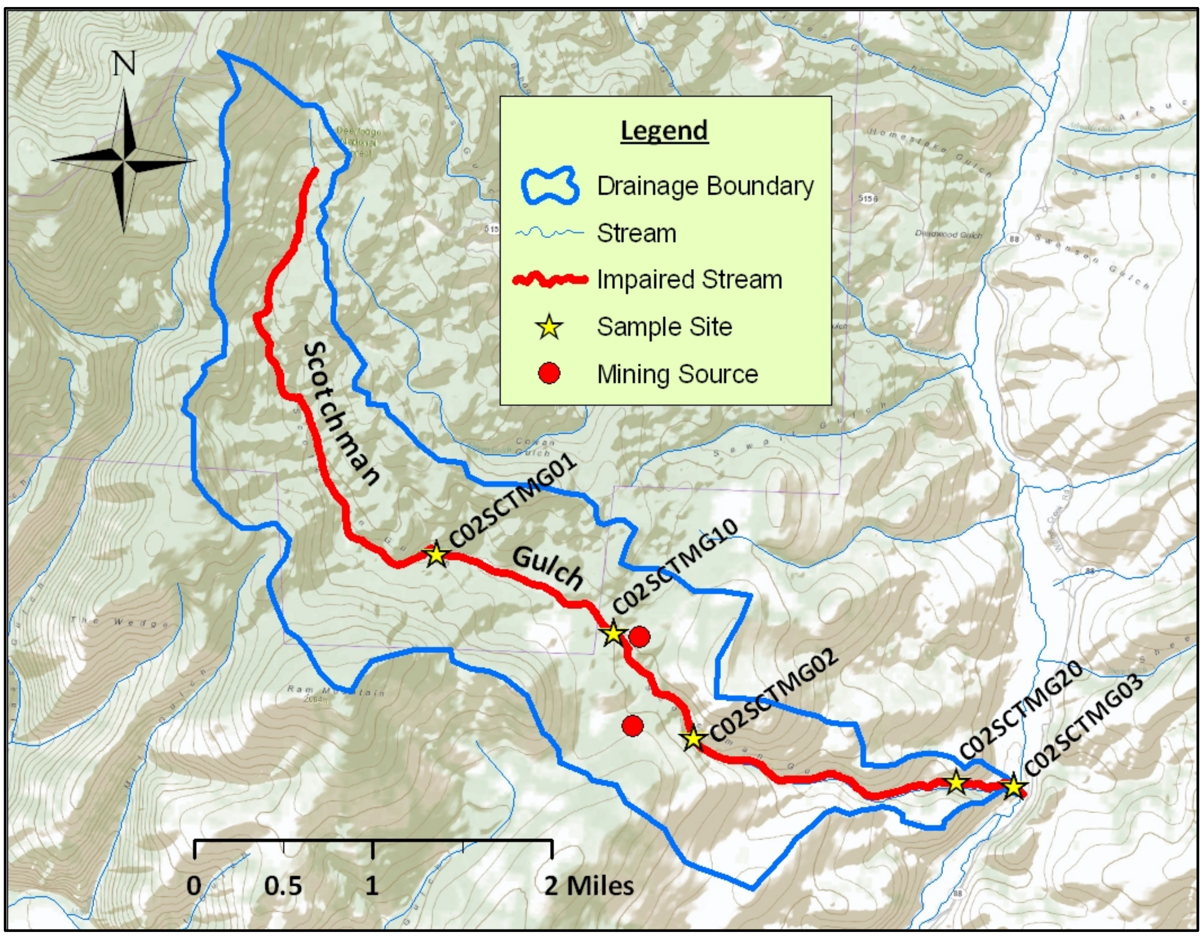

Figure M-5. Scotchman Gulch watershed, stream extent, monitoring sites, and mining sources.

