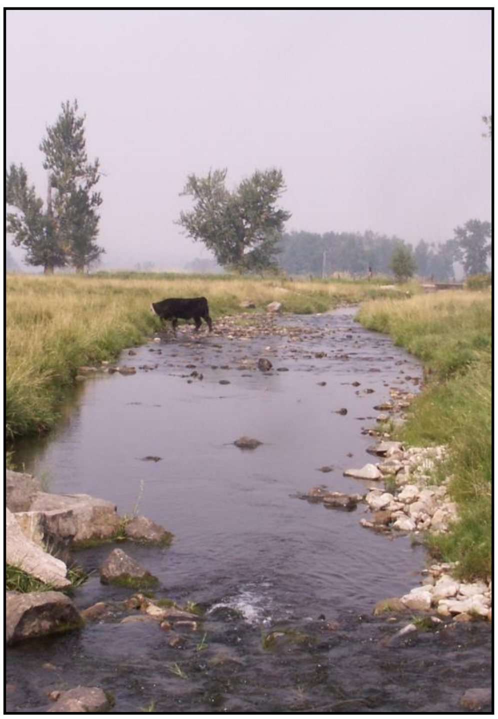
# Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan



**August 17, 2011**

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# ERRATA SHEET FOR THE BITTERROOT TEMPERATURE AND TRIBUTARY SEDIMENT TOTAL MAXIMUM DAILY LOADS AND FRAMEWORK WATER QUALITY IMPROVEMENT PLAN

This TMDL was approved by EPA on August 17, 2011. Several copies were printed and spiral bound for distribution, or sent electronically on compact disks. The original version had minor changes that are explained and corrected on this errata sheet. If you have a bound copy, please note the corrections listed below or simply print out the errata sheet and insert it in your copy of the TMDL. If you have a compact disk please add this errata sheet to your disk or download the updated version from our website.

Appropriate corrections have already been made in the downloadable version of the TMDL located on our website at: http://deq.mt.gov/wqinfo/TMDL/finalReports.mcpx

The following table contains corrections to the TMDL. The first column cites the page and paragraph where there is a text error. The second column contains the original text that was in error. The third column contains the new text that has been corrected for the Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan document. The text in error and the correct text are underlined.

| **Location in the TMDL** | **Original Text** | **Corrected Text** |
|---|---|---|
| Page 6-17, Section 6.5.1.2.2, Table 6-7, last cell in the last column | <u>880,054</u> | <u>88,054</u> |

# ACKNOWLEDGEMENTS

DEQ would like to acknowledge multiple entities for their contributions in the development of the sediment and temperature TMDLs contained in this document. PBS&J (now Atkins) provided significant contributions in the development of the sediment and habitat data collection methods used for this project, the collection of bank erosion and sediment and habitat data, and development of **Appendices D** and **E** (*2007 Sediment and Habitat Data Collection Methods and Summary*, *Stream Bank Erosion Source Assessment,* respectively). Water & Environmental Technologies provided significant contribution in the sediment assessment of the unpaved road network in this TMDL planning area, and in the development of **Appendix G**, *Unpaved Road Sediment Source Assessment*.

Watershed Consulting, LLC conducted flights to capture thermal infrared imagery that assisted in the identification of thermal sources for the temperature TMDLs. Watershed Consulting also authored **Attachment A**, *Bitterroot River FLIR Temperature Analysis and Interpretive Report*. Modeling of water temperature was completed with assistance from HDR Engineering, Inc. (HDR). HDR also co-authored **Attachment B**, *Modeling Streamflow and Water Temperature in the Bitterroot River, Montana*. Additionally, information provided by the Bitter Root Irrigation District aided the development of the temperature model. Project input was provided by the Montana Department of Transportation and the City of Missoula for the assessment of thermal loading from the city's storm sewer system.

Draft versions of these TMDLs were sent to various stakeholders for review and input. The involvement of all reviewers led to improvements in this document and is greatly appreciated. DEQ would like to thank the Lolo and Bitterroot national forests and the Tri State Water Quality Council for their comments and contributions. Additionally, we would like to recognize the support of the Bitter Root Water Forum who provided assistance with identification of stakeholders and public outreach and education.

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# ACRONYMS

| Acronym | Definition |
|---|---|
| AFO | Animal Feeding Operation |
| AOP | Aquatic Organism Passage |
| ARM | Administrative Rules of Montana |
| BDNF | Beaverhead Deerlodge National Forest |
| BEHI | Bank Erosion Hazard Index |
| BER | Board of Environmental Review (Montana) |
| BFW | Bankfull Width |
| BLM | Bureau of Land Management (Federal) |
| BMP | Best Management Practice |
| BNF | Bitterroot National Forest |
| BRWF | Bitter Root Water Forum |
| CAFO | Concentrated (or Confined) Animal Feed Operation |
| CFR | Code of Federal Regulations |
| CFS | Cubic feet per second |
| CMP | Corrugated Metal Pipe |
| CWA | Clean Water Act |
| DEM | Digital Elevation Map |
| DEQ | Department of Environmental Quality (Montana) |
| DNRC | Department of Natural Resources & Conservation (Montana) |
| EC | Electrical Conductance or Electrical Conductivity |
| EF | East Fork |
| EPA | Environmental Protection Agency (US) |
| FWP | Fish, Wildlife, and Parks (Montana) |
| FWS | Fish & Wildlife Services (US) |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| GWIC | Groundwater Information Center |
| HRU | Hydrologic Response Unit |
| HUC | Hydrologic Unit Code |
| IB | Idaho Batholith [ecoregion] |
| INFISH | Inland Native Fish Strategy |
| ITML | Instantaneous Thermal Maximum Load |
| KNFLD | Kootenai National Forest Libby District |
| LA | Load Allocation |
| LBFT | Lower Blackfoot TMDL Planning Area |
| LID | Low Impact Development |
| LNF | Lolo National Forest |
| LWD | Large woody debris |
| LWG | Lolo Watershed Group |
| MCA | Montana Code Annotated |
| MBMG | Montana Bureau of Mines and Geology |
| MGWPCS | Montana Ground Water Pollution Control System |
| MMI | Multi-Metric Index |
| MOS | Margin of Safety |

| **Acronym** | **Definition** |
|---|---|
| MPDES | Montana Pollutant Discharge Elimination System |
| MR | Middle Rockies [ecoregion] |
| MS4 | Municipal Separate Storm Sewer System |
| MSU | Montana State University |
| MUSLE | Modified Universal Soil Loss Equation |
| NBS | Near Bank Stress |
| N/A | Not Applicable |
| NC | Not Collected |
| NHD | National Hydrology Dataset |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | Nonpoint Source |
| NR | Northern Rockies [ecoregion] |
| NRCS | National Resources Conservation Service |
| NRIS | Natural Resource Information System (Montana) |
| PIBO | PACFISH/INFISH Biological Opinion |
| RHCA | Riparian Habitat Conservation Area |
| RSI | Riffle Stability Index |
| SAR | Sodium Absorption Ratio |
| SDWIS | Safe Drinking Water Information System |
| SMZ | Streamside Management Zone |
| SNOTEL | Snowpack Telemetry |
| SOP | Standard Operating Procedure |
| SSTEMP | Stream Segment Temperature [model] |
| SSURGO | Soil Survey Geographic Database |
| SWAT | Soil & Water Assessment Tool |
| SWPPP | Storm Water Pollution Prevention Plan |
| TAG | Technical Advisory Group |
| TIR | Thermal Infrared [flight] |
| TKN | Total Kjehldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TPA | TMDL Planning Area |
| TSS | Total Suspended Solids |
| TSWQC | Tri-State Water Quality Council |
| UAA | Use Attainability Analysis |
| UILT | Upper Incipient Lethal Temperature |
| USDA | United States Department of Agriculture |
| USFS | United States Forest Service |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | United States Geological Survey |
| USLE | Universal Soil Loss Equation |
| VFS | Vegetated Filter Strips |
| WAG | Watershed Advisory Group |
| WARSSS | Watershed Assessment of River Stability and Sediment Supply |
| WEPP | Water Erosion Prediction Project |
| WF | West Fork |
| WLA | Wasteload Allocation |

| Acronym | Definition |
|---|---|
| WQA | Water Quality Act |
| WQS | Water Quality Standards |
| WRP | Watershed Restoration Plan |
| WWTF | Wastewater Treatment Facility |
| WWTP | Wastewater Treatment Plant |

# EXECUTIVE SUMMARY

This document presents a Total Maximum Daily Load (TMDL) and framework water quality improvement plan for 17 stream segments in the Bitterroot TMDL planning Area (TPA) including the Middle and Lower Bitterroot River, Ambrose Creek, Bass Creek, Lick Creek, Lolo Creek (3 segments), McClain Creek, Miller Creek, Muddy Spring Creek, North Burnt Fork Creek, Rye Creek, Sleeping Child Creek, Sweathouse Creek, Threemile Creek, and Willow Creek. 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 all streams and lakes can support and maintain their state-designated beneficial uses.

The Bitterroot River watershed is divided into three separate TMDL planning areas: The Bitterroot Headwaters TPA (TMDLs completed October, 2005), the Upper Lolo Creek TPA (TMDLs completed April, 2003), and the Bitterroot TPA. The Bitterroot TPA includes the Bitterroot River, which begins in Ravalli County at the confluence of the East and West Forks of the Bitterroot River near Conner, MT and flows north 84 miles to its confluence with the Clark Fork River near Missoula, MT in Missoula County; the Bitterroot River tributaries; and also the mainstem of Lolo Creek from just above Lolo Hot Springs to its confluence with the Bitterroot River.

DEQ has performed assessments determining that the above 17 stream segments do not meet the applicable water quality standards. The scope of the TMDLs in this document address sediment (in tributaries) and temperature related problems on the aforementioned streams. A total of 20 TMDLs are included and are shown in **Table E-1**. The document provides an evaluation of existing water quality data, assesses pollutant sources contributing to impairment conditions, and estimates pollutant loading reductions and allocations that will result in attainment of water quality standards. The document should be used as a guide to understanding water-quality related issues in the Bitterroot TPA and developing implementation plans to remedy known water quality problems related to sediment and temperature. Below is a brief synopsis of water quality issues addressed by this document.

**Sediment**
DEQ identified sediment-related effects as a cause of impairment on the following tributaries to the Bitterroot River: Ambrose Creek, Bass Creek, Lick Creek, Lolo Creek (3 segments), McClain Creek, Miller Creek, Muddy Spring Creek, North Burnt Fork Creek, Rye Creek, Sleeping Child Creek, Sweathouse Creek, Threemile Creek, and Willow Creek. Anthropogenic sources of sediment include upland and bank erosion associated with removal or riparian vegetation, unpaved roads, culvert failure, logging, disturbed ground on small and large acreage ranches, agriculture, and stormwater from construction sites.

Recommended strategies for reducing sediment include applying best management practices to maintain riparian vegetation, improve ground protection in disturbed areas (small acreages and construction sites), develop and implement grazing management plans, reduce the amount of erodible soil and runoff rate from agricultural lands, lessen the risk of culvert failure, and reduce the transport of unpaved road sediment into streams.

**Water Temperature**

DEQ identified temperature-related effects as a cause of impairment on the Middle and Lower stream segments of the Bitterroot River, Miller Creek, Sleeping Child Creek, and Willow Creek. Anthropogenic sources for temperature include reductions in riparian shade from large and small acreage ranching, crops, suburban land use, and timber harvest. Livestock grazing widens streams which then warm due to larger surface area. Inefficient irrigation systems reduce stream volumetric heat capacity, where less stream water heats more due to the same energy inputs. Irrigation return flow, waste water treatment plants, and urban runoff also provide heated water to certain segments.

Recommended strategies for reducing temperature include applying best management practices to improve shade producing riparian vegetation by reducing browse along streams, provide vegetated riparian buffers to provide shade where crop and suburban lands encroach on stream corridors, limit riparian timber harvest, increase irrigation efficiencies, and reduce water waste in irrigation systems.

**Implementation of Water Quality Improvement Plan**

Implementation of most water quality improvement measures described in this plan is based on voluntary actions of watershed stakeholders. Ideally, the TMDL and associated assessment and evaluation information in this document will be used by a local watershed groups, stakeholders and regulatory agencies as a tool to guide and prioritize local water quality improvement activities. These improvement and mitigation activities should be addressed further within a detailed watershed restoration plan consistent with DEQ and EPA recommendations. Presently, the Lolo Watershed Group is developing a comprehensive watershed restoration plan for Lolo Creek. Both the Lolo Watershed Group and the Bitter Root Water Forum are working on educating the public about water quality in the Bitterroot TPA.

It is recognized that a flexible and adaptive approach to most TMDL implementation activities may become necessary as more knowledge is gained through continued monitoring, assessment and restoration activities. The plan includes a framework strategy for further monitoring and assessment activities that will assist in refining source assessments and allow tracking of progress toward meeting TMDL water quality goals.

**Table E-1. List of Waterbodies, Impairment Causes, and Impaired Uses in the Bitterroot TPA with Completed TMDLs Contained in this Document**

| Waterbody & Location | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Use |
|---|---|---|---|---|
| **Ambrose Creek**, headwaters to the mouth (Threemile Creek) | MT76H004_120 | Sedimentation/Siltation* | Sediment | Aquatic Life,<br>Cold Water Fishery |
| **Bass Creek,** Selway-Bitterroot Wilderness boundary to mouth (confluence with the Bitterroot River) | MT76H004_010 | Sedimentation/Siltation* | Sediment | Aquatic Life,<br>Cold Water Fishery |
| **Bitterroot River,** Eightmile Creek to the mouth (Clark Fork River) | MT76H001_030 | Temperature (water)* | Temperature | Aquatic Life,<br>Cold Water Fishery |
| **Bitterroot River,** Skalkaho Creek to Eightmile Creek | MT76H001_020 | Temperature (water) | Temperature | Aquatic Life,<br>Cold Water Fishery |

**Table E-1. List of Waterbodies, Impairment Causes, and Impaired Uses in the Bitterroot TPA with Completed TMDLs Contained in this Document**

| Waterbody & Location | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Use |
|---|---|---|---|---|
| **Lick Creek,** headwaters to mouth (Bitterroot River) | MT76H004_170 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| **Lolo Creek**, headwaters to Sheldon Creek | MT76H005_013 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **Lolo Creek,** Mormon Creek to the mouth (Bitterroot River) | MT76H005_011 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **Lolo Creek,** Sheldon Creek to Mormon Creek | MT76H005_012 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **McClain Creek**, headwaters to mouth (Bitterroot River) | MT76H004_150 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **Miller Creek**, headwaters to the mouth (Bitterroot River) | MT76H004_130 | Temperature (water) | Temperature | Aquatic Life, Cold Water Fishery |
| | | Sedimentation/Siltation | Sediment | |
| **Muddy Spring Creek**, headwaters to mouth (Gold Creek) T7N, R19W, S2 | MT76H004_180 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **North Burnt Fork Creek,** confluence with South Burnt Fork Creek to Mouth (Bitterroot River) | MT76H004_200 | Bottom Deposits | Sediment | Aquatic Life, Cold Water Fishery |
| **Rye Creek**, North Fork to mouth (Bitterroot River) | MT76H004_190 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **Sleeping Child Creek**, headwaters to the mouth (Bitterroot River) | MT76H004_090 | Temperature (water) | Temperature | Aquatic Life, Cold Water Fishery |
| | | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| **Sweathouse Creek**, headwaters to mouth (Bitterroot River) | MT76H004_210 | Sedimentation/Siltation* | Sediment | Aquatic Life, Cold Water Fishery |
| **Threemile Creek**, headwaters to mouth (Bitterroot River) | MT76H004_140 | Sedimentation/Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **Willow Creek**, headwaters to the mouth (Bitterroot River) | MT76H004_110 | Temperature (water) | Temperature | Aquatic Life, Cold Water Fishery |
| | | Sedimentation/Siltation | Sediment | |

*Waterbody-pollutant combination not on the 2010 303(d) List. TMDL developed based on newly collected data.

# 1.0 – INTRODUCTION

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for sediment and temperature problems in the Bitterroot TMDL Planning Area (TPA). This document also presents a general framework for resolving these problems. **Map A-1** in **Appendix A** shows a map of waterbodies in the TPA with sediment and temperature 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 set water quality standards to protect designated beneficial water uses and to monitor the attainment of those uses. Fish and aquatic life, wildlife, recreation, agriculture, industrial, and drinking water are all types of beneficial uses designated in Montana. Streams and lakes (also referred to as waterbodies) not meeting the established standards are called impaired waters.

The waterbodies with their associated impairment causes are identified within a biennial integrated water quality report developed by DEQ (**Table 1-1** identifies impaired waters for the Bitterroot TPA). Impairment causes fall within two main categories: pollutant and non-pollutant. Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal Clean Water Act require the development of total maximum daily loads for impaired waters where a measurable pollutant (for example, sediment, nutrients, metals or temperature) is the cause of the impairment. The waterbody segments with pollutant impairment causes in need of TMDL development are contained within the 303(d) list portion of the state's integrated water quality report. The integrated report identifies impaired waters by a Montana waterbody segment identification, which is indexed to the National Hydrography Dataset.

A TMDL refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. The development of TMDLs and water quality improvement strategies in Montana includes several steps that must be completed for each impaired waterbody and for each contributing pollutant (or "waterbody-pollutant combination"). These steps include:

1. Characterizing the existing waterbody conditions and comparing these conditions to water quality standards. During this step, measurable target values are set to help evaluate the stream's condition in relation to the applicable standards.
2. Quantifying the magnitude of pollutant contribution from the pollutant sources
3. Determining the TMDL for each pollutant, based on the allowable loading limits (or loading capacity) for each pollutant-waterbody combination.
4. Allocating the total allowable load (the TMDL) into individual loads for each source (referred to as the load allocations or wasteload allocations).

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

The above four TMDL steps are further defined in **Section 4.0** of this document. Basically, TMDL development for an impaired waterbody is a problem solving exercise. The problem is excess pollutant loading negatively impacting a designated beneficial use. The solution is developed by identifying the total acceptable pollutant load to the waterbody (the TMDL), characterizing all the significant sources contributing to the total pollutant loading, and then identifying where pollutant loading reductions should be applied to one or more sources to achieve the acceptable load.

**Table 1-1. 2010 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Uses |
|---|---|---|---|---|
| **Ambrose Creek**, headwaters to mouth (Threemile Creek) | MT76H004_120 | Nitrogen (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Physical substrate habitat alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| **Bass Creek**, Selway-Bitterroot Wilderness boundary to mouth (un-named creek), T9N R20W S3 | MT76H004_010 | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Total Kjehldahl Nitrogen (TKN) | Nutrients | Aquatic Life, Cold Water Fishery |
| **Bear Creek**, Selway-Bitterroot Wilderness boundary to mouth (Fred Burr Creek), T7N R20W S7 | MT76H004_031 | Low flow alterations | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| **Bitterroot River**, East and West Forks to Skalkaho Creek | MT76H001_010 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Copper | Metals | Aquatic Life, Cold Water Fishery |
| **Bitterroot River**, Skalkaho Creek to Eightmile Creek | MT76H001_020 | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Nitrate/Nitrite (Nitrate + Nitrite as N) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Sedimentation / Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| | | **Temperature (water)** | **Temperature** | Aquatic Life, Cold Water Fishery |

**Table 1-1. 2010 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Uses |
|---|---|---|---|---|
| **Bitterroot River**, Eightmile Creek to mouth (Clark Fork River) | MT76H001_030 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Copper | Metals | Aquatic Life, Cold Water Fishery |
| | | Lead | Metals | Aquatic Life, Cold Water Fishery |
| | | Nitrogen (Nitrate) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Sedimentation / Siltation | Sediment | Aquatic Life, Cold Water Fishery |
| **Blodgett Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River) | MT76H004_050 | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| **Kootenai Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River) | MT76H004_020 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| **Lick Creek**, headwaters to mouth (Bitterroot River) | MT76H004_170 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Chlorophyll-*a* | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| | | Phosphorus (Total) | Nutrients | Primary Contact Recreation |
| | | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Total Kjehldahl Nitrogen (TKN) | Nutrients | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| **Lolo Creek**, Mormon Creek to mouth (Bitterroot River) | MT76H005_011 | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Physical substrate habitat alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |

**Table 1-1. 2010 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Uses |
|---|---|---|---|---|
| **Lolo Creek**, Sheldon Creek to Mormon Creek | MT76H005_012 | Physical substrate habitat alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| **Lolo Creek**, headwaters to Sheldon Creek | MT76H005_013 | Physical substrate habitat alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| **Lost Horse Creek**, headwaters to mouth (Bitterroot River) | MT76H004_070 | Low flow alterations | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| **McClain Creek**, headwaters to mouth (Sin-tin-tin-em-ska Creek), T11N R20W S23 | MT76H004_150 | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| **Mill Creek**, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek), T7N R20W S19 | MT76H004_040 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Cold Water Fishery |
| | | Low flow alterations | Not Applicable: Non-Pollutant | Cold Water Fishery, Primary Contact Recreation |
| | | **Temperature (water)** | **Temperature** | Cold Water Fishery |
| **Miller Creek**, headwaters to mouth (Bitterroot River) | MT76H004_130 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Chlorophyll-*a* | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Nitrate/Nitrite (Nitrite + Nitrate as N) | Nutrients | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Phosphorus (Total) | Nutrients | Primary Contact Recreation |
| | | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| | | **Temperature (water)** | **Temperature** | Aquatic Life, Cold Water Fishery |
| **Muddy Spring Creek**, headwaters to mouth (Gold Creek) T7N R19W S2 | MT76H004_180 | Nitrate / Nitrite (Nitrite + Nitrate as N) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | **Sedimentation / Siltation** | **Sediment** | Cold Water Fishery |

**Table 1-1. 2010 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Uses |
|---|---|---|---|---|
| **North Burnt Fork Creek**, confluence with South Burnt Fork Creek to mouth (Bitterroot River) | MT76H004_200 | **Bottom Deposits** | **Sediment** | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Total Kjehldahl Nitrogen (TKN) | Nutrients | Aquatic Life, Cold Water Fishery |
| **North Channel Bear Creek**, headwaters to the mouth (Fred Burr Creek), T8N R20W S32 | MT76H004_032 | Low flow alterations | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| **North Fork Rye Creek**, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby) | MT76H004_160 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Nitrogen (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| **Rye Creek**, North Fork to mouth (Bitterroot River) | MT76H004_190 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Nitrogen (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | **Sedimentation / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| **Skalkaho Creek**, headwaters to mouth (Bitterroot River) | MT76H004_100 | Low flow alterations | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| | | Mercury | Metals | Drinking Water |
| **Sleeping Child Creek**, headwaters to mouth (Bitterroot River) | MT76H004_090 | Nitrogen (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | **Sediment / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | **Temperature (water)** | **Temperature** | Aquatic Life, Cold Water Fishery |
| **South Fork Lolo Creek**, Selway-Bitterroot Wilderness boundary to mouth (Lolo Creek) | MT76H005_020 | Low flow alterations | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| | | Physical substrate habitat alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |

**Table 1-1. 2010 Impaired Waterbodies, Impairment Causes, and Impaired Beneficial Uses in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Impairment Cause | TMDL Pollutant Category | Impaired Uses |
|---|---|---|---|---|
| **Sweathouse Creek**, headwaters to mouth (Bitterroot River) | MT76H004_210 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| **Threemile Creek**, headwaters to mouth (Bitterroot River) | MT76H004_140 | Low flow alterations | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Nitrate/Nitrite (Nitrite + Nitrate as N) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | Phosphorus (Total) | Nutrients | Aquatic Life, Cold Water Fishery |
| | | **Sediment / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| **Tin Cup Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River) | MT76H004_080 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Total Kjehldahl Nitrogen (TKN) | Nutrients | Aquatic Life, Cold Water Fishery |
| **Willow Creek**, headwaters to mouth (Bitterroot River) | MT76H004_110 | Alteration in stream-side or littoral vegetative covers | Not Applicable: Non-Pollutant | Aquatic Life, Cold Water Fishery |
| | | Chlorophyll-*a* | Not Applicable: Non-Pollutant | Primary Contact Recreation |
| | | **Sediment / Siltation** | **Sediment** | Aquatic Life, Cold Water Fishery |
| | | **Temperature (water)** | **Temperature** | Aquatic Life, Cold Water Fishery |
| | | Total Kjehldahl Nitrogen (TKN) | Nutrients | Aquatic Life, Cold Water Fishery, Primary Contact Recreation |

This document addresses those waterbody-pollutant combinations identified by **bold text**.

## 1.2 Water Quality Impairments and TMDLs Addressed by This Plan

**Table 1-1** shows there are several different types of impairment causes which fall into different TMDL pollutant categories. For each impairment cause in the Bitterroot TPA, the impaired beneficial uses are also identified and include: aquatic life, coldwater fishery, drinking water, and primary contact recreation. This framework water quality improvement plan addresses the pollutant impairment causes identified by bold text in **Table 1-1**. These pollutant impairment causes fall within the categories of sediment and temperature. TMDL development for each pollutant category will follow a similar process as reflected by the organization of this document and discussed further in **Section 1.3** below.

**Table 1-1** identifies a combined total of 17 waterbody-pollutant combinations being addressed in this document: 12 sediment and 5 temperature. TMDLs were completed for all of these combinations, with the exception of the Mill Creek temperature impairment. A temperature TMDL for Mill Creek will be completed during future TMDL work in the TPA (see **Sections 6.1** and **6.5.3**). New data collected during this project justified the development of four additional TMDLs (**Table 1-2**). These 4 TMDLs along with the 16 TMDLs identified above result in a total of 20 TMDLs provided in this document.

**Table 1-2. Additional TMDLs Developed in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Impairment Cause | TMDL Pollutant Category |
|---|---|---|---|
| **Ambrose Creek**, headwaters to mouth (Threemile Creek) | MT76H004_120 | Sedimentation/Siltation | Sediment |
| **Bass Creek**, Selway-Bitterroot Wilderness boundary to mouth (un-named creek), T9N R20W S3 | MT76H004_010 | Sedimentation/Siltation | Sediment |
| **Bitterroot River**, Eightmile Creek to mouth (Clark Fork River) | MT76H001_030 | Temperature (water) | Temperature |
| **Sweathouse Creek**, headwaters to mouth (Bitterroot River) | MT76H004_210 | Sedimentation/Siltation | Sediment |

It is important to note that this document only addresses the sediment causes of impairment for the tributaries of the Bitterroot River. The sediment listings for the mainstem of the Bitterroot River (segments: MT76H001_020 and MT76H001_030) will also be addressed during future TMDL development. DEQ recognizes there are also other pollutant listings for this TPA in the nutrients and metals TMDL pollutant categories. However, this document only addresses those identified in bold in **Table 1-1** and listed above. This is because DEQ sometimes develops TMDLs in a watershed at varying phases with focus on one or a couple of specific pollutant types. Furthermore, there are several non-pollutant related types of impairment. 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 written in this document and the non-pollutant impairment causes is discussed in **Section 7.0**. **Section 8.0** also provides some basic water quality solutions to address those non-pollutant causes not specifically addressed by TMDLs in this document.

## 1.3 Document Layout

The main body of the document provides a summary of the TMDL components. Additional technical details of these components are contained in the appendices and attachments of this report. In addition to this introductory section which includes the background and identification of TMDLs developed, this document has been organized into the following sections:

**Section 2.0** Bitterroot River Watershed Description:
Description of the physical and social characteristics of the watershed

**Section 3.0** Montana Water Quality Standards:
Discusses the water quality standards that apply to the Bitterroot River watershed

**Section 4.0** Description of TMDL Components:

Defines the components of a TMDL and the process by which they are developed

**Sections 5.0 – 6.0** Tributary Sediment and Temperature TMDL Components, sequentially:
Discusses the pollutant category's impact to beneficial uses, the existing water quality conditions and the water quality targets, the quantified pollutant contributions from the identified sources, the TMDLs, and the allocations for each individual TMDL

**Section 7.0** Other Identified Issues or Concerns:
Describes other issues that may potentially be contributing to water quality impairment and how the TMDLs in the plan may address some of these concerns.

**Section 8.0** Framework Water Quality Restoration and Monitoring Strategy:
Discusses the framework for TMDL implementation. Also presents a monitoring strategy to help ensure successful TMDL implementation and attainment of water quality standards.

**Section 9.0** Public Participation & Public Comments:
Describes the involvement of other agencies and stakeholder groups who were involved with the development of the plan, the public participation process used in review of the draft document, and addresses comments received during the public comment period.

# 2.0 - BITTERROOT RIVER WATERSHED DESCRIPTION

This section contains a summary of the physical and social characteristics of the Bitterroot River watershed that has been excerpted from the "Bitterroot River Watershed Description." The entire watershed description and corresponding maps is contained in **Appendix B**.

## 2.1 PHYSICAL CHARACTERISTICS

### 2.1.1 Location

The Bitterroot TMDL Planning Area encompasses an area of 1,891 square miles, approximately 75% of which lies within Ravalli County, just under 25% in Missoula County, and a small portion in Mineral County. The watershed is bounded by the Bitterroot Mountains on the west and the Sapphire Mountains on the east. The Bitterroot River begins at the confluence of the East and West Forks of the Bitterroot River near Conner, Montana, and flows north to its confluence with the Clark Fork River near Missoula (**Map A-1** in **Appendix A**).

### 2.1.2 Topography

Elevations in the Bitterroot TPA range from 3,087 – 10,157 feet above mean sea level (**Map A-3** in **Appendix A**). The TPA geography is characterized on the west by glacially sculpted U-shaped alpine valleys draining the Bitterroot Mountains and on the east by dendritic V-shaped valleys draining the Sapphire Mountains. Slopes are generally 10 to 20 percent steeper in the Bitterroot Range than in the Sapphire Range (**Map A-8** in **Appendix A**). The Bitterroot Valley is roughly 10 miles across at the widest.

### 2.1.3 Geology and Soils

The bedrock of the TPA includes Precambrian metamorphic and metasedimentary rocks, Cretaceous and Tertiary igneous intrusions, and Tertiary volcanic rocks (Ross, et al., 1955). Granitic rocks of the Idaho Batholith and similar igneous bodies dominate the Bitterroot Range and the Sapphire Range south of Skalkaho Creek. Metasedimentary rocks of the Precambrian Belt Series dominate the Sapphire Range north of Skalkaho Creek and most of the Lolo Creek watershed. **Map A-4** in **Appendix A** provides an overview of the geology.

Nearly half (49%) of the TPA has soils with low susceptibility to erosion; another 41% is has low-moderate susceptibility. Nearly all of the moderate-high susceptibility soils (3%) correspond to the Tertiary benches and the foothills of the Sapphire Range. Majority (80%) of the soils in the planning area have moderate infiltration rate and runoff potential (B type soils). Many of the Quaternary sediments along the front of the Bitterroot Range have high infiltration rates and a low runoff potential (A type soils). See **Maps A-5 through A-7** in **Appendix A**.

### 2.1.4 Hydrography and Climate

The Bitterroot Mountains contribute nearly four times as many tributary streams as the drier Sapphire Mountains (Briar and Dutton, 2000). The Bitterroot Mountains also receive considerably more precipitation than the Sapphire Range. Annual average precipitation ranges from 13 inches in the valley, 32 inches in the Sapphire Mountains, and 83 inches in the Bitterroot Mountains, with the wettest months being May and June. **Map A-11** in **Appendix A** shows the distribution of average annual precipitation.

Stream flow in the TPA generally peaks in late spring, declines in the summer, and remains stable through the winter (Briar and Dutton, 2000). Monthly mean discharges in the mainstem Bitterroot River vary over an order of magnitude. Statistically, flow peaks in June and is lowest in January. Annual peak flows occur almost exclusively (>97%) in May and June. See **Map A-9** for the locations of stream gages and **Figures A-1 through A-4** for streamflow data (**Appendix A**).

Temperature patterns reveal that July is the hottest month and January is the coldest throughout the watershed. Summertime highs are typically in the low eighties (°F) and winter lows are in the upper teens (°F). See **Map A-11** in **Appendix A**.

## 2.2 Ecological Parameters

### 2.2.1 Vegetation and Fire History

The primary cover in the TPA is conifer forest. Spruce-Fir communities dominate in the Bitterroot Range. Lodgepole Pines are more common in the Sapphire Range. **Maps A-12 and A-13** in **Appendix A** illustrate land covers found in the TPA. Large areas of the TPA have burned within the last two decades (see **Map A-15**), particularly in the Sapphire Range. The Bear and Coyote fires of 2000 burned much of the southeastern portion of the TPA, an area that includes the headwaters of Skalkaho Creek and much of the drainages of Sleeping Child and North Fork Rye Creeks.

### 2.2.2 Aquatic Life

Two fish species found in the TPA are of particular note. Bull trout are designated "threatened" by the U.S. Fish and Wildlife Service (USFWS). Westslope cutthroat trout are designated "Species of Concern" by Montana Department of Fish, Wildlife and Parks. Within the planning area, the USFWS has designated 131 miles of stream as bull trout critical habitat. Critical habitat is designated in the Bitterroot River and in Blodgett, Burnt Fork, Fred Burr, Mill, Skalkaho, and Sleeping Child Creeks. Non-native brook, rainbow and brown trout are also present in the TPA. Fish species distribution is shown in **Map A-14** in **Appendix A**.

## 2.3 Cultural Parameters

### 2.3.1 Population and Land Ownership

An estimated 68,000 persons lived within the TPA in 2000 (NRIS,2002). Nearly half (33,093) of that population is reported from Missoula County, which includes portions of Missoula and its southern suburbs. Some of the population is concentrated in or near the towns and unincorporated communities: Hamilton, Lolo, Stevensville, Grantsdale, Florence, Victor, Pinesdale, Darby, Corvallis and Woodside. These communities had a cumulative population of 13,584 in the 2000 census. The remaining population is distributed across the valley floor. Much of the TPA is unpopulated. Census data are shown in **Map A-16** in **Appendix A**.

The USFS is the dominant landholder in the Bitterroot TMDL Planning Area., which administers 57% of the TPA, mostly in the higher elevations. Private land is extensive, however. Individual private smallholdings comprise 33.5% of the TPA; Plum Creek Timber Company owns another 7% of the TPA. Land ownership data is shown in **Map A-17** in **Appendix A**.

### 2.3.2 Land Cover and Land Use

Land cover is dominated by evergreen forest (see **Map A-12**). The valley floor however is a mixture of developed property, grassland, mixed forest, and shrubland. The Bitterroot TPA contains portions of both the Bitterroot and Lolo National Forests. Within the Bitterroot portions of the national forests, 88,228 acres have been harvested between 1906 and 2007. Timber harvests have ranged in size from a low of an acre to a high of 468 acres. **Map A-21** in **Appendix A** shows the majority of timber harvests have occurred in the northeastern and southwestern portions of the planning area.

The principal transportation routes in the TPA are US Highways 93 and 12 (**Map A-19**). Highway 93 runs the length of the Bitterroot Valley, and Highway 12 runs along Lolo Creek. Mining was not prominent in the Bitterroot Valley. Abandoned and inactive mines are present, but at relatively low density (**Map A-20**). A substantial quantity of streamflow within the Bitterroot River watershed is diverted and used for irrigation throughout the valley. **Map A-18** in **Appendix A** shows locations of irrigation diversions and dams within the TPA.

### 2.3.3 Wastewater

The communities of Hamilton, Lolo, Stevensville, Victor, Darby and Corvallis are sewered. Hamilton, Lolo, Stevensville and Darby systems discharge to surface water. There are multiple groundwater discharge permits for human waste disposal within the TPA as well. **Tables B4-4** and **B4-5** in **Appendix B** contain a list of permitted facilities, including general stormwater permits for industrial and mining activities.

DEQ estimates that the TPA includes ~18,000 residential septic systems. The estimate is based upon a GIS layer of residential structures. The highest densities are clustered south of Missoula, and around Lolo and Hamilton. Other population centers such as Grantsdale, Darby, Woodside, Victor, Stevensville, and Florence corresponded to increased density of septic systems, as compared with the "background" density of 11-50 drain fields per square mile across much of the valley. Septic system density and permitted wastewater discharge locations are shown on **Map A-22** in **Appendix A**.

# 3.0 - MONTANA WATER QUALITY STANDARDS

The goal of the federal Clean Water Act is to ensure that the quality of all surface waters is capable of supporting all designated uses. Water quality standards also form the basis for impairment determinations for Montana's 303(d) list, TMDL water quality improvement goals, formation of TMDLs and allocations, and standards attainment evaluations. The Montana water quality standards include four main parts: 1) stream classifications and designated uses, 2) numeric and narrative water quality criteria designed to protect the designated uses, 3) nondegradation provisions for existing high quality waters, and 4) prohibitions of various practices that degrade water quality. The components applicable to this document are reviewed briefly below. More detailed descriptions of the Montana water quality standards that apply to Bitterroot TPA streams can be found **Appendix C**.

## 3.1 BITTERROOT RIVER WATERSHED STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Classification is the designation of a single use or group of uses to a waterbody based on the potential of the waterbody to support those uses. All Montana waters are classified for multiple beneficial uses. All streams and lakes within the Bitterroot River watershed are classified B-1 which specifies that all of the following uses must be supported: 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. On the "2010 Water Quality Integrated Report", 28 waterbody segments are listed as not supporting or partially supporting one or more beneficial uses (**Table 3-1**). Waterbodies that are not supporting or partially supporting a beneficial use are impaired and require a TMDL.

While some of the Bitterroot River watershed streams might not actually be used for a specific use (e.g. drinking water supply) the quality of the water must be maintained at a level that can support that use to the extent possible based on a stream's natural potential. More detailed descriptions of Montana's surface water classifications and designated beneficial uses are provided in **Appendix C**.

**Table 3-1. Impaired Waterbodies and their Beneficial Use Support Status on the "2010 Water Quality Integrated Report" in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Use Class | Agriculture | Aquatic Life | Cold Water Fishery | Drinking Water | Industry | Primary Contact Recreation |
|---|---|---|---|---|---|---|---|---|
| **Ambrose Creek**, headwaters to mouth (Threemile Creek) | MT76H004_120 | B-1 | F | N | N | X | F | P |
| **Bass Creek**, Selway-Bitterroot Wilderness boundary to mouth (un-named creek), T9N R20W S3 | MT76H004_010 | B-1 | F | P | P | F | F | F |
| **Bear Creek**, Selway-Bitterroot Wilderness boundary to mouth (Fred Burr Creek), T7N R20W S7 | MT76H004_031 | B-1 | F | X | X | X | F | P |
| **Bitterroot River**, East and West Forks to Skalkaho Creek | MT76H001_010 | B-1 | F | P | P | F | F | F |

**Table 3-1. Impaired Waterbodies and their Beneficial Use Support Status on the "2010 Water Quality Integrated Report" in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Use Class | Agriculture | Aquatic Life | Cold Water Fishery | Drinking Water | Industry | Primary Contact Recreation |
|---|---|---|---|---|---|---|---|---|
| **Bitterroot River**, Skalkaho Creek to Eightmile Creek | MT76H001_020 | B-1 | F | P | P | X | F | P |
| **Bitterroot River**, Eightmile Creek to mouth (Clark Fork River) | MT76H001_030 | B-1 | F | P | P | F | F | F |
| **Blodgett Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River) | MT76H004_050 | B-1 | F | P | P | X | F | P |
| **Kootenai Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River) | MT76H004_020 | B-1 | F | P | P | X | F | P |
| **Lick Creek**, headwaters to mouth (Bitterroot River) | MT76H004_170 | B-1 | F | P | P | F | F | P |
| **Lolo Creek**, Mormon Creek to mouth (Bitterroot River) | MT76H005_011 | B-1 | F | P | P | X | F | P |
| **Lolo Creek**, Sheldon Creek to Mormon Creek | MT76H005_012 | B-1 | F | P | P | X | F | F |
| **Lolo Creek**, headwaters to Sheldon Creek | MT76H005_013 | B-1 | F | P | P | X | F | F |
| **Lost Horse Creek**, headwaters to mouth (Bitterroot River) | MT76H004_070 | B-1 | F | F | F | X | F | P |
| **McClain Creek**, headwaters to mouth (Sin-tin-tin-em-ska Creek), T11N R20W S23 | MT76H004_150 | B-1 | F | P | P | X | F | X |
| **Mill Creek**, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek), T7N R20W S19 | MT76H004_040 | B-1 | X | X | P | X | X | P |
| **Miller Creek**, headwaters to mouth (Bitterroot River) | MT76H004_130 | B-1 | F | P | P | F | F | P |
| **Muddy Spring Creek**, headwaters to mouth (Gold Creek) T7N R19W S2 | MT76H004_180 | B-1 | F | P | P | F | F | F |
| **North Burnt Fork Creek**, confluence with South Burnt Fork Creek to mouth (Bitterroot River) | MT76H004_200 | B-1 | F | P | P | F | F | F |
| **North Channel Bear Creek**, headwaters to the mouth (Fred Burr Creek), T8N R20W S32 | MT76H004_032 | B-1 | F | X | X | X | F | P |
| **North Fork Rye Creek**, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby) | MT76H004_160 | B-1 | F | P | P | X | F | F |
| **Rye Creek**, North Fork to mouth (Bitterroot River) | MT76H004_190 | B-1 | F | P | P | X | F | X |
| **Skalkaho Creek**, headwaters to mouth (Bitterroot River) | MT76H004_100 | B-1 | F | F | F | N | F | P |

**Table 3-1. Impaired Waterbodies and their Beneficial Use Support Status on the "2010 Water Quality Integrated Report" in the Bitterroot TMDL Planning Area**

| Waterbody & Location Description | Waterbody ID | Use Class | Agriculture | Aquatic Life | Cold Water Fishery | Drinking Water | Industry | Primary Contact Recreation |
|---|---|---|---|---|---|---|---|---|
| **Sleeping Child Creek**, headwaters to mouth (Bitterroot River) | MT76H004_090 | B-1 | F | P | P | X | F | P |
| **South Fork Lolo Creek**, Selway-Bitterroot Wilderness boundary to mouth (Lolo Creek) | MT76H005_020 | B-1 | F | P | P | F | F | P |
| **Sweathouse Creek**, headwaters to mouth (Bitterroot River) | MT76H004_210 | B-1 | X | P | P | X | X | N |
| **Threemile Creek**, headwaters to mouth (Bitterroot River) | MT76H004_140 | B-1 | F | N | N | X | F | X |
| **Tin Cup Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River) | MT76H004_080 | B-1 | F | P | P | F | F | F |
| **Willow Creek**, headwaters to mouth (Bitterroot River) | MT76H004_110 | B-1 | F | P | P | F | F | P |

F = Fully Supporting, P = Partially Supporting, N = Not Supporting, X = Not Assessed

## 3.2 Bitterroot River Watershed Water Quality Standards

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria that are designed to protect the designated uses. **Appendix C** defines each of these. For the sediment and temperature TMDL development in the Bitterroot TPA, only the narrative standards are applicable.

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. Narrative standards describe either the allowable condition or an allowable increase of a pollutant over "naturally occurring" conditions or pollutant levels. DEQ uses a reference condition to determine whether or not narrative standards are being achieved.

Reference condition is defined as 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 and temperature narrative water quality standards that apply to the Bitterroot TPA are summarized in **Appendix C**.

# 4.0 - Description of TMDL Components

A TMDL is the pollutant loading capacity for a particular waterbody and refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. Therefore, when a TMDL is exceeded, the waterbody will be impaired.

More specifically, a TMDL is the sum of the allowable loading from all sources to the waterbody. These loads are applied to individual sources or categories of sources as a logical method to allocate water quality protection responsibilities and overall loading limits within the contributing watershed(s). The allocated loads are referred to as wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. Natural background loading is considered a type of nonpoint source and therefore represents a specific load allocation. In addition, the TMDL includes a Margin of Safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The inclusion of a MOS results in less load allocated to one or more WLAs or LAs to help ensure attainment of water quality standards.

TMDLs are expressed by the following equation which incorporates the above components:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

The allowable pollutant load must ensure that the waterbody being addressed by the TMDL will be able to attain and maintain water quality standards for all applicable seasonal variations in streamflow, and pollutant loading. **Figure 4-1** is a schematic diagram illustrating 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.

The major components that go into TMDL development are target development, source quantification, establishing the total allowable load, and allocating the total allowable load to sources. Although the way a TMDL is expressed may vary by pollutant, these components are common to all TMDLs, regardless of pollutant. Each component is described in further detail below.

The following two sections of the document (**Sections 5 and 6**) are organized by the two pollutants of concern in the Bitterroot TPA: sediment and temperature. Each section includes a discussion on the waterbody segments of concern, how the pollutant of concern is impacting beneficial uses, the information sources and assessment methods to evaluate stream health and pollutant source contributions, water quality target development along with a comparison of existing conditions to targets, quantification of loading from identified sources, the determination of the allowable loading (TMDL) for each waterbody, and the allocations of the allowable loading to sources.

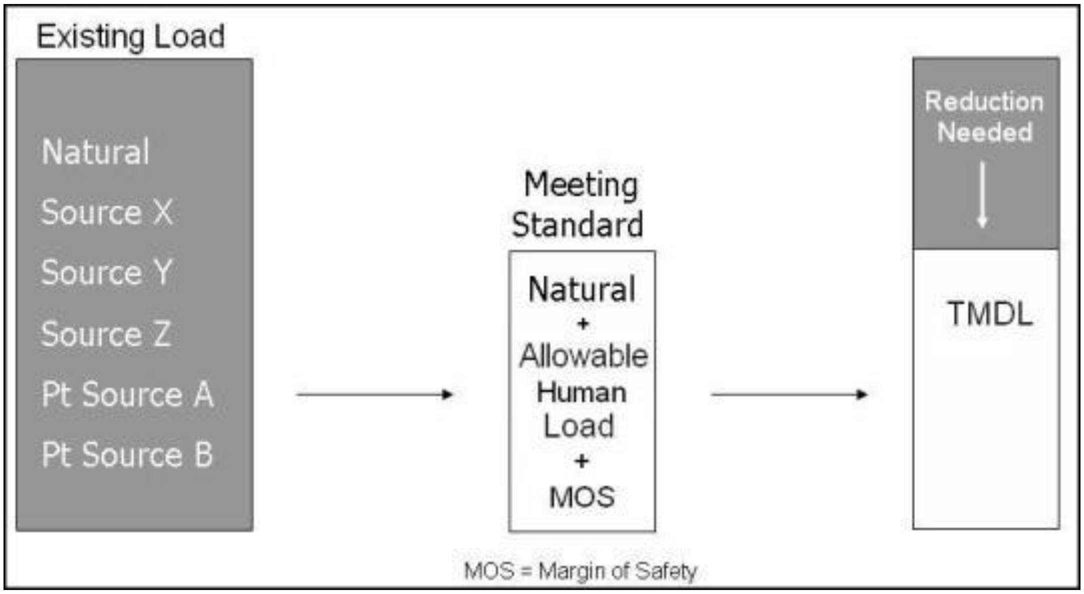



**Figure 4-1. Schematic example of TMDL development**

## 4.1 Target Development

Because loading capacity is evaluated in terms of meeting water quality standards, quantitative water quality targets are developed to help assess the condition of the waterbody relative to the applicable standard(s) and to help determine successful TMDL implementation. This document outlines water quality targets for each pollutant of concern in the Bitterroot TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For pollutants with established numeric water quality standards, the numeric value(s) within the standard(s) are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets provide a site-specific interpretation of the narrative standard(s), along with an improved understanding of impairment conditions. Water quality targets typically include a suite of in-stream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to provide benchmarks to evaluate overall success of restoration activities. By comparing existing stream conditions to target values, there will be 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. Source assessments often have to evaluate the seasonal nature and ultimate fate of the pollutant loading since water quality impacts can vary throughout the year. The source assessment usually helps to further define the extent of the problem by putting human caused loading into context with natural background loading.

A pollutant load is usually quantified for each point source of the pollutant permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Most other pollutant sources, typically referred to as nonpoint sources, are quantified by source categories such as unpaved roads and/or by land uses such as crop production or forestry. These source categories or land uses can be further divided by ownership such as federal, state, or private. Alternatively, a sub-watersheds or tributaries approach can be used, whereby most or all sources in a sub-watershed or tributary are combined for quantification purposes.

The source assessments are performed at a watershed scale because all potentially significant sources of the water quality problems must be evaluated. The source quantification approaches may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading (40CFR 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 and sensible time period necessary to comply with the applicable water quality standard(s). Although the concept of allowable daily load is incorporated into the TMDL term, a daily loading period 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 using a time period consistent with the application of the water quality standard(s) and consistent with established approaches to properly characterize, quantify, and manage pollutant sources in the watershed. For example, sediment TMDLs may be expressed as an allowable yearly load whereas a TMDL for metals may be expressed as a daily average concentration.

Where numeric water quality standards exist for a stream, the TMDL or allowable loading, typically represents the allowable concentration multiplied by the flow of water over the time period of interest. This same approach can be applied for situations where a numeric target is developed to interpret a narrative standard and the numeric value is based on an in-stream concentration of the pollutant of concern.

For some narrative standards such as those relating to sediment, there is often a suite of targets based on stream substrate conditions and other similar indicators. In many of these situations, it is difficult to link the desired target values to highly variable and often episodic in-stream loading conditions. In these situations, 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 Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period as discussed above.

## 4.4 Determining Allocations

Once the loading capacity (i.e. TMDL) is determined, that total must be divided, or allocated, among the contributing sources. In addition to basic technical and environmental considerations, this step introduces economic, social, and political considerations. The allocations are often determined by quantifying feasible and achievable load reductions associated with the application of reasonable land, soil, and water conservation practices. Reasonable land, soil, and water conservation practices generally include best management practices (BMPs), but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses. It is important to note that implementation of the TMDL does not conflict with water rights or private property rights. **Figure 4-2** contains a schematic diagram of 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.

Under the current regulatory framework for development of TMDLs, flexibility is allowed in the expression of 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, such as a percent increase in canopy density for temperature TMDLs.

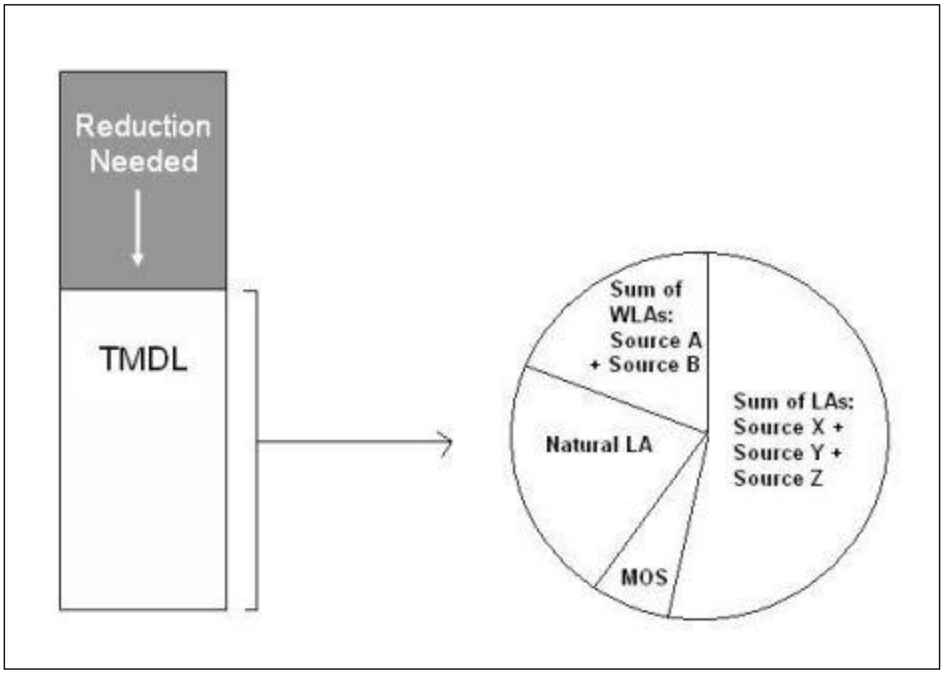



**Figure 4-2. Schematic diagram of TMDL and allocations**

Incorporating a margin of safety is a required component of TMDL development. The MOS accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. 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 (Environmental Research Laboratory-Duluth, 1999).

# 5.0 - SEDIMENT

This section focuses on sediment as an identified cause of water quality impairments in tributaries in the Bitterroot TMDL Planning Area (TPA). It describes: 1) the mechanisms by which sediment can impair beneficial uses, 2) the specific stream segments of concern, 3) the available data pertaining to sediment impairment characterization in the watershed, 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.

The term "sediment" is used in this document to refer collectively to two pollutant categories: sedimentation/siltation and bottom deposits.

## 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 vegetation and natural instream barriers, such as large woody debris, beaver dams, or overhanging vegetation, help trap sediment and build channel and floodplain features. When these barriers are absent, or excessive sediment loading enters the system from increased bank erosion or other sources, it may alter channel form and function. It can also negatively affect fish and other aquatic life by increasing turbidity and causing excess sediment to accumulate in critical aquatic habitats.

More specifically, sediment may block light and cause a decline in primary production of fish. It can also interfere with reproduction and survival of fish and macroinvertebrate. Fine sediment deposition reduces the availability of suitable spawning habitat for salmonid fishes and can smother eggs or fry. 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). 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 effecting recreational use. Excessive sediment can increase filtration costs for water treatment facilities that provide safe drinking water.

## 5.2 STREAM SEGMENTS OF CONCERN

A total of 12 waterbody segments in the Bitterroot TPA, not including the Bitterroot River, appear on the 2010 Montana 303(d) List because of sediment impairments **(Table 5-1)**; Listing causes are bottom deposits and sedimentation/siltation. The listed waterbodies include Lick Creek, Lolo Creek (3 segments), McClain Creek, Miller Creek, Muddy Spring Creek, North Burnt Fork Creek, Rye Creek, Sleeping Child Creek, Threemile Creek, and Willow Creek. Seven of those waterbodies are also listed for habitat alterations, which are non-pollutants (noted in **Table 5-1**). Ambrose, Bear, Blodgett, Kootenai, Lost Horse, Mill, North Fork Rye, Skalkaho, South Fork Lolo, Sweathouse, Bass, and Tin Cup creeks are also listed for habitat alterations but were not listed for sediment impairments (**Table 5-2**). TMDLs are limited to pollutants; however, streams listed for habitat alterations were also assessed because habitat alterations are frequently associated with sediment impairment.

**Table 5-1. Waterbody Segments in the Bitterroot TPA with Sediment Listings and Possible Sediment-related Non-Pollutant Listings on the 2010 303(d) List**

| Waterbody Name | Waterbody Segment ID | Sediment Pollutant Listing | Non-Pollutant Causes of Impairment Potentially Linked to Sediment Impairment |
|---|---|---|---|
| Lick Creek | MT76H004_170 | Sedimentation/Siltation | Alteration in stream-side or littoral vegetative covers |
| Lolo Creek (headwaters to Sheldon Creek) | MT76H005_013 | Sedimentation/Siltation | Physical substrate habitat alterations |
| Lolo Creek (Mormon Creek to Mouth) | MT76H005_011 | Sedimentation/Siltation | Physical substrate habitat alterations and Low flow alterations |
| Lolo Creek (Sheldon Creek to Mormon Creek) | MT76H005_012 | Sedimentation/Siltation | Physical substrate habitat alterations |
| McClain Creek | MT76H004_150 | Sedimentation/Siltation | |
| Miller Creek | MT76H004_130 | Sedimentation/Siltation | Alteration in stream-side or littoral vegetative covers |
| Muddy Spring Creek | MT76H004_180 | Sedimentation/Siltation | |
| Rye Creek | MT76H004_190 | Sedimentation/Siltation | Alteration in stream-side or littoral vegetative covers |
| Sleeping Child Creek | MT76H004_090 | Sedimentation/Siltation | |
| Threemile Creek | MT76H004_140 | Sedimentation/Siltation | Low flow alterations |
| Willow Creek | MT76H004_110 | Sedimentation/Siltation | Alteration in stream-side or littoral vegetative covers |
| North Burnt Fork Creek | MT76H004_200 | Bottom deposits | |

**Table 5-2: Waterbody Segments in the Bitterroot TPA in the 2010 Integrated Report with Possible Sediment-Related Non-Pollutant Listings**

| Waterbody Name | Waterbody Segment ID | Non-Pollutant Causes of Impairment Potentially Linked to Sediment Impairment |
|---|---|---|
| Ambrose Creek | MT76H004_120 | Physical substrate habitat alterations |
| Kootenai Creek | MT76H004_020 | Alteration in stream-side or littoral vegetative covers and Low flow alterations |
| Mill Creek | MT76H004_040 | Alteration in stream-side or littoral vegetative covers and Low flow alterations |
| North Fork Rye Creek | MT76H004_160 | Alteration in stream-side or littoral vegetative covers |
| South Fork Lolo Creek | MT76H005_020 | Physical substrate habitat alterations and Low flow alterations |
| Sweathouse Creek | MT76H004_210 | Alteration in stream-side or littoral vegetative covers and Low flow alterations |
| Tin Cup Creek | MT76H004_080 | Alteration in stream-side or littoral vegetative covers |
| Bass Creek | MT76H004_010 | Low flow alterations |
| Bear Creek | MT76H004_030 | Low flow alterations |
| Blodgett Creek | MT76H004_050 | Low flow alterations |
| North Channel Bear Creek | MT76H004_032 | Low flow alterations |
| Skalkaho Creek | MT76H004_100 | Low flow alterations |
| Lost Horse Creek | MT76H004_070 | Low flow alterations |

## 5.3 Information Sources and Assessment Methods to Characterize Sediment Conditions

For TMDL development, information sources and assessment methods fall within two general categories: characterizing overall stream health with focus on sediment and related water quality conditions (discussed in this section) and quantifying sources of sediment loading in the watershed (discussed in **Section 5.6**).

### 5.3.1 Summary of Information Sources

To characterize sediment conditions for TMDL development purposes, a sediment data compilation was completed and additional monitoring was performed during 2007. The below listed data sources were used to characterize water quality and/or develop TMDL targets. The first three are described in the following sections:

- DEQ assessment files
- DEQ 2007 sediment and habitat assessments
- Relevant local and regional reference data
- GIS data layers and publications regarding historical land use, channel stability, and sediment conditions

#### *5.3.1.1 DEQ Assessment File*

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 1991 and 2005, as well as other historical information collected or obtained by DEQ. The files include information on sediment water quality characterization, as well as information on potentially significant sources of sediment. The files also include information on determinations of non-pollutant impairment and associated rationale. Files are available electronically on the DEQ's website: http://cwaic.mt.gov/.

#### *5.3.1.2 DEQ 2007 Sediment and Habitat Assessment Work*

To help characterize instream sediment conditions and aid in TMDL development, field measurements of channel morphology and riparian and instream habitat parameters were collected by DEQ in 2007 from 32 monitoring reaches on the listed waterbodies and other tributaries **(Appendix D** and **Map A-23** in **Appendix A)**. To aid in the characterization of bank erosion, an additional 23 reaches were assessed in 2007 for bank erosion severity and source identification (**Appendix E** and **Map A-23** in **Appendix A**).

Initially, all streams of interest were assessed by aerial survey. Four main attributes not linked to human activity were looked at: 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.

Next, the aerial assessment identified near-stream land uses because land management practices can have a significant influence on stream morphology and sediment characteristics. This process stratifies streams into reaches, allowing reaches with the same natural morphological characteristics to be compared. The process also identifies reaches where land management practices could further influence stream morphology. Along with field reconnaissance, stratifying streams provided the basis for selecting the monitoring reaches. The selected monitoring reaches represent various reach characteristics and anthropogenic influences. Because the primary goal of sediment TMDL development is to further characterize sediment impairment conditions, we tended to sample reaches where human influences would most likely lead to impairment conditions. Thus, the sample is not random and stream reaches do not necessarily represent all potential impairment and non-impairment conditions. Instead, this targeted sampling design aims to assess a representative subset of reach types, while ensuring that reaches in 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); therefore, these stream conditions were the focus of the field effort (**Table 5-3**). Although the TMDL development process necessitates this targeted sampling design, DEQ acknowledges that this approach yields less certainty regarding conditions in 1st order streams and higher gradient reaches, and that conditions within sampled reaches are not necessarily representative of conditions throughout the entire stream.

Ecoregion and geology play an important role in the Bitterroot TPA. There are three level III ecoregions in the planning area: Idaho Batholith, Middle Rockies, and Northern Rockies (Woods, et al., 2002). Most of the 2007 DEQ field work sites were sampled in the Middle Rockies ecoregion; however, streams located at least partially in the Idaho Batholith ecoregion are influenced by its ecoregion's unique geological makeup, which is mountainous, deeply dissected, partially glaciated, and underlain by granitic rocks. The soils derived from these granitic rocks are highly erodible when vegetation is removed (Omernik, 1987). Therefore, streams originating in the Idaho Batholith ecoregion that were assessed in 2007 are considered to be part of that ecoregion. Additionally, McClain Creek and Lolo Creek are split between two ecoregions with similar characteristics: the Northern Rockies and Middle Rockies. Because of the similar nature of these ecoregions, these streams will be assigned an ecoregion based on where the majority of the stream is located. McClain Creek resides partly in the Northern Rockies ecoregion with the majority of the stream located in the Middle Rockies ecoregion. The lowest segment of Lolo Creek is partially situated in the Middle Rockies ecoregion; however, the majority of the stream is located in the Northern Rockies ecoregion. Consequently, streams are sequenced by ecoregion accordingly: <u>Idaho Batholith</u>: Bass, Kootenai, Sweathouse, Bear, Mill, Blodgett, Lost Horse, Lick, Tin Cup, Rye North Fork Rye, Sleeping Child, and South Fork Lolo; <u>Middle Rockies</u>: Miller, McClain, Threemile, Ambrose, North Burnt Fork, Muddy Spring, Willow, and Skalkaho; <u>Northern Rockies</u>: Lolo (3 segments) **(Map A-23** in **Appendix A)**.

**Table 5-3. Reach Types Assessed in the Bitterroot TPA**

| Level III Ecoregion Sequence | Gradient | Strahler Stream Order | Confinement | Reach Type | Number of Monitoring Sites | Monitoring Sites |
|---|---|---|---|---|---|---|
| Idaho Batholith | 0-<2% | 2 | U | IB-0-2-U/M | 2 | KOOT-52, MILL-50 |
| | | 3 | U | IB-0-3-U/M | 5 | BEAR-30, LOST-43, NBEAR-08, SWEA-29, TINC 31/32 |
| | | 4 | U | IB-0-4-U/M | 3 | RYEC-28, RYEC-36, SLEE-43 |
| | 2 to <4% | 2 | U | IB-2-2-U/M | 5 | BASS-24, BASS-27, BLOD-49, LICK-19, MILL-43 |
| | | 3 | U | IB-2-3-U/M | 2 | NFRC-22,SFLO-43 |
| Middle Rockies | 0-<2% | 2 | U | MR-0-2-U/M | 1 | MILR-21 |
| | | 3 | U | MR-0-3-U/M | 5 | AMBR-30, MILR-33, NFBC-11, NFBC-15, WILL-38 |
| | | 4 | U | MR-0-4-U/M | 3 | SKAL-33, SKAL-48, THRE-35 |
| | 2 to <4% | 1 | U | MR-2-1-U/M | 1 | MILR-11 |
| | | 3 | U | MR-2-3-U/M | 1 | WILL-28 |
| | >4% | 2 | U | MR-4-2-U/M | 1 | MCCL-15 |

**Table 5-3. Reach Types Assessed in the Bitterroot TPA**

| Level III Ecoregion Sequence | Gradient | Strahler Stream Order | Confinement | Reach Type | Number of Monitoring Sites | Monitoring Sites |
|---|---|---|---|---|---|---|
| Northern Rockies | 0-<2% | 4 | U | NR-0-4-U/M | 3 | LOLO-26, LOLO-34, LOLO-56 |

The field parameters assessed in 2007 include standard measures of stream channel morphology, fine sediment, stream habitat, riparian vegetation, and streambank erosion. To help increase sample sizes and capture variability in assessed streams, reaches ranged from 500 to 2,000 feet (depending on the channel bankfull width) and were broken into five cells. Generally, channel morphology and fine sediment measures were performed in three of the cells, and stream habitat, riparian, and bank erosion measures were performed in all cells. Field parameters are briefly described in **Section 5.4**, and methodology descriptions and summaries of field data are found in **Appendix D**.

### *5.3.1.3 Relevant Local and Regional Reference Data*

Regional reference data was derived from the Bitterroot National Forest (BNF) reference dataset, the Beaverhead Deerlodge National Forest (BDNF) reference dataset, the Kootenai National Forest Libby District (KNFLD) reference dataset, and the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO). The BNF data was collected between 1990 and 2006, including 50 reference sites in the Idaho Batholith ecoregion and 27 reference sites in the Middle Rockies ecoregion. The BDNF data was collected between 1991 and 2002, including approximately 260 sites located in the Middle Rockies ecoregion in southwest Montana (Bengeyfield, unpublished 2002). The KNFLD data was collected between 1995 and 2004 and includes 77 reference sites located in the Northern Rockies ecoregion. The PIBO reference dataset includes data collected between 2001 and 2008 from USFS and BLM sites throughout the Pacific Northwest. To increase the comparability of the data to conditions in the Bitterroot TPA, only data collected in the Middle Rockies ecoregion (64 sites), Idaho Batholith ecoregion (23 sites), and Northern Rockies ecoregion (29 sites) in Montana was evaluated.

## 5.4 Water Quality Targets and Comparison with Existing Conditions

The concept of water quality targets was presented in **Section 4.1**: this section provides the rationale for each sediment-related target parameter. In addition it discusses the basis of the target values and compares those values with available data for the stream segments of concern, as well as the additional stream segments that were monitored in the Bitterroot TPA (**Tables 5-1** and **5-2**). Although placement on the 303(d) list indicates impaired water quality, comparing water quality targets with existing data helps define the level of impairment and establishes a benchmark to evaluate the effectiveness of restoration efforts.

In developing targets, natural variation throughout the river continuum must be considered. 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 to use reference site data: however, modeling, professional judgment, and literature values may also be used. DEQ defines "reference" as the condition of a waterbody such that it supports 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 and current land-use activities. 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 from human activity.

The basis for the value for each water quality target may vary depending on the availability and comparability of reference data to the 2007 DEQ data. Relevant regional and local reference data is preferred for target development. However, if discrepancies exist between the regional reference data and DEQ data because of data collection methods and their application, or because of the type or condition of the investigated streams such that the available reference data is no longer deemed appropriate for comparison, then statistics may be applied to the DEQ data and used for target development. DEQ uses several statistical approaches for target development, including using percentiles of reference data or percentiles of the entire sample dataset, if reference data are limited. For example, if low values reflect desired conditions, 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, the representativeness and range of variability of the data, the severity of human disturbance to streams , and the dataset size all have a bearing on which percentile to use to reflect the desired condition. For each target, descriptive statistics were generated relative to any available reference data (e.g., BNF, PIBO, or KNFLD), as well as for the entire sample dataset. The preferred approach for setting target values is to use reference data, where preference is given to the most protective reference dataset that uses collection methods comparable to those for the waterbody of interest. Additionally, the target value for some parameters may apply to all streams in the Bitterroot TPA, whereas others may be stratified by reach type characteristics (i.e., ecoregion, gradient, stream order, and/or confinement) or by Rosgen stream type. 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. MOS is discussed in additional detail in **Section 5.8**.

### 5.4.1 Water Quality Targets

The sediment water quality targets for the Bitterroot TPA are summarized in **Table 5-4** and described in detail in the following sections. Listed in order of preference, sediment-related targets for the Bitterroot TPA are based on a combination of reference data from the Bitterroot National Forest (BNF) dataset, PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO) dataset, Beaverhead Deerlodge National Forest (BDNF) dataset, Kootenai National Forest Libby District (KNFLD) dataset, along with data collected from the Montana DEQ in 2007. Target values from the Upper Lolo TPA were also considered in target development in relationship to the Northern Rockies ecoregion. **Appendix D** provides a summary of the DEQ 2007 sample data, including many of the statistics used to help with target development.

Consistent with EPA guidance for sediment TMDLs (EPA, 1999), water quality targets for the Bitterroot 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 on aquatic life habitat are given the most weight (i.e., fine sediment and biological indices). The water quality targets presented in this section (see **Table 5-4**) are based on the best available science and information at publication. However, during future TMDL review, targets will be examined for their applicability and may be modified under certain situations, such as a better understanding of reference conditions or assessment procedure improvements, including new or modified field methods. In some cases, new targets may be added in the future to better characterize sediment conditions.

For all water quality targets, future surveys should document stable (if meeting target) or improving trends. The exceedance of one target value does not necessarily equate to impairment. Instead, the degree to which one or more targets are exceeded is taken into account; thus, 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 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. A description and justification of the target parameters used in the analysis is included in the sections that follow, and regional reference and DEQ summary statistics considered for target development are included in **Appendix F**.

**Table 5-4. Sediment Targets**

| Parameter Type | Target Description | Criterion |
|---|---|---|
| **Fine Sediment** | Percentage of fine surface sediment in riffles < 6mm (reach average via pebble count method) | Idaho Batholith : ≤ 14<br>Middle Rockies : ≤ 14<br>Northern Rockies : ≤ 15<br>E channel type : ≤ 45 for IB and ≤ 36 for MR |
| | Percentage of fine surface sediment in riffles < 2mm (reach average via pebble count method) | Idaho Batholith : ≤ 8<br>Middle Rockies : ≤ 10<br>Northern Rockies : ≤ 7<br>E channel type : All ecoregions ≤ 20 |
| | Percentage of fine surface sediment <6mm in riffles and pool tails (reach average via grid toss method) | Riffles:<br>All Ecoregions: ≤ 10<br>Pools:<br>Idaho Batholith : ≤ 10<br>Middle Rockies : ≤ 6<br>Northern Rockies : ≤ 8 |
| **Channel Form and Stability** | Bankfull width/depth ratio<br>(median of channel x-sec measurements) | Bankfull width ≤ 35' : ≤ 16<br>Bankfull width > 35' : ≤ 29<br>E channel : 6-11 |
| | Entrenchment ratio<br>(median of channel x-sec measurements) | B channel type: ≥ 1.5<br>C channel type: ≥ 2.5<br>E channel type: ≥ 2 |
| **Instream Habitat** | Residual pool depth (reach average) | < 20' bankfull width : ≥ 0.8 (ft)<br>20'-35' bankfull width : ≥ 1.1 (ft)<br>> 35' bankfull width : ≥ 1.3 (ft) |
| | Pools/mile | < 20' bankfull width : ≥ 84<br>20'-35' bankfull width : ≥ 49<br>> 35' bankfull width : ≥ 26 |
| | LWD/mile | < 20' bankfull width : ≥ 573<br>20'-35' bankfull width : ≥ 380<br>> 35' bankfull width : ≥ 195 |
| **Riparian Health** | Percent of streambank with understory shrub cover | ≥ 57% understory shrub cover |

**Table 5-4. Sediment Targets**

| Parameter Type | Target Description | Criterion |
|---|---|---|
| **Sediment Source** | Riffle stability index | <70 for B stream types<br>>45 and <75 for C stream types |
| | Significant and controllable sediment sources | Identification of significant and controllable anthropogenic sediment sources throughout the watershed |
| **Biological Indices** | Macroinvertebrate bioassessment impairment thresholds | Mountain MMI : > 63<br>Valley MMI : > 48<br>O/E : > 0.80 |

### *5.4.1.1 Fine Sediment*

The percent of surface fines less than 6 millimeters (< 6 mm) and 2 millimeters (< 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; Shepard, et al., 1984; Weaver and Fraley, 1991; Suttle, et al., 2004; Bryce, et al., 2010). Excess fine sediment can also decrease macroinvertebrate abundance and taxa richness (Mebane, 2001; Zweig and Rabeni, 2001; Cover, et al., 2008; Bryce, et al., 2010). Literature values for harmful fine sediment thresholds are highly variable because: (1) similar concentrations of sediment can cause different degrees of impairment to different species, and even age classes within a species; (2) the particle size defined as "fine" varies; and (3) some assessment methods measure surficial sediment, while other measures include subsurface fine sediment. Some studies of salmonid and macroinvertebrate survival found an inverse relationship between fine sediment and survival (Suttle, et al., 2004); other studies have concluded the most harmful percentage falls within 10% and 40% fine sediment (Bjorn and Reiser, 1991; Relyea, et al., 2000; Mebane, 2001). A recent 5-year study on 557 U.S. western mountain streams indicates that a minimum-effect sediment level (for pebble count fine sediment ≤ 2 mm) for four sediment sensitive salmonid species, including bull trout and cutthroat trout, is 13%. This same study also found a minimum-effect level (for pebble count fine sediment < 2 mm) of 10% for macroinvertebrates (Bryce, et al., 2010). Targets are developed using a conservative statistical approach (consistent with Montana's water quality standard for sediment as described in **Section 3.1)**, particularly in those streams with the potential for salmonid spawning. Literature values are also taken into consideration as increasing concentrations of fine sediment are known to be harmful to salmonid spawning success, including bull trout and cutthroat trout (Kondolf, 1997; Weaver and Fraley, 1991; Bryce, et al., 2010).

Because geology and soils can differ significantly between ecoregions, fine sediment targets were evaluated within the context of the Level III ecoregions in the Bitterroot TPA. Most sediment-listed waterbodies in the Bitterroot TPA are in the Middle and Northern Rockies Level III ecoregions (**Map A-23** in **Appendix A**). The remainder of sediment-listed or evaluated streams in the TPA originate in the Idaho Batholith Level III ecoregion and flow into the Middle Rockies Level III ecoregion (with the exception of South Fork Lolo Creek, which flows into the Northern Rockies Level III ecoregion). Fine sediment values are similar between these ecoregions for 6 mm pebble counts but vary among the other fine sediment target parameters. Therefore, Bitterroot TPA fine sediment targets are broken out by ecoregion.

**Riffle Substrate Percent Fine Sediment <6mm and <2mm via Pebble Count**

Surface fine sediment measured in riffles by the modified Wolman pebble count (Wolman, 1954) indicates the particle size distribution across the channel width and points to excessive sediment loading in the aquatic habitat. DEQ used a modified Wolman riffle pebble count in the 2007 sediment and habitat assessment.

Several reference datasets were examined during the development of these targets. The BNF reference dataset used a Wolman pebble count method frequently at one representative riffle per reach, instead of an average of pebble counts at multiple riffle sites within each reach, which is used for TMDL related data collection. Additionally, if a riffle was difficult to find, alternate channel forms (glide/run) were used for pebble counts in the BNF data collection, which can result in a higher percentage of fines. The BDNF reference data for pebble count was collected using the "zigzag" method, which includes both riffles and pools. Variances in the BNF and BDNF collection methods likely resulted in a higher percentage of fines than a riffle-only pebble count, the method used for TMDL related data collection, resulting in lower confidence of comparable data (Bunte, et al., 2010). Pebble count reference data from the KNFLD reference dataset were a composite count of riffles and pools. Typically, a composite count can increase the fine sediment percentage values relative to a riffle-only pebble count; however, in a review of the KNFLD field forms, pools did not typically increase the overall percentage of fines, indicating that results between the KNFLD reference dataset and Bitterroot TPA sample dataset are comparable.

Riffle substrate percent fine sediment < 2 mm and < 6 mm targets for the Bitterroot TPA are based on the median of the DEQ 2007 dataset for streams in the Idaho Batholith ecoregion, the 25th percentile of the DEQ 2007 dataset for streams in the Middle Rockies ecoregion, and the 75th percentile of the KNFLD reference dataset for streams in the Northern Rockies ecoregion (**Tables 5-5** and **5-6**). This variable approach used for target value development, as discussed in **Section 5.4** and in detail below, is justified to differing reference methods and varying stream conditions. Most of the streams in the Idaho Batholith ecoregion sequence, sampled in 2007, are listed only for habitat impairments: according to field observations, they appear to be in fair condition and healthier than Middle and Northern Rockies streams, justifying the use of the median. Field observations noted that several of the Middle Rockies streams had significant sources and visible impacts and were comparably unhealthy relative to the Idaho Batholith streams, justifying the use of a 25th percentile. Compared with the reference datasets, it appears the variability in pebble count methods causes problems when relating them to applicable targets, given the statistics in the DEQ collected data, thus justifying the use of the DEQ data over the reference data. On the other hand, the KNFLD reference data compares favorably to the DEQ collected data statistics and the use of the 75th percentile of the KNFLD reference data is therefore an appropriate target choice for this ecoregion, because only a small number of reaches were sampled for the Northern Rockies ecoregion through the 2007 DEQ field effort. These indicators should be assessed based on the reach average pebble count. Due to an inherently high percentage of fines in Rosgen Type E channels, E channel values were excluded from reference data sets and the DEQ sample dataset. E channel targets are based on the applied targets in the Lower Blackfoot TMDL Planning Area (LBFT), which used the 75th percentile of the LBFT dataset for E channels. E channel targets for percent fines < 6 mm are set at ≤ 36 for streams in the Middle Rockies ecoregion and set at ≤ 45 for streams in the Idaho Batholith ecoregion. The latter target is based on similar streams in the LBFT that have granitic geology which can commonly results in a high production of sand-sized sediment. Target values for percent fines < 2 mm are set at ≤ 20, based on applied targets in the LBFT planning area.

**Table 5-5. Percentiles of reference data and 2007 Bitterroot sample data for riffle substrate percent fine sediment <6 mm (pebble count) used for target development.**
Targets are shown in **bold**.

| Level III Ecoregion | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| Idaho Batholith | BNF Reference | 49 | 23 | 33 | |
| | DEQ 2007 | 16 | **14** | | 10 |
| Middle Rockies | BNF Reference | 26 | 20 | 29 | |
| | BDNF Reference | 79 | 11 | 22.5 | |
| | DEQ 2007 | 10 | 23 | | **14** |
| Northern Rockies | KNFLD Reference | 76 | 7 | **15** | |
| | DEQ 2007 | 3 | 16 | | 15 |

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

**Table 5-6. Percentiles of reference data and 2007 Bitterroot sample data for riffle substrate percent fine sediment < 2 mm (pebble count) used for target development.**
Targets are shown in **bold**.

| Level III Ecoregion | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| Idaho Batholith | BNF Reference | 49 | 17 | 24 | |
| | DEQ 2007 | 16 | **8** | | 5 |
| Middle Rockies | BNF Reference | 26 | 16 | 24 | |
| | DEQ 2007 | 10 | 12 | | **10** |
| Northern Rockies | KNFLD Reference | 76 | 4 | **7** | |
| | DEQ 2007 | 3 | 5 | | 4 |

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

In examining the 2007 DEQ data and reference datasets for riffle pebble counts by both ecoregion and Rosgen stream type, data generally show an approximate 10% variation between the "B3/C3's" and "B4/C4's" for 6 mm results and an approximate 6% variation between the "B3/C3's" and "B4/C4's" for 2 mm results. Therefore, when applying target values, an allowance will be considered to adjust the target up or down as much as 5% for 6 mm and as much as 3% for 2 mm, depending on Rosgen channel substrate, if there is a high level of confidence in both the current and potential Rosgen stream type.

**Percent Fine Sediment < 6mm in Riffle via Grid Toss**

Grid toss measurements in riffles are an alternative measure to pebble counts and assess the level of fine sediment accumulation in macroinvertebrate habitat and potential fish spawning sites. Riffle grid toss measurements were not collected for the BNF, BDNF, or KNFLD reference efforts: however, regional riffle grid toss data are available in a report by the Lolo National Forest (Riggers, et al., 1998). Samples were taken at 111 unroaded sites. An interpretation of the distributed data taken at these sites (see Figure 7 in Riggers, 1998) reveals a 75th percentile of approximately 10%. These sites reflect a mix of geologies throughout the Lolo National Forest; however, the values correspond with the 2007 DEQ collected data, with 10% falling between the 75th percentile and median for Idaho Batholith (streams appear healthier), between the 25th and median for Middle Rockies (streams with visible sediment sources), and just above the 25th and median of the Northern Rockies (**Table 5-7**). Grid toss was measured with a 49-point grid and summary statistics were prepared based on the average value of three tosses for each pool and riffle assessed in the Bitterroot TPA in 2007. These indicators should be assessed based on the reach average grid toss value. Due to an inherently high percentage of fines in Rosgen Type E channels, E channel values were excluded from reference data sets and the DEQ sample dataset, and reaches will be evaluated independently.

**Table 5-7. Percentiles of 2007 Bitterroot sample data for riffle substrate percent fine sediment <6mm (grid toss) used for target development.**
Targets are shown in **bold**.

| Level III Ecoregion | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| Idaho Batholith | DEQ 2007 | 15 | 6 | 14 | 4 |
| Middle Rockies | DEQ 2007 | 10 | 15 | 23 | 2 |
| Northern Rockies | DEQ 2007 | 3 | 6 | 7 | 6 |
| Lolo National Forest report (Riggers) | | **10** | | | |

**Percent Fine Sediment <6mm in Pool Tails via Grid Toss**
A 49-point grid toss was used to estimate the percent surface fine sediment < 6 mm in pool tails in the Bitterroot TPA. Three tosses, or 147 points, were performed and averaged for each riffle and pool tail assessed. Reference values for pool tail grid toss measurements are available through the PIBO reference dataset; however, the PIBO reference values vary substantially from the DEQ data. Although methods are similar, when compared with the DEQ dataset, the PIBO dataset appears to be misrepresentative of typical conditions in a reference type setting for this metric in Idaho Batholith and Middle Rockies streams. As a result, because of the closer familiarity with the methods, site selection, and results from the 2007 DEQ dataset, the DEQ data is focused on for pool-tail target development for Idaho Batholith and Middle Rockies streams. As discussed with pebble count percent fine target development (**Section 5.4.1.1**), most of the 2007 sampled streams in the Idaho Batholith ecoregion appear to be in fair condition and healthier than Middle and Northern Rockies streams, justifying the use of the median for Idaho Batholith streams and the 25th percentile for Middle and Northern Rockies streams. However, only a small number of reaches were sampled from just one stream in the Northern Rockies ecoregion and therefore, the median of the PIBO dataset is the most appropriate target because it dataset most closely correlates with the target values from the DEQ dataset in all ecoregions (**Table 5-8**). These indicators should be assessed based on the reach average grid toss value. Due to an inherently high percentage of fines in Rosgen Type E channels, E channel values were excluded from reference data sets and the DEQ sample dataset, and reaches will be evaluated independently.

**Table 5-8. Percentiles of reference data and 2007 Bitterroot sample data for pool tail percent fine sediment <6mm (grid toss) used for target development.**
Targets are shown in **bold**.

| Level III Ecoregion | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| Idaho Batholith | PIBO Reference | 23 | 17 | 25 | |
| | DEQ 2007 | 11 | **10** | | 8 |
| Middle Rockies | PIBO Reference | 64 | 9 | 16 | |
| | DEQ 2007 | 8 | 10 | | **6** |
| Northern Rockies | PIBO Reference | 29 | **8** | 16 | |
| | DEQ 2007 | 3 | 31 | | 24 |

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

### *5.4.1.2 Channel Form and Stability*

**Width/Depth Ratio and Entrenchment Ratio**

The width/depth ratio and the entrenchment ratio are fundamental aspects of channel morphology; each provides a measure of channel stability and indicates a stream’s ability 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 to indicate 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 rather than dissipating energy to 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 (Knighton, 1998; Rowe, et al., 2003; Rosgen, 1996). Width/depth and entrenchment ratios were calculated for each 2007 assessment reach based on five riffle cross-section measurements.

**Width/Depth Ratio Target Development**

The 75th percentile of the Bitterroot National Forest dataset was applied as a target for width/depth ratio. The 2007 DEQ Bitterroot dataset is primarily comprised of B and C channels, and although on average B channels tend to have a smaller width/depth ratio than C channels (Rosgen, 1996), the ratio can vary quite a bit between small and large streams. Therefore, the 75th percentile values of the BNF reference dataset were split into two groups: bankfull widths ≤ 35 feet and bankfull widths ≥ 35 feet (**Table 5-9**). The target width/depth ratios are set at less than or equal to bolded values indicated by channel type and bankfull width (BFW) in **Table 5-9**.

**Table 5-9. Bitterroot TPA tributary targets for width to depth ratio.**

Targets are shown in **bold** and are equal to or less than the bolded value.

| Bankfull Width | Data Source | Summary Statistics | | |
|---|---|---|---|---|
| | | **n** | **Median** | **75th** |
| ≤ 35’ | BNF Reference | 93 | | **16** |
| | DEQ 2007 | 69 | 16 | |
| > 35’ | BNF Reference | 20 | | **29** |
| | DEQ 2007 | 57 | 31 | |

Values exclude E channels. E channel targets are set at a range of 6-11 based on a combination of the 75th percentile of the BNF dataset and ranges applied in completed TMDL documents.

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

Width/depth ratio values are comparable between the Bitterroot National Forest dataset and the median of the Montana DEQ 2007 Bitterroot dataset. The values presented in **Table 5-9** exclude E channels. E channel targets are set as a range from 6 to 11 based on the 75th percentile of the BNF dataset and ranges applied in completed TMDL documents including the Lower and Middle Blackfoot TPAs.

**Entrenchment Ratio Target Development**
The target value for entrenchment ratio is set at ≥ 25th percentile of the BNF reference data (**Table 5-10**). When comparing assessment results with target values, more weight will be given to those values that fail to satisfy the identified target and fail to meet the minimum value associated with literature values for Rosgen stream type (i.e. B=1.4-2.2 ± 0.2, C & E>2.2 ± 0.2) (Rosgen, 1996). Reaches with multiple potential channel types will be evaluated using the lowest target value (e.g., target for B3/C3 = 1.4). The BNF dataset had limited reference data for E channels, therefore E channels should meet the minimum value as identified in Rosgen literature (> 2).

**Table 5-10. Entrenchment targets for the Bitterroot TPA based on BNF reference data**

| Rosgen Stream Type | Sample Size | 25th Percentile of BNF Reference Data |
|---|---|---|
| B | 32 | **1.5** |
| C | 12 | **2.5** |

### *5.4.1.3 Instream Habitat Measures*
For all instream habitat measures (i.e. residual pool depth, pool frequency, and large woody debris frequency), there is available reference data from the KNFLD and PIBO reference datasets. All of the instream habitat measures are important indicators of sediment input and movement, as well as fish and aquatic life support, but they may be given less weight in the target evaluation if they do not seem to be directly related to sediment impacts. Furthermore, their use in evaluating or characterizing impairment should be considered according to whether these measures are linked to fine, course, or total sediment loading impacts.