M2.7.1 Scotchman Gulch Sources

Two abandoned placer mining operations appear in the DEQ abandoned mine database. The locations of these placer operations are depicted as red circles in **Figure M-5**. The property nearer sampling site C02SCTMG10 consists of stabilized coarse aggregate piles, near the stream and remnants of wooden water conveyance structures from past placer mining. Evidence of breached channel impoundments occur farther downstream and fine sediment accumulations may be related to past placer mining. The stream channel conditions reflect heavy past grazing pressure that has been more recently controlled by electrified and conventional fencing. Some timber harvesting has occurred in the lower reaches of the forested portion of the drainage. Near the mouth the land adjacent to the channel is used for hay production. Aluminum exceedances were reported during high flow conditions, suggesting that aluminum is bound in the sediment and only becomes mobile when there is a significant disturbance (high flow events). Therefore, metals loading (Fe and Hg) is likely to be associated with local sources of sediment such as fine sediment deposition resulting from past mining and livestock grazing.

M2.7.2 Scotchman Gulch Target Departures

The metals data set for Scotchman Gulch consists of 13 samples collected at 5 sites (**Figure M-5**) during August of 2004 and low-flow periods of 2009, 2010, and 2011. **Table M-15** summarizes the results of the target departure analysis in terms of TMDL decision factors.

Table M-15. Scotchman Gulch TMDL Decision Factors and TMDL Conclusions

Pollutant Parameter	Sample Size	CAL Exceedance Rate > 10%	Results Twice the AAL Criterion	Human Health Criterion exceeded	Sediment PEL Exceeded	Human-Caused Sources Present	2012 303(d) Listing Status	TMDL Decision
Aluminum	16	Y	N	NA	NA	Y	Unlisted	Al TMDL
Arsenic	16	N	N	N	N	N	Unlisted	No TMDL
Cadmium	16	N	N	N	N	N	Unlisted	No TMDL
Copper	14	N	N	N	N	N	Unlisted	No TMDL
Iron	12	N	NA	NA	NA	Y	Unlisted	No TMDL
Lead	16	N	N	N	N	N	Unlisted	No TMDL
Mercury	0	N	N	N	N	Y	Unlisted	No TMDL
Silver	16	NA	N	N	NA	N	Unlisted	No TMDL
Zinc	13	N	N	N	N	N	Unlisted	No TMDL

Four of the 16 aluminum results (31%) exceed the 87 µg/L chronic aquatic life criterion. No sample contained detectable concentrations of cadmium, lead, or silver. The concentrations of other metal parameters were either less than method detection levels or within the most restrictive target value.

Eight sediment chemistry samples are available from 4 of the Scotchman Gulch sample sites. The values in **Table M-16** express the sediment chemistry data as the ratios of the metal concentrations measured in the samples, to the PEL concentration recommended of metals parameters in fresh water stream sediment. Since all numeric values in the table are equal to or less than 1, no sediment chemistry concentrations exceed the corresponding PEL values.

Table M-16. Ratios of measured sediment metals concentrations to PELs for sediment samples from Scotchman Gulch.

SITE ID	Site Location	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
C02SCTMG01	Headwaters	0.2	< 0.07	0.05	0.07	--	0.07
C02SCTMG01		0.4	< 0.07	0.05	0.07	0.19	0.08
C02SCTMG10	50 above of Scotchman Gulch Road crossing	1.0	< 0.07	0.05	0.08	--	0.15
C02SCTMG10		0.6	< 0.07	0.05	0.07	0.25	0.12
C02SCTMG02	1 mile below National Forest boundary	0.3	< 0.07	0.07	0.08	0.19	0.12
C02SCTMG02		0.4	< 0.07	0.07	0.08	0.16	0.11
C02SCTMG03	Near mouth	0.3	< 0.07	0.05	0.08	0.12	0.12
C02SCTMG03		0.3	< 0.07	0.06	0.08	0.10	0.14

M2.7.3 Scotchman Gulch TMDL Summary

The chronic aquatic life criteria exceedance for aluminum requires development of a TMDL for aluminum in Scotchman Gulch. The listing status and TMDL conclusions for metals in Scotchman Gulch are summarized in **Table M-17.**