**Residual Pool Depth**
Residual pool depth (the difference between the maximum depth and the tail crest depth) is a discharge-independent measure of pool depth and indicates 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 (Sedell, et al., 1990). Similar to channel morphology measurements, residual pool depth integrates the effects of several stressors. Pool depth can be decreased by filling with excess sediment, a reduction in channel obstructions (such as large woody debris), and changes in channel form and stability (Bauer and Ralph, 1999). Residual pool depth is typically greater in larger systems. During DEQ sampling in 2007, pools were defined as depressions in the streambed bounded by a “head crest” at the upstream end and a “tail crest” at the downstream end, with a maximum depth that is 1.5 times the pool-tail depth (Kershner, et al., 2004).

Residual pool depths for the 75th percentile of the 2007 DEQ dataset are comparable with the median of the KNFLD reference dataset and the 25th percentile of the PIBO reference dataset (**Table 5-11**). The definition of “pools” for the PIBO protocol matches the definition used for the 2007 Bitterroot sample dataset (therefore the 25th percentile is appropriate), but that used for the KNFLD reference dataset defines pools as slack water areas occupying at least one-third of the bankfull channel with a scour feature and hydraulic control. Therefore, the KNFLD reference dataset excludes small pools that occupy less than one-third of the bankfull channel but were counted and evaluated as part of the PIBO reference dataset and 2007 Bitterroot sample dataset. The target for residual pool depths is established as ≥ 25th percentile of the PIBO dataset based on bankfull width. The indicator should be assessed based on the reach’s average residual pool depth value. This range of target values is comparable with the target of ≥ 1.5 established for the Bitterroot Headwaters TPA. Future monitoring should document an improving trend (i.e. deeper pools) at sites that fail to meet the target, while a stable trend should be documented at established monitoring sites that are currently meeting the target.

**Table 5-11. Percentiles of reference data and 2007 Bitterroot sample data for residual pool depth (ft) used for target development.**
Targets are shown in **bold**.

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| <20’ | KNFLD Reference | 57 | 0.8 | | 0.6 |
| | PIBO Reference | 40 | 1.0 | | **0.8** |
| | DEQ 2007 | 8 | 0.71 | 0.8 | |
| 20-35’ | KNFLD Reference | 18 | 1.4 | | 1.2 |
| | PIBO Reference | 50 | 1.4 | | **1.1** |
| | DEQ 2007 | 11 | 1.19 | 1.5 | |
| >35’ | PIBO Reference | 25 | 1.7 | | **1.3** |
| | DEQ 2007 | 13 | 1.5 | 1.7 | |

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

### 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. Excess fine sediment may limit pool habitat by filling in pools. 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 and gradient decreases.

Pool frequency within both the KNFLD and PIBO reference datasets are lower than the 75$^{th}$ percentile of the 2007 DEQ sample data, which may be because of the difference in method/pool definition. Because the median pool frequency values in the PIBO reference dataset compare favorably with both the 25th percentile of the KNFLD reference data and the median of the 2007 Bitterroot TPA sample data, the pool frequency target is greater than or equal to the median of the PIBO dataset (**Table 5-12**). Future monitoring should document an improving trend (i.e., more pools) at sites that fail to meet the target, while a stable trend should be documented at established monitoring sites that are currently meeting the target.

**Table 5-12. Percentiles of reference data and 2007 Bitterroot sample data for pool frequency (pools/mile) used for pool frequency target development.**
Targets are shown in **bold**.

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| <20’ | KNFLD Reference | 57 | 114 | | 81 |
| | PIBO Reference | 40 | **84** | | 64 |
| | DEQ 2007 | 8 | 90 | 148 | |
| 20-35’ | KNFLD Reference | 18 | 53 | | 38 |
| | PIBO Reference | 50 | **49** | | 36 |
| | DEQ 2007 | 11 | 42 | 69 | |
| >35’ | PIBO Reference | 25 | **26** | | 17 |
| | DEQ 2007 | 13 | 13 | 29 | |

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

**Large Woody Debris Frequency**

Large woody debris (LWD) is a critical component of stream ecosystems, providing habitat complexity, quality 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 is sensitive to land management activities, particularly during the long term, and its frequency tends to be greater in smaller streams (Bauer and Ralph, 1999). For DEQ sampling in 2007, wood was counted as LWD if it was greater than 9 feet long, or two-thirds of the wetted stream width, and 4 inches in diameter at the small end (Overton, et al., 1997).

The LWD count for both available reference datasets was compiled using a different definition of LWD than the 2007 DEQ sample dataset. If measurements were conducted in the same reach, the KNFLD LWD count would likely be less than the 75$^{th}$ percentile of the DEQ LWD count because the protocol only counted wood if it was larger than 6 inches in diameter and longer than the BFW. The PIBO median LWD count would likely be greater because it includes pieces 3 feet long and 4 inches in diameter. An analysis of LWD frequency in the Lolo National Forest showed an average of 590 pieces per mile in 2$^{nd}$ order streams in undeveloped watersheds, which is comparable with the 75th percentile of the 2007 DEQ dataset for streams with a bankfull width less than 20 feet (Riggers, et al., 1998). The LWD target, based on the 2007 DEQ protocol, is set at $\geq$ 75th percentile of the DEQ dataset (**Table 5-13**).

**Table 5-13. Percentiles of reference data and 2007 Bitterroot sample data for LWD frequency (LWD/mile) used for target development.**

Targets are shown in **bold**.

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | **n** | **Median** | **75th** | **25th** |
| <20’ | KNFLD Reference | 57 | 359 | | 183 |
| | PIBO Reference | 40 | 402 | | 214 |
| | DEQ 2007 | 8 | 153 | **573** | |
| 20-35’ | KNFLD Reference | 18 | 242 | | 92 |
| | PIBO Reference | 45 | 459 | | 293 |
| | DEQ 2007 | 11 | 222 | **380** | |
| >35’ | PIBO Reference | 24 | 662 | | 387 |
| | DEQ 2007 | 13 | 195 | **195** | |

Summary statistics shown in table were used for target development. Additional summary statistics are available in **Appendix F**.

## *5.4.1.4 Riparian Health*

**Greenline Understory Shrub Cover**

Interactions between the stream channel and the riparian vegetation along the streambanks are a vital component in supporting the beneficial uses of coldwater fish and aquatic life. Riparian vegetation provides food for aquatic organisms and supplies large woody debris that influences sediment storage and channel morphology. Riparian vegetation also helps stabilize streambanks and can provide shading, cover, and habitat for fish. During assessments conducted in 2007, ground cover, understory vegetation and overstory vegetation were cataloged at 10- to 20- foot intervals along the greenline at the bankfull channel margin on both sides of the stream channel for each survey reach. The percent of understory shrub cover is of particular interest in valley bottom streams historically dominated by willows and other riparian shrubs. While shrub cover is important for stream health, not all reaches have the potential for dense shrub cover and are, instead, well armored with rock or have the potential for a dense riparian community of a different composition, such as wetland vegetation or mature pine forest. Therefore, when applying target values, an understory shrub cover potential will be considered for each reach.

Greenline measurements were performed in 160 cells at 32 monitoring sites, with an average value of 51% understory shrub cover and a median value of 53% understory shrub cover. Based on this assessment, an target value of ≥ 53% is established for understory shrub cover in the Bitterroot TPA. This indicator should be assessed based on the reach average greenline understory shrub cover value. The selected target value compares favorably with the median value of ≥ 49% in the Middle and Lower Big Hole TMDL based on reference data from the Upper Big Hole River watershed.

### *5.4.1.5 Sediment Supply and Sources*

**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 (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 Bitterroot 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.

**Anthropogenic Sediment Sources**

The presence of anthropogenic sediment sources does not always result in sediment impairment of a beneficial use. When there are no significant historic or current identified anthropogenic sources of sediment within the watershed of a 303(d) listed steam, no TMDL will be prepared because Montana's narrative criteria for sediment cannot be exceeded in the absence of human causes. There are no specific target values associated with sediment sources, but the overall extent of human sources will be used to supplement any characterization of impairment conditions. This includes evaluation of human-induced and natural sediment sources, along with field observations and watershed scale source assessment information from aerial imagery and GIS data layers. Because sediment transport through a system can take years, or decades, and because channel form and stability can influence sediment transport and deposition, any evaluation of anthropogenic sediment impacts must consider both historical sediment loading as well as historical effects to channel form and stability. This is because the historical effects still have the potential to contribute sediment and/or to habitat impairment. Source assessment analysis will be provided by 303(d) listed waterbody in **Section 5.6**, with additional information in **Appendices B, D**, and **E**.

### *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. Macroinvertebrates respond predictably to siltation, shifting from natural or expected taxa (those that prefer clean gravel substrates) to a prevalence of sediment-tolerant taxa. Macroinvertebrate bioassessment scores record the macroinvertebrate taxa at a site. DEQ uses two bioassessment methodologies to evaluate impairment condition and aquatic life beneficial-use support. Aquatic insect assemblages may be altered because 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.

Two macroinvertebrate assessment tools are the Multi-Metric Index (MMI) and the Observed/Expected model (O/E). The rationale and methodology for both indices are presented in "Biological Indicators of Stream Condition in Montana Using Benthic Macroinvertebrates" (Jessup, et al., 2006). Unless noted otherwise, macroinvertebrate samples discussed in this TMDL document were collected according to DEQ protocols.

The MMI is organized based on different bioregions in Montana (i.e., mountain, low valley, and plains), and the Bitterroot TPA falls within the Mountain MMI and Valley MMI regions; here, the threshold value is an MMI score less than 63 and 48, respectively. These values are established as sediment targets in the Bitterroot TPA. 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; it is expressed as a ratio of the observed/expected taxa (O/E value). The O/E threshold value for all Montana streams is any O/E value < 0.8. Therefore, an O/E score of > 0.80 is a sediment target in the Bitterroot TPA. For both metrics, 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 non-pollutants such as habitat disturbance, they will be evaluated in consideration of more direct indicators of excess sediment.

## 5.4.2 Existing Condition and Comparison with Water Quality Targets

This section presents summaries and evaluations of relevant water quality data for Bitterroot TPA waterbodies appearing on the Montana 2010 303(d) list. The weight-of-evidence approach described earlier in **Section 4.2**, 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 2007. Results of the 2007 assessment are supported by additional data collected by DEQ in the DEQ Assessment Files and by data supplied by the Bitterroot and Lolo national forests. This section is not intended to provide an exhaustive review of all available data.

### *5.4.2.1 Ambrose Creek*

Ambrose Creek flows through mostly private lands for approximately 12.7 miles, from its headwaters in the Sapphire Mountains on the east side of the Bitterroot Valley to its confluence with Threemile Creek near the Lee Metcalf Wildlife Refuge north of Stevensville, Montana. Ambrose Creek was listed for physical substrate habitat alterations, a non-pollutant commonly linked to sediment impairment. Suspected sources include agriculture and grazing in riparian zones. Although the stream is not currently listed for sediment, it is listed for habitat alterations, and previous assessment studies suggest a potential problem with excess fine sediment accumulation in its channel. Additionally, Ambrose Creek is the largest tributary to Threemile Creek, which is currently listed as impaired by sediment. For these reasons, Ambrose Creek was included in this analysis.

**Physical Condition and Sediment Sources**

DEQ performed a stream assessment at one site along Ambrose Creek in 2007, using the methodology described in "Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat

Impairments." The monitoring reach, Ambrose 30 (AMBR-30), was located in the lower watershed, a short distance upstream from the confluence with Threemile Creek, and at the time of assessment was classified as a Rosgen E4 stream type, however upon further review of the reach data, the stream is characteristic of a Rosgen B4c channel type and may be transitioning to a Rosgen C4b stream type. Therefore, a Rosgen C4 stream type will be applied to Ambrose Creek when comparing targets to existing conditions. The field assessment team reported that near this reach the stream flowed through a rural-residential area. Young cottonwoods sprouted along the channel and on the floodplain. The low streambanks were well vegetated with grass, which minimized erosion in this low intensity system. Small undercuts at meander bends were associated with cottonwoods, and there was a short section of cobble riprap. The channel was primarily a run, with short riffles and a few pools. The substrate was sand and fine gravel, except in the riffles where small cobbles dominated.

**2007 DEQ Data and Comparison with Water Quality Targets**
The existing sediment and habitat data compared with the targets for Ambrose Creek are summarized in **Table 5-14**.

**Table 5-14. Ambrose Creek Data Compared with Targets**

| | | | | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach ID** | **Mean BFW (ft)** | **Level III Ecoregion** | **Potential Stream Type** | **% <6mm** | **% <2mm** | **Riffle % <6mm** | **Pool % <6mm** | **W/D Ratio** | **Entrenchment Ratio** | **Residual Pool Depth (ft)** | **Pools / Mile** | **LWD / Mile** | **Greenline % Shrub Cover** | **Riffle Stability Index** |
| AMBR-30 | 6.7 | MR | C4 | **75** | **30** | **57** | **87** | 8.6 | 5 | **0.7** | **74** | **11** | **46** | NC |

**Bold** indicates target value was not met. NC = not collected

During the 2007 assessment, the composite riffle pebble count surface fines < 6 mm exceeded the target criteria of < 14% for Middle Rockies streams with a value of 75%. The percent surface fines < 2 mm also exceeded the target criteria of < 10%, with a value of 30%. Percent fines as measured by the grid toss methodology were 57% in riffles and 87% in pool tail-outs, exceeding the target values of < 10% and < 6%, respectively. The median width/depth ratio and entrenchment ratio were meeting the set targets. The mean residual pool depth of 0.7 failed to meet the target value of > 0.8. A pool frequency of 74/mile was observed in the reach, missing the target of > 84/mile. Large woody debris frequency was 11/mile, falling short of the target value of > 573/mile. Along the length of the monitoring reach, 46% of the near-stream riparian vegetation was dominated by deciduous shrubs, falling short of the target of > 57%. RSI data was not collected in Reach AMBR-30 due to a shortage of suitable riffles.

**Other Assessments**
In October 1995 the Bitterroot National Forest conducted a stream survey approximately 40 feet upstream of the Forest Service boundary (**Table 5-15**). Rosgen stream type was B4. Riffle pebble count percent fines less < 2 mm was 26% and percent fines < 6 mm was 33%, both of which exceed the target values established for Middle Rockies stream types. At this location bankfull width was 9 feet and bankfull depth was 0.84 feet, resulting in a width-to-depth ratio of 10.7, meeting the target value of < 16. The entrenchment ratio was 2.9, meeting the target value of > 1.5.

**Table 5-15. Selected BNF Data from Ambrose Creek Mile 9.3**

| Agency | Location | Year | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|---|---|
| BNF | Mile 9.3 | 1995 | **33** | **26** | 11 | 2.9 |

In 2005, DEQ collected pebble count data at three sites on Ambrose Creek. At the upper site near the forest boundary, surface fines < 2 mm were 28%, and fines < 6 mm were 64%. At the middle site, surface fines < 2 mm were 15% and fines < 6 mm were 32%. At the lower site, a short distance upstream from the confluence with Threemile Creek, surface fines < 2 mm were 8% and fines < 6 mm were 23%. The surface fines < 2 mm target of ≤ 10% that has been established for all Middle Rockies stream types was met at the lower site, but exceeded at the middle and upper. The surface fines <6mm target of ≤14% that has been established for all Middle Rockies stream types was exceeded at all sites.

In May 1991 DEQ conducted a Nonpoint Source Stream Reach Assessment on the lower three-quarters of Ambrose Creek, which indicated notable sediment production from riparian grazing, livestock bank trampling, silvicultural activities, and roads. Road encroachment was noted in the upper stream reaches. Intensive, poorly managed grazing activities were identified as major sources of habitat alteration and sediment delivery in the lower reach.

During 2003 and 2004 the Tri-State Water Quality Council (TSWQC) conducted an extensive watershed assessment of Ambrose Creek as part of a larger watershed assessment of Threemile Creek and two tributaries (Ambrose and Wheelbarrow creeks). During the assessment, TSWQC delineated Ambrose into four reaches. Progressing downstream, surface fines < 6 mm were reported at 45%, 55%, 69%, and 72%.

TSWQC reported large woody debris densities in the four reaches (proceeding downstream) of 51 pieces per 1,000 feet, 21 pieces per 1,000 feet, 28 pieces per 1,000 feet, and 16 pieces per 1,000 feet, equating to 269, 111, 148, and 84 pieces per mile, respectively. Pool frequency was measured twice and was reported as 136/ mile near the headwaters and 45/mile near the mouth. Width-to-depth ratios were reported as 6.6 near the headwaters, and 13.5 near the mouth of Ambrose Creek.

**Biological Data**

Macroinvertebrate data samples were collected at two sites on Ambrose Creek in September 2005 (**Table 5-16**). The MMI target values for valley and mountain streams were met at sites AMBR1 and AMBR 2. The O/E target was not met at either site.

**Table 5-16. Macroinvertebrate Metrics for Ambrose Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| AMBR1 – near forest boundary | 9/15/2005 | 71 | Not applicable | **0.65** |
| AMBR2 – near mouth | 9/15/2005 | Not applicable | 70 | **0.26** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

These results indicate an increased sediment supply in Ambrose Creek. All of the percent surface fines measures for the 2007 DEQ assessment failed to meet their water quality targets, suggesting increased sediment supply. Low LWD frequency and reduced coverage of woody stream side vegetation all suggest potential negative effects to habitat in Ambrose Creek. Biological data generally indicate potential impairment. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) found that of the 25.4 miles of streambank along Ambrose Creek (double its 12.7-mile length to account for both banks), 12.7 miles (50%) had significant anthropogenic effects within 100 feet of the channel. These anthropogenic effects appeared to be having a negative impact on riparian health. Of the more than 18 miles of its banks rated as poor or fair condition, 17.6 miles (98%) were in areas where anthropogenic effects were observed. In contrast, all but a trace amount of the riparian areas in which no anthropogenic effects were observed as being in good condition.

Overall, the data collected by DEQ in 2007, along with previous studies, suggests a problem with excess fine sediment accumulation in the stream channel. This problem is linked to land-use activities in the watershed. For this reason, a sediment TMDL will be developed.

The 2003-04 TSWQC study reached the same conclusion, stating that “the aquatic habitat of Ambrose Creek…is impaired by sediment, especially ‘siltation’ or deposition of heavy loads of sediment in stream channels.” This same report described the major sediment sources as: 1) excess streambank erosion; 2) gully erosion on tertiary benches; 3) erosion of unpaved roads and crossing structures; and 4) upland sheet and rill erosion, particularly where weeds or livestock have degraded native grasses. Note “impairment” as used by TSWQC is not the same as defined in the Integrated 303(d)/305(b) Water Quality Report because only DEQ has authority to determine whether or not a stream is impaired, thereby including it in the official Integrated Water Quality Report.

### *5.4.2.2 Bass Creek*

Bass Creek begins at Bass Lake in the Bitterroot Mountains on the west side of the Bitterroot Valley, and flows for approximately 10 miles from its headwaters to its confluence with the Bitterroot River near the Lee Metcalf Wildlife Refuge. For approximately 8 miles the creek flows thorough a roadless portion of the Bitterroot National Forest; the lower two miles flow through mostly private agricultural lands. Although the stream is not currently listed for sediment, it is listed for flow alterations, and previous assessment studies suggest a potential problem with excess fine sediment accumulation in the channel of Bass Creek. For this reason, Bass Creek was included in this analysis.

**Physical Condition and Sediment Sources**

DEQ performed stream assessments at two sites along Bass Creek in 2007. The channel in both reaches was classified as Rosgen B3. Monitoring reach Bass 24 (BASS-24) was located on the Lolo National Forest downstream of a bridge crossing. According to the field assessment crew, there was some indication of historic timber harvest, with stumps along the channel, though channel form appeared essentially intact in this large substrate step-pool system. Scour pools with good LWD cover were observed. There was no streambank erosion observed due to the large cobble substrate and woody vegetation along the channel margin. The riparian zone was a mix of cottonwoods and conifers, with alder in the understory. Assessment reach Bass 27 (BASS-27) was located on private property in the lower watershed a short distance upstream of the creek’s confluence with the Bitterroot River. Field crews observed that this site appeared in a state of recovery, though portions were still over-widened in an area that flowed through what appeared to be a former CAFO. The reach was primarily comprised of riffles. Pools were poorly defined and relatively shallow. The substrate was dominated by cobbles, even in the over-widened areas. There was no streambank erosion due to the cobble substrate and dense riparian vegetation, which included cottonwoods, alder, and hawthorn, with grasses and forbs in the understory. The channel in both monitoring reaches was classified as a Rosgen B3 stream type.

**2007 DEQ Data and Comparison with Water Quality Targets**

The existing sediment and habitat data compared with the targets for Bass Creek are summarized in **Table 5-17**.

**Table 5-17. Bass Creek Data Compared with Targets**

| | | | | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| BASS-24 | 24.7 | IB | B3 | 7 | 3 | 5 | 4 | **17.9** | 1.9 | 1.1 | 74 | **317** | **39** | 52 |
| BASS-27 | 19.5 | IB | B3 | **18** | 4 | **14** | **20** | 14.4 | 1.9 | **0.7** | **79** | **158** | 60 | 50 |

**Bold** indicates target value was not met.

During the 2007 assessment, the upper reach, Bass 24, was meeting its target values for all four fine sediment target variables. At the lower site, Bass 27, the composite riffle pebble count surface fines < 6 mm exceeded the target of < 14%; while surface fines < 2 mm met the target of < 8%. In Bass 27, percent fines as measured by the grid toss methodology were 14% in riffles and 20% in pool tail-outs, exceeding the target value of <10% for both parameters. The median width-to-depth ratio in Bass 24 exceeded the target value of < 16, and the entrenchment ratios for both reaches met the target value > 1.5. The mean residual pool depth in Bass 27 did not meet the target value of > 0.8. Pool frequency did not meet target values in Bass-27. Large woody debris frequency did not meet target values in either reach. In Bass 24, 39% of the near-stream riparian vegetation contained deciduous shrubs, falling short of the target value of > 57%. The mean RSI values met target values in both reaches.

### Other Assessments

DEQ collected data at two sites on Bass Creek in 2004, one near the forest boundary and one on private property in the lower watershed, and the Bitterroot National Forest collected data near the forest boundary in 2003 and 1995. Rosgen B3 channel types were found at all of these locations. Selected results from these studies are presented in **Table 5-18**. The composite riffle pebble count surface fines < 6 mm and < 2 mm exceeded the target values of ≤ 14% and ≤ 10%, respectively, in all sites and time periods, with the exception of the BNF data collected for < 6 mm in 1995. Width-to-depth ratio exceeded the target value in 2004 at the DEQ site near the USFS boundary and the entrenchment ratio was below the target value at the BNF site in 1995.

**Table 5-18. Selected DEQ and BNF Data from Bass Creek**

| Agency | Location | Year | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|---|---|
| DEQ | Near USFS boundary | 2004 | **30** | **30** | **27.8** | 7.57 |
| DEQ | Lower Bass | 2004 | **17** | **17** | 7.28 | 5.16 |
| BNF | Near USFS boundary | 2003 | **15** | **15** | 14.4 | 1.5 |
| BNF | Near USFS boundary | 1995 | 14 | **11** | 15.8 | **1.4** |

**Bold** indicates target value was not met.

### Biological Data

Macroinvertebrate data samples were collected at two sites on Bass Creek in July 2004. All biological targets were met at both sites (**Table 5-19**).

**Table 5-19. Macroinvertebrate Metrics for Bass Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| BASS10 – near forest boundary | 7/9/2004 | 83 | Not applicable | 1.26 |
| BASS20 – near mouth | 7/9/2004 | Not applicable | 60 | 1.04 |

**Summary and TMDL Development Information**

At the time of the 2007 sampling, many target variables were within reference ranges at Bass 24. Upstream of this reach, there are very limited anthropogenic effects from which excessive sediment loading could result and much of the area is within the Selway-Bitterroot Wilderness. Downstream of the forest boundary at reach Bass 27, excessive surface fines were observed in both the <6mm substrate particle size class, and grid toss-based target value thresholds for riffle and pool tail-out percent fines were also above optimal levels. Land use in the lower reaches of Bass Creek are dominated by agriculture, and the data collected as part of the assessment by DEQ field crew in 2007 suggested that agriculture is having a potentially significant impact on stream health. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) found that of the 20 miles of streambank along Bass Creek (double its 10 mile length to account for both banks) four miles (20%) had significant anthropogenic effects within 100 feet of the channel. In general, the stream appeared to be in good health based on the riparian assessment results. Approximately 16 of the 20 miles of streambank were rated as good condition (80%). However, the remaining 4 miles that were rated as in fair or poor condition were all in areas were near-stream anthropogenic effects were observed, suggesting that while limited in area, human effects were influencing the stream. Those portions of Bass Creek's riparian areas that were rated as good condition were dominated by forest land uses; while those as fair or poor conditions were dominated by agriculture and near-stream roads. Although the impairment for sediment is unclear, the available data indicates that below the USFS boundary, sediment levels in Bass Creek are elevated and it appears that the lower impacted portions of the stream would recover well with riparian plantings and grazing management. For this reason, a sediment TMDL will be developed.

### *5.4.2.3 Lick Creek*

Lick Creek headwaters from north of Lake Como and the stream flows for 6.4 miles mostly through Bitterroot National Forest lands before joining the Bitterroot River just north of Como, Montana. Private lands border the stream for approximately 1 mile before the confluence with the Bitterroot. Lick Creek was placed on the 2010 303(d) List for sedimentation/siltation. Suspected pollutant sources are grazing in riparian areas, livestock (grazing or feeding operations), and silvicultural activities.

**Physical Condition and Sediment Sources**

DEQ performed a stream assessment at one site along Lick Creek in 2007. The monitoring reach, LICK 19, was located on private land a short distance upstream from Highway 93 and at the time of assessment was classified as a Rosgen E4b stream type, however upon further review of the reach data, the steep valley slope and low sinuosity of the reach indicate that the stream may be in transition from an E4b to a B4 type stream. Therefore, a Rosgen B4 stream type will be applied to Lick Creek when comparing targets to existing conditions. According to the stream survey crew, there appeared to be minimal watershed disturbance upstream of this site, though there was a flood irrigated field along the river left of the reach and signs of historic grazing on the hillslopes. The reach was primarily comprised of runs with small riffles and pools. Some spawning-size gravels were observed. Dense alders along the channel margin minimized streambank erosion.

### 2007 DEQ Data and Comparison with Water Quality Targets

The existing sediment and habitat data compared with the targets for Lick Creek are summarized in **Table 5-20**.

**Table 5-20. Lick Creek Data Compared with Targets**

| | | | | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| LICK-19 | 11.9 | IB | B4 | **37** | **20** | **22** | 5 | 10 | 11.4 | 0.8 | 148 | 1172 | 69 | NC |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment, the composite riffle pebble count surface fines < 6 mm was 37%, exceeding the target value of < 14%. The composite riffle pebble count surface fines < 2 mm was 20%, exceeding the target value of < 8%. Percent fines as measured by the grid-toss methodology were 22% in riffles and 5% in pool tail-outs, with the riffle grid toss exceeding the target value of <10%. The median width-to-depth ratio was 10, meeting the target value of < 16, and the entrenchment ratio of 11.4 met the target value of > 1.5 established for B stream types. The mean residual pool depth of 0.8 just met the target value of > 0.8. A pool frequency of 148/mile was observed in the reach, meeting the target of > 84/mile. Large woody debris frequency was 1,172/mile, meeting the target of > 573/mile. Along the length of the monitoring reach, 66% of the near-stream riparian vegetation was dominated by deciduous shrubs, meeting the target of > 57%. RSI data was not collected because of a lack of suitable riffles.

### Other Assessments

DEQ collected data at one site in lower Lick Creek in 2004. Selected results from this assessment are presented in **Table 5-21**. Percent fines < 6 mm and < 2 mm exceeded the targets of < 14% and < 8%, respectively. The other parameters were within target ranges.

**Table 5-21. Selected DEQ Data from Lower Lick Creek**

| % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|
| **31** | **30** | 10.9 | 4.43 |

The Bitterroot National Forest conducted stream surveys at several sites on Lick Creek in 2003. Selected results are presented in **Table 5-22**. At mile 1.3 the stream was classified as a Rosgen F4 channel. Percent fines < 2 mm and < 6 mm exceeded the targets of < 8% and < 14 respectively for streams in the Idaho Batholith ecoregion. Width-to-depth ratio targets were exceeded at sites Mile 1.3 and Mile 2.4.

**Table 5-22. Selected BNF Data from Lick Creek**

| Location | Stream Type | Year | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|---|---|
| Mile 1.3 | F4 | 2003 | **42** | **30** | **17.2** | 1.2 |
| Mile 2.4 | B4 | 2003 | **28** | **19** | **16.1** | 2.2 |
| Mile 3.7 | A3 | 2003 | **18** | **17** | 11.1 | 1.2 |

**Biological Data**

Macroinvertebrate data samples were collected at two sites on Lick Creek in July 2004. At both sites, all metrics were meeting target values (**Table 5-23**).

**Table 5-23. Macroinvertebrate Metrics for Lick Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| C05LICKC10 | 7/14/2004 | 71 | Not applicable | 0.87 |
| C05LICKC20 | 7/14/2004 | Not applicable | 70 | 1.05 |

**Summary and TMDL Development Information**

The data collected by DEQ in 2007 indicate elevated levels of fine sediment in the substrate of Lick Creek, but biological data collected in 2004 indicated beneficial-use support. An assessment of riparian conditions and near-stream land uses that was conducted (concurrently with the 2007 DEQ study) found relatively few impacts. Of the 12.8 miles of streambank along Lick Creek (double its 6.4 mile length to account for both banks), only 2.5 miles (20%) had significant anthropogenic effects within 100 feet of the channel. Approximately 10 of the 12.8 miles of streambank were rated as good condition. The remaining 2.8 miles (20%) were rated as in fair or poor condition, all in areas where adjacent human activity was observed. Because the data collected by the DEQ in 2007 exhibits elevated fine sediment, a sediment TMDL will be developed for Lick Creek.

### *5.4.2.4 Lolo Creek (Upper, Middle, and Lower Segments)*

Lolo Creek begins near the Montana/Idaho border on the west side of the Bitterroot Valley and flows for 31.5 miles through a mix of public and private lands before reaching its confluence with the Bitterroot River in Lolo, Montana. Lolo Creek (segments MT76H005_013, MT76H005_012, and MT76H005_013) was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include agriculture, silvicultural activities, streambank modification/destabilization, habitat modification other than hydromodification, and site clearance (land development or redevelopment).

**Physical Condition and Sediment Sources**

DEQ performed stream assessments at three locations on Lolo Creek in 2007. LOLO 26 was the uppermost reach assessed. According to the stream assessment crew, this reach was channelized on river-left along its entire length, through the use of large rock riprap, and Highway 12 runs within approximately 30 feet of the channel along most of the reach. Riparian shrubs have grown between the riprap and the river along a portion of the left bank, while the right bank was covered by shrubs and conifers. A power line crosses the channel in this reach, and the reach lacked well-formed pools and LWD. Excessive scour likely occurs along this section of river during high water, which may exacerbate streambank erosion along the right bank. According to the field crew, LOLO 34 was situated away from the road and downstream of a bridge crossing. The stream flowed through dense riparian vegetation, with alders and willows along the channel margin and conifers in the overstory. It appeared that timber was harvested along the floodplain and included a staging area that led to increased streambank erosion, locally. Stumps were observed on the floodplain. Some LWD aggregates were found in this reach, and the pools included some potential spawning gravels. Finally, assessment reach LOLO 56 was located along Fort Fizzle. The stream flowed through dense riparian vegetation, with alders and willows along the channel margin and conifers in the overstory, with some cottonwoods as well. The stream appeared to be in an essentially natural condition along this reach, though LWD inputs may have been decreased historically from extensive silviculture throughout the watershed. There was a small streambank stabilization project along the river-left bank where the trail meets the river. It used mess fabric and the upstream portion appeared to have blown out. There was one cutslope sediment source along the right bank, though whether this was natural, or influenced by upstream riprap was unclear. All three assessment reaches were classified as Rosgen C4 stream types.

**2007 DEQ Data and Comparison with Water Quality Targets**
The existing sediment and habitat data compared with the targets for Lolo Creek are summarized in **Table 5-24**.

**Table 5-24. Lolo Creek Data Compared with Targets**

| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| LOLO-26 | 48.1 | NR | C4 | **20** | 5 | 6 | **35** | 28.5 | **1.6** | **1.2** | **13** | **45** | 65 | **81** |
| LOLO-34 | 51.4 | NR | C4 | 13 | 2 | 7 | **31** | **31.1** | 4.5 | 1.6 | **11** | **161** | 82 | 61 |
| LOLO-56 | 82.5 | NR | C4 | **16** | **8** | 6 | **17** | **39.4** | 3.7 | 1.4 | **16** | **92** | 86 | **80** |

**Bold** indicates target value was not met.

During the 2007 assessment, the composite riffle pebble count surface fines < 6 mm exceeded the target value of < 5% at reaches LOLO 26 and 56. The composite riffle pebble count surface fines < 2 mm exceeded the target value of < 7% at reach LOLO 56. All three reaches met the target of < 10% for percent fines in riffles as measured by the grid toss methodology, but were well above the target value of < 8% for fines in pool tail outs. The median width-to-depth ratio exceeded the target value of < 29 at reaches LOLO 34 and 56. At reach LOLO 26, an entrenchment ratio of 1.6 failed to meet the target value of ≥ 2.2, while the other two sites were meeting target criteria. The mean residual pool depth fell below the target of > 1.3 ft. at reach LOLO 26. Pool frequency failed to meet the target of > 26/mile in all three reaches. Large woody debris also failed to meet the target of > 195/mile. Along the length of all three monitoring reaches, the near-stream riparian vegetation was dominated by deciduous shrubs, meeting the target of >57%. The mean RSI did not meet the target of > 45 and <75 in LOLO 26 and LOLO 56, respectively.

**Biological Data**
Macroinvertebrate samples were collected at three sites on Lolo Creek in September, 2005 (**Table 5-25**). All macroinvertebrate metrics at all sites were within target ranges.

**Table 5-25. Macroinvertebrate Metrics for Lolo Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| Upper Lolo | 9/11/2005 | 77 | Not applicable | 1.19 |
| Middle Lolo | 9/10/2005 | Not applicable | 57 | 1.23 |
| Lower Lolo | 9/8/2005 | Not applicable | 63 | 1.23 |

**Summary and TMDL Development Information**

Macroinvertebrate results suggest full support of aquatic life beneficial uses; however, some fine sediment and habitat parameters fall outside of target ranges. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) showed that of the 63 miles of streambank along Lolo Creek (double its 31.5-mile length to account for both banks) 43.5 miles (69%) had significant anthropogenic effects within 100 feet of the channel. Approximately 21 of the 63 miles of streambank were rated as good condition, and these were located predominantly in areas where no significant near-stream human activities were observed. The remaining 42 miles (67%) were rated as in fair or poor condition. Those portions of Lolo Creek's riparian areas that were rated as food condition were dominated by forest land uses; those areas rated fair or poor were in areas dominated by roads, timber harvest/fire, rural farms, and hay/pasture lands. While not specifically addressed in DEQ's 2007 assessment, Highway 12 parallels Lolo Creek for much of its length and has been identified in previous studies as a potentially significant sediment source. Construction and maintenance of the highway have also resulted in channel straightening and bank hardening. Because Lolo Creek is currently listed for sediment impairment and significant controllable sediment sources were identified, a TMDL for sediment will be written for all three segments of Lolo Creek.

### *5.4.2.5 McClain Creek*

McClain Creek is a small stream on the west side of the Bitterroot Valley that flows for approximately 5.4 miles through mostly private lands before joining the Bitterroot south of Lolo, Montana. McClain Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include forest roads (road construction and use).

**Physical Condition and Sediment Sources**

DEQ performed a stream assessment at one site along McClain Creek in 2007. The monitoring reach, MCCL 43, was located on private land in the lower watershed, a short distance upstream of the frontage road. According to the stream assessment crew, there were fields along both sides of the channel, and it appeared that the site had been historically heavily grazed with pugging and hummocking along the channel margin, indicating ongoing grazing. Areas of streambank erosion and bare ground were present, caused by cattle. Small rock riprap had been used in some sections, and dense hawthorn formed a narrow band along the channel, with grass and rose in the understory. Overall, there was a fairly well-developed riffle-pool sequence in this small stream, and pools were often associated with LWD. At the time of assessment, the reach was classified as a Rosgen E4 stream type, however upon further review of the reach data, the steep valley slope and low sinuosity of the reach indicate that the stream may be in transition from an E4b to a G4 with a potential stable channel type of B4. Therefore, the Rosgen B stream type will be applied to McClain Creek when comparing targets to existing conditions.

**2007 DEQ Data and Comparison with Water Quality Targets**

The existing sediment and habitat data compared with the targets for McClain Creek are summarized in **Table 5-26**.

**Table 5-26. McClain Creek Data Compared w Targets**

| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| MCCL-15 | 5.6 | MR | B4 | **50** | **33** | **43** | **31** | 5.3 | 7 | **0.6** | 211 | **148** | 61 | NC |

**Bold** indicates target value was not met. NC = not collected.

The reach sampled during the 2007 assessment was classified as a Rosgen E channel type, however, upon further review DEQ has reclassified it as a Rosgen G4 channel type, which is currently transitioning to a B4 channel type. The composite riffle pebble count surface fines < 6 mm was 50% and the percent surface fines < 2 mm was 33%, failing to meet the targets of ≤ 14% and ≤ 10% respectively. Percent fines as measured by the grid-toss methodology were 43% in riffles and 31% in pool tail-outs, failing to meet the target values of ≤ 10% and ≤ 6%, respectively. The median width-to-depth-ratio of 5.3 met the target value of ≤ 16, and the entrenchment ratio of 7 was meeting the target of ≥ 1.5 for B channel types. The mean residual pool depth of 0.6 feet did not meet the target of ≥ 0.8 feet. The pool frequency met the target of ≥84/mile, but the LWD frequency did not meet the target of ≥ 573/mile. Along the length of the monitoring reach, 61% of the near-stream riparian vegetation was dominated by deciduous shrubs, meeting the target of ≥57%. RSI data was not collected because of a lack of suitable riffles.

### Other Assessments

In 2005, DEQ collected pebble count data at one site below Highway 93. Surface fines < 2 mm were 59% and fines < 6 mm were 71%. These values are above the targets that have been established for streams in the Middle Rockies ecoregion, suggesting excessive fine sediment in the channel of lower McClain Creek.

The Bitterroot National Forest conducted a stream assessment at mile 4.4 in 1992, 1994, and 2003, classified as a Rosgen Type B4 stream. Selected data are presented in **Table 5-27**. Percent fines < 2 mm and < 6 mm exceeded target values of ≤ 10 and ≤ 14% respectively (based on B4 stream type) at all locations and in all years for which data is available. Width/depth and entrenchment ratios were within target ranges in all cases.

**Table 5-27. Selected BNF Data from McClain Creek Mile 4.4**

| Year | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|
| 1992 | **56** | **44** | 8.7 | 1.9 |
| 1994 | **50** | **33** | NC | NC |
| 2003 | NC | **34** | 6.4 | 2.2 |

**Bold** indicates target value was not met. NC = not collected.

### Biological Data

Macroinvertebrate data samples were collected at two sites on McClain Creek in September 2005. Both sites were classified as valley sites (**Table 5-28**). At the upper site, MCCL-1, both applicable metrics were within target ranges. At the lower site, MCCL-2, neither target was met.

**Table 5-28. Macroinvertebrate Metrics for McClain Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| MCCL1 | 9/20/2005 | Not applicable | 65 | 0.85 |
| MCCL2 | 9/20/2005 | Not applicable | **39** | **0.39** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

The available data provides compelling evidence that fine sediment levels are elevated within the channel substrate of McClain Creek. At all locations and in all years for which data is available, fine sediment levels exceeded target levels. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) supports this conclusion. Riparian health was rated as poor or fair along more than half of the stream length. Areas that were classified as good condition were located entirely where no human activities were present. As a result, a TMDL for sediment will be written for McClain Creek.

### *5.4.2.6 Miller Creek*

Miller Creek begins near Miller Peak in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 18.3 miles through a mix of state, Plum Creek, Lolo National Forest, and private lands before joining the Bitterroot River just south of Missoula, Montana. Miller Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include crop production (crop land or dry land), grazing in riparian or shoreline zones, loss of riparian habitat, and silvicultural activities.

**Physical Condition and Sediment Sources**

DEQ performed stream assessments at three sites along Miller Creek in 2007. In the upper monitoring reach, MILR 11, field crews noted that the reach was located in a dense coniferous forest, with alders, red osier dogwood and mountain maple in the understory. There were numerous pools formed by alder LWD, which had potential spawning gravels. Channel form appeared generally intact, though one over-widened crossing was noted. There was no active streambank erosion. It appeared that the site was logged historically and there was an old two-track road within 150 feet of the stream along both sides. MILR 11 was classified as a Rosgen B4 channel type. At the middle reach, MILR 21, field crews noted that the reach flowed through a mountain meadow that appeared to have been logged at one time and also potentially used for agriculture/grazing. Recent logging along the river-left hillslope was observed. The channel was over-widened, though colonization of the channel margin by wetland vegetation suggests the channel is getting narrower. Primarily grass/wetland vegetation grew along the banks, and vertically eroding streambanks occurred at the outsides of meander bends. Pools were also located at meander bends. There was a small amount of “small” riprap to protect the road at one meander bend. At the lower reach, MILR 33, field crews noted it was comprised of one continuous riffle, with no pools and no LWD. The stream was partially channelized by low berms and flowed through a weed-covered floodplain area that was likely used for grazing and/or irrigated agriculture at one time. It is now primarily open space within a semi-rural subdivision. Grass and weeds line the banks, though some small cottonwoods were becoming established along the channel margin. It appeared that bankfull flows would still spill out on the floodplain in some places, particularly along river-left. Reaches MILR 21 and MILR 33 were classified as Rosgen C4 channel types.

### 2007 DEQ Data and Comparison with Water Quality Targets

The existing sediment and habitat compared with the targets for Miller Creek are summarized in **Table 5-29**.

**Table 5-29. Miller Creek Data Compared with Targets**

| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| MILR-11 | 8.2 | MR | B4 | **27** | 10 | **21** | **11** | 9.8 | 5.0 | **0.6** | 148 | **570** | 86 | NC |
| MILR-21 | 23.5 | MR | C4 | **32** | **12** | **15** | **20** | **31.3** | 3.9 | **1.0** | 69 | **222** | **7** | NC |
| MILR-33 | 28.6 | MR | C4 | **24** | **14** | **24** | NC | **48.0** | 5.1 | **0.0** | **0** | **0** | **20** | NC |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment the composite riffle pebble count surface fines < 6 mm were not meeting the target value of < 14% in all three reaches. The composite riffle pebble count surface fines < 2 mm did not meet the target value of < 10% in MILR 21 and MILR 33. Percent fines < 6 mm in riffles, as measured by the grid-toss methodology, failed to meet the target value of < 10% in all three reaches. Percent fines < 6 mm in pool tail-outs did not meet the target value of < 6% in the two reaches where data was collected. The median width-to-depth ratio exceeded the target value of < 16 in MILR 21 and MILR 33. The entrenchment ratio was meeting the target values for B channel types in MILR 11 and for C channel types in MILR 21 and MILR 33. The mean residual pool depth did not meet its target value in all three reaches. The pool frequency target was not met in MILR 33 as there were no pools found in the reach. LWD frequency was below target values in all three reaches. Along the length of the reach MILR 11, 86% of the near-stream riparian vegetation was dominated by deciduous shrubs, meeting the target value of >57%. Shrub cover in MILR 21 and MILR 33 was considerably lower than the target value. No RSI data was collected due to a lack of suitable riffles.

### Other Assessments

In 2005, DEQ collected pebble count data at two sites on Miller Creek. At the upper site, surface fines <2mm were 38% and fines <6mm were 47%. At the lower site, surface fines <2mm were 14% and fines <6mm were 23%. Values at both sites were above target ranges for streams in the Middle Rockies ecoregion.

### Biological Data

Macroinvertebrate data samples were collected at one site near the mouth of Miller Creek in September 2005 (**Table 5-30**). The Valley MMI target value for macroinvertebrates was met, however the O/E metric target was not.

**Table 5-30. Macroinvertebrate Metrics for Miller Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| MILR1 – near mouth | 9/20/2005 | Not applicable | 55 | **0.52** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

Across the length of Miller Creek, a wide range of targets fell outside of reference ranges, and macroinvertebrate data indicated a potential impact to aquatic life. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) found that of the 36.6 miles of streambank along Miller Creek (double its 18.3 mile length to account for both banks) 26.5 miles (72%) had significant anthropogenic effects within 100 feet of the channel. Approximately 9.6 of the 36.6 miles of streambank were rated as good condition, and these were located almost entirely in areas where no significant near-stream human activities were observed. The remaining 27 miles (74%) were rated as in fair or poor condition, generally in areas where human activity was observed. Those portions of Miller Creek's riparian areas that were rated as good condition were dominated by forest land uses; those rated fair and poor condition were in areas dominated by rural farms and agricultural and forest lands. Most of the Miller Creek watershed is heavily impacted by silviculture, forest roads, agriculture, and suburban development, and the available data suggest that these activities may have increased sediment loading and degraded near- and in-stream habitat. For these reasons, TMDL development will be pursued in Miller Creek.

### *5.4.2.7 Muddy Spring Creek*

Muddy Spring Creek is a 2-mile long tributary to Gold Creek on the east side of the Bitterroot Valley. Muddy Spring Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include rangeland grazing.

**Physical Condition and Sediment Sources**

Muddy Spring Creek was not included in DEQ's 2007 assessment. However DEQ did collect limited data on the creek in 2004 and 2006.

**Existing Data and Comparison with Water Quality Targets**

The existing sediment data compared with the targets for Muddy Spring Creek are summarized in **Table 5-31**.

**Table 5-31. Selected DEQ Data, Muddy Springs Creek, 2004/06**

| Date | Stream Type | %<6mm | %<2 mm | Width/depth ratio | Entrenchment Ratio |
|---|---|---|---|---|---|
| 9/20/2006 | Unknown | 13 | 9 | NC | NC |
| 7/10/2004 | E4b | **50** | 24 | **4** | **4.4** |

**Bold** indicates target value was not met. NC = not collected.

Surface fines <2mm and <6mm collected in 2006 were both below target levels established for streams in the Middle Rockies ecoregion. At the monitoring location in 2004, the stream was classified as an E4 channel type, and surface fines <6mm were above the E channel target value of ≤45%. Width/depth and entrenchment ratios both exceeded target values for E channel types.

**Biological Data**
Macroinvertebrate data samples were collected at one site near the mouth of Muddy Springs Creek in June 2004 (**Table 5-32**). Macroinvertebrate metrics met their target values.

**Table 5-32. Macroinvertebrate Metrics for Muddy Spring Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | RIVPACS O/E |
|---|---|---|---|---|
| MS-1: near mouth | 7/10/2004 | Not applicable | 63 | 0.86 |

**Summary and TMDL Development Information**
An assessment of riparian condition and near-stream land uses that was conducted by DEQ in 2007 found that 99% of the riparian areas along Muddy Spring Creek were in good condition, with few signs of significant human impact. Muddy Spring Creek was listed as partially supporting its aquatic life and coldwater fisheries beneficial uses likely caused by agriculture and range land. Recent data and field observations suggest Muddy Spring Creek is recovering from historic management practices, but because it is still recovering and surface fines data from 2004 indicate potentially elevated sediment levels, a sediment TMDL will be developed.

### *5.4.2.8 North Burnt Fork Creek*
North Burnt Fork Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 10.9 miles through mostly private lands before joining the Bitterroot River just north of Stevensville, Montana. North Burnt Fork Creek was listed for bottom deposits on the 2010 303(d) List. Suspected pollutant sources include grazing in riparian zones and irrigated crop production.

**Physical Condition and Sediment Sources**
DEQ performed stream assessments at two sites along North Burnt Fork Creek in 2007. In the upper monitoring reach, NBFC 11, field crews noted that the stream flows through a rural-residential area. The stream was over-widened along this reach and reduced floodplain access appeared to be increasing near-bank stress. An irrigation structure and cattle access were leading to over-widening and bank erosion. Riparian vegetation consisted of a mature/decadent cottonwood gallery with grass ground cover. Assessment reach NBFC 11 was classified as a Rosgen C3 channel type. In the lower monitoring reach, NBFC 15, assessment field crews noted that the stream flows through an area that was actively being used for grazing during the site visit. It appeared that the channel was slightly over-widened, though it retained a relatively coarse substrate. Extensive streambank erosion was observed, with tall exposed banks. In places, cattle crossings have laid back the banks and created areas of bare ground. There was primarily grass along the channel margin, with pugging and hummocking observed. Assessment reach NBFC 15 was classified as a Rosgen C4 channel type.

2007 DEQ Data and Comparison with Water Quality Targets
The existing sediment and habitat data compared with the targets for North Burnt Fork Creek are summarized in **Table 5-33**.

**Table 5-33. North Burnt Fork Creek Data Compared with Targets**

| | | | | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach ID** | **Mean BFW (ft)** | **Level III Ecoregion** | **Potential Stream Type** | **% <6mm** | **% <2mm** | **Riffle % <6mm** | **Pool % <6mm** | **W/D Ratio** | **Entrenchment Ratio** | **Residual Pool Depth (ft)** | **Pools / Mile** | **LWD / Mile** | **Greenline % Shrub Cover** | **Riffle Stability Index** |
| NFBC-11 | 32.9 | MR | C3 | 12 | 10 | 0 | **8** | **23.7** | **1.9** | 1.4 | **32** | 444 | **55** | NC |
| NFBC-15 | 24.2 | MR | C3 | **18** | **15** | 1 | 1.4 | **18.7** | 2.7 | **1.0** | **42** | **74** | **3** | 73 |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment, the composite riffle pebble count surface fines < 6 mm and < 2 mm was meeting the target values of < 14% and < 10 % respectively in NFBC 11, but not in NFBC 15. Percent fines as measured by the grid-toss methodology met the target value of < 10% in riffles for both reaches. The target value of < 6% for fines measured by the grid-toss in pool tail-outs was not met in reach NBFC 11. The median width-to-depth ratio did not meet the target value of < 16 in both reaches, and in NFBC 11 the entrenchment ratio was not meeting the target of > 2.5. The mean residual pool depth target value of > 1.1 was not met in NFBC 18. The pool frequency target value of > 49/mile was not met in either reach. LWD frequency did not meet the target value of > 380/mile in NFBC 15. Along the length of both monitoring reaches, the near-stream riparian vegetation made up by deciduous shrubs, failed to meet the target value of > 57%. RSI data was not collected in NFBC 11 because of a lack of suitable riffles. The RSI target value of < 75 was met in NFBC 15.

### Other Assessments

In 2005, DEQ collected pebble count data at two sites on North Burnt Fork Creek. At the upper site, surface fines <2mm were 11% and fines <6mm were 19%, exceeding target values for the Middle Rockies Ecoregion. At the lower site, surface fines <2mm were 9% and fines <6mm were 9%.

### Biological Data

Macroinvertebrate data samples were collected at two sites in August 2005 and at one site in September 2005 (**Table 5-34**). The Valley MMI target value for macroinvertebrates was not met in C05BRFNC01. Both Mountain MMI and O/E target values for macroinvertebrates were not met for site BURN2, near the mouth of the creek.

**Table 5-34. Macroinvertebrate Metrics for North Burnt Fork Creek**

| **Station ID** | **Collection Date** | **Mountain MMI** | **Valley MMI** | **O/E** |
|---|---|---|---|---|
| C05BRFNC01 | 8/16/2005 | Not applicable | **44** | 0.89 |
| C05BRFNC02 | 8/17/2005 | Not applicable | 62 | 1.03 |
| BURN2 – near mouth | 9/16/2005 | **50** | Not applicable | **0.39** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

Percent fines data suggest a potential problem with sediment deposition in the substrate of North Burnt Fork Creek and much of the other available data suggest potentially significant effects to near and in-stream habitat. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) supports this conclusion, having found that of the 21.8 miles of streambank along North Burnt Fork Creek (double its 10.9 mile length to account for both banks), 21 miles (95%) had significant anthropogenic effects within 100 feet of the channel. Approximately 1.2 of the 21.8 miles of streambank were rated as good condition, and these were located almost entirely in areas where no significant near-stream human activities were observed. The remaining 20.6 miles (94%) were rated as fair or poor condition, entirely in areas where human activity was observed. Those portions of North Burnt Fork Creek's riparian areas that were rated as good condition were dominated by forest land uses; those rated fair or poor were in areas dominated by rural farms and agricultural and hay/pasture lands. Overall, the available data suggest elevated fine sediment levels which appear to be linked to land use activities within the watershed. For this reason, sediment TMDL development will be pursued.

### *5.4.2.9 Rye Creek*

Rye Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 17.5 miles before reaching its confluence with the Bitterroot River south of Darby, Montana. The stream's headwaters are predominately Bitterroot National Forest lands, while approximately the lower 6 miles are bordered by private lands. Rye Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include animal feeding operations (NPS), grazing in riparian or streamside zones, forest roads (road construction and use), and silvicultural activities.

**Physical Condition and Sediment Sources**

DEQ performed stream assessments at two sites along Rye Creek in 2007. The upper assessment reach, RYEC 28, was located a short distance downstream of the confluence with North Fork Rye Creek. The stream assessment crew noted that the channel was entrenched along this reach, with a narrow band of dense riparian shrubs, primarily comprised of willow and alder. Large eroding banks with notable stratification occurred within the reach. There is currently a horse pasture on the river-left terrace, though it is fenced away from the stream. There is evidence of skid logging on the hillslope along river-left, which burned during the 2000 fires. There were numerous car bodies in the channel at this site, covering approximately 160 feet of streambank. Grass and deciduous shrubs were growing out of the car-bodies. Assessment Reach RYEC 28 was classified as a Rosgen B4 channel type. Assessment reach RYEC 36 was located on private land in the lower watershed a short distance upstream from Highway 93. The stream assessment crew noted that the stream was converted to a ditch in this reach. There were mature/decadent cottonwoods in the overstory along the channel margin, as well as some alders. The banks were undercutting in places and exposed along much of the reach, though retreat was limited since the channel was straight. Assessment reach RYEC 36 was classified as a Rosgen C4 channel type.

**2007 DEQ Data and Comparison with Water Quality Targets**

The existing sediment and habitat data compared with the targets for Rye Creek are summarized in **Table 5-35**.

**Table 5-35. Rye Creek Data Compared with Targets**

| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| RYEC-28 | 23.0 | IB | B4 | **26** | **14** | **15** | 7 | **16.2** | 1.5 | 1.1 | 95 | **238** | 66 | **89** |
| RYEC-36 | 22.9 | IB | C4 | **28** | **22** | **27** | **17** | 15.3 | **1.5** | 1.3 | **32** | 523 | 57 | NC |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment in RYEC 28, the composite riffle pebble count surface fines < 6 mm and < 2 mm did not meet the target values of ≤ 14% and ≤ 8% respectively for either reach. Percent fines, as measured by the grid-toss methodology in riffles, failed to meet the target value of ≤ 10% in either reach. Percent fines in pool tail-outs did not meet the target value of ≤10% in reach RYEC 36. The median width-to-depth ratio did not meet the target value of ≤ 16 in RYEC 28, and the entrenchment ratio target value was not met in RYEC 36. The mean residual pool depth met target values in both reaches. Reach RYEC 28 did not meet its target value of greater than 380/mile. Along the length of both monitoring reaches the near-stream riparian vegetation met the target value of greater than 57% deciduous shrubs. RSI data collected on RYEC 28 did not meet the target value of < 70.

### Other Assessments

In 2005, DEQ collected pebble count data at two sites on Rye Creek. At the upper site, surface fines <2mm were 3% and fines <6mm were 12%, meeting target values for streams in the Idaho Batholith ecoregion. At the lower site, surface fines <2mm were 29% and fines <6mm were 36%, failing to meet the target values for streams in the Idaho Batholith ecoregion.

In 2003 the Bitterroot National Forest conducted stream assessments at two locations on Rye Creek in reaches classified as Rosgen B4 channel types. Selected results are presented in **Table 5-36**. All measures of surface fines exceeded target values for streams in the Idaho Batholith ecoregion, as did the width/depth ratio at the Mile 12.4 site.

**Table 5-36. Selected BNF data from Rye Creek**

| Site | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|
| Mile 12.4 | **38** | **38** | **21** | 1.8 |
| Mile 6.1 | **41** | **37** | 16 | 5 |

**Bold** indicates target value was not met.

### Biological Data

Macroinvertebrate data samples were collected at two sites in September 2005 (**Table 5-37**). Of the macroinvertebrate metrics, only the Valley MMI at RC1 met target values.

**Table 5-37. Macroinvertebrate Metrics for Rye Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| RC1: mile 6.1 | 9/7/2005 | Not applicable | 67 | **0.61** |
| RC2: near mouth | 9/7/2005 | Not applicable | **44** | **0.33** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

A comparison of existing data to target values suggest elevated levels of sediment in Rye Creek and macroinvertebrate data indicate possible effects to aquatic life. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) supports this conclusion. The study found that of the 35 miles of streambank along Rye Creek (double its 17.5-mile length to account for both banks) 22 miles (63%) had significant anthropogenic effects within 100 feet of the channel. Approximately 12 of the 35 miles of streambank were rated as good condition; while the remaining 23 miles (66%) were rated as fair or poor condition, primarily in areas with human activities. Those portions rated as good condition were dominated by forest land uses; those rated as fair or poor condition were in areas dominated by pastures, timber harvest/fire, and roads. Overall, the available data suggest possible elevated fine sediment levels as well as habitat alterations that appear to be linked to land use activities within the watershed. For this reason, sediment TMDL development will be pursued.

### *5.4.2.10 Sleeping Child Creek*

Sleeping Child Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 24.9 miles before reaching the Bitterroot River near Hamilton, Montana. The headwaters of the stream are dominated by Bitterroot National Forest lands, while the lower reaches are bordered by private lands. Sleeping Child Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include agriculture, highway/road/bridge runoff (non-construction related), and silvicultural activities.

**Physical Condition and Sediment Sources**

DEQ performed a stream assessment at one site along Sleeping Child Creek in 2007. The assessment reach, SLEE 43, was located on private land in the lower watershed and was classified as a C3 potential channel type. The field assessment crew noted that the creek was channelized along this reach and the banks were stabilized with cobble-size riprap in places. It was one long riffle with a few poorly defined pools. There was a field on river-left and grazing likely occurred historically, if not ongoing. There was a band of mature/decadent cottonwoods along the channel margin with periodic alders in the understory. There was an irrigation pipe across the stream channel upstream of the reach.

**2007 DEQ Data and Comparison with Water Quality Targets**

The existing sediment and habitat data compared with the targets for Sleeping Child Creek are summarized in **Table 5-38**.

**Table 5-38. Sleeping Child Creek Data Compared with Targets**

| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| SLEE-44 | 38.5 | MR | C3 | 12 | 6 | 8 | NC | 24.6 | **1.6** | 1.5 | **21** | 195 | **38** | **83** |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment in reach SLEE 43, the composite riffle pebble count surface fines < 6 mm was 12%, meeting the target of < 14%. The composite riffle pebble count surface fines < 2 mm was 6%, meeting the target of < 10 %. Percent fines as measured by the grid-toss methodology were 8% in riffles, meeting the target value of < 10%. The median width-to-depth ratio of 24.6 met the target value of < 29. The entrenchment ratio of 1.6 did not meet the target of > 2.5. The mean residual pool depth of 1.5 feet met the target value of > 1.3. A pool frequency of 21/mile was observed in the reach, failing to meet the target of >26/mile. LWD frequency was 195/mile, meeting the target of > 195/mile. Along the length of the monitoring reach, 38% of the near-stream riparian vegetation was made up of deciduous shrubs, failing to meet the target of > 57%. The RSI was 83, failing to meet the target value of < 75.

**Other Assessments**

In 2005, DEQ collected pebble count data at two sites on Sleeping Child Creek, one near the forest road and one near the mouth. Surface fines < 2 mm were 9% at the upper site and 18% at the lower; both sites failed to meet the target value of ≤ 8%. Surface fines <6mm were 10% at the upper site and 24% at the lower site, with the lower site failing to meet the target value of ≤ 14%.

The Bitterroot National Forest conducted stream assessments at two locations on Sleeping Child Creek in 2003. Selected results are presented in **Table 5-39**. Percent fines were generally above targets. Width/depth ratios were within expected ranges for the stream types at both sites.

**Table 5-39. Selected BNF Data from Sleeping Child Creek**

| Site | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|
| Mile 9.3 | **19** | **16** | 22 | 2.9 |
| Mile 20.7 | **87** | **61** | 7 | 2.3 |

**Biological Data**

Macroinvertebrate data samples were collected at two sites on Sleeping Child Creek in September 2005. O/E metrics fell below the target range for both sites (**Table 5-40**).

**Table 5-40. Macroinvertebrate Metrics for Sleeping Child Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| SCC1: near end of road | 9/5/2005 | 72 | Not applicable | **0.61** |
| SSC2: near mouth | 9/5/2005 | Not applicable | 61 | **0.54** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) also showed mixed results. The study found that of the 49.8 miles of streambank along Sleeping Child Creek (double its 24.9 mile length to account for both banks) only 16 miles (33%) had significant anthropogenic effects within 100 feet of the channel. Overall, the available data suggest possible elevated fine sediment levels as well as habitat alterations which appear to be linked to land-use activities within the watershed, macroinvertebrate results indicate potential effects to aquatic life. For this reason, a sediment TMDL will be developed.

### *5.4.2.11 Sweathouse Creek*

Sweathouse Creek begins in the Bitterroot Mountains on the west side of the Bitterroot Valley and flows for 11.2 miles before reaching the Bitterroot River near Victor, Montana. The headwaters of the stream are dominated by Bitterroot National Forest lands, while the lower reaches are bordered by private lands. Although the stream is not currently listed for sediment, it was listed for alterations in streamside vegetation on the 2010 303(d) List, which may be linked to sediment loading. For this reason, Sweathouse Creek was included in this analysis. Suspected sources include site clearing (land development or redevelopment) and loss of riparian habitat.

**Physical Condition and Sediment Sources**

DEQ performed a stream assessment at one site along Sweathouse Creek in 2007. The assessment reach, SWEA 29, was located on private land in the lower watershed, a short distance upstream from Highway 93 and was classified as a C4 stream type. The assessment field crew noted that this reach flows through grazed area. There was boulder riprap at several meander bends. It appeared that the channel was slightly over-widened and slightly entrenched in places, though wetland vegetation along portions of the channel suggests some recovery. The few willows were heavily browsed. The pools lacked cover. Eroding streambanks were associated with slumping.

**2007 DEQ Data and Comparison with Water Quality Targets**

The existing sediment and habitat data compared with the targets for Sweathouse Creek are summarized in **Table 5-41**.

**Table 5-41. Sweathouse Creek Data Compared with Targets**

| | | | | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach ID** | **Mean BFW (ft)** | **Level III Ecoregion** | **Potential Stream Type** | **% <6mm** | **% <2mm** | **Riffle % <6mm** | **Pool % <6mm** | **W/D Ratio** | **Entrenchment Ratio** | **Residual Pool Depth (ft)** | **Pools / Mile** | **LWD / Mile** | **Greenline % Shrub Cover** | **Riffle Stability Index** |
| SWEA-29 | 29 | IB | C4 | **21** | **12** | 8 | 10 | **25** | 3 | 1.6 | **42** | **100** | **12** | **91** |

**Bold** indicates target value was not met.

During the 2007 assessment in reach SWEA 29, the composite riffle pebble count surface fines < 6 mm and < 2 mm were 21% and 12%, exceeding their target values of < 14% and < 8%, respectively. Percent fines, as measured by the grid-toss methodology, were 8% in riffles and 10% in pool tail-outs, meeting the target values of < 10%. The median width-to-depth ratio was 25, exceeding the target value of < 16. The entrenchment ratio was 3.0, meeting the target value of > 2.5 for C stream types. The mean residual pool depth of 1.6 met the target of > 1.1. A pool frequency of 42/mile was observed in the reach, not meeting the target of > 49/mile. LWD frequency was 100/mile, not meeting the target value of > 380/mile. Along the length of the monitoring reach, 12% of the near-stream riparian vegetation was deciduous shrubs, falling short of the target value of > 57%. The RSI was 91, which failed to meet the target of < 75.

**Other Assessments**

In 2005, DEQ collected pebble count data at two sites on Sweathouse Creek, one near the forest boundary and one near the mouth. Surface fines < 2 mm were 8% at the upper site and 29% at the lower. Surface fines < 6 mm were 8% at the upper site and 33% at the lower. Percent fines < 2 mm and < 6 mm failed to meet the target values for the lower site.

**Biological Data**

Macroinvertebrate data samples were collected at two sites on Sweathouse Creek in September 2005. At the lower site, the O/E target was not met; otherwise, all metrics fell within target ranges (**Table 5-42**).

**Table 5-42. Macroinvertebrate Metrics for Sweathouse Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| SHCR1: near forest boundary | 9/2/2005 | 81 | Not applicable | 1.1 |
| SHCR2: near mouth | 9/2/2005 | Not applicable | 55 | **0.34** |

**Bold** indicates target value was not met.

**Summary and TMDL Development Information**

An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) also showed mixed results. The study found that of the 22.4 miles of streambank along Sweathouse Creek (double its 11.2 mile length to account for both banks), 9.3 miles (42%) had significant anthropogenic effects within 100 feet of the channel. Approximately 14 of the 22.4 miles of streambank were rated as good condition; while the remaining 8.4 miles (38%) were rated as fair or poor condition. Those portions of Sweathouse Creek's riparian areas that were rated as good condition were dominated by forest land uses; those rated as fair or poor were in areas dominated by pastures and rural farms. Overall, the available data suggest possible elevated fine sediment levels as well as habitat alterations which appear to be linked to land-use activities within the watershed. It appears that this reach would recover well with riparian plantings and grazing management. For this reason, a sediment TMDL will be developed.

### *5.4.2.12 Threemile Creek*

Threemile Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows mostly through private lands for 18 miles before reaching the Bitterroot River north of Stevensville, Montana. Threemile Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include agriculture, irrigated crop production, and rangeland grazing.

**Physical Condition and Sediment Sources**

DEQ performed a stream assessment at one site along Threemile Creek in 2007. The assessment reach, THRE 35, was located on private land in the lower watershed and was classified as a C4 potential stream type. The field assessment crew noted that Threemile Creek was entrenched in the survey reach, where historic grazing and agriculture have given way to rural-residential development. Ongoing horse grazing was observed at the site and there were lawns up to the channel margin along most of the reach. There was a band of mature/decadent cottonwoods along the channel margin. Extensive streambank erosion, bare ground, and exposed banks were observed along the channel because of its entrenched character, though most of the banks are not likely retreating very rapidly. The substrate was comprised primarily of sand and fine gravel in pools and runs, while the riffles had some smaller cobbles.

### 2007 DEQ Data and Comparison with Water Quality Targets

The existing sediment and habitat data compared with the targets for Threemile Creek are summarized in **Table 5-43**.

**Table 5-43. Threemile Creek Data Compared with Targets**

| | | | | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| THRE-35 | 11.8 | MR | C4 | **61** | **29** | **49** | **94** | 7.1 | 3.1 | 0.9 | **74** | **137** | 63 | NC |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment in reach THRE 35, the composite riffle pebble count surface fines < 6 mm and < 2 mm did not meet target values of ≤ 14% and ≤ 10%, respectively. Percent fines as measured by the grid-toss methodology were 49% in riffles and 94% in pool tail-outs, failing to meet the target values of ≤ 10% and ≤ 6%, respectively. The median width-to-depth ratio met the target value of ≤ 16. The entrenchment ratio was 3.1, meeting the target value of > 2.5 for C4 stream types. The mean residual pool depth of 0.9 met its target value of greater than 0.8 feet. A pool frequency of 74/mile was observed in the reach, missing the target value of greater than 84/mile. LWD frequency was 137/mile, not meeting the target value of ≥ 573/mile. Along the length of the monitoring reach, 63% of the near-stream riparian vegetation was dominated by deciduous shrubs, meeting the target of ≥ 57%. No RSI data was collected because of a lack of suitable riffles.

### Other Assessments

DEQ collected data at three sites on Threemile Creek in 2005, and the Bitterroot National Forest collected data near the forest boundary in 2004. Selected results from these studies are presented in **Table 5-44**. At the upper site percent fines < 6 mm and < 2 mm were below targets established for streams in the Middle Rockies ecoregion, as were percent fines <2mm at the middle site. Percent fines < 2 mm were exceeded at the lower and middle DEQ sites and the BNF site. Percent fines < 6 mm at the lower DEQ site and the BNF site exceeded the target values established for streams in the Middle Rockies ecoregion. The width/depth ratio at the BNF site exceeded the target value of ≥ 16 for streams with a bankfull width below 20 feet.

**Table 5-44. Selected DEQ and BNF Data from Threemile Creek**

| Agency | Stream Type | Location | Year | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|---|---|---|
| DEQ | unknown | Upper | 2005 | 4 | 0 | NC | NC |
| DEQ | unknown | Middle | 2005 | **30** | 9 | NC | NC |
| DEQ | unknown | Lower | 2005 | **40** | **30** | NC | NC |
| BNF | B4 | Mile 14.4 | 2004 | **18** | **15** | **18** | NC |

**Bold** indicates target value was not met.

### Biological Data
Macroinvertebrate data samples were collected at three sites on Threemile Creek in September 2005 (**Table 5-45**). All targets were met for macroinvertebrate metrics at the upper site. For macroinvertebrate metrics at the middle and lower sites, the Valley MMI target was met but the O/E was not.

**Table 5-45. Macroinvertebrate Metrics for Threemile Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| Upper Threemile | 9/19/2005 | 78 | Not applicable | 0.84 |
| Middle Threemile | 9/19/2005 | Not applicable | 51 | **0.47** |
| Lower Threemile | 9/19/2005 | Not applicable | 51 | **0.39** |

**Bold** indicates target value was not met.

### Summary and TMDL Development Information
Measures of fine substrate sediment levels were consistently outside of target ranges, and macroinvertebrate results suggest potentially negative effects on aquatic life. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) found that of the 36 miles of streambank along Threemile Creek (double its 18 mile length to account for both banks), 27 miles (75%) had significant anthropogenic effects within 100 feet of the channel. Only 12 of the 36 miles of streambank were rated as good condition, while the remaining 24 miles (67%) were rated as in fair or poor condition. Those portions of Threemile Creek's riparian areas that were rated as good were dominated by forest land uses; those rated as fair or poor condition were in areas dominated by agriculture and near-stream roads. Overall, the available data suggests possible elevated fine sediment levels, as well as habitat alterations, which appear to be linked to land-use activities within the watershed. For this reason, a sediment TMDL will be developed.

## *5.4.2.13 Willow Creek*
Willow Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 20.1 miles through mostly private lands to its confluence with the Bitterroot River near Corvallis, Montana. Willow Creek was listed for sedimentation/siltation on the 2010 303(d) List. Suspected pollutant sources include irrigated crop production, loss of riparian habitat, silvicultural activities, and natural sources.

### Physical Condition and Sediment Sources
DEQ performed stream assessments at two sites along Willow Creek in 2007. The upper assessment reach, WILL 28, was located on USFS land in the upper watershed. The stream assessment crew noted that there was a field on the terrace on river-right. It appeared that historic vegetation removal may

have lead to the stream cutting into the terrace along river-right at two sites within the reach. These cutslopes were contributing sediment from bank erosion process. The area was being used for horse grazing. Pools were formed by LWD and boulders. Some potential spawning gravels were observed. Assessment reach WILL 28 was classified as a Rosgen B4 channel type. The lower assessment reach, WILL 38, was located on private land in the lower watershed. The field assessment crew noted that Willow Creek had essentially been converted to a ditch in this reach and was one long riffle with a few poorly defined pools. There was an irrigation diversion, streambank erosion was limited, and some small riprap was associated with the rural-residential development. Grass and weeds lined the channel, along with a few willows. Assessment reach WILL 38 was classified as a Rosgen C4 channel type.

**2007 DEQ Data and Comparison with Water Quality Targets**

The existing sediment and habitat data compared with the targets for Willow Creek are summarized in **Table 5-46**.

**Table 5-46. Willow Creek Data Compared with Targets**

| Reach ID | Mean BFW (ft) | Level III Ecoregion | Potential Stream Type | Riffle Pebble Count (mean) | | Grid Toss (mean) | | Channel Form (median) | | Instream Habitat | | | Riparian | Sediment Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % <6mm | % <2mm | Riffle % <6mm | Pool % <6mm | W/D Ratio | Entrenchment Ratio | Residual Pool Depth (ft) | Pools / Mile | LWD / Mile | Greenline % Shrub Cover | Riffle Stability Index |
| WILL-28 | 21.4 | MR | B4 | **21** | **11** | **14** | NC | 14.4 | 4.1 | 1.2 | 69 | 1753 | 90 | NC |
| WILL-38 | 17 | MR | C4 | **49** | **33** | **37** | **21** | **18.2** | 6.3 | **0.9** | **26** | **11** | **8** | NC |

**Bold** indicates target value was not met. NC = not collected.

During the 2007 assessment both reaches failed to meet their target values for riffle pebble count surface fines < 6 mm and < 2 mm. In both reaches, percent fines as measured by the grid toss methodology exceeded the target value of < 10% in riffles and in reach WILL 38 exceeded the target value of < 6% for fines for pool-tails. The median width-to-depth ratio in reach WILL 38 did not meet the target value of ≤ 16. The entrenchment ratio of both reaches met their target values. The mean residual pool depth did not meet the target value in WILL 38. Pool frequency was low and did not meet the target value in WILL 38. Along the length of reach WILL 28, 90% of the near-stream riparian vegetation was dominated by deciduous shrubs; however, only 8% of the length of reach WILL 38 had shrub cover, failing to meet the target value of > 57%. RSI was not collected in either reach due a lack of suitable bars.

**Other Assessments**

DEQ collected data at three sites on Willow Creek in 2004, and the Bitterroot National Forest collected data at two sites in 2003. Selected results from these studies are presented in **Table 5-47**. Both fine sediment targets were exceeded at the upper and lower DEQ sites and the Mile 9 BNF site, and percent fines <2mm were also exceeded at the Middle DEQ site. Width-to-depth ratio met the target values at all but the Mile 9 BNF site and entrenchment ratio failed to meet targets at the Middle DEQ site and the Mile 9 BNF site.

**Table 5-47. Selected DEQ and BNF Data from Willow Creek**

| Agency | Stream Type | Location | Year | % <6mm | % <2mm | Width / Depth Ratio | Entrenchment Ratio |
|---|---|---|---|---|---|---|---|
| DEQ | B4 | Upper | 2004 | **45** | **39** | 12.3 | 1.9 |
| DEQ | E4 | Middle | 2004 | 28 | **24** | 10 | **2.2** |
| DEQ | E5 | Lower | 2004 | **72** | **66** | 9.4 | 7 |
| BNF | B4 | Mile 11.0 | 2003 | 7 | 7 | 12.7 | 1.6 |
| BNF | B3 | Mile 9.0 | 2003 | **33** | **26** | **29.8** | **1.4** |

**Bold** indicates target value was not met.

### Biological Data

Macroinvertebrate data samples were collected at three sites on Willow Creek in July 2004 (**Table 5-48**). For macroinvertebrates at the lower site the O/E target was not met; otherwise, all metrics fell within target ranges.

**Table 5-48. Macroinvertebrate Metrics for Willow Creek**

| Station ID | Collection Date | Mountain MMI | Valley MMI | O/E |
|---|---|---|---|---|
| Upper Willow | 7/11/2004 | Not applicable | 62 | 1.08 |
| Middle Willow | 7/11/2004 | Not applicable | 61 | 1.01 |
| Lower Willow | 7/14/2004 | Not applicable | 55 | **0.74** |

**Bold** indicates target value was not met.

### Summary and TMDL Development Information

The available fine sediment data generally indicate potentially elevated sediment loading, with most measures of fine substrate particles in excess of established targets. An assessment of riparian condition and near-stream land uses (conducted concurrently with this study) also showed mixed results. The study found that of the 40.2 miles of streambank along Willow Creek (double its 20.1 mile length to account for both banks), 21.8 miles (54%) had significant anthropogenic effects within 100 feet of the channel. Approximately 18.4 miles of the 40.2 miles of streambank were rated as good condition; while the remaining 21.8 miles were rated as fair or poor condition. Those portions of Willow Creek's riparian areas that were rated as good condition were dominated by forest land uses and were entirely in areas with no significant human impact within 100 feet of the stream; those rated as fair or poor condition were in areas dominated by agricultural uses and roads. Overall, the available data suggests elevated fine sediment levels, as well as habitat alterations which appear to be linked to land-use activities within the watershed. For this reason, a sediment TMDL will be pursued.

## 5.5 TMDL Development Summary

Based on the 303(d) sediment listings and a comparison of existing conditions to water quality targets, 15 sediment TMDLs will be developed in the Bitterroot TPA. **Table 5-49** summarizes the sediment TMDL development determinations and corresponds to **Table E-1**, which contains the TMDL development status for all listed waterbody segments on the 2010 303(d) List. Three of the waterbodies in **Table 5-49** were listed for habitat/low flow alterations, but based on a comparison of existing conditions to water quality targets, will have sediment TMDLs developed.

**Table 5-49. Summary of TMDL development determinations**

| Stream Segment | Waterbody ID | TMDL Development Determination (Y/N) |
|---|---|---|
| Ambrose Creek* | MT76H004_120 | Y |
| Bass Creek* | MT76H004_010 | Y |
| Lick Creek | MT76H004_170 | Y |
| Lolo Creek (headwaters to Sheldon Creek) | MT76H005_013 | Y |
| Lolo Creek (Mormon Creek to Mouth) | MT76H005_011 | Y |
| Lolo Creek (Sheldon Creek to Mormon Creek) | MT76H005_012 | Y |
| McClain Creek | MT76H004_150 | Y |
| Miller Creek | MT76H004_130 | Y |
| Muddy Spring Creek | MT76H004_180 | Y |
| North Burnt Fork Creek | MT76H004_200 | Y |
| Rye Creek | MT76H004_190 | Y |
| Sleeping Child Creek | MT76H004_090 | Y |
| Sweathouse Creek* | MT76H004_210 | Y |
| Threemile Creek | MT76H004_140 | Y |
| Willow Creek | MT76H004_110 | Y |

*Listed for habitat/low flow alterations, but based on a comparison of existing conditions to water quality targets, will have sediment TMDLs developed.

TMDL development for each waterbody segment also addresses the tributary streams in each watershed. Several of these streams were heavily affected by land management activities and the development of sediment allocations throughout the watershed helps focus loading reductions in all tributary watersheds where significant human-caused sediment loading occurs. This results in a comprehensive watershed protection approach versus sorting out individual tributaries for additional sediment TMDL development work in a piece-meal fashion, which uses resources that could be focused on implementation.

## 5.6 Source Assessment and Quantification

This section summarizes the assessment approach, current sediment load estimates, and rationale for load reductions from anthropogenic activities within four main source categories: streambank erosion, upland erosion, roads, and stormwater permitted point sources (which generally involve upland erosion or road construction). EPA sediment TMDL development guidance for source assessments states that an inventory of sediment sources should be compiled using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (EPA 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 in 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. Until better information is available, and the linkage between loading and instream conditions becomes clearer, the loading estimates presented here should be considered as an evaluation of the relative contribution from sources and areas that can be further refined in the future through adaptive management.

### 5.6.1 Streambank Erosion

As discussed in **Section 5.3**, streambank erosion was assessed in 2007 during two monitoring timeframes, with 32 monitoring sites assessed during June/August and 23 monitoring sites assessed during October/November. Streambank erosion data collected at field monitoring sites was extrapolated to the stream reach and stream segment scales based on information in the Aerial Assessment Database, which was compiled in GIS before the data was collected in the field. Streambank erosion data was also used to estimate sediment loading at the watershed scale and to assess the potential to decrease sediment inputs due to streambank erosion. Sediment loading from eroding streambanks was assessed using Bank Erosion Hazard Index (BEHI) measurements and evaluating the Near Bank Stress (NBS) (Rosgen, 1994; Rosgen, 2004). At each assessment reach, BEHI scores were determined 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 in stream energy
- natural sources
- other

Based on the aerial assessment process (described in **Section 5.3**) in which each 303(d) listed waterbody segment is divided into different reaches, streambank erosion data from each 2007 monitoring site was used to extrapolate to the reach scale. The mean value for each unique reach category was applied to unmonitored reaches in the corresponding category to estimate loading associated with bank erosion at the listed stream segment and watershed scales. The potential for sediment load reduction was estimated as a percent reduction that could be achieved if all eroding streambanks could be reduced to a moderate BEHI score (i.e., moderate risk of erosion). For streambanks already achieving this rate, no reduction was applied. The most appropriate BMPs will vary by site, but streambank stability and erosion rates are largely a factor of the health of vegetation near the stream, and the application of riparian BMPs are anticipated to lower the BEHI scores and result in the estimated reductions. Although a moderate risk of erosion may not be achievable in all areas, greater reductions will likely be achievable in some areas; reference data (Bengeyfield, 2004) indicate a moderate BEHI score is a reasonable goal. The results are provided to determine a reasonable amount of sediment reduction to sources that influence streambank erosion. For bank erosion, some sources are the result of historical land management activities that are not easily mitigated through changes in current management. In addition, they may be costly to restore and have been irreversibly altered. Therefore, although the sediment load associated with bank erosion is presented in separate source categories (e.g., silviculture and mining), the allocation is presented as a percent reduction expected collectively from human sources.

**Assessment Summary**

A total sediment load of 758 tons/year was attributed to eroding streambanks within the monitoring sites. Approximately 60% of the sediment load from streambank erosion at the monitoring sites was due to anthropogenic sources, while approximately 40% was from natural sources. Monitoring site assessments suggest that riparian grazing and cropland are the greatest anthropogenic contributors of sediment loads from streambank erosion in the Bitterroot TPA, followed by the "other" category, which primarily describes the effects of residential and commercial encroachment in the watershed. For loads extrapolated to watersheds selected for TMDL development streambank erosion contributes an estimated 21,195 tons of sediment per year, 44% of which is from natural sources **(Table 5-50)**. For loads extrapolated to the entire Bitterroot TPA streambank erosion contributes an estimated 53,514 tons of sediment per year. In addition to that figure, which includes the Upper Lolo Creek TPA, a sediment load of 21,059 tons/year was estimated for the Bitterroot Headwaters TPA based on an estimated sediment load of 18.6 tons/mile/year and 1,132.23 miles of stream. Thus, a total sediment load of 74,574 tons/year is estimated for the entire Bitterroot River watershed. **Appendix E** contains additional information about the streambank erosion source assessment and associated load estimates for the 303(d) listed streams in the Bitterroot TPA.

**Table 5-50. Sediment Load from Streambank Erosion and Comparison among Watersheds and Individual Sources**

| Stream Segment | Stream Segment Length (Miles) | Sediment Load | Sources | | | | | | | | Total Load (Tons/ Year | Total Load per Mile (Tons/ Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Transportation | Riparian Grazing | Cropland | Mining | Silviculture | Irrigation - shifts in stream energy | Natural Sources | Other | | |
| **Ambrose** | 38.1 | **Tons/ Year** | 79.9 | 211.7 | 341.9 | 0.0 | 0.0 | 0.0 | 237.6 | 87.9 | 959.0 | 25.2 |
| | | *Percent* | *8%* | *22%* | *36%* | *0%* | *0%* | *0%* | *25%* | *9%* | | |
| **Bass** | 16.1 | **Tons/ Year** | 5.2 | 18.7 | 0.0 | 0.0 | 0.0 | 1.7 | 205.2 | 9.9 | 240.6 | 14.9 |
| | | *Percent* | *2%* | *8%* | *0%* | *0%* | *0%* | *1%* | *85%* | *4%* | | |
| **Lick** | 9.8 | **Tons/ Year** | 15.5 | 47.5 | 0.0 | 0.0 | 0.0 | 0.0 | 113.9 | 3.4 | 180.3 | 18.4 |
| | | *Percent* | *9%* | *26%* | *0%* | *0%* | *0%* | *0%* | *63%* | *2%* | | |
| **Lolo (Including S. Fork Lolo Creek)** | 245.8 | **Tons/ Year** | 1145.7 | 613.2 | 188.8 | 0.0 | 113.4 | 127.4 | 2761.8 | 477.1 | 5427.5 | 22.1 |
| | | *Percent* | *21%* | *11%* | *3%* | *0%* | *2%* | *2%* | *51%* | *9%* | | |

**Table 5-50. Sediment Load from Streambank Erosion and Comparison among Watersheds and Individual Sources**

| Stream Segment | Stream Segment Length (Miles) | Sediment Load | Sources | | | | | | | | Total Load (Tons/ Year | Total Load per Mile (Tons/ Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Transportation | Riparian Grazing | Cropland | Mining | Silviculture | Irrigation - shifts in stream energy | Natural Sources | Other | | |
| **McClain** | 7.0 | **Tons/ Year** | 21.2 | 40.5 | 11.1 | 2.7 | 0.0 | 7.1 | 29.8 | 0.0 | 112.4 | 16.1 |
| | | *Percent* | *19%* | *36%* | *10%* | *2%* | *0%* | *6%* | *26%* | *0%* | | |
| **Miller** | 56.9 | **Tons/ Year** | 123.7 | 308.0 | 554.0 | 0.0 | 1.1 | 46.0 | 656.5 | 381.8 | 2074.0 | 36.4 |
| | | *Percent* | *6%* | *15%* | *27%* | *0%* | *0%* | *2%* | *32%* | *18%* | | |
| **Muddy Spring Creek** | 2.0 | **Tons/ Year** | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| | | *Percent* | *100%* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* | | |
| **North Burnt Fork** | 107.0 | **Tons/ Year** | 199.4 | 1667.2 | 383.7 | 0.0 | 0.0 | 70.5 | 659.6 | 245.3 | 2725.7 | 25.5 |
| | | *Percent* | *7%* | *43%* | *14%* | *0%* | *0%* | *3%* | *24%* | *9%* | | |
| **Rye (Including N. Fork Rye Creek)** | 85.8 | **Tons/ Year** | 113.4 | 245.0 | 155.6 | 0.0 | 39.1 | 62.6 | 1310.4 | 9.1 | 1935.2 | 22.6 |
| | | *Percent* | *6%* | *13%* | *8%* | *0%* | *2%* | *3%* | *68%* | *0%* | | |
| **Sleeping Child** | 117.4 | **Tons/ Year** | 80.1 | 355.9 | 236.9 | 0.0 | 91.2 | 48.5 | 1495.0 | 79.6 | 2387.2 | 20.3 |
| | | *Percent* | *3%* | *15%* | *10%* | *0%* | *4%* | *2%* | *63%* | *3%* | | |
| **Sweathouse** | 33.7 | **Tons/ Year** | 17.2 | 537.7 | 9.3 | 0.1 | 0.0 | 51.6 | 286.7 | 134.3 | 1036.9 | 30.8 |
| | | *Percent* | *2%* | *52%* | *1%* | *0%* | *0%* | *5%* | *28%* | *13%* | | |
| **Threemile (Including Ambrose Creek)** | 120.6 | **Tons/ Year** | 824.1 | 194.1 | 495.2 | 0.0 | 0.0 | 48.6 | 1087.0 | 720.6 | 3369.6 | 27.9 |
| | | *Percent* | *24%* | *6%* | *15%* | *0%* | *0%* | *1%* | *32%* | *21%* | | |
| **Willow** | 61.3 | **Tons/ Year** | 70.4 | 351.4 | 239.8 | 0.0 | 0.0 | 62.7 | 784.0 | 196.8 | 1705.0 | 27.8 |
| | | *Percent* | *4%* | *21%* | *14%* | *0%* | *0%* | *4%* | *46%* | *12%* | | |

## 5.6.2 Upland Erosion and Riparian Buffering Capacity

Upland sediment loading due to hillslope erosion in the Bitterroot TPA was assessed using a hydrologic simulation model known as SWAT (Soil and Water Assessment Tool). SWAT is a river basin scale model developed that quantifies the impact of land management practices in large, complex watersheds. It incorporates hydrologic, climactic, and water chemistry data with detailed land cover/land use and topography information to predict pollutant loading for seasonal and annual time frames. A SWAT model for the Bitterroot, currently underway for evaluation of sediment and nutrient loads, is being used to represent the typical land uses and associated conditions affecting sediment production. The workings of the model are detailed as part of an initial calibration report (Van Liew, unpublished); however, the tool will be complete when it is refined as part of the nutrient TMDL. Even in its initial form, the tool is useful for estimating landscape sediment yields. Because the model and associated sedimentation results are only preliminary, a simplified approach was implemented for the TMDL analysis. This consisted of the following:

- using the preliminary SWAT model for estimating existing condition baseline upland sediment sources for impaired tributaries in the Bitterroot TPA.
- and analyzing scenarios outside of the model. In this case loads from the preliminary SWAT model are multiplied by a literature-based BMP efficiency to establish the load reductions for the TMDL.