Table M-17. Metals listing status and TMDL conclusions for Scotchman Gulch

Metal	Listing Status	TMDL Needed? (Y/N)
Aluminum	New Listing	Y
Arsenic	Not a Cause	N
Cadmium	Not a Cause	N
Copper	Not a Cause	N
Iron	Not a Cause	N
Lead	Not a Cause	N
Silver	Not a Cause	N
Zinc	Not a Cause	N
Mercury	Remove Current Listing	N
Number of metals TMDLs Required		1

M3.0 REFERENCES

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APPENDIX N - CLEANUP/RESTORATION AND FUNDING OPTIONS FOR MINE OPERATIONS OR OTHER SOURCES OF METALS CONTAMINATION

There are several approaches for cleanup of mining operations or other sources of metals contamination in the State of Montana. Most of these are discussed below, with focus on abandoned or closed mining operations.

N1.0 THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

CERCLA is a federal law that addresses cleanup on sites, such as historic mining areas, where there has been a hazardous substance release or threat of release. Sites are prioritized on the National Priority List (NPL) using a hazard ranking system with significant focus on human health. Petroleum related products and associated raw materials are not covered under CERCLA. Other federal regulations such as Resource Conservation and Recovery Act and associated Leaking Underground Storage Tank cleanup requirements tend to address petroleum.

Under CERCLA, the potentially responsible party or parties must pay for all remediation efforts based upon the application of a strict joint and several liability approach whereby any existing or historical land owner can be held liable for restoration costs. Where viable landowners are not available to fund cleanup, funding can be provided under Superfund authority. Federal agencies can be delegated Superfund authority, but cannot access funding from Superfund.

Cleanup actions under CERCLA must be based on professionally developed plans and can be categorized as either Removal or Remedial. Removal actions can be used to address the immediate need to stabilize or remove a threat where an emergency exists. Cleanup of metals-contaminated soils in the Town of Superior was performed as a removal action.

Once removal activities are completed, a site can then undergo Remedial Actions or may end up being scored low enough from a risk perspective that it no longer qualifies to be on the NPL for Remedial Action. Under these conditions the site is released back to the state for a "no further action" determination. At this point there may still be a need for additional cleanup since there may still be significant environmental threats or impacts, although the threats or impacts are not significant enough to justify Remedial Action under CERCLA. Any remaining threats or impacts would tend to be associated with wildlife, aquatic life, or aesthetic impacts to the environment or aesthetic impacts to drinking water supplies versus threats or impacts to human health. A site could, therefore, still be a concern from a water quality restoration perspective, even after CERCLA removal activities have been completed.

Remedial actions may or may not be associated with or subsequent to removal activities. A remedial action involves cleanup efforts whereby Applicable or Relevant and Appropriate Requirements and Standards (ARARS), which include state water quality standards, are satisfied. Once ARARS are satisfied, then a site can receive a "no further action" determination.

N2.0 The Montana Comprehensive Cleanup and Restoration Act (CECRA)

The 1985 Montana Legislature passed the Environmental Quality Protection Fund Act. This Act created a legal mechanism for the Department to investigate and cleanup, or require liable persons to investigate and cleanup, hazardous or deleterious substance facilities in Montana. The 1985 Act also established the Environmental Quality Protection Fund (EQPF). The EQPF is a revolving fund in which all penalties and costs recovered pursuant to the EQPF Act are deposited. The EQPF can be used only to fund activities relating to the release of a hazardous or deleterious substance. Although the 1985 Act established the EQPF, it did not provide a funding mechanism for the Department to administer the Act. Therefore, no activities were conducted under this Act until 1987.