An initial existing-condition scenario was used that incorporated some basic assumptions regarding land use management practices to estimate current existing loads. Changes were then made to parameters outside of the model to represent potential improvements to land management practice improvements, and thereby estimate the sediment loads that could be expected if those practices were adopted. Improvement scenarios were applied to three land-use categories including upland range brush and grass, cultivated crops, and small acreages. It is assumed that in the Bitterroot TPA these land-use categories have real potential for improvement and are often not meeting all applicable land, soil, and water conservation practices. The sediment contributions from other land uses in the Bitterroot TPA are presumed to be either negligible or have little potential to alter the current management to reduce sediment from the existing load. Loads from unpaved roads were assessed separately and are described in **Section 5.6.3**. Because riparian vegetation can greatly influence sediment loading to streams, model results were adjusted downward to reflect the sediment removal capacity associated with existing riparian vegetation and with that reflective of improved riparian health associated with implementation of additional riparian BMPs. Riparian health was classified as poor, fair, or good per listed waterbody for both right and left banks during the aerial stratification process described in **Section 5.3.1.2**. A conservative assumption was made that poor riparian conditions can filter close to 25% of sediment, moderate riparian condition 50% of the sediment, and good riparian condition can reduce upland sediment load by 75%.

The initial model outputs represent an estimate of current conditions and practices that contribute to the upland sediment load. Allocations for upland sediment sources were derived based on a combination of reductions in sediment loads that will occur by improving range brush and grass, cultivated crop, and small acreage management by implementing upland BMPs and improving the condition (i.e., sediment-trapping efficiency) of near-channel vegetation using riparian BMPs. DEQ acknowledges, however, that this simplistic approach may not represent the true potential for that load reduction within a particular land use. Other factors that might otherwise alter the reduction potential of a given source include geography, the association of the riparian conditions to the various land uses, and the actual potential for the application of best management practices within a given land use. However, at the most basic scale, this approach does identify the relative contributions among the land-use categories and therefore serves as a starting point for focusing sediment reduction efforts and assessing those areas most likely to be affecting the stream (and most likely to have the potential for improvement). 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 by historic land uses.

**Assessment Summary**
Based on the source assessment, hillslope erosion from assessed tributaries contributes approximately 15,463 tons per year to the Bitterroot TPA. Upland erosion from the completed Upper Lolo TMDL was found negligible in the completed TMDL document; therefore, no additional load from the Upper Lolo TPA is included. Hillslope erosion from watersheds selected for TMDL development contributes an approximate 10,797 tons of sediment per year (**Table 5-51**). Based on the assessment on watersheds selected for TMDL development, 70% of the annual load is from range grass and brush, 21% from forests and wetlands, 6% from cultivated crops, 2% from small acreages, and 1% from urban areas. **Appendix H** has a more detailed description of the model setup and results and the riparian adjustment factor.

**Table 5-51. Sediment Load from Upland Sources and Comparison among Watersheds***

| Subbasin | Loads by SWAT HRU Category (T/year) | | | | | | Delivered Sediment Load (T/year) | Subbasin Area (sq. miles) | Normalized to tons per square mile |
|---|---|---|---|---|---|---|---|---|---|
| | AGRL | BARN | FRST | RNGB | RNGE | URML | | | |
| **Ambrose** | 101.2 | 18.0 | 75.9 | 182.4 | 210.9 | 2.2 | **590** | **21.1** | **28.0** |
| **Bass** | 20.0 | 0.2 | 6.4 | 130.9 | 211.8 | 0.0 | **369** | **15.3** | **24.1** |
| **Lick** | 0.4 | 0.0 | 1.7 | 0.2 | 0.2 | 0.5 | **3** | **8.5** | **0.4** |
| **Lolo (Including S. Fork Lolo Creek)** | 184.0 | 41.8 | 1744.5 | 1914.6 | 1044.5 | 15.5 | **4944.9** | **203** | **24.4** |
| **McClain** | 2.4 | 0.0 | 32.4 | 39.0 | 4.0 | 0.2 | **78** | **4.1** | **19.2** |
| **Miller** | 0.4 | 0.2 | 35.1 | 41.9 | 53.1 | 0.2 | **131** | **47.3** | **2.8** |
| **Muddy Spring Creek** | 0.0 | 0.0 | 2.6 | 8.0 | 6.9 | 0.0 | **17** | **1.7** | **10.3** |
| **North Burnt Fork** | 165.2 | 22.5 | 11.5 | 487.1 | 1591.6 | 0.9 | **2279** | **85.9** | **26.5** |
| **Rye (Including N. Fork Rye Creek)** | 0.8 | 0.3 | 0.0 | 4.0 | 4.7 | 0.0 | **10** | **41.7** | **0.2** |
| **Sleeping Child** | 1.3 | 2.7 | 76.9 | 101.5 | 60.8 | 0.1 | **243** | **89.5** | **2.7** |
| **Sweathouse** | 6.8 | 7.0 | 27.3 | 83.5 | 2.0 | 0.3 | **127** | **28.3** | **4.5** |
| **Threemile (Including Ambrose Creek)** | 286.7 | 57.6 | 280.0 | 523.1 | 819.2 | 7.5 | **1974** | **70.7** | **27.9** |
| **Willow** | 18.2 | 14.6 | 90.4 | 296.7 | 200.6 | 0.1 | **621** | **48.3** | **12.8** |

***SWAT HRU Categories (AGRL – Alfalfa/Grass/Hay/Cultivated Crops; BARN – Small Rural Properties/Livestock; FRST – Deciduous Forest, Evergreen Forest, Wetland; RNGB – Range Brush; RNGE – Range Grass; URML – Medium/ Low Density Urban

## 5.6.3 Unpaved Roads

Sediment loading from roads was assessed within the Bitterroot TPA in 2007. Roads located near stream channels can affect streams by degrading riparian vegetation, encroaching on the channel, and increasing sediment loading. The degree of damage depends on many factors including road type, construction specifications, drainage, soil type, topography, precipitation, and the use of best management practices (BMPs). Through a combination of GIS analysis, field assessment, and application of the Water Erosion Prediction Project (WEPP) model, estimated sediment loads were developed for unpaved road crossings and parallel road segments. Road crossings and parallel segments were identified and classified relative to $6^{th}$ code subwatershed, land ownership, and landscape type. These classifications captured a statistically representative sample of roads in the entire watershed, based on a number of road conditions (subwatershed, road design, soil type, maintenance level, etc). Existing road conditions were modeled and future road conditions were estimated after the application of sediment reducing best management practices (BMPs). Existing culverts were also assessed for fish passage and failure. Field assessments were conducted at 136 unpaved crossings, 63 parallel segments, and 67 culverts.

**Unpaved Road Crossings and Parallel Segments**

Based on the field measurements, the sediment load was modeled in WEPP by road surface and usage (i.e., high vs. low) and the average for each crossing type and parallel segment was extrapolated to the remaining roads in the watershed. The model was used to approximate the sediment load associated with existing road crossings and parallel segments (and current BMP usage) and the achievable sediment loading reductions associated with implementing additional BMP implementation. Various BMP sediment reduction scenarios were evaluated based on reductions in contributing road length, reductions in road crossing density, and combinations of the two approaches. The selected scenario for estimating sediment load reductions was calculated by assuming a uniform reduction in contributing road length of 200 feet for each unpaved crossing and 500 feet for each parallel road segment. Reductions could be achieved by a variety of BMPs that reduce sediment delivery to streams such as improving ditch relief at crossings, adding water bars, adding vegetative buffers, improving maintenance, and using rolling dips and cross slopes. Additional details regarding the roads assessment are provided in **Appendix G**.

**Culverts**

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, as part of the roads assessment, the potential sediment load at risk during culvert failure was estimated and culverts were evaluated for fish passage. Culverts were analyzed for their ability to allow for fish passage, and for their ability to pass adequate flood flows. However, it is difficult to develop specific road crossing allocations for sediment delivered in the event of a culvert failure, as there are several factors that may impact the accuracy of the data, therefore specific sediment loads were not developed for each crossing. More details of the culvert analysis are provided in **Appendix G**.

**Assessment Summary**

Mean sediment loads from field sites were used to extrapolate existing loads throughout the entire watershed. Mean loads for unpaved crossings in mountain (0.12 tons/year), foothill (0.22 tons/year), and valley (0.07 tons/year) landscape types were applied to the total number of crossings in the TPA and further classified by 6th code HUC and land ownership. The existing total Bitterroot watershed sediment load from unpaved road crossings was estimated at 461.3 tons/year; and the total existing load from parallel road segments is estimated at 248.4 tons/year. Loads from unpaved road crossings and parallel segments from watersheds selected for TMDL development contribute an approximate 338 tons of sediment per year (**Table 5-52**).

**Table 5-52. Sediment Load from Unpaved Roads and Comparison among Watersheds**

| Subbasin | Sediment Load From Unpaved Road Crossings | Sediment Load From Unpaved Parallel Road Segments | Total Sediment Load from Unpaved Road Crossings and Parallel Segments | Normalized to tons per square mile |
|---|---|---|---|---|
| Ambrose | 8.1 | 3.2 | 11.3 | 0.54 |
| Bass | 1.8 | 0.4 | 2.3 | 0.15 |
| Lick | 3.3 | 2.1 | 5.4 | 0.64 |
| Lolo (Including S. Fork Lolo Creek) | 90.4 | 81.4 | 171.7 | 0.85 |
| McClain | 6.6 | 2.4 | 9.1 | 2.24 |
| Miller | 14 | 12.7 | 26.7 | 0.56 |
| Muddy Spring Creek | 0.12 | 0.04 | 0.16 | 0.08 |
| North Burnt Fork | 12.4 | 8.4 | 20.8 | 0.24 |
| Rye (Including N. Fork Rye Creek) | 33.6 | 30.5 | 64.1 | 1.54 |
| Sleeping Child | 17.9 | 12.8 | 30.7 | 0.34 |
| Sweathouse | 8 | 2 | 10 | 0.35 |
| Threemile (Including Ambrose Creek) | 23.8 | 9.1 | 32.8 | 0.46 |
| Willow | 9.7 | 5 | 14.7 | 0.30 |

The majority of sediment load from unpaved road crossings throughout the Bitterroot TPA is generated from crossings on private land (216.6 tons/year), followed by USFS land (177.5 tons/year), and Plum Creek Timber land (57.1 tons/year). The majority of sediment load from unpaved parallel road segments is generated from parallel road segments on USFS land (127.4 tons/year), followed by private land (57.1 tons/year), and Plum Creek Timber land (54.1 tons/year). Additional details regarding these results are included within **Appendix G**. The completed Upper Lolo TMDL document attributes the total sediment contribution from forest roads and sanding on U.S. Highway 12 to be between approximately 623 – 716 tons/year.

## 5.6.4 Point Sources

There are no municipal or individual permitted point sources of sediment that discharge to tributary streams listed for sediment impairment (**Table 5-1**). However, as of December 8, 2010, there was one stormwater permit covered under the general permit for stormwater discharges associated with mining, oil, and gas activities that discharges into Lolo Creek, and there were seven permits covered under the general permit for stormwater discharges associated with construction activity for the listed tributaries in the in the Bitterroot TPA.

**Stormwater Discharge – Mining, Oil, and Gas Activities**

The Billingsley Placer Mine has a MPDES stormwater permit covered under the general permit for stormwater discharges associated with mining, oil, and gas activities. This permit regulates the direct discharge of stormwater draining the facility and its grounds. Under the stipulations of that permit, the facility maintains an approved Stormwater Pollution Prevention Plan (SWPPP). The SWPPP sets forth the procedures, methods, and equipment used to prevent the pollution of stormwater discharges from the facility. In addition, this SWPPP describes general practices used to reduce pollutants in stormwater discharges.

According to Attachment B (Monitoring Parameter Benchmark Concentrations) within the general stormwater permit, the benchmark value for TSS is 100 mg/l. The SWPPP for the Billingsley Placer Mine provides information pertaining to site conditions. Based on this information, an area of approximately 3 acres drains the facility to Lolo Creek. The annual average precipitation for this site is approximately 13 inches. Given the 3 acres of disturbed area, 13 inches of precipitation, and using the condition of the benchmark value (100 mg/l), the maximum allowable annual sediment load from this site would equate to approximately 0.4 tons/year. The WLA is provided because it is a requirement for permitted point sources (of the pollutant category of concern) but is not intended to add load limits to the permit; it is assumed that the WLA will be met by adherence to the General Permit requirements (MTR300000), which include a Stormwater Pollution Prevention Plan (SWPPP) with numerous BMPs and site stabilization before a permit can be terminated.

**Stormwater Discharge – Construction Activities**

Stormwater construction permits are all authorized under General Permit MTR100000. Sediment loadings from regulated construction activities are considered point sources of sediment to surface waters. These discharges occur in response to storm events and the purpose of these permits is to eliminate or minimize the discharge of pollutants from construction activities. Since construction activities at a site are relatively temporary and short term nature, the number of construction sites covered by the general permit at any given time varies. Collectively, these areas of severe ground disturbance have the potential to be significant sediment sources if proper BMPs are not implemented and maintained. Observations during field work related to TMDL development indicate that most sediment loading associated with permitted construction activities are likely related to inadequate BMP usage and improper maintenance.

Because construction activities are of a temporary nature and the number of construction sites covered by the general permit at any instant of time varies throughout the watershed, we must make a conservative estimate of potential sediment loading that could occur in each impaired watershed at any given time. To estimate the disturbed acreage associated with construction stormwater permits for each listed segment, current permit files for Bitterroot tributaries were evaluated. Each file contains the number of anticipated acres to be disturbed. Currently, only one stormwater construction permit exists that is over 50 acres, which is for ongoing construction of a ski resort in the McClain Creek watershed; however the permit covers a six and a half year time period. All other projects are <50 acres of disturbed area. Project schedules currently range from 1 to 7 years. To use a conservative approach we will estimate the maximum amount of disturbed acres from all construction projects in one year in any given watershed to be 50. Any construction project or combination of construction projects exceeding 50 acres per year in one watershed will need to follow the general permit, specific attention given to the development of the SWPPP and incorporation and installation of the appropriate BMP and BMP combinations necessary for minimizing erosion, maximizing sediment retention on site, and protecting surface waters.

Sediment erosion rates for construction sites were calculated for each specific subbasin using the small rural properties category from the SWAT model (**Appendix H**); due to similarities in land use cover type. These erosion rates were applied to the 50 acre maximum amount of disturbed area due to construction in each watershed to generate a sediment load from construction sites (**Table 5-53**).

The stormwater general permit for construction projects requires each permittee to develop a Stormwater Pollution Prevention Plan (SWPPP), and prior to permit termination, disturbed areas are required to have a vegetative density equal to or greater than 70 percent of the pre-disturbed level (or an equivalent permanent method of erosion prevention). Inspection and maintenance of BMPs is required. BMP implementation is variable throughout the watershed and frequently related to the age of the construction project (i.e. newer projects generally have better BMPs). However, assumptions must be made at a watershed scale; BMPs for disturbed soil are assumed to be the same and have the same potential for sediment reduction in both permitted and non-permitted areas. Based on studies from the U.S. EPA and the International Stormwater Best Management Practices Database, an estimated average of 65% of sediment is removed when all onsite construction BMPs are in place (Geosyntec Consultants and Wright Water Engineers, Inc., 2008; EPA, 2009b). In addition to onsite construction BMPs minimizing sediment, literature review (Wegner, 1999; Knutson and Naef, 1997) indicates that a 100 foot wide, well vegetated riparian buffer zone can be expected to filter 75-90% of incoming sediment from reaching a stream channel. Using both the efficiency percentages of 65% for onsite construction BMPs and 75% for a minimum 100 foot wide buffer between the site and the stream, we get the maximum allowable annual sediment load for each site shown in **Table 5-53**.

**Table 5-53. Sediment Loading and Reductions from Permitted Construction Sites**

| | Loading rate based on SWAT (T/Acre/ Year) | Load based on 50 acres of disturbance (T/ Year) | Load based on 50 acres of disturbance with ONLY construction site BMPs in place (T/Year) | Sediment load with 100 ft. vegetated buffer ONLY - BMP efficiency of 75% (T/Year) | Resultant sediment load with vegetated buffer applied and all construction BMPs in place (T/Year) | Total possible % reduction from construction sites |
|---|---|---|---|---|---|---|
| **Ambrose** | 2.62 | 131 | 46 | 33 | 11 | 92% |
| **Bass** | 2.03 | 101 | 35 | 25 | 9 | 91% |
| **Lick** | 0.22 | 11 | 4 | 3 | 1 | 91% |
| **Lolo** | 1.51 | 75 | 26 | 19 | 7 | 91% |
| **McClain** | 2.25 | 112 | 39 | 28 | 10 | 91% |
| **Miller** | 0.05 | 2 | 1 | 1 | 0 | 100% |
| **Muddy Spring Creek** | 2.62 | 131 | 46 | 33 | 11 | 92% |
| **North Burnt Fork** | 4.42 | 221 | 77 | 55 | 19 | 91% |
| **Rye** | 0.07 | 4 | 1 | 1 | 0 | 100% |
| **Sleeping Child** | 0.64 | 32 | 11 | 8 | 3 | 91% |
| **Sweathouse** | 0.99 | 49 | 17 | 12 | 4 | 92% |
| **Threemile** | 2.62 | 131 | 46 | 33 | 11 | 92% |
| **Willow** | 2.62 | 131 | 46 | 33 | 11 | 92% |
| **AVERAGE OF ALL SUBBASINS** | 1.74 | 87 | 30 | 22 | 8 | 91% |

**Assessment Summary**

Based on calculated loads from permitted sites, erosion from permitted point sources in the Bitterroot tributaries have the potential to contribute approximately 100 tons per year, with 0.4 tons per year contributed from the Billingsley Placer Mine and 97 tons per year coming from construction sites covered under General Permit MTR100000 (if each listed watershed had construction permits totaling 50 acres of disturbed area).

### 5.6.5 Source Assessment Summary

The estimated annual sediment load from all identified sources for the watersheds selected for TMDL development within the Bitterroot TPA is 32,330 tons per year. Each source type has different seasonal loading rates, and the relative percentage from each source category does not necessarily indicate its importance as a loading source given the variability between source assessment methods. Additionally, the different source assessment methodologies introduce differing levels of uncertainty, as discussed in **Section 5.6**. However, the modeling results for each source category, and the ability to proportionally reduce loading with the application of improved management practices (**Appendices B, D** and **E**), provide an adequate tool to evaluate the relative importance of loading sources (e.g., subwatersheds and/or source types) and to focus water quality restoration activities for this TMDL analysis. Based on field observations and associated source assessment work, all assessed source categories represent significant controllable loads.

## 5.7 TMDL AND ALLOCATIONS

The sediment TMDLs for the Bitterroot TPA will adhere to the TMDL loading function discussed in **Section 4**, but use a percent reduction in loading allocated among sources. 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 will correspond to a decrease in fine sediment and result in attainment of water quality standards. A percent-reduction approach is used because there is no numeric standard for sediment to calculate the allowable load with and because of the uncertainty associated with the loads derived from the source assessment (which are used to establish the TMDL). Additionally, the percent-reduction TMDL approach is more applicable for restoration planning and sediment TMDL implementation because it shifts the focus from a set number to loading reductions associated with improvements in land management practices, many of which were identified during TMDL development activities. Within this section, the existing load and allocations to the sources will be given for each waterbody segment and then the TMDL will be provided.

The TMDL is expressed as a percentage of the existing load and is composed of allocations to sources expressed as percent reductions that incorporate an implicit margin of safety. Because sediment generally has a cumulative effect on beneficial uses, and all sources in the Bitterroot TPA (including construction stormwater permits) are associated with periodic loading, an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation. Although EPA encourages TMDLs to be expressed in the most applicable timescale, TMDLs are also required to be presented as daily loads (Grumbles 2006); daily loads are provided in **Appendix I**.

**Allocation Approach**

The percent-reduction allocations are based on the modeled BMP scenarios for each major source type (e.g. roads, upland erosion, and streambank erosion) and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Sediment loading reductions are expected to be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. A summary of the reduction scenarios and BMPs are discussed in **Section 5.6** per major source category, with specific details regarding reductions given in the following paragraphs.

***Streambank Erosion***

Bank erosion percent reductions are calculated by estimating a potential decrease in sediment loading from anthropogenic sources by improving streambank stability. For assessed stream reaches, reductions were applied by reducing BEHI values that exceeded the "moderate" category down to "moderate." This was done for each actively eroding streambank due to anthropogenic sources, and the results were extrapolated across the stream segment. Reductions for un-assessed streams were estimated by using the percent reductions calculated for the stream segment(s) associated with that watershed. To discern a distinction between anthropogenic and natural loads for un-assessed streams, the percentage of each category within the associated assessed stream segment(s) for a watershed was applied to the un-assessed streams. This approach assumes that the same anthropogenic impacts exist throughout the watershed.

***Upland Erosion***
The initial model outputs represent an estimate of current conditions and practices that result in the upland sediment load. To determine the total allowable load from upland sources, land use/land cover categories where management practices may be improved are modified (through an alteration to the C-Factor, or vegetative condition) to simulate the resultant sediment loads that exist when all reasonable land, soil, and water conservation practices are employed. Upland percent-reductions are based on applying specific land use BMPs to agricultural, range, and small acreage lands in combination with riparian BMPs for all land uses. The naturally occurring load is considered equal to the load achieved with all reasonable land, soil and water conservation practices in place.

***Unpaved Roads***
Percent-reductions for unpaved roads are based on applying BMPs to road crossings and parallel segments to reduce the contributing road length to 200 feet for each unpaved crossing and 500 feet for each parallel road segment. No load or allocation is given to undersized, improperly installed, or inadequately maintained culverts. At a minimum, culverts should meet the 25-year event, but for fish-bearing streams, for those with a high level of road and impervious surface development upstream, or for culvert sites with large fills, meeting the 100-year event is recommended.

***Point Source***
The WLA is provided because it is a requirement for permitted point sources (of the pollutant category of concern) but is not intended to add load limits to the permit; it is assumed that the WLA will be met by adherence to the General Permit requirements for stormwater under mining, oil, and gas (MTR300000) and construction (MTR100000), which include a Stormwater Pollution Prevention Plan (SWPPP) with numerous BMPs and site stabilization before a permit can be terminated.

**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.

Sediment loading values and the resulting TMDLs and allocations are acknowledged to be coarse estimates. Progress towards TMDL achievement will be gauged by permit adherence for WLAs, BMP implementation for nonpoint sources, and improvement in or attainment of water quality targets. 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 5-54 through 5-56 and tables 5-59 through 5-70**).

## 5.7.1 Ambrose Creek (MT76H004_120)

**Table 5-54. Ambrose Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 11 | 4 | 65% |
| Eroding Banks | Anthropogenically Influenced | 721 | 296 | 44% |
| | Natural | 238 | 238 | |
| Upland Erosion | All Land Uses | 590 | 338 | 43% |
| Point Source | Stormwater Construction | 0 | 11* | 0% |
| Total Sediment Load | | 1560 | 887 | 43% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.2 Bass Creek (MT76H004_010)

**Table 5-55. Bass Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 2 | 0.7 | 68% |
| Eroding Banks | Anthropogenically Influenced | 36 | 30 | 2% |
| | Natural | 204 | 204 | |
| Upland Erosion | All Land Uses | 369 | 313 | 15% |
| Point Source | Stormwater Construction | 0 | 9* | 0% |
| Total Sediment Load | | 611 | 556.7 | 9% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

### 5.7.3 Lick Creek (MT76H004_120)

**Table 5-56. Lick Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 5 | 2 | 66% |
| Eroding Banks | Anthropogenically Influenced | 66 | 47 | 11% |
| | Natural | 114 | 114 | |
| Upland Erosion | All Land Uses | 3 | 2 | 32% |
| Point Source | Stormwater Construction | 0 | 1* | 0% |
| Total Sediment Load | | 188 | 166 | 12% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

### 5.7.4 Lolo Creek

Bank erosion and unpaved road source assessments for Lolo Creek were originally estimated for the entire Lolo watershed, which includes the Upper Lolo TPA. In order to calculate loads and reductions specific to the subwatersheds for each listed segment, the area was calculated for each subwatershed and that percent area in comparison to the total Lolo Creek watershed area was used to recalculate totals for each listed segment subwatershed.

Although presented separately in the following tables, each impaired segment's TMDL consists of any upstream allocations as well, including any allocations from the Upper Lolo TMDL document (**Table 5-57**). **Table 5-58** describes the TMDL and allocation components for each listed segment of Lolo Creek.

**Table 5-57. Upper Lolo TPA Sediment TMDL**

| Sediment Sources | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|
| Roads | 2201 - 2294 | 1940 - 2002 | 12 - 13% |
| Eroding Banks | N/A | N/A | N/A |
| Upland Erosion | N/A | N/A | N/A |
| Point Source | N/A | N/A | N/A |
| Total Sediment Load | 2201 - 2294 | 1940 - 2002 | 12 - 13% |

**Table 5-58. Lolo Creek Cumulative Sediment TMDL**

| Subwatershed | Cumulative Sediment TMDL |
|---|---|
| Upper Lolo TPA | Upper Lolo TPA TMDL |
| Lolo Creek MT76H005_013 | Upper Lolo TPA TMDL + Lolo Creek MT76H005_013 TMDL |
| Lolo Creek MT76H005_012 | Upper Lolo TPA TMDL + Lolo Creek MT76H005_013 TMDL + Lolo Creek MT76H005_012 TMDL |
| Lolo Creek MT76H005_011 | Upper Lolo TPA TMDL + Lolo Creek MT76H005_013 TMDL + Lolo Creek MT76H005_012 TMDL + Lolo Creek MT76H005_011 TMDL |

### *5.7.4.1 Lolo Creek – Headwaters to Sheldon Creek (MT76H005_013)*

**Table 5-59. Lolo Creek MT76H005_013 Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 41 | 15 | 63% |
| Eroding Banks | Anthropogenically Influenced | 863 | 362 | 28% |
| | Natural | 897 | 897 | |
| Upland Erosion | All Land Uses | 1125 | 820 | 27% |
| Point Source | Stormwater Construction | 0 | 7* | 0% |
| Total Sediment Load | | 2926 | 2101 | 28% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

### *5.7.4.2 Lolo Creek – Sheldon Creek to Mormon Creek (MT76H005_012)*

**Table 5-60. Lolo Creek MT76H005_012 Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 84 | 31 | 63% |
| Eroding Banks | Anthropogenically Influenced | 1762 | 740 | 28% |
| | Natural | 1833 | 1833 | |
| Upland Erosion | All Land Uses | 2690 | 2086 | 22% |
| Point Source | Stormwater Construction | 0 | 7* | 0% |
| | Billingsley Placer Mine | 0 | 0.4 | 0% |
| Total Sediment Load | | 6369 | 4697.4 | 26% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

### *5.7.4.3 Lolo Creek – Mormon Creek to Mouth (MT76H005_011)*

**Table 5-61. Lolo Creek MT76H005_011 Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 1.72 | 0.64 | 63% |
| Eroding Banks | Anthropogenically Influenced | 37 | 16 | 28% |
| | Natural | 37 | 37 | |
| Upland Erosion | All Land Uses | 199 | 122 | 39% |
| Point Source | Stormwater Construction | 0 | 7* | 0% |
| Total Sediment Load | | 275.72 | 182.64 | 34% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.5 McClain Creek (MT76H004_150)

**Table 5-62. McClain Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 9 | 3 | 67% |
| Eroding Banks | Anthropogenically Influenced | 82 | 71 | 10% |
| | Natural | 30 | 30 | |
| Upland Erosion | All Land Uses | 78 | 57 | 28% |
| Point Source | Stormwater Construction | 0 | 10* | 0% |
| Total Sediment Load | | 199 | 171 | 14% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.6 Miller Creek (MT76H004_130)

**Table 5-63. Miller Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 27 | 10 | 63% |
| Eroding Banks | Anthropogenically Influenced | 1415 | 792 | 30% |
| | Natural | 659 | 659 | |
| Upland Erosion | All Land Uses | 131 | 77 | 41% |
| Point Source | Stormwater Construction | 0 | 0* | 0% |
| Total Sediment Load | | 2232 | 1538 | 31% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit.

## 5.7.7 Muddy Spring Creek (MT76H004_180)

**Table 5-64. Muddy Spring Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 0.16 | 0 | 0% |
| Eroding Banks | Anthropogenically Influenced | 0 | 0 | 0% |
| | Natural | 0* | 0 | |
| Upland Erosion | All Land Uses | 17 | 15 | 14% |
| Total Sediment Load** | | 17 | 15 | 14% |

*Bank erosion sediment loads from 1st order streams were assumed to be negligible due to their relatively low sediment contribution. As a result, for extrapolation purposes, 1st order streams were given a sediment load of 0. Muddy Spring Creek is a first order stream for its entire length. DEQ acknowledges that there may be a small natural sediment load occurring in Muddy Spring Creek; however, to be consistent with the approach, the bank erosion load is set at 0. (**See Appendix E**). **Because Muddy Spring Creek resides in USFS land, and no new construction is foreseen by the USFS, point sources due to stormwater construction were not included.

## 5.7.8 North Burnt Fork Creek (MT76H004_200)

**Table 5-65. North Burnt Fork Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 21 | 8 | 62% |
| Eroding Banks | Anthropogenically Influenced | 2070 | 952 | 41% |
| | Natural | 656 | 656 | |
| Upland Erosion | All Land Uses | 2279 | 1195 | 48% |
| Point Source | Stormwater Construction | 0 | 19* | 0% |
| Total Sediment Load | | 5026 | 2830 | 44% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.9 Rye Creek (MT76H004_190)

**Table 5-66. Rye Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 64 | 24 | 63% |
| Eroding Banks | Anthropogenically Influenced | 621 | 379 | 13% |
| | Natural | 1314 | 1314 | |
| Upland Erosion | All Land Uses | 10 | 7 | 33% |
| Point Source | Stormwater Construction | 0 | 0* | 0% |
| Total Sediment Load | | 2009 | 1724 | 14% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit.

## 5.7.10 Sleeping Child Creek (MT76H004_090)

**Table 5-67. Sleeping Child Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 31 | 11 | 63% |
| Eroding Banks | Anthropogenically Influenced | 885 | 593 | 12% |
| | Natural | 1502 | 1502 | |
| Upland Erosion | All Land Uses | 243 | 197 | 19% |
| Point Source | Stormwater Construction | 0 | 3* | 0% |
| Total Sediment Load | | 2661 | 2306 | 13% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.11 Sweathouse Creek (MT76H004_210)

**Table 5-68. Sweathouse Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 10 | 3 | 68% |
| Eroding Banks | Anthropogenically Influenced | 749 | 315 | 42% |
| | Natural | 288 | 288 | |
| Upland Erosion | All Land Uses | 127 | 95 | 25% |
| Point Source | Stormwater Construction | 0 | 4* | 0% |
| Total Sediment Load | | 1174 | 705 | 40% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.12 Threemile Creek (MT76H004_140)

**Table 5-69. Threemile Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 22 | 7 | 67% |
| Eroding Banks | Anthropogenically Influenced | 2288 | 1098 | 35% |
| | Natural | 1082 | 1082 | |
| Upland Erosion | All Land Uses | 1384 | 836 | 40% |
| Point Source | Stormwater Construction | 0 | 11* | 0% |
| Total Sediment Load | | 4776 | 3034 | 36% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.7.13 Willow Creek (MT76H004_110)

**Table 5-70. Willow Creek Sediment TMDL**

| Sediment Sources | | Current Estimated Load (Tons/Year) | Total Allowable Load (Tons/Year) | Sediment Load Allocation (Percent Reduction) |
|---|---|---|---|---|
| Roads | | 15 | 5 | 66% |
| Eroding Banks | Anthropogenically Influenced | 922 | 461 | 27% |
| | Natural | 783 | 783 | |
| Upland Erosion | All Land Uses | 621 | 394 | 37% |
| Point Source | Stormwater Construction | 0 | 11* | 0% |
| Total Sediment Load | | 2341 | 1654 | 29% |

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit. Full compliance with all conditions of the permit should achieve a load less than this amount.

## 5.8 Seasonality and Margin of Safety

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

### 5.8.1 Seasonality

The seasonality of sediment impact to aquatic life is taken into consideration in the analysis within this document. Sediment loading varies considerably with season. For example, sediment delivery increases during spring when snowmelt delivers sediment from upland sources and the resulting higher flows scour streambanks. However, these higher flows also scour fines from streambeds and sort sediment sizes, resulting in a temporary decrease in the proportion of deposited fines in critical areas for fish spawning and insect growth. While fish are most susceptible to fine sediment deposition seasonally during spawning, fine sediment may affect aquatic insects throughout the year. Because both fall and spring spawning salmonids reside in the Bitterroot TPA, streambed conditions need to support spawning through all seasons. Additionally, reduction in pool habitat, by either fine or coarse sediment, alters the quantity and quality of adult fish habitat and can, therefore, affect the adult fish population throughout the year. Thus, sediment targets are not set for a particular season, and source characterization is geared toward identifying average annual loads. Annual loads are appropriate because the impacts of delivered sediment are a long-term impact once sediment enters the stream network, it may take years for sediment loads to move through a watershed. Although an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation, to meet EPA requirements daily loads are provided in **Appendix I**.

### 5.8.2 Margin of Safety

Incorporating a margin of safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. 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 (EPA 1999). All sediment TMDLs in this document incorporate an implicit MOS in a variety of ways:

- By using multiple targets, including biological indicators, to help verify beneficial use support determinations and assess standards attainment after TMDL implementation. Conservative assumptions were used during target development (see **Section 5.4.1**).
- By using targets and TMDLs that address both coarse and fine sediment delivery.
- Conservative assumptions were used for the source assessment process, including erosion rates, sediment delivery ratio, and BMP effectiveness (see **Appendices B**, **D**, and **E**).
- By considering seasonality (discussed above) and yearly variability in sediment loading.
- 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 and in **Section 8**).

- By using naturally occurring sediment loads as described in ARM 17.30.602(17) to establish the TMDLs and allocations. This includes an allocation process that addresses all known human sediment causing activities, not just the significant sources.
- TMDLs are developed at the watershed scale so that human sources are addressed beyond just the listed waterbody segment scale, which should also improve conditions within and reduce loading to other waterbodies within the watershed.

### 5.8.3 Uncertainty and Adaptive Management

A degree of uncertainty is inherent in any study of watershed processes related to sediment. Because sediment has narrative water quality standards, the impairment characterization is based on a suite of water quality targets and the TMDL is based on loads derived from the source assessment; the relationship between sources and the instream condition is not straightforward and is variable among watersheds. Additionally, the assessment methods and targets used in this study to characterize impairment and measure future restoration are each associated with a degree of uncertainty.

For the purpose of this document, adaptive management relies on continued monitoring of water quality and stream habitat conditions, continued assessment of effects 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. Adaptive management addresses important considerations, such as feasibility and uncertainty in establishing targets. For example, despite implementation of all restoration activities (**Section 8**), the attainment of targets may not be feasible due to natural disturbances, such as forest fires, flood events, or landslides.

The targets established in the document are meant to apply under median conditions of natural background and natural disturbance. The goal is to ensure that management activities achieve loading approximate to the TMDLs within a reasonable timeframe and prevent significant excess loading during recovery from significant natural events. Additionally, the natural potential of some streams could preclude achievement of some targets. For instance, natural geologic and other conditions may contribute sediment at levels that cause a deviation from numeric targets associated with sediment. Conversely, some targets may be underestimates of the potential of a given stream and it may be appropriate to apply more protective targets upon further evaluations. In these circumstances, 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.

Some of the target parameters can be indicators of excess coarse sediment (e.g. RSI, pool frequency, and residual pool depth), but most of the direct sediment measures used as targets to assess stream condition focus on the fine sediment fraction found on the stream bottom, while the source assessments included all sediment sizes. In general, roads and upland sources produce mostly fine sediment loads, while streambank erosion can produce all sizes of sediment. Additionally, none of the source assessment techniques were calibrated, so instream measurements of suspended solids/bedload and associated loads will likely not correlate to modeled loads. Therefore, because sediment source modeling may under- or over-estimate natural inputs due to selection of sediment monitoring sections and the extrapolation methods used, model results should not be taken as an absolutely accurate account of sediment production within each watershed. Instead, source assessment model results should be considered as a tool to estimate sediment loads and make general comparisons of sediment loads from various sources.

Cumulatively, the source assessment methodologies address average sediment source conditions over long timeframes. Sediment production from both natural and human sources is driven by storm events. Pulses of sediment are produced periodically, not uniformly, through time. Separately, each source assessments methodology introduces different levels of uncertainty. For example, the road erosion method focuses on sediment production and sediment delivery locations from yearly precipitation events. The analysis included an evaluation of road culvert failures, which tend to add additional sediment loading during large flood events and increase the average yearly sediment loading if calculated over a longer time period. However, estimated loads were not incorporated into the TMDLs because the probability of culvert failure in a given year is difficult to determine and calculated peak flows for each culvert may substantially over or underestimate peak discharge, which could greatly affect the estimated culvert capacities and fill at-risk. The bank erosion method focuses on both sediment production and sediment delivery. The hillslope erosion model focuses primarily on sediment production across the landscape during typical rainfall years. Sediment delivery is a function of distance to the stream channel; however, upland loads are likely overestimated because the model does not account for upland or instream sediment routing. The significant filtering role of near-stream vegetated buffers (riparian areas) was incorporated into the hillslope analysis (**Appendix H**), resulting in proportionally reduced modeled sediment loads from hillslope erosion relative to the average health of the vegetated riparian buffer throughout the watershed. Additional discussion regarding uncertainty for each source assessment is provided in **Appendices E, G,** and **H.**

Because the sediment standards relate to a waterbody's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental, or injurious to beneficial uses, the percent-reduction allocations are based on the modeled upland and riparian BMP scenarios for each major source type. The allocations reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. However, if new information becomes available regarding the feasibility or effectiveness of BMPs, adaptive management allows for the refinement of TMDLs and allocations.

Additionally, as part of this adaptive management approach, shifts in the amount or intensity of land use activities should be tracked and incorporated into the source assessment to determine if allocations need to be revised. Cumulative impacts from multiple projects must also be considered. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity.

# 6.0 - Temperature

This section focuses on temperature as an identified cause of water quality impairment in the Bitterroot TPA. It describes: 1) the specific stream segments of concern; 2) the mechanisms by which temperature impairs beneficial uses of streams; 3) temperature targets and the available data pertaining to temperature impairments; 4) contributing sources of temperature impairment (thermal load) based on recent studies; and 5) the temperature TMDLs, allocations, and margin of safety.

## 6.1 Stream Segments of Concern

A number of waterbody segments in the Bitterroot TMDL Planning Area (TPA) appeared on the 2010 Montana impaired waters list with temperature limiting a beneficial use. The middle segment of the Bitterroot River (from Skalkaho Creek to Eightmile Creek) was identified as impaired by temperature conditions on Montana's 2010 impaired waters list. Mill, Miller, Sleeping Child, and Willow creeks are also identified as impaired by thermal conditions. A thermal-loading TMDL will be completed for all these waterbodies except Mill Creek. A temperature TMDL will also be completed for the lower section of the Bitterroot River because the TMDL assessment indicated this segment doesn't meet temperature standards.

## 6.2 Assessment Methods

DEQ collected temperature, vegetation, channel condition, and stream flow data using both aerial photos and on-the-ground monitoring. A thermal infrared video flight (TIR) was also completed on the Bitterroot River and selected tributaries (**Attachment A**). Using the collected data for calibration, a QUAL2K hydrology, shade, and temperature model was constructed. The results of this assessment and modeling are provided in **Attachment B**. The results of the monitoring and modeling efforts form the basis for the TMDL components that follow. **Section 6.5** includes a summary of the source assessment results for each stream.

Wasteloads for wastewater treatment plants (WWTPs) were assessed using a QUAL2K model; however, the modeled wasteloads were based on average monthly flows reported to DEQ by the facilities (**Attachment B**). Additional assessments after the QUAL2K modeling estimated peak WWTP and Missoula Stormwater (MS4) discharges to compare instream conditions with wasteload allocations (WLAs) during warm, midsummer afternoons. Hourly peak WWTP and MS4 discharge rates were compared to 7Q10 instream flows using mixing equations. The QUAL2K model was also used to assess interactions between individual discharges and is provided as an addendum to the modeling report (**Attachment C**). Peak flows are used for assessing WWTP and MS4 discharges because of hourly dynamic thermal conditions found in western Montana, which are likely to affect the trout fishery, the most sensitive use related to thermal conditions (**Attachment D**).

## 6.3 Thermal Effects on Sensitive 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. Warm temperatures have negative effects on aquatic life and fish, which depend upon cool water for survival. Warmer water temperatures exert more stress on fish by effecting metabolism and reducing the amount of oxygen available in the water. This in turn may cause coldwater fish, and other aquatic species, to feed less frequently and use additional energy to survive in thermal conditions above their tolerance range. Assessing thermal effects upon a use is an important initial consideration during the TMDL process, although the TMDL components will be based on Montana's water quality temperature standards, which are reviewed in the next section.

Special temperature considerations are warranted for the westslope cutthroat trout, which are listed in Montana as a species of concern. Recently conducted research by Bear et al, (2005) found the upper incipient lethal temperature (UILT) for westslope cutthroat trout is 67°F (20°C). The UILT is the temperature considered to be survivable indefinitely by 50% of the westslope cutthroat population (Bear, et al., 2007). The lethal concentration (LD10) for westslope cutthroat is 71°F (21.8°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). Westslope cutthroats have maximum growth around 56.5°F (13.6°C) (Bear, et al., 2007).

Bull trout are listed as threatened under the U.S. Endangered Species Act. 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).

The whole length of the Bitterroot River is designated critical bull trout core habitat. Low numbers of bull trout are found in the upper reaches of the Bitterroot River above Hamilton and its two main forks. Bull trout are uncommon below Skalkaho Creek (near Hamilton) in the thermally impaired segment of the Bitterroot River. The upper segment of the Bitterroot River supports cutthroat trout, with a small portion of the population containing pure genetics. Rainbow and brown trout dominate the Bitterroot River fishery in the middle and lower segments.

Mill Creek maintains rainbow and brown trout in the lower elevations. Hybrid cutthroat trout and a small population of bull trout are found in the higher elevations of Mill Creek. Willow Creek contains brook, rainbow, and hybrid cutthroat trout. Miller Creek supports similar fish species as Willow Creek. Sleeping Child Creek contains populations of bull trout and pure cutthroat trout in higher elevations and brown and rainbow trout in the lower elevations. Sleeping Child Creek is proposed as core bull trout habitat.

## 6.4 Temperature Standards and Targets

### 6.4.1 Temperature Standards and Interpretation

Montana's water quality standard for temperature 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, 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 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 [ARM 17.30.622(e) and ARM 17.30.623(e)]. Note that under Montana water quality law, "naturally occurring" temperatures incorporate natural sources, yet may also include human sources with reasonable land and water management activities. Instream temperature monitoring and predictive modeling both indicate that naturally occurring stream temperatures in most of the Bitterroot TPA are likely at or greater than 66.5°F during part of the summer, which is the most sensitive timeframe for supporting fishery use. Based on this analysis, the maximum allowable increase from unmitigated human causes would be 0.5°F.

Water temperature, flow, channel dimension, and riparian shade data were incorporated in a QUAL2K water quality model (**Attachment B**) to assess existing water temperatures. Modeling is used to determine if human-caused disturbances in the watershed increase the water temperature above the naturally occurring level, and if so, to what degree. The potential to reduce stream temperatures through various management measures was also modeled based on varied scenarios.

Model results from an existing condition scenario and a scenario simulating reasonable land, soil, and water conservation practices were used to assess existing and potential water temperature conditions relative to Montana's water quality standards. The difference in temperatures is used to indicate if Montana's water quality temperature standard is likely being met or exceeded. The relationship between human disturbances and water temperature impairments as described in ARM 17.30.623(e) was evaluated for each stream of concern. The following decision process is applied for each stream:

> If the existing condition QUAL2K result equals or is less than 0.5°F higher than the restoration condition QUAL2K model scenario where all reasonable land, soil and water conservation practices were applied, then anthropogenic sources were concluded to not be causing or contributing to violations of the relevant B-1 water temperature standards and the stream is considered to meet the standard. In this case a TMDL is not provided.
>
> If the existing condition QUAL2K result is higher than 0.5°F compared to the restoration condition QUAL2K model scenario where all reasonable land, soil and water conservation practices were applied, then anthropogenic sources were concluded to be causing or contributing to violations of the relevant B-1 water temperature standards and the stream is considered to not meet the temperature standard. In this case a TMDL was completed.

### *6.4.1.1 Framework for Setting Temperature Targets*

Ultimately, Montana's temperature water quality standard forms the primary basis for all temperature targets. The standard is difficult to assess without the use of a water quality model. DEQ collected data relative to the targets and used a QUAL2K model to simulate thermal conditions in each watershed; however, no model can ever fully simulate all the dynamic and complex factors that affect water quality without making some assumptions and expecting some error. Montana's temperature standard is the primary target that must be satisfied. Alternatively, compliance with standards can be satisfied by meeting all other targets: shade, channel width-to-depth (W/D) ratio, discrete sources, and streamflow that define naturally occurring conditions for each temperature influencing factor.

In this alternative approach, if all reasonable land, soil, and water conservation practices are installed or practiced, state standards are met. These alternative targets, which need to be met in combination, are referred to as "temperature-influencing targets" (**Table 6-1**). These targets are prescribed to the whole watershed.

**Riparian Canopy Cover**

Increased shading from riparian vegetation reduces sunlight hitting the stream, and thus reduces heat load from directly entering the stream. Riparian vegetation also creates a microclimate that is cooler than the surrounding landscape, which also reduces stream temperature. The target is a percent change in riparian canopy cover that will achieve reference potential. Human influences reducing riparian canopy cover are due to present or historic agricultural activities, suburban areas, timber harvest, and some limited areas of recreational activity in the Bitterroot watershed.

**Width-to-Depth Ratio**
A lower width to depth ratio equates to a deeper, narrower channel that has a smaller contact area with warm afternoon air. Also a lower width to depth ratio will increase the effectiveness of shading produced by the riparian canopy. Almost all stream channel widening in the watershed is due to present or historic agricultural activities, mostly riparian area grazing. Suburban impacts are a lesser source of channel widening. The targets provided are a reduction in bankfull width to depth ratios.

**Instream Discharge Rate** (stream flow conditions)
Larger volumes of water take longer to heat up during the day. The volumetric heat capacity of the stream is reduced if water is diverted from a stream and used inefficiently. Increased instream flow volume may be accomplished by voluntary actions of irrigators to improve irrigation efficiency. Reduced stream flow is entirely due to agricultural or suburban land activities where inefficient irrigation practices are used. This target is presented as an increase in irrigation efficiencies. These efficiencies should be implemented in a way that does not significantly reduce groundwater return flow to the watershed's streams during July through September.

**Irrigation Return Flow**
Irrigation return flows may result from agricultural irrigation systems. This source may provide increased thermal load and warm a stream. The target is a specific reduction in surface water irrigation return flows which are warmer than natural stream water temperature.

**Wastewater Treatment Plant Effluents**
Wastewater treatment plant (WWTP) effluents may increase a stream's water temperature. WWTP effluents shall not warm the stream individually or in combination by more than 0.25°F. This is half of the allowable increase in temperature under Montana's temperature standard which applies to the Bitterroot River.

**Missoula Urban Runoff (permitted MS4 point source)**
The initial flush of heated urban runoff from paved areas during summer storms may increase a stream's water temperature. The affects upon water temperature from this source are brief and very periodic. The target for this source will be to follow conditions in the Missoula MS4 permit, which should provide little to no increase in initial flush of heated urban runoff from paved areas by promoting water retention and infiltration at building sites.  If runoff rates increase, infiltration of initial runoff should be considered in the collection system.

**Table 6-1. Temperature Targets**

| Water Quality Targets | Criteria |
|---|---|
| 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. |
| **OR meet ALL of the temperature influencing restoration targets below** | |
| Riparian Shade | Comparable to reference areas where riparian vegetation is managed with reasonable conservation practices. |
| Channel width/depth ratio | Comparable to reference conditions. See **Section 5.4.1.2**. |

**Table 6-1. Temperature Targets**

| Water Quality Targets | Criteria |
|---|---|
| Irrigation water management | 15% improvement in irrigation efficiency during the summer (June through September). |
| Inflows to stream network | Reduce warm irrigation return flow water entering the stream network by 75%. |
| Wastewater Treatment Plants (if present) | No WWTP caused surface water inflow, in single or in combination, will increase temperatures more 0.25°F during the summer (June-Sept). |
| Missoula Urban Runoff (if present) | At minimum, follow the control measures provided in Part II, 5.a.vii. of the Missoula Area MS4 permit, or any comparable initial flush stormwater capture or interception control measures in subsequent permits renewals. |

## 6.4.2 Framework for 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 (**Equation 6-1**). 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.

**Equation 6-1** $TMDL = \Sigma WLA + \Sigma LA + MOS$.

Where:

$\Sigma$WLA = Wasteload Allocation = Pollutants from NPDES Point Sources
$\Sigma$LA = Load Allocation = Pollutants from Nonpoint Sources + Natural Sources
MOS = Margin of Safety

For temperature TMDLs, because of the dynamic temperature conditions throughout the course of a day, the 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 streams in the Bitterroot TPA 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 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 [ARM 17.30.622(e) and ARM 17.30.623(e)]. Montana's temperature standard for B1 classified waters is depicted in **Figure 6-1**.

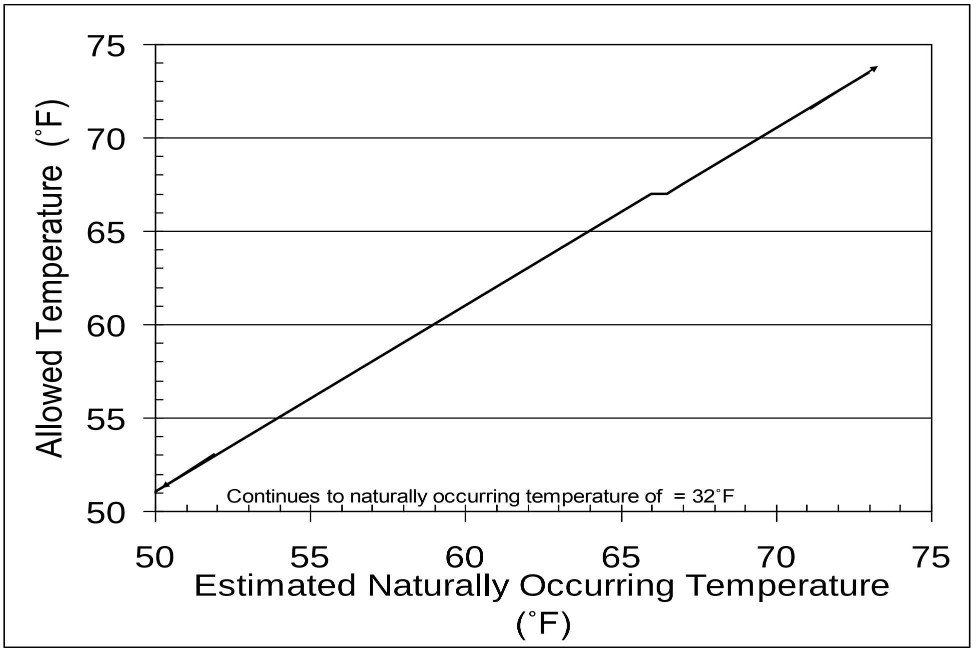



**Figure 6-1. Instream Temperatures Allowed by Montana's B-1 Classification Temperature Standard**

An instantaneous load is computed by the second and applies at all times. The allowed temperature can be calculated using Montana's B1 classification temperature standards (**Figure 6-1**) and using a modeled, measured, or estimated naturally occurring instantaneous temperature. The instantaneous total maximum load (per second) at any location in the waterbody is provided by **Equation 6-2**. The allowable loading over a second is expressed as the allowable loading to the liquid form of the water in the stream. This is defined as 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 6-1**.

**Equation 6-2**

$(\Delta-32)*(Q)*(15.6)$ = Instantaneous Thermal Maximum Load (ITML)

Where:

$\Delta$ = allowed temperatures from **Figure 6-1**
Q = instantaneous discharge in CFS
ITML = Allowed thermal load per second in kilocalories, above waters melting point
Conversion factor = 15.7

A total maximum daily heat load is easily calculated using average daily temperature calculations and applying them to **Figure 6-1** and **Equation 6-3**. The resulting average daily load is not of much use since diurnal shifts in temperature create average daily conditions, which in many circumstances do not deviate from Montana's temperature standard at a daily timeframe and do not protect the use. Fish are most distressed by temperatures during summer afternoons; this is also usually the most sensitive timeframe in regard to human-caused thermal loading. Providing thermal loads based upon an average daily temperature does not protect fish because extreme conditions are averaged throughout the day.

Nevertheless, EPA requires total maximum daily loads be provided (**Equation 6-3**). This equation pertains to all TMDLs presented in this document but is not used in any further analysis. ITML (**Equation 6-2**) is used for all further numeric heat load analysis and is protective of the affected use.

**Equation 6-3**

$(\Delta\text{-}32)*(Q)*(1.36*10^6)$ = Total Maximum Daily Load (TMDL)

Where:

Δ = allowed temperatures from **Figure 6-1**
Q = instantaneous discharge in CFS
TMDL = Allowed thermal load per day in kilocalories, above waters melting point
Conversion factor = $1.36*10^6$

While the above equations and translation of temperature to an instantaneous thermal load allows for a quantitative expression to compare with Montana's state standard and accurately defines a thermal load, in practical terms this is not readily translatable to on-the-ground management. Alternatively, along with numeric heat loads, the TMDL may also be expressed as surrogate indicators that would result in compliance with the temperature standard. In this case, the allocations necessary to achieve the TMDL are similar to the restoration targets by which to measure achievement of the state temperature standard. These surrogates may include an increase in riparian shade conditions, improved irrigation efficiencies, reductions in warm irrigation water return flow to the waterbody, temperature reductions in tributaries, and a heat load or surrogate based limits for each point source discharge.

## 6.5 Temperature TMDL Components

This section provides a review of existing conditions, targets, TMDL, and allocations for each of the stream segments identified in **Section 6.1**.

### 6.5.1 Middle Bitterroot River (MT76H001_020)

The middle segment of the Bitterroot River begins at the confluence of Skalkaho Creek, near the city of Hamilton, and continues to the confluence of Eightmile Creek, below Stevensville. The middle segment of the Bitterroot River was listed as impaired due to temperature on the 2010 impaired waters list. A TMDL for the middle segment of the Bitterroot River is provided in the following sections.

#### *6.5.1.1 Existing Conditions and Targets Comparison*

Data and reports reviewed in the impairment status determination describe summer maximum temperatures during low flow conditions near 71°F. The file reports that thermal conditions are influenced by reduced instream flows due to irrigation.

Although Montana Fish Wildlife and Parks (FWP) monitors water temperatures along the Bitterroot River on a yearly basis, DEQ collected the most spatially robust annual data set available for temperature of the middle segment of the Bitterroot River during the 2004 field season. The 2004 monitoring results represent a warm, low streamflow condition that approach worst-case thermal conditions. Temperature data loggers were placed at 14 sites in the middle segment of the Bitterroot River during the summer of 2004, yet only 9 were recovered after the field season. Data loggers were deployed at the latest on July 16 and retrieved at the earliest on September 1, 2004. The maximum daily temperature and the 7-day average maximum temperature data are reviewed to identify the warmest period of the season. Maximum daily temperatures were monitored between July 16 and 17, depending on the site. The weekly 7-day average of the daily maximum temperatures also occurred during the same week as maximum water temperatures were detected. Monitoring devices detected from 46 to 61 days above 59°F, depending upon location. Multiple days above 70°F occurred at all sampling locations, and no 7-day average daily maximum occurred below 62°F for any site (**Table 6-2, Map A-24** in **Appendix A)**. The warmest monitored temperature on the whole Bitterroot River, including the lower segment, was at VXING1. Temperatures in the middle segment of the Bitterroot River are above levels known to negatively affect native trout species.

**Table 6-2. DEQ Middle Bitterroot River 2004 Temperature Data Summary**

| Site ID | Seasonal Max. | | 7-Day Average during warmest week of the summer | | | | Days > 59 ˚F | Days > 70 ˚F |
|---|---|---|---|---|---|---|---|---|
| | Date | Value | Date | Daily Max | Daily Min | Delta T | | |
| WTP1 | 07/16 | 72.9 | 07/16 | 71.0 | 62.1 | 8.8 | 46 | 19 |
| BLOD1B | 07/16 | 74.4 | 07/16 | 72.1 | 62.8 | 9.3 | 54 | 27 |
| BLOD2 | 07/17 | 74.2 | 07/17 | 72.4 | 63.6 | 8.8 | 56 | 30 |
| BLOD3 | 07/17 | 73.7 | 07/17 | 72.1 | 64.0 | 8.1 | 54 | 21 |
| STEVI2 | 07/17 | 74.0 | 07/17 | 72.2 | 64.1 | 8.1 | 60 | 33 |
| STEVI3 | 07/17 | 74.5 | 07/17 | 72.7 | 64.8 | 7.9 | 61 | 33 |
| VXING1 | 07/17 | 75.3 | 07/17 | 73.2 | 64.5 | 8.8 | 56 | 37 |
| VXING2 | 07/17 | 74.4 | 07/17 | 73.0 | 64.3 | 8.7 | 58 | 36 |

During the 2004 data logger deployment, a thermal infrared flight (TIR) was conducted along the Bitterroot River (**Attachment B**). The River heats significantly from the headwaters to near Victor. The TIR results include warm and cold water influences along with temperatures of the main channel (**Figure 6-2**). Identified warm water tributaries include Kootenai and Tin Cup creeks, while most other identified tributaries in this segment had temperatures similar to, or lower than, the Bitterroot River. Many tributaries were not identified in the TIR due to dry conditions or canopy overhang. The TIR report also provides a review of cold water springs entering the river, which cumulatively slightly reduce water temperatures near Stevensville.

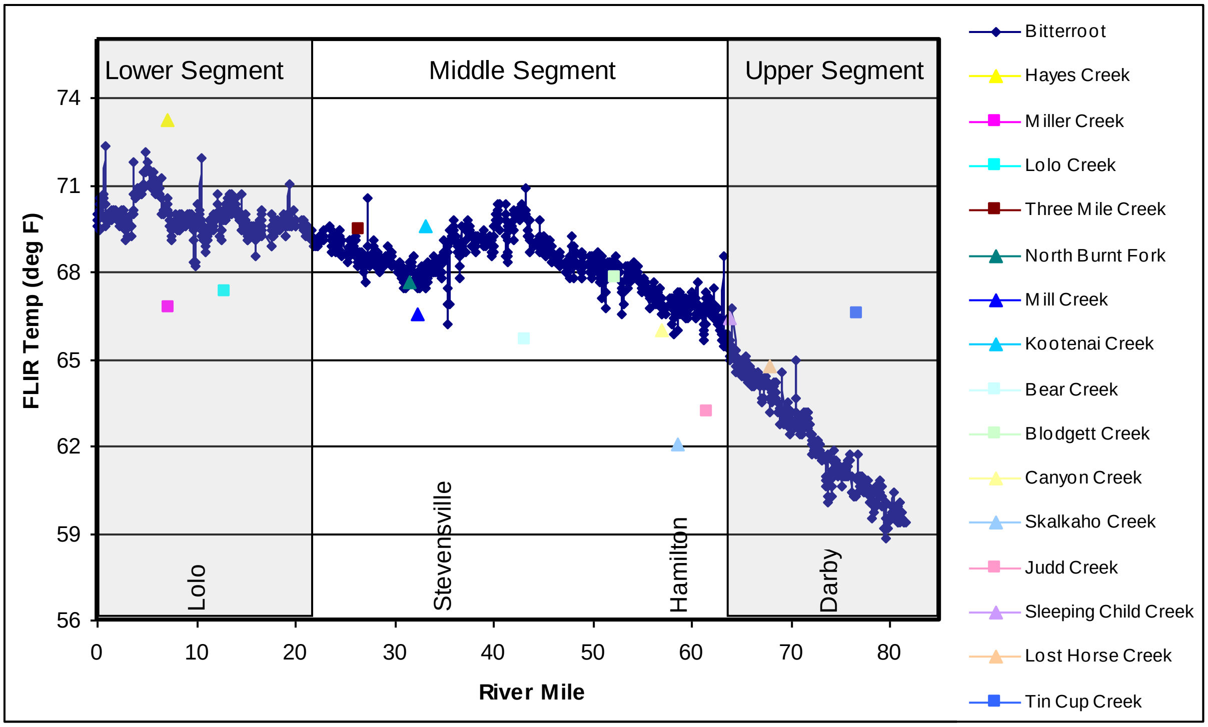



**Figure 6-2. Bitterroot River Thermal Infrared Assessment Results**

**6.5.1.1.1 Water Quality Modeling using QUAL2K for Source Assessment and Standards Assessment**
While currently available data suggests elevated stream temperatures in the middle segment of the Bitterroot River, a QUAL2K water quality model was used to determine if the temperatures are a result of natural conditions or human activities. The model results will help determine if human-caused disturbances in the watershed have increased the water temperature above the naturally occurring level, and if so, to what degree. The model incorporated temperature, flow, stream channel, and shade information and calibrated to thermal infrared data, which was used to calibrate the model to best represent existing average summer conditions. Additionally, various scenarios that represent thermal restoration approaches in the watershed were applied in the model to determine targeted temperatures. A full description of the model and results can be found in **Attachment B**. The following is a summary of the modeling considerations:

1. Although the river channel is wide, spring runoff has the greatest influence in forming the river's channel. Summer flows are low and usually form a wide channel margin between water's edge and streambanks. Overall, the segment does not have an apparently over-wide channel from human influences. Although slight human influences are present that may over-widen the channel in limited areas, restoration is not warranted when considering the liabilities associated with restoring a river channel formed in large part by natural spring runoff conditions. A narrowing of the channel was not modeled as a restoration scenario.
2. Thermal conditions in the East and West Fork Bitterroot rivers were assessed independently from this effort yet are the driving factor of temperature to the upper Bitterroot River. Reductions in temperature from these two main tributaries, along with all other smaller tributaries that enter the Bitterroot River, were assessed in a restoration scenario.
3. Shade conditions along the Bitterroot River were incorporated into the model. Reference riparian vegetation shade conditions were modeled in a restoration scenario.

4. Wastewater Treatment Plant (WWTP) loads were incorporated into the model. Scenarios were completed to determine the WWTPs' effects on stream temperatures.
5. The Bitterroot watershed has a complex irrigation network. Irrigation water withdrawals were incorporated into the model. Estimated irrigation water efficiencies were modeled in restoration scenarios. Warm irrigation water returns are poorly understood and were not explicitly incorporated into the model but are likely present.

The following sections review existing conditions and restored conditions about each of the human-influenced thermal factors. Temperature monitoring and modeling results relative to each source are reviewed briefly.

**6.5.1.1.2 Targets and Linkage to Stream Temperature**

**Riparian and Stream Channel Conditions**

During 2007 DEQ conducted an assessment of riparian vegetation class, height, density, and offset using a stereoscope and aerial photos (**Attachment A**). Riparian effective shade was estimated along each 500-meter reach (**Figure 6-3**). Field verification was also conducted. The riparian canopy information was used to calibrate the shade components of the QUAL2K water quality temperature model.

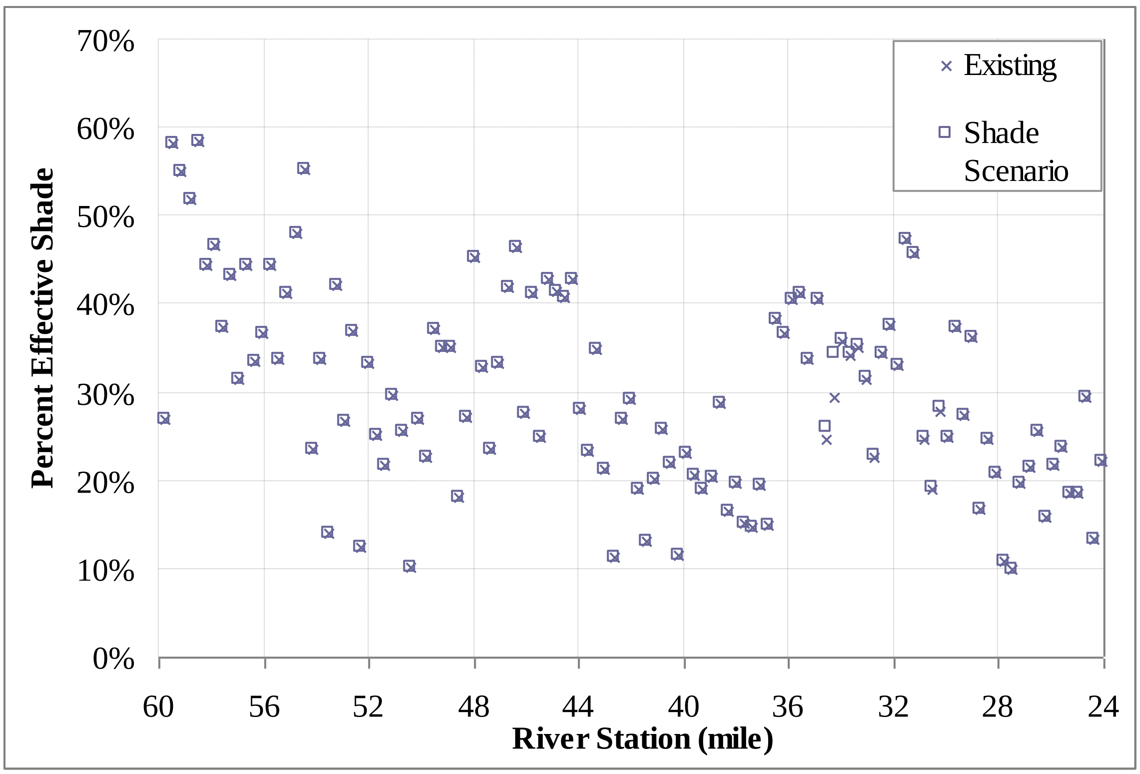



**Figure 6-3. Middle Bitterroot River Effective Shade Assessment Results**

Average daily effective shade ranged from 10% to 58% along the middle segment of the Bitterroot River (**Figure 6-3**). This segment is a relatively large stream with average active channel widths of approximately 220 feet. The channel size is mostly influenced by a large spring runoff from the surrounding mountains, which in turn forms the channel. Channel widths are not considered significantly influenced by human activities.

Riparian habitat along this segment consists of intermittent plant communities, including forbs/grasses, mixed deciduous trees, coniferous trees, and shrubs. A major portion of the segment contains in-tact riparian areas, but agricultural fields, residential areas, a golf course, roads, and other human influences slightly reduce shade along the stream. These influences did not reduce effective stream shade to a large extent because of the wide channel and the generally north/south aspect of the river. Current shade is estimated at 30.2%, and restored riparian vegetation would increase effective shade to 30.8%. This is only a 0.4% increase in shade, which equates to a 0.03°F reduction in maximum daily temperature in this segment of the Bitterroot River during average summer afternoons. Even though shade restoration will likely result in small temperature decreases, shade targets are provided because they are part of a straightforward riparian restoration approach that supports reduction of other pollutants and also because healthy riparian areas benefit fish and wildlife.

**Headwater and Tributary Thermal Influence**

Temperature TMDLs were completed during 2005 for both the East and West forks of the Bitterroot River during a TMDL project for the Bitterroot Headwaters TMDL planning area. Shade and stream channel assessment results from the Bitterroot Headwaters TMDLs were used to generally populate a Stream Segment Temperature (SSTEMP) model for estimation of temperature reduction from the headwaters area. The results indicated that shade improvement in the Bitterroot Headwaters TMDL planning area could likely decrease water temperatures by about 1°F at the upper boundary of the river's upper segment. Along with the two major forks of the Bitterroot River, all other immediate tributary temperatures along the river were reduced by 1°F. The tributary cooling effect was shown to dissipate as the water flowed downstream and is estimated at 0.6°F decrease in maximum daily temperature at the upper boundary of the middle segment of the river (**Attachment B**).

**Wastewater Influences**

Darby, Hamilton, and Stevensville WWTPs discharge to the upper or middle segments of the Bitterroot River. Darby's system consists of lagoons, while the Hamilton and Stevensville facilities are secondary treatment systems. Stevensville uses a polishing pond on the end of its treatment process, which acts thermally like a lagoon. Darby and Hamilton WWTP discharges increase instream temperatures during the heat of the summer afternoons, while Stevensville appears to have a minimal affect (**Attachment C**). Temperature modeling indicates that effluents can be assessed by mixing calculations because initial heat loads are dissipated or offset by volumetric heat capacity between the effluents. If each of these WWTPs were discharging at current daily peak rates to a 7Q10 flow condition, they would heat the river approximately 0.09°F during the heat of summer afternoons in the most sensitive location (**Attachment C**). This maximum heat increase spatially occurs just below Hamilton WWTP's mixing zone.

If each WWTP were to discharge at double their existing hourly peak flow rate, or at their design capacity hourly peak flow, whichever is greater, in combination they would heat the river by about 0.25°F, once again the most affected location being directly below Hamilton's mixing zone (**Attachment C**). The target for wastewater influences is to not heat any part of the middle segment of the Bitterroot River outside of mixing zones higher than 0.25°F during June-September. To ensure the WWTPs are meeting this target, any municipality shall not increase their effluent temperature and shall discharge at rates below double their existing hourly peak flow rate, or at their design capacity hourly peak flow, whichever is greater. All of the flow rates provided are based upon doubling existing hourly peak flow rates except Hamilton, which is based upon the design capacity hourly peak flow rate. The WWTP flow rates associated with the target conditions are provided in **Table 6-3**. If these conditions are not met, the facility must initiate action to prove they do not heat the Bitterroot River more than 0.25°F.

If changes to a waste treatment process occur that are likely to increase the temperature of any effluent in the watershed, or if flow rates will increase above the thresholds given for the surrogate WLA approach, an effluent temperature assessment must be initiated to determine if the plant will meet the target requirement of $\leq$ 0.25°F temperature increase at the end of the mixing zone due to the future WWTP plant modification (**Table 6-4**). Monitoring and reporting requirements for this process are provided in **Section 8.0**. The WWTP target conditions will also be interpreted into a WLA process and expressed as a discrete heat load in the heat-based numeric TMDL.

**Table 6-3. Data and mixing calculation results for existing WWTP discharge at hourly peak flow conditions**

| | Darby | Hamilton | Stevensville |
|---|---|---|---|
| Upstream Discharge at 7Q10 (cfs) | 120 | 152 | 159 |
| Upstream Temperature (˚F) | 63.4 | 66.7 | 69.5 |
| Effluent Discharge hourly Peak Flow (cfs) | 1.18 | 3.54 | 2.26 |
| Effluent Temperature (˚F) | 69 | 70.5 | 70.5 |
| Mixed Instream Temperature (˚F) | 63.4 | 66.8 | 69.5 |
| Mixed Instream Δ T due to Effluent (˚F) | 0.06 | 0.09 | 0.01 |

**Table 6-4. Data and mixing calculation results for WWTP discharge rates at build out scenario using existing discharge temperature and hourly discharge peak flow condition**

| | Darby | Hamilton | Stevensville |
|---|---|---|---|
| Upstream Discharge at 7Q10 (cfs) | 120 | 152 | 159 |
| Upstream Temperature (˚F) | 63.4 | 66.7 | 69.5 |
| Effluent Discharge hourly Peak Flow* (cfs) | 2.36 | 10.30 | 4.52 |
| Effluent Temperature (˚F) | 69 | 70.5 | 70.5 |
| Mixed Instream Temperature (˚F) | 63.5 | 66.9 | 69.5 |
| Mixed Instream Δ T due to Effluent (˚F) | 0.108 | 0.241 | 0.028 |

*Hourly peaks calculated using double the existing peak flow rate, or the design capacity peak flow rate from the permit statement of basis, whichever is greater, multiplied by hourly peaking factor from DEQ Circular 4.

**Irrigation - Depletion of Instream Volumetric Heat Capacity**

Irrigation depletes the volume of water in the stream and reduces instream volumetric heat capacity. The reduced stream water volume heats up more quickly, and to a higher temperature, given the same amount of thermal input. Therefore, the higher temperatures are manifested well downstream of irrigation withdrawals. Also, there are a number of irrigation reservoirs in the watershed, most notable are East Fork Reservoir and Como Lake. The reservoirs may possibly be used in conjunction with increased irrigation efficiency to provide instream flow during the heat of the summer. Implementation of irrigation efficiencies could result in a 15% reduction in irrigation water use. The irrigation savings should be applied to instream flow during the heat of the summer, while not significantly affecting groundwater return flow rates to the stream network. Maximum daily temperatures in the middle segment could be reduced by about 0.9°F during an average summer day if a 15% irrigation water use savings were applied to instream flow during the summer months (**Attachment B**).

**Irrigation - Warm Irrigation Return Flow**

Irrigation-return flows may increase stream temperatures by putting heated water back into the stream network. These return flows are difficult to assess because of their intermittent nature and therefore not all have been measured. Three irrigation-return flows warmer than the Bitterroot River were found via the Thermal Infrared (TIR) flight, and on average they were 2°F higher than the Bitterroot River

(**Attachment A**). Other warm irrigation-return flows likely enter the Bitterroot River but are difficult to assess because of their small size and intermittent nature. Also, irrigation-returns are present on tributaries. All mainstem and tributary irrigation-returns should be more fully assessed (see **Section 8.0**). Within the watershed, irrigation-return flows that are warmer than the stream they enter should be reduced by 75% on a volume basis.

#### 6.5.1.1.3 Summary of Targets and Existing Conditions for the Middle Segment of the Bitterroot River

**Table 6-5** reviews temperature targets for the middle segment of the Bitterroot River. The targets will incorporate an "or" statement where Montana's temperature standards should be met, or all the temperature-influencing targets should be met. The temperature-influencing targets include target conditions for tributary watershed areas, shade along the segment, channel conditions, irrigation water use and waste, and wastewater effluents. If all these targets are met in combination, Montana's water temperature standards will be achieved in the middle segment of the Bitterroot River.

**Table 6-5. Temperature Targets and Existing Conditions for the Middle Segment of the Bitterroot River**

| Water Quality Targets | Criteria | 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. | Calibrated QUAL2K model results are compared to restoration scenario results. Modeling conclusions indicate Montana's temperature standard is not being met during average summer afternoon conditions. If conditions provided below for sources are met, daily maximum summertime temperatures would likely be reduced the most near river mile 46.5, by about 1.5°F (**Attachment B**). |
| **OR meet ALL of the temperature influencing restoration targets below** | | |
| Tributary temperatures | Reduce all tributary temperatures by an average of 1°F from current conditions via increased shade, irrigation efficiencies and channel restoration. | The EF and WF Bitterroot River temperature TMDLs developed during 2005 and subsequent SSTEMP modeling indicate a 1°F reduction is likely in these tributaries. Specific warm tributaries found during TIR include Hayes, Threemile, Kootenai, McClain, and Tin Cup Creeks. Other moderate temperature tributaries may also easily be cooled via restoration practices. |
| Effective Shade | 30.8% Effective Shade | 30.2% Effective Shade |
| Channel Condition | No change. | Cumulative Widths ≈ 220 ft |
| Irrigation water management (Higher efficiency) | 15% improvement in irrigation efficiency during the warmest months (mid-June through August), while not affecting groundwater recharge or base flow volume of the Bitterroot River. | The irrigation system should be assessed for inefficiencies to determine if this estimated efficiency based upon regional irrigation management studies is achievable and to identify specific strategies to reduce irrigation use, maintain groundwater conditions, and keep water in the River. Effects to groundwater returning to the river should be considered during implementation of |

**Table 6-5. Temperature Targets and Existing Conditions for the Middle Segment of the Bitterroot River**

| Water Quality Targets | Criteria | Existing Condition |
|---|---|---|
| | | this target condition. |
| Irrigation return flow | Reduce volume of warm irrigation water entering any of the watersheds stream network by 75%. | There are three known warm irrigation return flow locations to the main channel of the Bitterroot River. Others are likely present, yet are likely smaller or intermittent. The irrigation system should be assessed thoroughly to reduce warm irrigation water waste into the state's surface waters and to further quantify heat loads from this source. |
| Wastewater Treatment Plants | No WWTP caused surface water inflow, in single or in combination, may increase temperatures more than 0.25°F. Do not increase loads associated with current temperature of effluent at double the facilities current peak hourly discharge or peak hourly design capacity whichever is greater. If modifications to waste treatment process are likely to heat a discharge or discharge rates are above the thresholds, a thermal study must be conducted prior to modification. | All three WWTPs in combination currently increase daily max temp by 0.09°F, while Hamilton is the most significant contributor of heat loads. Wastewater increases volumetric heat capacity and thus also cools portions of the River. Modeling results indicate that simple mixing calculations can be used to assess each source in the future. |

A naturally occurring model scenario defines water temperature conditions resulting from the implementation of 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 0.5°F temperature increase is allowable in this segment. This, in turn, can be used to identify if standards are exceeded and a TMDL is needed. The naturally occurring scenario for the middle segment of the Bitterroot River (miles 24–60) is a full collection of the restoration scenarios described in the previous sections of this report. In a significant portion of the segment, more than a 0.5°F increase in summertime daily maximum temperature is apparent when compared with a restored scenario, where reasonable land, soil, and water conservation practices are in place (**Figure 6-4)**. At river mile 46, the most sensitive location on this segment, maximum daily temperatures can likely be reduced by 1.5°F on an average summer afternoon with reasonable conservation practices.

None of the shade, irrigation water use, irrigation water return flow, or tributary targets are fully met. Both the temperature modeling and target assessments indicate Montana's water temperature standards are not being met. Therefore, the segment is in need of a temperature TMDL.

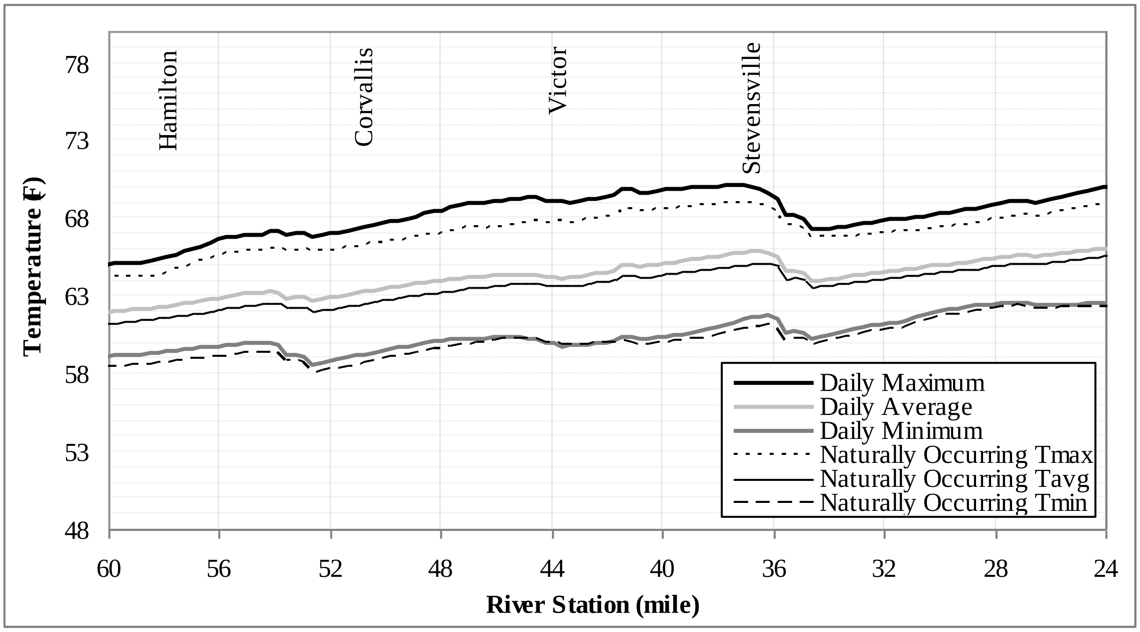



**Figure 6-4. Middle segment of the Bitterroot River simulated water temperatures for existing conditions and naturally occurring scenario**

## *6.5.1.2 TMDL, Allocations and Margin of Safety*

Thermal conditions in the middle segment of the Bitterroot River are largely the result of complex interactions among the factors reviewed in **Table 6-5**, which prevents an easy interpretation of the influence of each one independent of the others. Modeling results indicate that irrigation use and an array of human sources in the tributaries have the largest human-caused heating effect upon this segment of river. Irrigation return-flows in the watershed may have a moderate heating effect on temperatures of this segment. Reduced riparian canopy conditions along the upper and middle segments of the Bitterroot River are only a small source of heating. Also, point sources have a small affect upon thermal conditions, yet were provided wasteload allocations to ensure they do not increase above a significant level. If all allocations provided in this section are met, Montana's temperature standards will be achieved in the middle segment of the Bitterroot River.

### 6.5.1.2.1 Surrogate TMDL for Promoting Nonpoint Source Load Reductions

Monitoring and modeling results provided much of the technical framework for developing a surrogate temperature TMDL and allocation approach. Applying a surrogate TMDL is more useful for guidance of nonpoint source restoration approaches than a heat-based numeric TMDL. The surrogate TMDL approach also affords point sources with a straightforward operating approach to meet the difficult to monitor, heat wasteload allocations. Influences to stream temperatures are not always intuitive at a watershed scale, and a modeling effort helped estimate the relative thermal effects from stream shading, tributary influences, WWTP discharges, and instream flow to stream temperatures during the warmest time of year. Significant sources and surrogate allocation approaches for each source are provided in **Table 6-6**. If each surrogate allocation is followed, the temperature standard will be met.

**Table 6-6. Temperature TMDL for the middle segment of the Bitterroot River**

| **The TMDL equals the resultant thermal load associated with stream temperature when all conditions below are met:** | |
|---|---|
| **Source Type** | **Load Allocation (surrogate)** |
| Agricultural, urban and other land uses that could reduce riparian health and resultant **shade** provided by the near stream vegetation along the Bitterroot River. | The thermal load that can reach the stream segment when there is an average daily shade along the segment of 30.8%. |
| Forestry, agricultural, suburban, other land uses and inefficient use of water that could negatively affect shade, channel width/depth ratio or flow on **tributaries**. | No measurable or modeled increase in thermal loading from preventable human caused increases in any tributaries contributing flow to the Bitterroot River. No reduction in thermal buffering capacity due to inefficient irrigation or urban water use practices. |
| **WWTPs** (WLA) | No individual or cumulative increase above 0.25˚F due to WWTP effluents in the watershed. This may be achieved by each WWTP if they do not discharge more than double the facilities current peak hourly discharge or peak hourly design capacity whichever is greater. If modifications to waste treatment process are likely to heat a discharge or discharge rates increase above thresholds provided, a thermal study must be conducted prior to modification. Monitor effluent temperatures during June-September in first year of first permit renewal cycle according to requirements in **Section 8.3.1**. |
| Inefficient agricultural or urban **water use**. | No reduction in thermal buffering capacity due to inefficient irrigation or urban water use practices along the segment. |
| Warm **irrigation return water** | A load associated with a condition where 75% reduction in irrigation water entering the Bitterroot River or tributaries in which the irrigation water is warmer than instream conditions. |

#### 6.5.1.2.2 Numeric TMDL, Allocations and Margin of Safety

The TMDL is also expressed as a numeric heat load to compare with heat-based wasteload allocations. The numeric TMDL applied to the middle segment of the Bitterroot River is **Equation 6-2**. An example heat load is developed using **Equation 6-2**, **Figure 6-1**, and modeling results from **Appendices B** and **C**. An applied example of how the temperature TMDL for the middle segment of the Bitterroot River equates to stream temperature and heat loading during an average midsummer afternoon is provided in **Table 6-7**. Temperature and heat results provided in this table are based on conditions approximating 7Q10 flow near Victor, Montana, during the heat of an average warm midsummer afternoon (159 cfs). This area is the most heated location of the segment. The TMDL along with associated load and wasteload allocations are provided in kilocalories per second above water’s melting point.