The 1987 Montana Legislature passed a bill creating a delayed funding mechanism that appropriated 4 percent of the Resource Indemnity Trust (RIT) interest money for Department activities at non-National Priority List facilities beginning in July 1989 (§ 15-38-202 MCA). In October 1987, the Department began addressing state Superfund facilities. Temporary grant funding was used between 1987 and 1989 to clean up two facilities and rank approximately 250 other facilities. Beginning in fiscal year 1995, the 4 percent allocation was changed to 6 percent to adjust for other legislative changes in RIT allocations. Effective July 1, 1999, the 6 percent allocation was increased to 9 percent.

The 1989 Montana Legislature significantly amended the Act, changing its name to the Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA) and providing the Department with similar authorities as provided under the federal Superfund Act (CERCLA). With the passage of CECRA, the state Superfund program became the CECRA Program. Major revisions to CECRA did not occur until the 1995 Legislature, when the Voluntary Cleanup and Redevelopment Act (VCRA), a mixed-funding pilot program, and a requirement to conduct a collaborative study on alternative liability schemes were added and provisions related to remedy selection were changed. Based on the results of the collaborative study, the 1997 Legislature adopted the Controlled Allocation of Liability Act, which provides a voluntary process for the apportionment of liability at CECRA facilities and establishes an orphan share fund. Minor revisions to CECRA were also made by the 1999 and 2001 Legislatures.

CECRA facilities are ranked maximum, high, medium, low and operation and maintenance priority based on the severity of contamination at the facility and the actual and potential impacts of contamination to public health, safety, and welfare and the environment. The Department maintains database narratives that explain contamination problems and status of work at each state Superfund facility.

N2.1 The Controlled Allocation of Liability Act (CALA)

The Montana Legislature added the Controlled Allocation of Liability Act (CALA; §§ 75-10-742 through 752, Montana Code Annotated (MCA)) to the Comprehensive Environmental Cleanup and Responsibility Act (CECRA; §§ 75-10-701 through 752, MCA), the state Superfund law, in 1997. The department administers CALA including the orphan share fund it establishes.

CALA is a voluntary process that allows Potentially Responsible Parties (PRP) to petition for an allocation of liability as an alternative to the strict, joint and several liability scheme included in CECRA. CALA provides a streamlined alternative to litigation that involves negotiations designed to allocate liability among persons involved at facilities requiring cleanup, including bankrupt or defunct persons. Cleanup of these facilities must occur concurrently with the CALA process and CALA provides the funding for the orphan share of the cleanup. Since CECRA cleanups typically involve historical contamination, liable persons often include entities that are bankrupt or defunct and not affiliated with any viable person by stock ownership. The share of cleanup costs for which these bankrupt or defunct persons are responsible is the orphan share. Department represents the interests of the orphan share throughout the CALA process.

The funding source known as the orphan share fund is a state special revenue fund created from a variety of sources. These include an allocation of 8.5 percent of the metal mines license tax, certain penalties and additional funds from the resource indemnity trust fund and 25 percent of the resource indemnity and groundwater assessment taxes (which will increase to 50 percent when the RIT reaches $100 million). The current balance of the Orphan Share Fund is around $4 million and revenues projected for the rest of this biennium are about $2 million.

In the absence of a demonstrated hardship, claims for orphan share reimbursement may not be submitted until the cleanup is complete. This ensures that facilities are fully remediated before reimbursement. The result is that a PRP could be expending costs it anticipates being reimbursed for some time before the PRP actually submits a claim.

CALA was designed to be a streamlined, voluntary allocation process. For facilities where a PRP does not initiate the CALA process, strict, joint and several liability remains. Any person who has been noticed as being potentially liable as well as any potentially liable person who has received approval of a voluntary cleanup plan can petition to initiate the CALA process. CALA includes fourteen factors to be considered in allocating liability. Based on these factors causation weighs heavily in allocation but is not the only factor considered.

N2.2 The Voluntary Cleanup and Redevelopment Act (VCRA)

The 1995 Montana Legislature amended the Comprehensive Environmental Cleanup and Responsibility Act (CECRA), creating the Voluntary Cleanup and Redevelopment Act (VCRA) (Sections 75-10-730 through 738, MCA). VCRA formalizes the voluntary cleanup process in the state. It specifies application requirements, voluntary cleanup plan requirements, agency review criteria and time frames, and conditions for and contents of no further action letters.