**Table 6-7. Middle segment of the Bitterroot River numeric TMDL, allocation and MOS example at 7Q10 during a typical hot sunny summer afternoon near Victor, MT**

| **TMDL Component** | **Collective Load Allocation** | | **Waste Load Allocation** | **Margin of Safety** | | |
|---|---|---|---|---|---|---|
| **Source Description** | Estimated Natural Sources | Human sources with all reasonable land, soil and water conservation practices in place. This includes:<br>• Well managed agricultural and suburban land use activities along the Bitterroot River and tributaries that provide similar shading as reference areas<br>• Irrigation occurring with 15% efficiency savings applied to summer stream flow<br>• 75% reduction of warm irrigation return flow water entering the Bitterroot River and tributaries.<br>• Tributary temperature reductions | WWTP WLAs | Reserved for safety factor and uncertainty in analysis | = | **TMDL** |
| **Estimated Contribution to Temperature TMDL** | 66 °F | 1.3°F | 0.25°F | 0.25°F | | 67.8°F |
| **Heat Load in Kcal/Sec** | 84,334 | 2,480 | 620 | 620 | | 88,054 |

Surface water dischargers currently are a small source of heating to the Bitterroot River but could become a significant source and are therefore given wasteload allocations. The wasteload allocations (WLAs) are premised upon an approach that any WWTP may not discharge more than their current design capacity estimated hourly peak discharge, or double their existing peak hourly discharge rate, whichever is higher. This would assure all WWTPs in combination will accumulatively contribute to no more than a 0.25°F increase in temperature. This equates to half of the allowable increase allowed under the standard for B-1 waters over a naturally occurring temperature of 66.5°F.

The WLAs may be expressed alternatively by permitting each facility to discharge up to double their existing peak discharge rate or up to their design capacity, whichever is higher as long as existing thermal conditions of the effluent are not increased. Yet, if updates to water treatment process increase the temperature conditions of an effluent, or a facility discharges at a higher rate than provided by the WLA at any time, the facility must measure and report temperature for one year, following monitoring requirements in **Section 8.3.1**.

Modeling indicated that loads associated with each WWTP are attenuated and offset by additional volumetric heat capacity between discharges (**Attachment C**). Therefore, each facility can use mixing equations as a tool to determine compliance and not have to worry about cumulative effects of all WWTPs. A facility must provide verification via monitoring and assessment that it will not increase thermal conditions in the river below their mixing zone by more than 0.25°F prior to updates to their system or if they exceed discharge rates provided in this document. These analyses shall use effluent peak flow estimates and 7Q10 instream flow.

All other stormwater, CAFO and groundwater discharge permitted activities in the watershed have negligible effects on water temperature of the middle segment of the Bitterroot River during critical conditions and, therefore, do not need wasteload allocations due to their insignificance and timing of runoff conditions compared to impacts to the fishery.

The thermal WLAs do not represent all pollutant WLAs that will be developed in the Bitterroot River watershed. Other pollutant category TMDLs (e.g., nutrients) developed during future TMDL projects may contain WLAs, which may or may not be more restrictive to a facilities management than the thermal WLAs.

## 6.5.2 Lower Bitterroot River (MT76H001_030)

The lower segment of the Bitterroot River begins at the confluence of Eightmile Creek, below Stevensville, and flows to the confluence with the Clark Fork River near Missoula. The lower segment of the Bitterroot River is not currently listed as impaired due to temperature on the 2010 impaired waters list. TMDL project monitoring and modeling of the Bitterroot River included this segment along with the upper and middle segments of the Bitterroot River. Results from this effort indicate the segments temperature standard is not being met. This segment will be listed as impaired by temperature during the next accessible listing cycle to incorporate data from this assessment. A TMDL for the lower segment of the Bitterroot River is provided in the following sections.

### *6.5.2.1 Existing Conditions and Targets Comparison*

Data and reports reviewed in the impairment status determination describe summer maximum temperatures during low flow conditions near 72°F during the early 1990s. The file mentions that temperatures become quite elevated in this segment and bull trout are not present. Yet temperature is not indicated as a cause of impairment. Therefore this segment was included in TMDL temperature project field monitoring and temperature modeling.

Although Montana Fish Wildlife and Parks (FWP) monitors water temperatures along the Bitterroot River on a yearly basis, DEQ collected the most spatially robust annual data set available for temperature of the lower segment of the Bitterroot River during the 2004 field season. The 2004 monitoring results represent a warm, low stream flow condition which approach worst case thermal conditions. Temperature data loggers were placed at 7 sites in the lower segment of the Bitterroot River during the summer of 2004, yet only 6 were recovered after the field season. Data loggers were deployed at the latest on July 16 and retrieved at the earliest on September 1, 2004. The maximum daily temperature and the 7-day average maximum temperature data are reviewed to identify the warmest period of the season. Maximum daily temperatures were monitored between July 16 and 17, depending on the site. The weekly 7-day average of the daily maximum temperatures also occurred during the same week as maximum water temperatures were detected. Monitoring devices detected from 44 to 61 days above 59°F, depending upon location. Many days above 70°F occurred at all sampling locations and no 7-day average maximum occurred below 62°F for any site (**Table 6-8, Map A-24** of **Appendix A)**. Temperatures in the lower segment of the Bitterroot River are above levels known to negatively affect native trout species which are managed for in this watershed.

**Table 6-8. DEQ Lower Bitterroot River 2004 Temperature Data Summary**

| Site ID | Seasonal Max. | | 7-Day Average during warmest week of the summer | | | | Days > | Days > |
|---|---|---|---|---|---|---|---|---|
| | Date | Value | Date | Daily Max | Daily Min | Delta T | 59 °F | 70 °F |
| KEL1 | 07/16 | 74.4 | 07/19 | 72.0 | 66.4 | 5.6 | 48 | 28 |
| STEVI5 | 07/17 | 74.3 | 07/18 | 73.0 | 65.3 | 7.6 | 61 | 33 |
| CLG3 | 07/16 | 74.7 | 07/18 | 73.1 | 66.2 | 6.9 | 50 | 33 |
| CLG2 | 07/17 | 74.6 | 07/18 | 73.1 | 65.9 | 7.2 | 50 | 33 |
| CLG6 | 07/16 | 74.7 | 08/14 | 73.5 | 63.9 | 9.7 | 51 | 36 |

During the 2004 data logger deployment, a thermal infrared flight (TIR) was conducted along the Bitterroot River (**Attachment A**). The River heats significantly from the headwaters to near Victor, then levels off from victor to the mouth. The warmest temperatures detected in the Thermal Infrared (TIR) flight were found just downstream of Hayes Creek in the lower segment of the Bitterroot River. Temperatures remain relatively consistent, and warm, throughout this segment. The TIR results include warm and cold water influences along with temperatures of the main channel (**Figure 6-2**). Identified warm water tributaries include Hayes, McClain, and Three Mile Creeks, while most other identified tributaries in this segment were similar to or had lower temperatures than the Bitterroot River. Many tributaries were not identified in the TIR effort due to dry conditions or canopy overhang. The TIR report also provides a review of cold water springs entering the River, which cumulatively slightly reduce water temperatures near Stevensville.

#### 6.5.2.1.1 Water Quality Modeling using QUAL2K for Source Assessment and Standards Assessment

While currently available data suggests elevated stream temperatures in this segment of the Bitterroot River, a QUAL2K water quality model was used to determine if the temperatures are a result of natural conditions or human activities. The model results will help determine if human-caused disturbances in the watershed have increased the water temperature above the naturally occurring level, and if so, to what degree. The model incorporated temperature, flow, stream channel, and shade information and calibrated to thermal infrared data, which was used to calibrate the model to best represent existing average summer conditions. Additionally, various scenarios that represent thermal restoration approaches in the watershed were applied in the model to determine targeted temperatures. A full description of the model and results can be found in **Attachment B**. A summary of the modeling considerations is presented in **Section 6.5.1.1.1**.

The following sections review existing conditions and restored conditions about each of the human-influenced thermal factors. Temperature monitoring and modeling results relative to each source are reviewed briefly.

#### 6.5.2.1.2 Targets and Linkage to Stream Temperature

**Riparian and Stream Channel Conditions**

During 2007 DEQ conducted an assessment of riparian vegetation class, height, density, and offset using a stereoscope and aerial photos (**Attachment A**). Riparian effective shade was estimated along each 500-meter reach (**Figure 6-5**). Field verification was also conducted. The riparian canopy information was used to calibrate the shade components of the QUAL2K water quality temperature model.

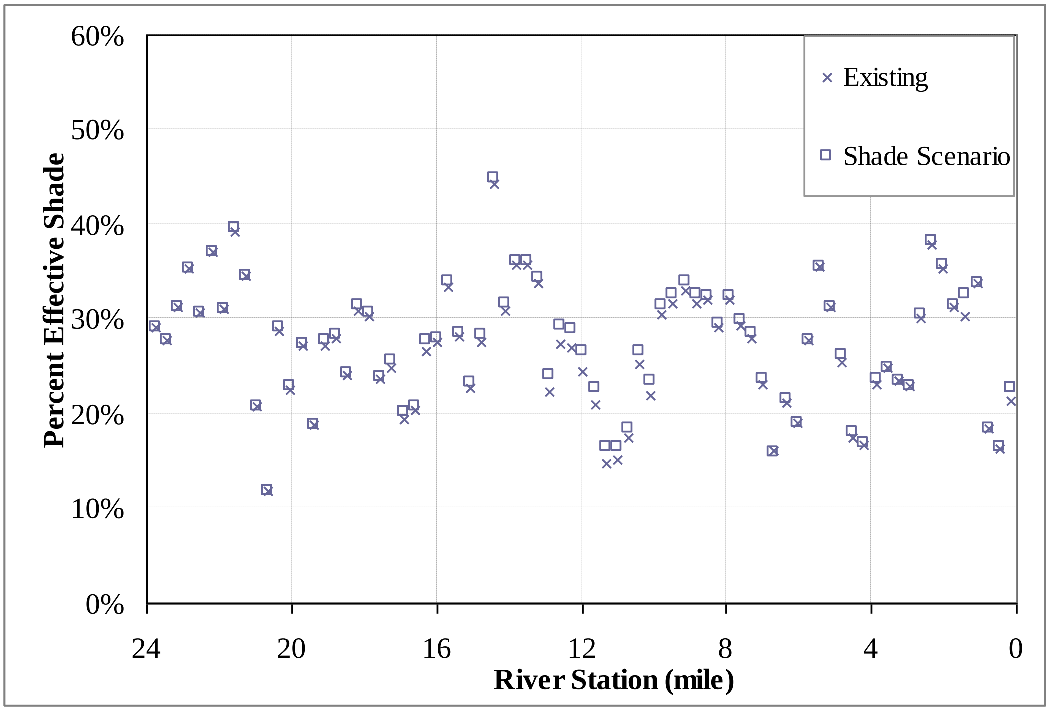



**Figure 6-5. Lower Bitterroot River Effective Shade Assessment Results**

Average daily effective shade ranged from 12% to 45% along the lower segment of the Bitterroot River (**Figure 6-5**). This segment of river is a relatively large stream with average active channel widths of approximately 240 feet. The stream width is mostly driven by natural hydrological process of spring snow melt from the surrounding mountains. Therefore, riparian vegetation is less likely to affect stream temperature than on smaller streams.

Riparian habitat along this segment consists of intermittent plant communities, including forbs/grasses, mixed deciduous trees, pine trees, and shrubs. A major portion of the segment has intact riparian areas, but agricultural fields, residential areas, and other human influences reduce shade along the river. These influences did not reduce effective stream shade to a large extent because of the wide channel and the generally north/south aspect of the river. Current shade is estimated at 26.8%, and restored riparian vegetation would increase effective shade to 27.3%. This is only a 0.5% increase in shade, which equates to a 0.07°F reduction in maximum daily temperature during average summer afternoons. Even though shade restoration will likely result in small temperature decreases, shade targets are provided because they fit into a straightforward riparian restoration approach that supports reduction of other pollutants and also because healthy riparian areas benefit fish and wildlife

**Headwater and Tributary Thermal Influence**

Temperature TMDLs were completed during 2005 for both the East and West forks of the Bitterroot River during a TMDL project for the Bitterroot Headwaters TMDL planning area. Shade and stream channel assessment results from the Bitterroot Headwaters TMDLs were used to generally populate a Stream Segment Temperature SSTEMP model for estimation of temperature reduction from the headwaters area. The results indicated that shade improvement in the Bitterroot Headwaters TMDL planning area could likely decrease water temperatures by about 1°F at the upper boundary of the river's upper segment. Along with the two major forks of the Bitterroot River, all other immediate tributary temperatures along the river were reduced by 1°F. The tributary cooling effect was shown to dissipate as the water flowed downstream and is estimated at 0.4°F decrease in maximum daily temperature at the upper boundary of the lower segment of the river (**Attachment B**).

#### 6.5.2.1.4 Wastewater Influences

Darby, Hamilton, Stevensville and Lolo WWTPs discharge to the Bitterroot River. Darby, Hamilton and Stevensville discharge upstream of this segment. Modeling indicates the upstream dischargers do not contribute to heating of this segment due to heat dissipation and increased volumetric heat capacity of the river (**Attachment D**). Because these heat loads are completely offset and do not affect this segment, they are not provided heat WLAs. Lolo discharges to the Lower Bitterroot River. Lolo currently does not significantly increase instream temperatures (**Attachment D**). Yet, a WLA is provided for Lolo because of the potential for future growth.

The target for the Lolo WWTP will be to not heat any part of the lower segment of the Bitterroot River outside of mixing zone higher than 0.25°F during June-September. To determine if a facility is meeting this target, any municipality shall not shift their effluent temperature and shall discharge at rates below double their existing hourly peak flow rate, or at their design capacity hourly peak flow, whichever is greater. The flow rates associated with the target conditions are provided in **Table 6-9**. If these conditions are not met, the facility must initiate action to prove they do not heat the Bitterroot River more than 0.25°F.

If changes to a waste treatment process occur that are likely to increase the temperature of any effluent in the watershed, or if flow rates will increase above the thresholds given for the surrogate WLA approach, an effluent temperature assessment must be initiated to determine if the plant will meet the target requirement of ≤ 0.25°F temperature increase at the end of the mixing zone due to the future WWTP plant modification (**Table 6-10**). Monitoring and reporting requirements for this process are provided in **Section 8.3.1**. The WWTP target conditions will also be interpreted into a WLA process and expressed as a discrete heat load in the heat-based numeric TMDL.

**Table 6-9. Data and mixing calculation results for existing WWTP discharge at hourly peak flow conditions**

| | **Lolo** |
|---|---|
| Upstream Discharge at 7Q10 (cfs) | 392 |
| Upstream Temperature (˚F) | 70.2 |
| Effluent Discharge hourly Peak Flow (cfs) | 1.23 |
| Effluent Temperature (˚F) | 70.5 |
| Mixed Instream Temperature (˚F) | 70.2 |
| Mixed Instream Δ T due to Effluent (˚F) | 0.001 |

**Table 6-10. Data and mixing calculation results for WWTP discharge rates at build out scenario using existing discharge temperature and hourly discharge peak flow condition**

| | **Lolo** |
|---|---|
| Upstream Discharge at 7Q10 (cfs) | 392 |
| Upstream Temperature (˚F) | 70.2 |
| Effluent Discharge hourly Peak Flow* (cfs) | 2.47 |
| Effluent Temperature (˚F) | 70.5 |
| Mixed Instream Temperature (˚F) | 70.2 |
| Mixed Instream Δ T due to Effluent (˚F) | 0.002 |

*Hourly peaks calculated using double the existing peak flow rate, or the design capacity peak flow rate from the permit statement of basis, whichever is greater, multiplied by hourly peaking factor from DEQ Circular 4.

**Irrigation - Depletion of Instream Volumetric Heat Capacity**
Irrigation depletes the volume of water in the stream and reduces instream volumetric heat capacity. The reduced stream water volume heats up more quickly, and to a higher temperature, given the same amount of thermal input. Therefore, the higher temperatures are manifested well downstream of irrigation withdrawals. Also, there are a number of irrigation reservoirs in the watershed, most notable are East Fork Reservoir and Como Lake. The reservoirs may possibly be used in conjunction with increased irrigation efficiency to provide instream flow during the heat of the summer. Implementation of irrigation efficiencies could result in a 15% reduction in irrigation water use. The irrigation savings should be applied to instream flow during the heat of the summer, while not significantly affecting groundwater return flow rates to the stream network. Maximum daily temperatures in the lower segment could be reduced by about 0.9°F during an average summer day if a 15% irrigation water use savings were applied to instream flow during the summer months (**Attachment B**).

**Irrigation - Warm Irrigation Return Flow**
Irrigation-return flows may increase stream temperatures by putting heated water back into the stream network. These return flows are difficult to assess because of their intermittent nature and therefore not all have been measured. Three irrigation-return flows warmer than the Bitterroot River were found via the Thermal Infrared (TIR) flight, and on average they were 2°F higher than the Bitterroot River (**Attachment A**). Other warm irrigation-return flows likely enter the Bitterroot River but are difficult to assess because of their small size and intermittent nature. Also, irrigation-returns are present on tributaries. Alternatively, without irrigation returns, some streams would not have enough water to sustain fish. A notable irrigation water return empties into lower Threemile Creek, where it increases daily maximum stream temperature of this tributary up to 4°F during warm summer afternoons (McDowell and Rokosch, 2005). All mainstem and tributary irrigation-returns should be investigated to determine approaches for reducing heat loads. Within the watershed, irrigation-return flows that are warmer than the stream they flow into should be reduced by 75% on a water volume or heat load basis.

**6.5.2.1.3 Summary of Targets and Existing Conditions for the Lower Segment of the Bitterroot River**
**Table 6-11** reviews temperature targets for the lower segment of the Bitterroot River. The targets will incorporate an “or” statement where Montana’s temperature standards should be met, or all the temperature influencing targets should be met. The temperature-influencing targets include target conditions for tributary watershed areas, shade along the segment, channel conditions, irrigation water use and waste, stormwater and wastewater effluents. If all these targets are achieved in combination, a condition that attains Montana’s water temperature standards will be met in the lower segment of the Bitterroot River.

**Table 6-11. Temperature Targets and Existing Conditions for the Lower Segment of the Bitterroot River**

| Water Quality Targets | Criteria | 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. | Calibrated QUAL2K model results are compared to restoration scenario results. Modeling conclusions indicate Montana's temperature standard is not being met during average summer afternoon conditions. If conditions provided below for sources are met, daily maximum summertime temperatures would likely be reduced the most near river mile 11, by about 0.8°F (**Attachment B**). |
| **OR meet ALL of the temperature influencing restoration targets below** | | |
| Tributary temperatures | Reduce all tributary temperatures by an average of 1°F from current conditions via increased shade, irrigation efficiencies and channel restoration. | The EF and WF Bitterroot River temperature TMDLs developed during 2005 and subsequent SSTEMP modeling indicate a 1°F reduction is likely in these tributaries. Specific warm tributaries found during TIR include Hayes, Three Mile, Kootenai, McClain, and Tin Cup Creeks. Other moderate temperature tributaries may also easily be cooled via restoration practices. |
| Effective Shade | 26.8% Effective Shade | 27.3% Effective Shade |
| Channel width/depth ratio | No change. | Cumulative Widths ≈ 240 ft |
| Irrigation water management (Higher efficiency) | 15% improvement in irrigation efficiency during the warmest months (mid-June through August), while not affecting base flow volume of the Bitterroot River. | The irrigation system should be assessed for inefficiencies to determine if this estimated efficiency based upon regional irrigation management studies is achievable and to identify specific strategies to reduce irrigation use, maintain groundwater conditions, and keep water in the stream. Effects to groundwater returning to the river should be considered during implementation of this target condition. |
| Irrigation return flow | Reduce warm irrigation water entering any of the watersheds stream network by 75%. | There are three known warm irrigation return flow locations. Others are likely present, yet are likely smaller or intermittent. The irrigation system should be assessed thoroughly to reduce overland waste to the state's surface waters and to further quantify heat loads from this source. |

**Table 6-11. Temperature Targets and Existing Conditions for the Lower Segment of the Bitterroot River**

| Water Quality Targets | Criteria | Existing Condition |
|---|---|---|
| Wastewater Treatment Plants | No WWTP caused surface water inflow, in single or in combination, may increase temperatures more than 0.25°F. Do not increase loads associated with current temperature of effluent at double the facilities current peak hourly discharge or peak hourly design capacity whichever is greater. If modifications to waste treatment process are likely to heat a discharge, a thermal study must be conducted prior to modification. | Modeling and mixing calculations indicate WWTPs in combination currently increase daily max temp very slightly in the lower segment of the Bitterroot River (See **Table 6-9**). |
| Missoula Urban Runoff (MS4) | Follow the minimum control measure provided in Part II. 5.a.vii. of the MPDES Missoula small MS4 permit authorization (MTR040007), or any updated runoff reduction or initial flush stormwater capture control measures in subsequent permits renewals. Renewed permits must contain initial flush mitigation measures. | Modeling and mixing calculations indicate potential for increased stream temperature up to 0.25°F due to storm runoff. This happens very infrequently and for very short duration (**Attachment D**). |

A naturally occurring model scenario defines water temperature conditions resulting from the implementation of 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 0.5°F temperature increase is allowable in this segment. This, in turn, can be used to identify if standards are exceeded and a TMDL is needed. The naturally occurring scenario for the lower segment of the Bitterroot River (miles 0–24) is a full collection of the restoration scenarios described in the previous sections of this report. In a significant portion of the segment, more than a 0.5°F increase in summertime daily maximum temperature is apparent when compared with a restored scenario, where reasonable land, soil, and water conservation practices are in place (**Figure 6-6)**. At river mile 11, the most sensitive location on this segment, maximum daily temperatures can likely be reduced by at least 0.8°F with reasonable conservation practices.

None of the shade, irrigation water use, irrigation water return flow, or tributary targets are fully met. Both the temperature modeling and target assessments indicate Montana's water temperature standards are not being met. Therefore, the segment is in need of a temperature TMDL.

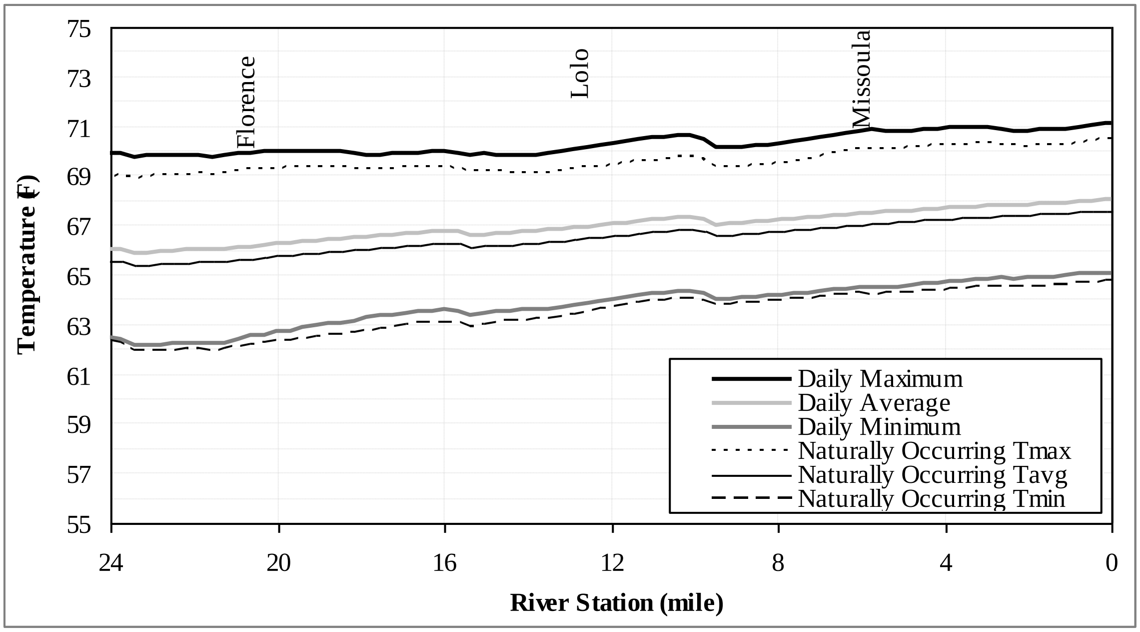



**Figure 6-6. Lower segment of Bitterroot River simulated water temperatures for existing conditions and naturally occurring scenario**

### *6.5.2.2 TMDL, Allocations and Margin of Safety*

Thermal conditions in the middle segment of the Bitterroot River are largely the result of complex interactions among the factors reviewed in **Table 6-5**, which prevents an easy interpretation of the influence of each one independent of the others. Modeling results indicate that irrigation use and an array of human sources in the tributaries have the largest human-caused heating effect upon this segment of river. Irrigation return-flows in the watershed may have a moderate heating effect on temperatures of this segment. Reduced riparian canopy conditions along the Bitterroot River are only a small source of heating. Also, point sources have a small affect upon thermal conditions, yet were provided wasteload allocations to ensure they do not increase above a significant level. Missoula's stormwater runoff poses a moderate heating effect, yet it is a very brief and periodic source. If all allocations provided in this section are met, Montana's temperature standards will be achieved in the middle segment of the Bitterroot River.

#### 6.5.2.2.1 Surrogate TMDL for Promoting Nonpoint Source Load Reductions

Monitoring and modeling results provided much of the technical framework for developing a surrogate temperature TMDL and allocation approach. Applying a surrogate TMDL is more useful for guidance of nonpoint source restoration approaches than a heat-based numeric TMDL. Influences to stream temperatures are not always intuitive at a watershed scale, and the modeling effort helped estimate the relative effects that stream shading, tributary influences, WWTP discharges, and stream flow have on stream temperature during the warmest time of year. Significant sources and surrogate allocation approaches for each are provided in **Table 6-12**. If each surrogate allocation is followed, the temperature standard will be met.

**Table 6-12. Temperature TMDL for the lower segment of the Bitterroot River**

| **The TMDL equals the resultant thermal load associated with stream temperature when all conditions below are met:** | |
|---|---|
| **Source Type** | **Load Allocation (surrogate)** |
| Agricultural, urban and other land uses that could impact riparian health and resultant **shade** provided by the riparian or near stream vegetation along the Bitterroot River. | The thermal load that can reach the stream segment when there is an average daily shade of 27.3% using a Solar Pathfinder along the segment. |
| Inefficient agricultural or urban **water use**. | No reduction in thermal buffering capacity due to inefficient irrigation or urban water use practices along the segment. |
| Forestry, agricultural, suburban, other land uses and inefficient use of water that could impact shade, channel width/depth ratio or flow on **tributaries**. | No measurable increase in thermal loading from preventable human caused increases in any tributaries contributing flow to the Bitterroot River. No reduction in thermal buffering capacity due to inefficient irrigation or urban water use practices. |
| Warm **irrigation return water** | A load associated with a condition where 75% reduction in irrigation water or associated heat loads entering the Bitterroot River or tributaries in which the irrigation water is warmer than instream conditions. |
| **WWTPs** (WLA) | No individual or cumulative increase above 0.25˚F due to WWTP effluents in the watershed. This may be achieved by each WWTP if they do not discharge more than double the facilities current peak hourly discharge or peak hourly design capacity whichever is greater. If modifications to waste treatment process are likely to heat a discharge or discharge rates increase above thresholds provided, a thermal study must be conducted prior to modification. Monitor effluent temperatures during June-September in first year of first permit renewal cycle according to requirements in **Section 8.3.1**. |
| Missoula Stormwater (WLA) | No measurable or modeled increase in total first flush stormwater volumes. This should be achieved by following the minimum control measure provided in Part II. 5.a.vii. of the MPDES Missoula small MS4 permit authorization (MTR040007), or any updated runoff reduction or initial flush stormwater capture control measures in subsequent permits renewals. Renewed permits must contain initial flush mitigation measures. |

#### 6.5.2.2.2 Numeric TMDL, Allocations and Margin of Safety

The TMDL is also expressed as a numeric heat load to compare with heat-based waste load allocations. The numeric TMDL applied to the lower segment of the Bitterroot River is **Equation 6-2**. An example heat load is developed using **Equation 6-2**, **Figure 6-2,** and modeling results from **Appendices B** and **C**. An applied example of how the temperature TMDL for the lower segment of the Bitterroot River equates to stream temperature, heat load and Montana's temperature standard and heat loading during an average summer afternoon is provided in **Table 6-13**. Temperature and heat results provided in this table are based on conditions approximating 7Q10 flow near Missoula, Montana during the heat of an average warm summer afternoon (392 cfs). The TMDL along with associated load and wasteload allocations are provided in kilocalories per second above water's melting point. A composite load allocation to all nonpoint sources is given in this example with natural temperatures provided in a separate load allocation.

**Table 6-13. Lower segment of the Bitterroot River numeric TMDL, allocation and MOS example at 7Q10 during a typical hot sunny summer afternoon near Missoula, MT**

| TMDL Component | Load Allocation | | Waste Load Allocation* | Margin of Safety | | |
|---|---|---|---|---|---|---|
| **Source Description** | Estimated Natural Sources | Human sources with all reasonable land, soil and water conservation practices in place. This includes:<br>• Well managed agricultural and suburban land use activities along the Bitterroot River and tributaries that provide similar shading as reference areas<br>• Irrigation occurring with 15% efficiency savings applied to summer stream flow<br>• 75% reduction of heat load from warm irrigation return flow entering the Bitterroot River and tributaries.<br>• Tributary temperature reductions | WWTP WLAs | Reserved for safety factor and uncertainty in analysis | = | **TMDL** |
| **Estimated Contribution to Temperature TMDL** | 68.2°F | 1.7°F | 0.25°F | 0.25°F | | 70.4°F |
| **Heat Load in Kcal/Sec** | 221,370 | 10,396 | 1,529 | 1,529 | | 234,824 |

*Missoula MS4 WLA is not represented in the numeric TMDL table due to the infrequent and short lived nature of the source. See **Table 6-12** for a surrogate wasteload allocation approach for the Missoula MS4 permit area.

### Wasteload Allocations

Surface water dischargers currently are a small source of heating to the Bitterroot River but could become a significant contribution of heat and are therefore given wasteload allocations. The waste load allocations (WLAs) are premised upon an approach that any WWTP may not discharge more than their current design capacity estimated hourly peak discharge or double their existing peak hourly discharge rate, whichever is higher. This would assure all WWTPs in combination will accumulatively contribute to no more than a 0.25˚F increase in temperature. This equates to half of the allowable increase allowed under the standard for B-1 waters over a naturally occurring temperature of 66.5˚F.

The WLAs may be expressed alternatively by permitting each facility to discharge up to double their existing peak discharge rate or up to their design capacity, whichever is higher as long as existing thermal conditions of the effluent are not increased. Yet, if updates to water treatment process increase the temperature conditions of an effluent or a facility discharges at a higher rate than provided by the WLA at any time, the facility must measure temperature and calculate loads for one year, following monitoring requirements in **Section 8.3.1**.

Modeling indicated that loads associated with each WWTP are attenuated and offset by additional volumetric heat capacity between discharges (**Attachment C**). Therefore, each facility can use mixing equations as a tool to determine compliance and not have to worry about cumulative effects of all WWTPs. A facility must provide verification via monitoring and assessment that it will not increase thermal conditions in the river below their mixing zone by more than 0.25°F prior to updates to their system or if they exceed discharge rates provided in this document. These analyses shall use effluent peak flow estimates and 7Q10 instream flow.

The Missoula MS4 urban area has the only NPDES permitted stormwater system with direct connectivity to the Bitterroot River. Much of Missoula's permitted area (>80%) does not reach the Bitterroot River via surface runoff. A major portion is not in the Bitterroot watershed, and a significant fraction of the area within the watershed is mitigated via dry wells, retrofitted with other infiltration techniques, or used for irrigation. The remainder of runoff from Missoula that may reach the Bitterroot River drains during timeframes where storms have cooled the landscape via cloud cover, cool precipitation and evaporation. Yet this source contributes a warm first flush of runoff during very limited storm events after the landscape is initially heated on days with air temperatures above 75°F. Estimated temperature increases from the runoff indicate this source heats the lower Bitterroot River by less than 0.25°F (**Attachment D**). The frequency of this source is estimated at 1-2 times per year and the duration is estimated at about 1-2 hours during critical thermal timeframes for supporting the fishery. Because of moderate magnitude, but very low duration and frequency, a surrogate allocation is provided. The surrogate WLA is that the Missoula MS4 permit area shall not significantly increase runoff volume. This surrogate allocation shall be met by following minimum runoff control measures provided in Part II, 5.a.vii. of the Missoula Area MS4 permit, or any updated initial flush stormwater capture or interception control measures in subsequent permits renewals. Renewed permits must contain similar or greater Low Impact Development (LID) water retention and infiltration requirements as the current permit in order to meet the intent of this WLA.

A special consideration for meeting the WLA and capturing initial stormwater runoff in Missoula will be infiltration of the stormwater into the ground via LID designs, instead of surface detention. Surface detention may provide increased heat load to the Bitterroot River via flushing of warmed water from ponds or wetlands, especially if these are located near the river. Groundwater will cool the river, whereas pond water may increase temperatures. Infiltration ponds, dry wells, grassy swales, and other LID designs to infiltrate water are preferred approaches to reducing runoff for mitigation of thermal conditions in the Bitterroot River. Already, many areas of the city have these types of water infiltration approaches in place. New development and redevelopment must continue and enhance this trend.

All other stormwater, CAFO and groundwater discharge permitted activities in the watershed have negligible effects on water temperature of the middle segment of the Bitterroot River during critical conditions and, therefore, do not need wasteload allocations due to their insignificance and timing of runoff conditions compared to impacts to the fishery.

The thermal WLAs do not represent all pollutant WLAs that will be developed in the Bitterroot River watershed. Other pollutant category TMDLs (e.g., nutrients) developed during future TMDL projects may contain WLAs, which may or may not be more restrictive to a facilities management than the thermal WLAs.

### 6.5.3 Mill Creek (MT76H004_040)

Source assessment data collected on Mill Creek was not robust enough in relation to sources present in the watershed for completing a temperature TMDL at this time. Mill Creek's temperature TMDL will be addressed during future TMDL development efforts using a rotating watershed approach for schedule completion.

## 6.5.4 Miller Creek (MT76H004_130)

Miller Creek originates in the Sapphire Mountains and flows west to its confluence with the Bitterroot River between Lolo and Missoula. Miller Creek is currently listed as impaired due to temperature on the 2010 impaired waters list.

### *6.5.4.1 Existing Conditions and Targets Comparison*

Data and reports reviewed in the impairment status determination describe temperatures that are likely negatively affecting bull and cutthroat trout. Temperatures increased between monitoring sites during the summer of 2004. The file mentions that temperatures become quite elevated in this segment and bull trout are not present.

Timber harvest near stream corridors has occurred intermittently in the mountainous headwater areas within the watershed. Livestock grazing practices and irrigated hay production have the potential to reduce riparian vegetation shrub and tree growth and reduce stream flows throughout the watershed. Suburban development from Missoula occurs in the middle and lower portions of this watershed. Suburban activities such as lawn care (watering and encroachment to the stream) and small acreage livestock tending impact riparian shade in the suburban landscape.

Temperature data was collected during the 2004 and 2007 summer field seasons at three sites (**Map A-25** of **Appendix A**). Monitoring in the headwaters indicates cool water conditions that support native fish species. Water temperatures rise in a downstream direction until the warm stream water is used for irrigation. Below Trails End Road, stream water is almost fully diverted for irrigation use during the summer and springs provide water cool groundwater to the stream channel in the lowest mile of Miller Creek (**Map A-25** of **Appendix A**). In the warmest section of the stream, monitoring devices detected 69 days above 59°F and 47 days above 70°F. Temperatures in the middle and lower reaches of Miller Creek are above levels known to negatively affect native trout species (**Table 6-14**).

**Table 6-14. Miller Creek Temperature Data Summary**

| Site ID | Seasonal Max. | | 7-Day Average during warmest week of the summer | | | | Days > | Days > |
|---|---|---|---|---|---|---|---|---|
| | Date | Value | Date | Daily Max | Daily Min | Delta T | 59 °F | 70 °F |
| Mil1 | 08/17/04 | 86.6 | 08/14/04 | 81.9 | 54.6 | 27.3 | 44 | 38 |
| Mil2 | 07/17/04 | 57.3 | 08/14/04 | 55.9 | 48.4 | 7.6 | 0 | 0 |
| Mil3 | 07/17/04 | 74.6 | 07/26/04 | 71.6 | 49.9 | 21.7 | 43 | 24 |
| MILLR-1 | 07/28/07 | 57.4 | 07/28/07 | 56.7 | 50.0 | 6.7 | 0 | 0 |
| MILLR-2 | 07/18/07 | 71.0 | 07/17/07 | 69.5 | 54.4 | 15.1 | 53 | 3 |
| MILLR-3 | 07/28/07 | 78.7 | 07/28/07 | 76.5 | 58.5 | 18.0 | 69 | 47 |

During the 2004 data logger deployment, a thermal infrared flight (TIR) was conducted along Miller Creek (**Attachment A**). The Creek heats significantly from the headwaters to below Trails End Road, then most of the water is diverted from the stream for irrigation and springs provide cold water to the lowest section of the stream. Temperatures in the middle reaches of Miller Creek were estimated at 80°F.

#### 6.5.4.1.1 Water Quality Modeling using QUAL2K for Source Assessment and Standards Assessment

While currently available data strongly suggests elevated stream temperatures in the middle and lower reaches of Miller Creek, a QUAL2K water quality model was used to determine if the temperature increases are the result of anthropogenic activities. The model results assist in determining if human caused disturbances within the watershed have increased the water temperature above the "naturally occurring" level and, if so, to what degree. The model incorporated actual temperature, flow, and shade information collected during the warmest part of the summer, which was used to calibrate the model to best represent existing condition. Additionally, various scenarios that represent thermal restoration approaches in the watershed were applied within the model to determine targeted temperature conditions. The full description of the model and results can be found in **Attachment B**.

The following sections review existing conditions and estimated restored conditions about each of the human caused thermal influencing factors affecting Miller Creek. Temperature monitoring and modeling results relative to each source are reviewed briefly in the following sections.

#### 6.5.4.1.2 Riparian and Stream Channel Conditions

During 2007 DEQ conducted a riparian vegetation class, height, vegetation density and offset assessment using a stereo scope and aerial photos. From this effort, riparian effective shade was estimated along each 500 m reach and a desired condition was also estimated (**Figure 6-7**). A field verification effort was also conducted. This riparian canopy information was used to calibrate the riparian shade components of the QUAL2K water quality temperature model.

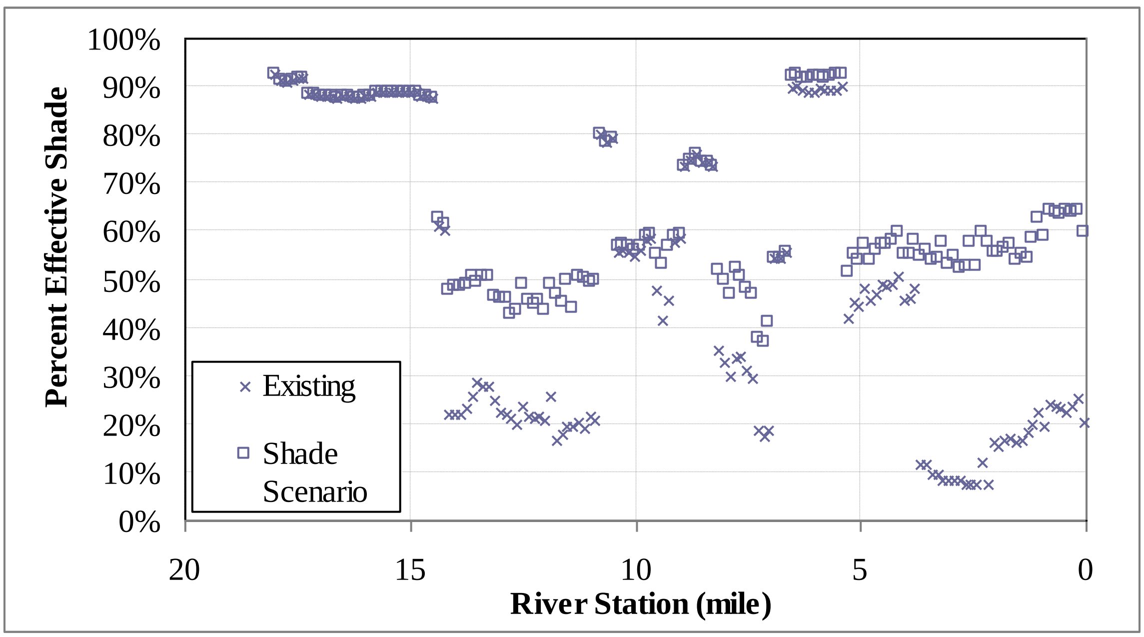



**Figure 6-7. Miller Creek Effective Shade Assessment Results**

Daily effective shade ranged from 92% in the headwaters to 7% near the Bitterroot River (**Figure 6-7**). Miller Creek is a small stream with a very narrow active channel and thus shading from riparian vegetation is likely to affect stream temperatures to a high degree. Riparian vegetation along Miller Creek consists of conifer forest in the headwaters and intermixed shrubs, deciduous trees, forbs and grass in the remainder of the watershed. Predominant human impacts currently influencing streamside vegetation include livestock grazing and hay production between miles 0-4 and11-15 along with grazing and suburban development along river miles 4-11 (**Figure 6-7, Map A-26**). Also, timber harvest likely impacts shade on tributaries. Average current shade along Miller Creek is estimated at 48% and a restored riparian vegetation condition would increase effective shade to 65% along Miller Creek. This represents a significant potential increase in shade which equates to a 7.5°F reduction in maximum daily temperature during average summer afternoons in the middle section of the stream. Impacts to stream side vegetation are a significant source of heat to Miller Creek.

Miller Creek's channel is overly wide in some areas. This condition contributes to higher solar radiation entering the stream and higher stream temperatures. The width-to-depth targets provided in **Section 5.4.1.2** also apply to Miller Creek temperature TMDL.

#### 6.5.4.1.3 Irrigation Water Use

Use of stream water for irrigation depletes the volume of water in the stream. The reduced water volume heats up more quickly and to a higher temperature given the same amount of thermal input. Therefore, the higher temperatures due to reduced capacity for buffering heat are manifested downstream of irrigation withdrawals. Alternatively, irrigation and subsequent groundwater return flow may cool the stream in cases were severe dewatering occurs and subsequent stream flow is mostly groundwater.

Irrigation occurs along Miller Creek, but was not assessed within the model framework. The thermal infrared results indicate that the lowest mile of Miller Creek is not connected via surface water to upstream conditions during low flow: likely this is due to irrigation water use along with water loss to alluvial groundwater as the stream enters the Bitterroot Valley. In the lowest reach of Miller Creek, warmed stream water is used for irrigation and lost to groundwater, then returns via cool groundwater about a mile downstream. The stream is severely dewatered in this lower section of Miller Creek and thus downstream conditions are dominated by small springs.