The act was developed to permit and encourage voluntary cleanup of facilities where releases or threatened releases of hazardous or deleterious substances exist, by providing interested persons with a method of determining what the cleanup responsibilities will be for reuse or redevelopment of existing facilities. Any entity (such as facility owners, operators, or prospective purchasers) may submit an application for approval of a voluntary cleanup plan to the Department. Voluntary Cleanup Plans (VCPs) may be submitted for facilities whether or not they are on the CECRA Priority List. The plan must include (1) an environmental assessment of the facility; (2) a remediation proposal; and (3) the written consent of current owners of the facility or property to both the implementation of the voluntary cleanup plan and access to the facility by the applicant and its agents and Department. The applicant is also required to reimburse the Department for any costs that the state incurs during the review and oversight of a voluntary cleanup effort.

The act offers several incentives to parties voluntarily performing facility cleanup. Any entity can apply and liability protection is provided to entities that would otherwise not be responsible for site cleanup. Cleanup can occur on an entire facility or a portion of a facility. The Department cannot take enforcement action against any party conducting an approved voluntary cleanup. The Department review process is streamlined: the Department has 30 to 60 days to determine if a voluntary cleanup plan is complete, depending on how long the cleanup will take. When the Department determines an application is complete, it must decide within 60 days whether to approve or disapprove of the application; these 60 days also includes a 30-day public comment period. The Department's decision is based on the proposed uses of the facility identified by the applicant and the applicant conducts any necessary risk evaluation. Once a plan has been successfully implemented and Department costs have been paid, the applicant can petition the Department for closure. The Department must determine whether closure conditions are met within 60 days of this petition and, if so, the Department will issue a closure letter for the facility or the portion of the facility addressed by the voluntary cleanup.

The act is contained in §§ 75-10-730 through 738, MCA. Major sections include: § 75-10-732 - eligibility requirements; § 75-10-733 and § 75-10-734 - environmental property assessment and remediation proposal requirements; § 75-10-735 - public participation; § 75-10-736 - timeframes and procedures for Department approval/disapproval; § 75-10-737 - voluntary action to preclude remedial action by DEQ; and § 75-10-738 - closure process. Section 75-10-721, MCA of CECRA must also be met.

The Department does not currently have a memorandum of agreement (MOA) with the Environmental Protection Agency (EPA) for its Voluntary Cleanup Program. However, the Department and EPA are in the process of negotiating one. EPA has indicated that Montana's Voluntary Cleanup Program includes the necessary elements to establish the MOA. Currently, EPA is reviewing the latest draft of the MOA.

The Department has produced a VCRA Application Guide to assist applicants in preparing a new application; this guide is not a regulation and adherence to it is not mandatory.

As of 2012, the Department has approved 31 voluntary clean plans, including mining, manufactured gas, wood treating, dry cleaning, salvage, pesticide, fueling, refining, metal plating, defense, and automotive repair facilities. Applicants have expressed interest and/or submitted applications for voluntary cleanup at fifteen other facilities. The Department maintains a registry of VCRA facilities.

N3.0 Abandoned Mine Lands Cleanup

The purpose of the Abandoned Mine Lands Reclamation (AML) Program is to protect human health and the environment from the effects of past mining and mineral processing activities. Funding for cleanup is via the Federal Abandoned Mine Fund, which is distributed to the State of Montana via a grant program. The Abandoned Mine Fund is generated by a per ton fee levied on coal producers and the annual grant it based on coal production. There are no collections or contributions to the Abandoned Mine Fund from mineral production beyond coal production fees. Expenditures under the abandoned mine program can only be made on “eligible” abandoned mine sites. For a site to be eligible, mining must have ceased prior to August 4, 1977 (private lands, other dates apply to federal lands). In addition, there must be no continuing reclamation responsibility under any state or federal law. No continuing reclamation responsibility can mean no mining bonds or permits have been issued for the site, however, it has also been interpreted to mean that there can be no viable responsible party under State or Federal laws such as CERCLA or CECRA. While lands eligible for the Abandoned Mine Funds include hard rock mines and gravel pits (collectively categorized as “non-coal”), abandoned coalmines have the highest priority for expenditures from the Fund. As part of the approved plan for Montana, abandoned coal mines are required to be prioritized and funded for reclamation ahead of eligible non-coal mine sites. . Cleanup of any eligible site is prioritized based primarily on human health, which can include health risks such as open shafts, versus risks only associated with hazardous substances, as is the case under CERCLA.

Montana's AML Program maintains an inventory of all potential cleanup sites, and also has a list of non-coal priority sites from which to work from. The DEQ conducts cleanups under the Abandoned Mine Funds as public works contracts utilizing professional engineers for design purposes and private construction contractors to perform the actual work.

Limited scoping and ranking of water pollution from discharging abandoned coal mines has been completed and Montana’s AML program is evaluating how to proceed with funding water treatment and stream quality restoration at the highest priority abandoned coal mine sites. In cases of non-coal cleanups, mitigating impacts associated with discharging adits can be included within the cleanup, although ongoing water treatment is not pursued as a reclamation option to avoid long-term operational commitments, which are outside the scope of the program and funding source. Therefore, even after cleanup, an abandoned non-coal mine site could still represent a source of contaminant loading to a stream, especially if there is a discharging adit associated with the site. Where discharging adits are not of concern, cleanup of either coal or non-coal mines may generally represent efforts to achieve all reasonable land, water, and soil conservation practices for that site.

A Guide to Abandoned Mine Reclamation (Noble and Koerth, 1996) provides further description of the Abandoned Mine Lands Program and how cleanup activities are pursued.

N4.0 Cleanup on Federal Agency Lands

A Federal land management agency may pursue cleanup actions outside of any requirements under CERCLA or CECRA where such activities are consistent with overall land management goals and funding availability. This is the anticipated solutions for USFS lands within the Flat Creek watershed.

N5.0 Permitted or Bonded Sites

Newer mining sites that are or have been in recent operation are required to post bonds as part of their permit conditions. These bond and permit conditions help ensure cleanup to levels that will satisfy Montana Water Quality Standards during operation and after completion of a mining operation. Such sites also include larger placer mines greater than 5 acres in size. There are no permitted or bonded sites in the Bonita – Superior TMDL project area.

N6.0 Voluntary Cleanup Agreement

At least one location within Montana (the Upper Blackfoot Mining Complex) is being addressed via a voluntary cleanup approach based on an agreement between the responsible person and the State of Montana. Although similar in nature to the goals of CECRA, this cleanup effort is currently not considered a remedial action under CECRA. The responsible person is responsible for cleanup costs in this situation.

N7.0 Landowner Voluntary Cleanup Outside of a State Directed or State Negotiated Effort

A landowner could pursue cleanup outside the context of CECRA or other state negotiated cleanup approaches. Under such conditions, liability would still exist since there is presumably a lack of professional oversight and assurance of meeting appropriate environmental and human health goals. Regulatory requirements such as where waste can be disposed, stormwater runoff protection, and multiple other environmental conditions would still need to be followed to help ensure that the cleanup activity does not create new problems. This approach can be risky since the potential for additional future work would likely make it more cost effective to pursue cleanup under CECRA or some other state negotiated approach where PRP liability can be resolved.

N8.0 State Emergency Actions

Where a major emergency exists, the State can undertake remedial actions and then pursue reimbursement from a responsible party. This situation does not exist within the Bonita – Superior TMDL project area.

N9.0 References

Noble, Cassandra and John Koerth. 1996. Montana ... Bringing the Land Back to Life: A Guide to Abandoned Mine Reclamation. Helena, MT: Montana Department of Environmental Quality.