Yet upstream, from miles 4-14, irrigation uses are likely to have a significant warming influence upon the stream where water is used for irrigation but do not likely return much cool groundwater when compared to the reduced stream flow which heats up quickly. Stream temperatures in this reach were approaching 80°F during the summer with irrigation a likely influence along with stream shade reduction (**Table 6-14**). Targets relevant to irrigation efficiency and warm irrigation water return flow to the stream are provided in **Table 6-15**.

#### 6.5.4.1.4 Summary of Targets and Existing Conditions for Miller Creek

**Table 6-15** provides a review of temperature targets for Miller Creek. The targets will incorporate an "or" statement where Montana's temperature standards should be met or all the temperature influencing targets should be met. The temperature influencing targets include target conditions for timber harvest in headwaters tributaries, vegetation produced shade along the segment, channel conditions, irrigation water use and waste, and wastewater effluents. If all these targets are met, Montana's water temperature standards will be met in Miller Creek.

**Table 6-15. Temperature Targets and Existing Conditions for Miller Creek**

| Water Quality Targets | Criteria | 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. | Calibrated QUAL2K model results are compared to restoration scenario results. Modeling conclusions indicate Montana's temperature standard is not being met during average summer afternoon conditions. If conditions provided below for sources are met, daily maximum summertime temperatures would likely be reduced by at least 8°F (**Attachment B**). |
| **OR meet ALL of the temperature influencing restoration targets below** | | |
| Effective Shade (timber harvest, hay production, livestock grazing, and suburban land use) | 48% Effective Shade | 65% Effective Shade |
| Channel width/depth ratio | See **Table 5-4** | See **Table 5-29** |
| Irrigation water management (Higher efficiency) | 15% improvement in irrigation efficiency during the warmest months with water saving applied to in-stream flow (mid-June through August). | The irrigation system should be assessed for inefficiencies to determine if this estimated efficiency based upon regional irrigation management studies is achievable and to identify specific strategies to reduce irrigation use and keep water in the River. |
| Irrigation return flow | Reduce warm irrigation water entering any of the watersheds stream network by 75%. | Unknown |

A naturally occurring model scenario for Miller Creek defines water temperature conditions resulting from the implementation of all reasonable land, soil and water conservation practices as outlined in ARM 17.30.602. This scenario identifies the restored temperature condition in waterbodies of interest and establishes the temperatures to which a 0.5°F (0.23°C) temperature increase is allowable. This, in turn, can be used to identify if standards are exceeded and determine if a TMDL is needed. The naturally occurring scenario for Miller Creek assesses sources that impact shade along the segment. In a significant portion of the segment, more than a 0.5°F increase in daily maximum temperature is apparent when compared to a restored scenario where land and water conservation practices are in place (**Figure 6-8)**. Maximum daily temperatures can likely be reduced by at least 7.5 to 8°F with reasonable conservation practices that restore shade along the stream.

None of the targets have been attained. Both the modeling and temperature influencing target assessment approaches indicate Montana's water temperature standards are not being met. Therefore, Miller Creek is in need of a temperature TMDL.

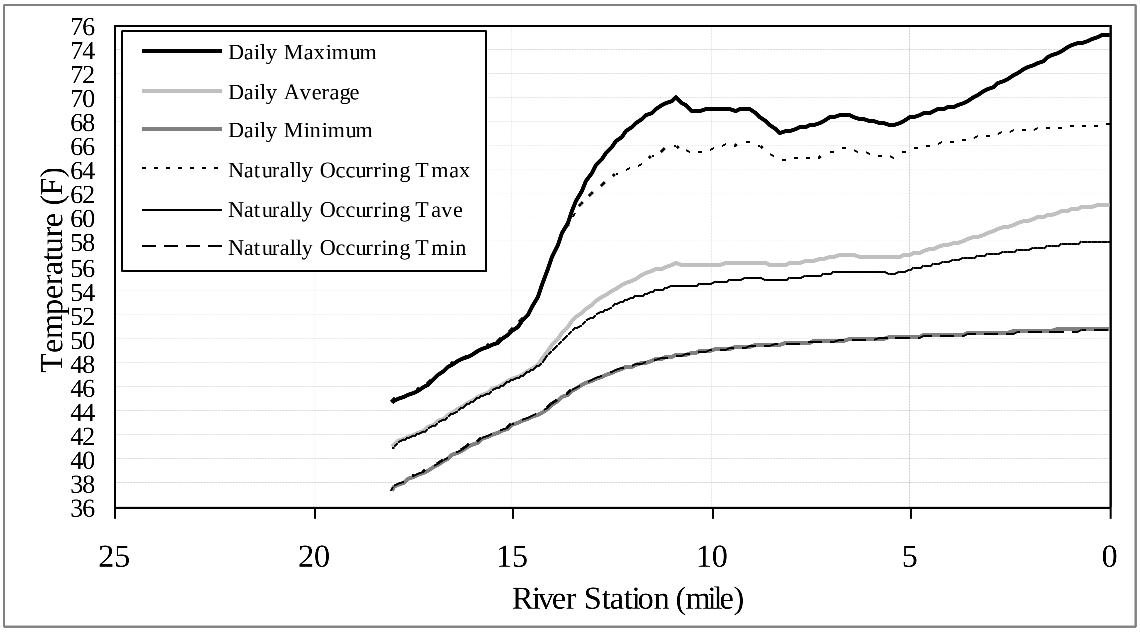



**Figure 6-8. Miller Creek simulated water temperatures for existing conditions and naturally occurring scenario.**

## *6.5.4.2 TMDL, Allocations and Margin of Safety*

Thermal conditions within Miller Creek are largely the result of complex interactions among the factors reviewed in **Table 6-15**, which prevents an easy interpretation of the influence of each one separate from the others. Modeling results indicate that vegetation impacts from grazing, hay production and suburban development along Miller Creek provide the largest heating effect upon this segment of stream. Inefficient irrigation practices and timber harvest within the watershed may have moderate impacts to temperatures within this segment of stream. No point sources are present. If all allocations provided in this section are met, Montana's temperature standards will be achieved in Miller Creek.

### 6.5.4.2.1 Surrogate TMDL for Promoting Nonpoint Source Load Reductions

Monitoring and modeling results provided much of the technical framework for developing a surrogate temperature TMDL and allocation approach. Applying a surrogate TMDL is more useful for guidance of nonpoint source restoration approaches than a heat based numeric TMDL. Influences to stream temperatures are not always intuitive at a watershed scale and the modeling effort helped estimate the relative effects that stream shading, tributary influences, and stream flow have on stream temperature during the warmest time of year. Significant sources and surrogate allocation approaches for each are provided in **Table 6-16**. If each surrogate allocation is followed, the temperature standard will be met. It is likely that the allocations will reduce afternoon summer temperatures by at least 8°F and potentially even higher if irrigation efficiencies and headwater tributary timber harvest allocations are assessed and met. The most influential nonpoint source restoration strategy for Miller Creek will be restoring shade producing vegetation along the whole segment.

**Table 6-16. Miller Creek temperature TMDL**

| **The TMDL equals the resultant thermal load associated with stream temperature when all conditions below are met:** | |
|---|---|
| **Source Type** | **Load Allocation (surrogate)** |
| Agricultural, urban and other land uses that could impact riparian health and resultant **shade** provided by the riparian or near stream vegetation along Miller Creek. | The thermal load that can reach the stream segment when there is an average daily shade of 65% along Miller Creek using a Solar Pathfinder. |
| Forestry land use in headwater **tributaries**. | No measurable or modeled increase in thermal loading from timber harvest in tributaries contributing flow to Miller Creek. |
| Inefficient agricultural or urban **water use**. | No reduction in thermal buffering capacity due to inefficient irrigation or urban water use practices along the segment. |
| Warm **irrigation return water** | A load associated with a condition where 75% reduction in irrigation water entering Miller Creek or tributaries in which the irrigation water is warmer than instream conditions. |

#### 6.5.4.2.2 Numeric TMDL

The TMDL may also be expressed as a numeric heat load to compare with heat based waste load allocations. **Equation 6-2** is the numeric TMDL applied to Miller Creek. An example heat load calculation for heat of the summer afternoon weather and stream flow conditions near Trails End Road crossing is developed using **Equation 6-2**, **Figure 6-1** and modeling results from **Attachment B**. An applied example of how the temperature TMDL for Miller Creek equates to stream temperature and heat loads during an average summer afternoon is provided in **Table 6-17**. This example is provided for the average summer flow of about 4cfs. The TMDL along with associated load and wasteload allocations are provided in kilocalories per second above water's melting point.

**Table 6-17. Miller Creek numeric TMDL, allocation and MOS example during a typical summer afternoon**

| **TMDL Component** | **Load Allocation** | | **Margin of Safety** | | |
|---|---|---|---|---|---|
| **Source Description** | Natural Sources | Human sources with all reasonable land, soil and water conservation practices in place. This includes:<br>• Well managed agricultural and suburban land use activities along the Miller Creek and tributaries that provide similar shading as reference areas<br>• Irrigation occurring with 15% efficiency savings applied to summer stream flow<br>• 75% reduction of warm irrigation return flow water entering the Miller Creek and tributaries. | Reserved for safety factor and uncertainty in analysis | = | **TMDL** |
| **Estimated Contribution to Temperature TMDL** | 66.5°F | 1.0°F | 0.5°F | | 68.0°F |
| **Heat Load in Kcal/Sec** | 2,153 | 62 | 31 | | 2,246 |

## 6.5.5 Sleeping Child Creek (MT76H004_090)

Sleeping Child Creek originates in the Sapphire Mountains and flows to its confluence with the Bitterroot River south of Grantsdale. Sleeping Child Creek is currently listed as impaired due to temperature on the 2010 impaired waters list.

### *6.5.5.1 Existing Conditions and Targets Comparison*

Sleeping Child Creek originates in the Sapphire Mountains and flows west to its confluence with the Bitterroot River. Much of Sleeping Child Creek's watershed is composed of mountainous terrain and includes timbered and grassland slopes. Timber harvest within the stream corridor has occurred in the headwaters. A forest road travels along the valley bottom, but is almost exclusively on the north side of the stream and therefore has an inconsequential impact on effective shade. Also, during 2000, fire burned about 10-12 miles of the stream corridor. The fire occurred in the middle reaches of the stream segment, between river miles 9 to 19. Livestock grazing practices and irrigated hay production have the potential to reduce riparian vegetation shrub and tree growth along the lowest seven miles of the stream corridor. Also in the lower reaches, water is diverted for hay production.

Temperature data was collected during 2007 summer field season at two sites. Monitoring site SCHI-1 is located near river mile 12, above hay and irrigation influences, and SCHI-2 is located near Sleeping Child Creek's confluence with the Bitterroot River. Water temperatures rise in a downstream direction. At site SCHI-2 monitoring equipment detected 60 days above 59°F and 17 days above 70°F. Temperatures in the middle reach of Sleeping Child Creek are slightly lower than near the mouth. Stream temperatures are above levels known to negatively affect native trout species and human caused sources are present (**Table 6-18**).

**Table 6-18. Sleeping Child Creek Temperature Data Summary**

| Site ID | Seasonal Max | | 7-Day Average during warmest week of the summer | | | | Days > | Days > |
|---|---|---|---|---|---|---|---|---|
| | Date | Value | Date | Daily Max | Daily Min | Delta T | 59 °F | 70 °F |
| SCHI-1 | 07/18/07 | 68.4 | 08/14/04 | 67.3 | 59.4 | 7.9 | 46 | 0 |
| SCHI-2 | 07/14/07 | 73.8 | 08/14/04 | 72.3 | 61.6 | 10.7 | 60 | 17 |

#### 6.5.5.1.1 Water Quality Modeling using QUAL2K for Source Assessment and Standards Assessment

While currently available data suggests elevated stream temperatures in Sleeping Child Creek, a QUAL2K water quality model was used to determine if the temperature conditions are the result of natural conditions or anthropogenic activities. The model results assist in determining if human caused disturbances within the watershed have increased the water temperature above the "naturally occurring" level and, if so, to what degree. The model incorporated actual temperature, flow and shade information collected during the warmest part of the summer, which was used to calibrate the model to best represent existing conditions. Additionally, various scenarios that represent thermal restoration approaches in the watershed were applied within the model to determine targeted temperature conditions. The full description of the model and results can be found in **Attachment B**.

The following sections review existing conditions and estimated restored conditions about each of the human caused thermally influencing factors. Temperature monitoring and modeling results relative to each source are reviewed briefly in the following sections.

#### 6.5.5.1.2 Riparian and Stream Channel Conditions

During 2007 DEQ conducted a riparian vegetation class, height, vegetation density and offset assessment using a stereo scope and aerial photos. From this effort, riparian effective shade was estimated along each 500 m reach and a desired condition was also estimated (**Figure 6-9**). A field verification effort was also conducted. This riparian canopy information was used to calibrate the riparian shade components of the QUAL2K water quality temperature model.

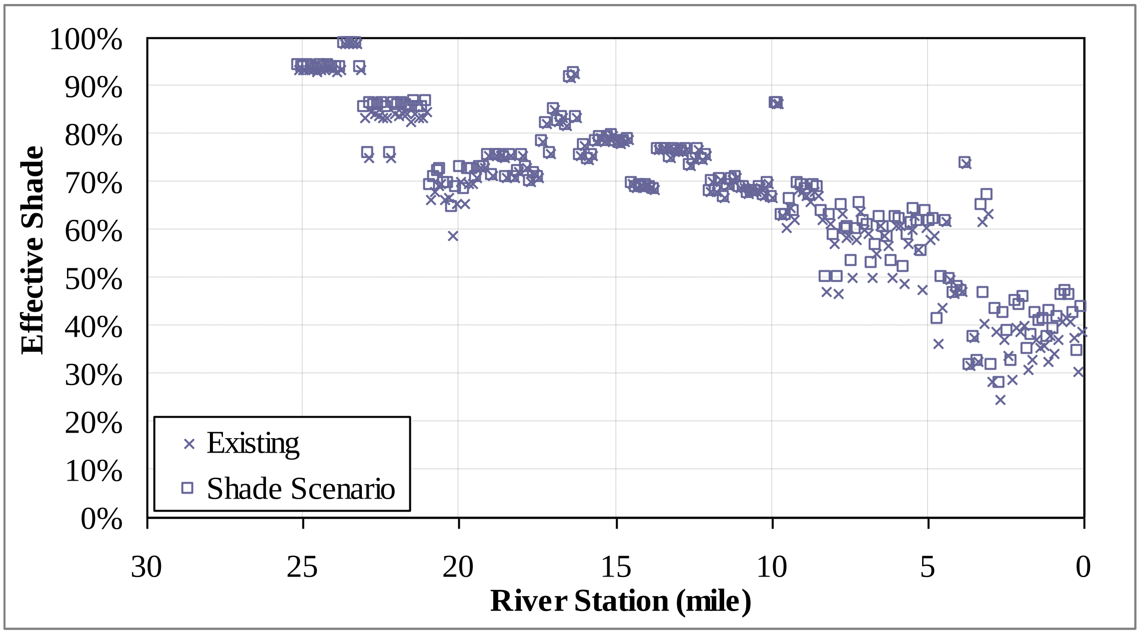



**Figure 6-9. Sleeping Child Creek Effective Shade Assessment Results.**

Daily effective shade ranged from 98% in the headwaters to 25% near the Bitterroot River (**Figure 6-9**). Sleeping Child Creek is a small stream with a narrow active channel and thus streamside shading from vegetation is likely to affect stream temperatures significantly. Riparian vegetation along Sleeping Child Creek consists of conifer forest in the headwaters and intermixed shrubs, deciduous trees, forbs and grass in the remainder of the watershed. Predominant human impacts currently impacting streamside vegetation include livestock grazing and hay production, particularly between miles 0 to 7 (**Figure 6-9**). Also, timber harvest likely impacts shade in the headwaters. Sleeping Child Creek flows through a clearcut section near mile 20. A wildfire burned portions of the riparian area between miles 9 to 19. Riparian vegetation condition aerial photo assessment results are provided in **Map A-27**.

Average current shade along Sleeping Child Creek is estimated at 67% and a restored riparian vegetation condition excluding fire impacted area regeneration, would increase effective shade to 68.5% along Sleeping Child Creek. If fire regeneration were to be included in the analysis restored conditions would be approximately 69% effective shade. The restoration scenario that does not include fire regeneration represents an increase in shade which equates to a 1.03°F reduction in maximum daily temperature during average summer afternoons near mile 20, and a similar increase near the confluence with the Bitterroot River. Impacts to stream side vegetation are a source of heat to Sleeping Child Creek.

Sleeping Child Creek's channel is overly wide in some areas. This condition contributes to higher solar radiation entering the stream and higher stream temperatures. The width-to-depth targets provided in **Section 5.4.1.2** also apply to Sleeping Child Creek temperature TMDL.

#### 6.5.5.1.3 Irrigation Water Use

Use of stream water for irrigation depletes the volume of water in the stream. The reduced water volume heats up more quickly and to a higher temperature given the same amount of thermal input. Therefore, the higher temperatures due to reduced capacity for buffering heat are manifested downstream of irrigation withdrawals. Alternatively, irrigation and subsequent groundwater return flow may cool the stream in cases were severe dewatering occurs and subsequent stream flow is mostly groundwater.

Irrigation occurs along Sleeping Child Creek, but was not assessed within the model framework. The aerial photo review indicates irrigation occurs in the lower seven miles of stream. The extent of water use is not fully understood at this time but likely contributes to warmer stream water in the lowest few miles of Sleeping Child Creek. Because of this, irrigation efficiency that reduce stream water use should occur and associated water savings should be left in the stream. Targets relevant to irrigation efficiency and warm irrigation water return flow to the stream are provided in **Table 6-19**.

#### 6.5.5.1.4 Summary of Targets and Existing Conditions for Sleeping Child Creek

**Table 6-19** provides a review of temperature targets for Sleeping Child Creek. The targets will incorporate an "or" statement where Montana's temperature standards should be met or all the temperature influencing targets should be met. The temperature influencing targets include target conditions for timber harvest in headwaters tributaries, vegetation produced shade along the segment, channel conditions and irrigation water use and waste. If all these targets are met, Montana's water temperature standards will be met in Sleeping Child Creek.

**Table 6-19. Temperature Targets and Existing Conditions for Sleeping Child Creek**

| Water Quality Targets | Criteria | 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. | Calibrated QUAL2K model results are compared to restoration scenario results. Modeling conclusions indicate Montana's temperature standard is not being met during average summer afternoon conditions. If conditions provided below for sources are met, daily maximum summertime temperatures would likely be reduced by over 1°F (**Attachment B**). |
| **OR meet ALL of the temperature influencing restoration targets below** | | |
| Effective Shade (timber harvest, hay production, and livestock grazing) | 69% Effective Shade | 67% Effective Shade |
| Channel width/depth ratio | See **Table 5-4** | Some reaches are likely exceeding targets. See **Table 5-38.** |

**Table 6-19. Temperature Targets and Existing Conditions for Sleeping Child Creek**

| Water Quality Targets | Criteria | Existing Condition |
|---|---|---|
| Irrigation water management (Higher efficiency) | 15% improvement in irrigation efficiency during the warmest months with water saving applied to in-stream flow (mid-June through August). | The irrigation system should be assessed for inefficiencies to determine if this estimated efficiency based upon regional irrigation management studies is achievable and to identify specific strategies to reduce irrigation use and keep water in the River. |
| Irrigation return flow | Reduce warm irrigation water entering any of the watersheds stream network by 75%. | Unknown |

A naturally occurring model scenario of Sleeping Child Creek defines water temperature conditions resulting from the implementation of 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 0.5°F (0.23°C) temperature increase is allowable. This, in turn, can be used to identify if standards are exceeded and determine if a TMDL is needed. The naturally occurring scenario for Sleeping Child Creek assesses sources that impact shade along the segment. In a small portion of the segment below a clear cut, more than a 1°F increase in daily maximum temperature is apparent when compared to a restored scenario where land conservation practices are in place (**Figure 6-10)**. Also, in the lower portion of the stream, water is heated slightly above the 0.5°F threshold from irrigated hay production and riparian grazing that reduce shade from riparian vegetation. The modeling results indicate that temperature standards are slightly exceeded in Sleeping Child Creek.

None of the targets have been attained. Both the modeling and temperature influencing target assessment approaches indicate Montana's water temperature standards are not being met. Therefore, Sleeping Child Creek is in need of a temperature TMDL.

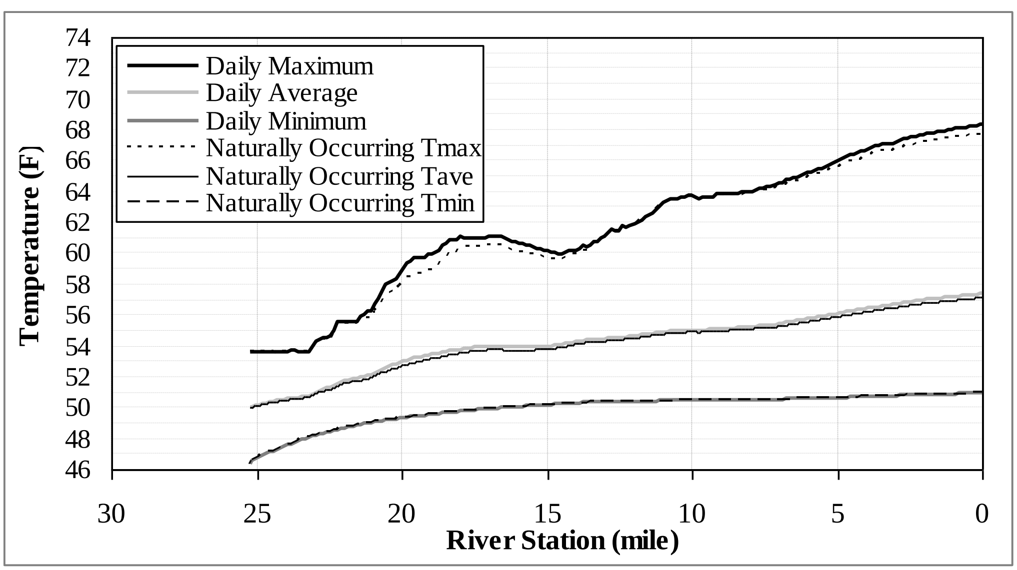



**Figure 6-10. Sleeping Child Creek simulated water temperatures for existing conditions and naturally occurring scenario.**

### *6.5.5.2 TMDL, Allocations and Margin of Safety*

Thermal conditions within Sleeping Child Creek are largely the result of complex interactions among the factors reviewed in **Table 6-19**, which prevents an easy interpretation of the influence of each one separate from the others. Modeling results indicate that vegetation impacts from timber harvest, grazing and irrigated hay production along Sleeping Child Creek provide the a heating effect upon this segment of stream, yet irrigation water use and return flows are similarly large influence upon stream temperatures. No point sources are present. If all allocations provided in this section are met, Montana's temperature standards will be achieved in Sleeping Child Creek. Additionally, the temperature reductions due to natural revegetation in the area affected by the fire were not considered in the TMDL document, but this area should be managed to recover as quickly as possible.

#### 6.5.5.2.1 Surrogate TMDL for Promoting Nonpoint Source Load Reductions

Monitoring and modeling results provided much of the technical framework for developing a surrogate temperature TMDL and allocation approach. Applying a surrogate TMDL is more useful for guidance of nonpoint source restoration approaches than a heat based numeric TMDL. Influences to stream temperatures are not always intuitive at a watershed scale and the modeling effort helped estimate the relative effects that stream shading, tributary influences, and stream flow have on stream temperature during the warmest time of year. Significant sources and surrogate allocation approaches for each are provided in **Table 6-20**. If each surrogate allocation is followed, the temperature standard will be met. It is likely that the allocations will reduce afternoon summer temperatures by at least 1°F and potentially even higher if irrigation efficiencies and headwater tributary timber harvest allocations are assessed and met. The most influential nonpoint source restoration strategy for Sleeping Child Creek will be restoring shade producing vegetation along the whole segment.

**Table 6-20. Sleeping Child Creek temperature TMDL**

| **The TMDL equals the resultant thermal load associated with stream temperature when all conditions below are met:** | |
|---|---|
| **Source Type** | **Load Allocation (surrogate)** |
| Agricultural, urban and other land uses that could impact riparian health and resultant **shade** provided by the riparian or near stream vegetation along the Bitterroot River. | The thermal load that can reach the stream segment when there is an average daily shade of 68.5% along Sleeping Child Creek using a Solar Pathfinder. |
| Forestry land use in headwater **tributaries**. | No measurable or modeled increase in thermal loading from timber harvest in tributaries contributing flow to Sleeping Child Creek. |
| Inefficient agricultural or urban **water use.** | No reduction in thermal buffering capacity due to inefficient irrigation or urban water use practices along the segment. |
| Warm **irrigation return water** | A load associated with a condition where 75% reduction in irrigation water entering Sleeping Child Creek or tributaries in which the irrigation water is warmer than instream conditions. |

#### 6.5.5.2.2 Numeric TMDL

The TMDL may also be expressed as a numeric heat load to compare with heat based waste load allocations. **Equation 6-2** is the numeric TMDL applied to Sleeping Child Creek. An example heat load calculation for heat of the summer afternoon weather and stream flow conditions near Trails End Road crossing is developed using **Equation 6-2**, **Figure 6-1** and modeling results from **Attachment B**. Two examples of how the temperature TMDL for Sleeping Child Creek equates to stream temperature and heat loads during an average summer afternoon is provided in **Table 6-21, 6-22**. These examples are provided for the average summer flow of about 5 cfs and provide information about each of the areas where standards are not met due to differing sources. The TMDL along with associated load and wasteload allocations are provided in kilocalories per second above water's melting point. Two examples are provided for differing source areas, **Table 6-21** represents a location downstream of a timber harvest area and **Table 6-22** represents a culmination of watershed influences near the watershed outlet.

**Table 6-21. Sleeping Child Creek numeric TMDL, allocation and MOS example during a typical summer afternoon below a clear cut section near mile 19**

| **TMDL Component** | **Load Allocation** | | **Margin of Safety** | | |
|---|---|---|---|---|---|
| **Source Description** | Natural Sources | Human sources with all reasonable land, soil and water conservation practices in place. This includes:<br>• Well managed agricultural and suburban land use activities along the Sleeping Child Creek and tributaries that provide similar shading as reference areas<br>• Irrigation occurring with 15% efficiency savings applied to summer stream flow<br>• 75% reduction of warm irrigation return flow water entering the Sleeping Child Creek and tributaries. | Reserved for safety factor and uncertainty in analysis | = | TMDL |
| **Estimated Contribution to Temperature TMDL** | 59.0°F | 1.0°F | 0.5°F | | 60.5°F |
| **Heat Load in Kcal/Sec** | 2,106 | 79 | 38 | | 2,223 |

**Table 6-22. Sleeping Child Creek numeric TMDL, allocation and MOS example during a typical summer afternoon near confluence with Bitterroot River**

| **TMDL Component** | **Load Allocation** | | **Margin of Safety** | | |
|---|---|---|---|---|---|
| **Source Description** | Natural Sources | Human sources with all reasonable land, soil and water conservation practices in place. This includes:<br>• Well managed agricultural and suburban land use activities along the Sleeping Child Creek and tributaries that provide similar shading as reference areas<br>• Irrigation occurring with 15% efficiency savings applied to summer stream flow<br>• 75% reduction of warm irrigation return flow water entering the Sleeping Child Creek and tributaries. | Reserved for safety factor and uncertainty in analysis | = | TMDL |
| **Estimated Contribution to Temperature TMDL** | 67.5°F | 1.0°F | 0.5°F | | 69.0°F |
| **Heat Load in Kcal/Sec** | 2,769 | 78 | 39 | | 2,886 |

## 6.5.6 Willow Creek (MT76H004_110)

Willow Creek originates in the Sapphire Mountains and flows to its confluence with the Bitterroot River near the Town of Corvallis. Willow Creek is currently listed as impaired due to temperature on the 2010 impaired waters list.

### *6.5.6.1 Existing Conditions and Targets Comparison*

The east half of Willow Creek's watershed consists of mountainous terrain and includes timbered and rangeland slopes. Timber harvest has occurred in the watershed, but not within the stream corridor. A forest road travels along the valley bottom, but is usually on the north side of the stream and therefore has an inconsequential impact on effective shade. Livestock grazing practices and irrigated hay production have the potential to reduce riparian vegetation shrub and tree growth along the lowest seven miles of the stream corridor. Also in the lower half of the watershed, water is diverted for hay and crop production and the stream mixes with irrigation ditches that originate from the Bitterroot River.

Three major ditches cross Willow Creek. The upper most canal crossing near river mile eight, usually referred to as the Big Canal is managed by the Bitterroot Irrigation District. At this crossing a flume moves irrigation canal water over the stream without mixing. About 0.15 cfs may be provided to Willow Creek via a gate at the flume during very low stream flow for irrigation use on about 10 acres of land downstream. Most of the water from irrigated land in the Willow Creek watershed managed by the Bitterroot Irrigation District derives from Lake Como. The Daily Ditch Company manages both the Republican and Hedge Ditches which both cross Willow Creek, each of these ditches mix with Willow Creek Water and are managed with a head gate on the downstream side of the ditch. Both of these ditches move water from the Bitterroot River into, and through, the Willow Creek watershed. Streamflows in the lower section of Willow Creek are highly managed by the irrigation system.

Temperature data was collected during 2007 summer field season at eight sites. Monitoring site Will-2 is located about a mile downstream of where irrigation crops begin. Sites Will-3 and Will-4 are above and below the Bitterroot Irrigation District Canal crossing. Sites Will-5 and Will-6 lie above and below the Hedge Ditch crossing. Sites Will-7 and Will-8 fall above and below the Republican Ditch crossing. Site Will-9 is downstream of Corvallis, and the Corvallis Ditch diversion.

Water temperatures rise in a downstream direction until Willow Creek mixes with the Hedge and Republican Ditches. At both of these locations ditch water derived from the Bitterroot River is mixed with Willow Creek stream water and summer daily maximum temperatures are lower below the ditch crossings but daily average temperatures are higher. At site SCHI-2 monitoring equipment detected 60 days above 59°F and 17 days above 70°F. (**Table 6-23**).

**Table 6-23. Willow Creek Temperature Data Summary**

| Site ID | Seasonal Max. | | 7-Day Average during warmest week of the summer | | | | Days > | Days > |
|---|---|---|---|---|---|---|---|---|
| | Date | Value | Date | Daily Max | Daily Min | Delta T | 59 °F | 70 °F |
| WILL-2 | 08/03/07 | 66.3 | 07/31/07 | 65.1 | 55.3 | 9.8 | 52 | 0 |
| WILL-3 | 07/28/07 | 76.7 | 07/22/07 | 74.0 | 60.5 | 13.5 | 67 | 22 |
| WILL-4 | 07/14/07 | 76.5 | 07/17/07 | 74.5 | 66.7 | 7.9 | 67 | 22 |
| WILL-5 | 07/20/07 | 79.5 | 07/17/07 | 78.1 | 64.1 | 14.0 | 67 | 21 |
| WILL-6 | 07/14/07 | 78.9 | 07/16/07 | 77.0 | 64.2 | 12.8 | 67 | 23 |
| WILL-7 | 07/14/07 | 77.8 | 07/16/07 | 75.7 | 64.3 | 11.4 | 65 | 22 |

**Table 6-23. Willow Creek Temperature Data Summary**

| Site ID | Seasonal Max. | | 7-Day Average during warmest week of the summer | | | | Days > | Days > |
|---|---|---|---|---|---|---|---|---|
| | Date | Value | Date | Daily Max | Daily Min | Delta T | 59 °F | 70 °F |
| WILL-8 | 07/14/07 | 76.1 | 07/16/07 | 74.7 | 66.1 | 8.6 | 67 | 21 |
| WILL-9 | 07/14/07 | 75.9 | 07/16/07 | 74.5 | 66.6 | 7.9 | 68 | 21 |
| WILL-10 | 07/14/07 | 76.4 | 07/16/07 | 74.5 | 67.2 | 7.3 | 67 | 21 |

#### 6.5.6.1.1 Water Quality Modeling using QUAL2K for Source Assessment and Standards Assessment

While currently available data suggests elevated stream temperatures in Sleeping Child Creek, a QUAL2K water quality model was used to determine if the temperature conditions are the result of natural conditions or anthropogenic activities. The model results assist in determining if human caused disturbances within the watershed have increased the water temperature above the “naturally occurring” level and, if so, to what degree. The model incorporated actual temperature, flow and shade information collected during the warmest part of the summer, which was used to calibrate the model to best represent existing conditions. Additionally, various scenarios that represent thermal restoration approaches in the watershed were applied within the model to determine targeted temperature conditions. The description of the model and results can be found in **Attachment B**.

The following sections review existing conditions and estimated restored conditions about each of the human caused thermally influencing factors. Temperature monitoring and modeling results relative to each source are reviewed briefly in the following sections.

#### 6.5.6.1.2 Riparian and Stream Channel Conditions

Riparian effective shade was estimated using conditions from aerial photo assessment throughout the Bitterroot watershed tributaries and coarsely applied to Willow Creek (See **Map A-28** in **Appendix A**). This riparian canopy information was used to calibrate the riparian shade components of the QUAL2K water quality temperature model.

Daily effective shade is estimated at 62% in the headwaters and 37% in the Bitterroot River Valley. Willow Creek is a small stream with a narrow active channel and thus streamside shading from vegetation is likely to affect stream temperatures significantly. Riparian vegetation along Willow Creek consists of conifer forest in the headwaters and intermixed shrubs, deciduous trees, forbs and grass in the remainder of the watershed. Predominant human impacts currently impacting streamside vegetation include livestock grazing and hay/crop production. Average current shade along all of Willow Creek is estimated at 57% and a restored riparian vegetation condition would likely increase effective shade to 65%.

Willow Creek’s channel is also overly wide in some areas. This condition contributes to higher solar radiation entering the stream and higher stream temperatures. The width-to-depth targets provided in **Section 5.4.1.2** also apply to Willow Creek temperature TMDL.

#### 6.5.6.1.3 Irrigation Water Use

Use of stream water for irrigation depletes the volume of water in the stream. The reduced water volume heats up more quickly and to a higher temperature given the same amount of thermal input. Therefore, the higher temperatures due to reduced capacity for buffering heat are manifested downstream of irrigation withdrawals. Alternatively, irrigation and subsequent groundwater return flow may cool the stream in cases were severe dewatering occurs and subsequent stream flow is mostly groundwater.

There are about 50 decreed water rights in the watershed originating in Willow Creek or its tributaries that cumulatively account for about 90 cfs. About 85 water appropriations could account for over 500 cfs of water use, yet are not verified (Buck, 1958). It is unlikely that this much water is available in the summer. Currently the eastern tributaries of the Bitterroot River are proceeding with the adjudication process but no results are available at this time. Water use from the streams in the watershed is extensive and the lower reaches of Willow Creek are fed by reemerging groundwater or irrigation canal water. During the summer timeframe in drought years, a section of Willow Creek carries little to no water from near Gottard-Hull Ditch to Republican Ditch.

Three major ditches cross Willow Creek. The upper most canal crossing near river mile eight, usually referred to as the Big Canal, is managed by the Bitterroot Irrigation District. At this crossing a flume moves irrigation canal water over the stream without mixing. About 0.15 cfs may be provided to Willow Creek via a gate at the flume during very low stream flow for irrigation use on about 10 acres of land downstream. Most of the water from irrigated land in the Willow Creek watershed managed by the Bitterroot Irrigation District derives from Lake Como. The Daily Ditch Company manages both the Republican and Hedge Ditches which both cross Willow Creek, each of these ditches mix with Willow Creek Water and are managed with a head gate on the downstream side of the ditch. Both of these ditches move water from the Bitterroot River into, and through, the Willow Creek watershed. Streamflows in the lower section of Willow Creek are highly managed by the irrigation system.

Stream temperatures likely increase due to irrigation diversions in the middle reaches of the stream but maximum daily temperatures are cooled by irrigation water canals that mix with the stream. Average daily temperatures are slightly increased by the mixing effect, yet maximum daily temperatures of the stream are decreased due to the thermal inertia of the ditches and the Bitterroot River. When the mixing of stream and irrigation water was removed from the model, the model would not run due to streambeds being dry. Therefore, this scenario could not be included in **Attachment B** and is not considered in a restoration approach at this time.

Because of the complex and extensive irrigation system found in this watershed and its varied effects upon water temperature and stream flow, the irrigation system return flow influences are not considered in the allocation approach or naturally occurring modeling scenarios (**Table 6-17**). Nevertheless, irrigation efficiencies and irrigation water management within this watershed are addressed in the TMDL, the adaptive management approaches, and follow-up monitoring components of the TMDL document and are included in the targets.

#### 6.5.6.1.4 Summary of Targets and Existing Conditions for Willow Creek

**Table 6-24** provides a review of temperature targets for Willow Creek. The targets will incorporate an "or" statement where Montana's temperature standards should be met or all the temperature influencing targets should be met. The temperature influencing targets include target conditions for vegetation produced shade along the segment, channel conditions, irrigation water use and waste. If all these targets are met, Montana's water temperature standards will be met in Willow Creek.

**Table 6-24. Temperature Targets and Existing Conditions for Willow Creek**

| Water Quality Targets | Criteria | 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. | Calibrated QUAL2K model results are compared to restoration scenario results. Modeling conclusions indicate Montana's temperature standard is not being met during average summer afternoon conditions. If conditions provided below for sources are met, daily maximum summertime temperatures would likely be reduced by at least 2.5°F (**Attachment B**). |
| **OR meet ALL of the temperature influencing restoration targets below** | | |
| Effective Shade (timber harvest, hay production, and livestock grazing) | 65% Effective Shade | 57% Effective Shade |
| Channel width/depth ratio | See **Table 5-4** | See **Table 5-46** |
| Irrigation water management (Higher efficiency) | 15% improvement in irrigation efficiency during the warmest months with water saving applied to in-stream flow (mid-June through August). | The irrigation system should be assessed for inefficiencies to determine if this estimated efficiency based upon regional irrigation management studies is achievable and to identify specific strategies to reduce irrigation use and keep water in the River. |
| Irrigation return flow | Complete study to determine best management practice which will benefit the fishery. | See text. |

A naturally occurring model scenario of Willow Creek defines water temperature conditions resulting from the implementation of 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 0.5°F (0.23°C) temperature increase is allowable. This, in turn, can be used to identify if standards are exceeded and determine if a TMDL is needed. The naturally occurring scenario for Willow Creek assesses sources that impact shade along the segment. In the lowest portion of the stream, water is heated at least 2.5°F from irrigated crop production and riparian grazing that reduce shade by impacting riparian vegetation. The modeling results indicate that temperature standards are exceeded in Willow Creek.

The streamside vegetation shade targets and W/D ratio targets are not met. It's also likely that the irrigation targets are not met. Both the modeling and temperature influencing target assessment approaches indicate Montana's water temperature standards are not being met. Therefore, Willow Creek is in need of a temperature TMDL.

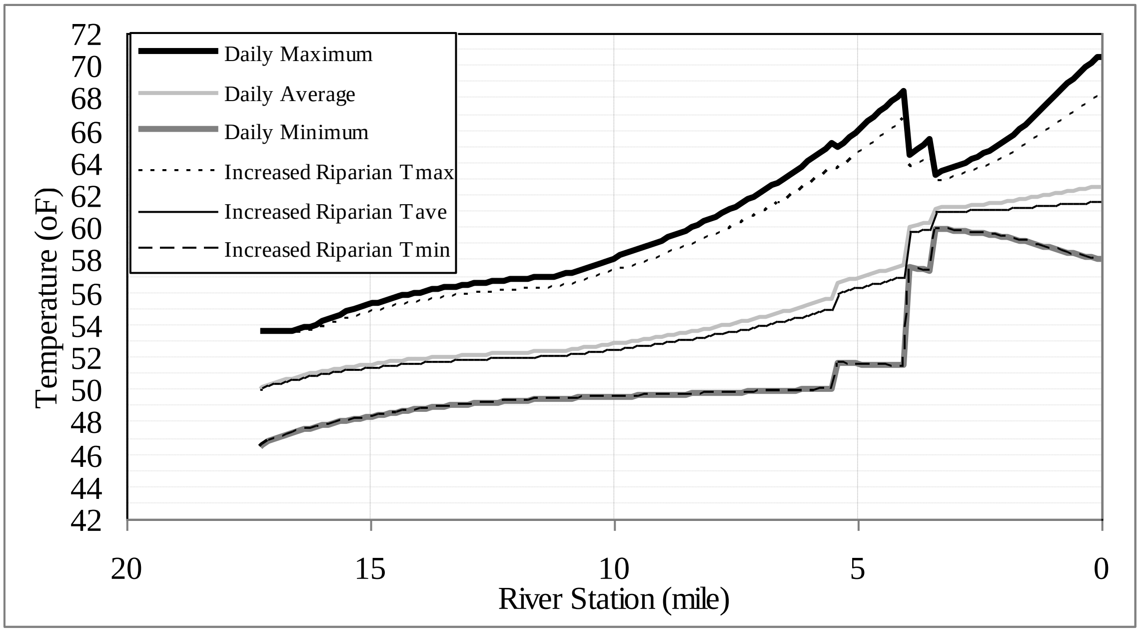



**Figure 6-11. Willow Creek simulated water temperatures for existing conditions and an increased shade scenario.**

## *6.5.6.2 TMDL, Allocations and Margin of Safety*

Thermal conditions within Willow Creek are largely the result of complex interactions among the factors reviewed in **Table 6-21**, which prevents an easy interpretation of the influence of each one separate from the others. Modeling results indicate that vegetation impacts from timber harvest, grazing and irrigated hay production along Willow Creek provide the largest heating effect upon this segment of stream. No point sources are present. If all allocations provided in this section are met, Montana's temperature standards will be achieved in Willow Creek.

### 6.5.5.2.1 Surrogate TMDL for Promoting Nonpoint Source Load Reductions

Monitoring and modeling results provided much of the technical framework for developing a surrogate temperature TMDL and allocation approach. Applying a surrogate TMDL is more useful for guidance of nonpoint source restoration approaches than a heat based numeric TMDL. Influences to stream temperatures are not always intuitive at a watershed scale and the modeling effort helped estimate the relative effects that stream shading, tributary influences, and stream flow have on stream temperature during the warmest time of year. Significant sources and surrogate allocation approaches for each are provided in **Table 6-25**. If each surrogate allocation is followed, the temperature standard will be met. It is likely that the allocations will reduce afternoon summer temperatures by at least 1°F and potentially even higher if irrigation efficiencies and headwater tributary timber harvest allocations are assessed and met. The most influential nonpoint source restoration strategy for Willow Creek will be restoring shade producing vegetation along the whole segment.

**Table 6-25. Willow Creek temperature TMDL**

| The TMDL equals the resultant thermal load associated with stream temperature when all conditions below are met: | |
|---|---|
| **Source Type** | **Load Allocation (surrogate)** |
| Agricultural, urban and other land uses that could impact riparian health and resultant shade provided by the riparian or near stream vegetation along the Bitterroot River. | The thermal load that can reach the stream segment when there is an average daily shade of 68.5% along Willow Creek using a Solar Pathfinder. |
| Forestry land use in headwater tributaries. | No measurable or modeled increase in thermal loading from timber harvest in tributaries contributing flow to Willow Creek. |
| Inefficient agricultural or urban water use. | No reduction in thermal buffering capacity due to inefficient irrigation or suburban water use practices along the segment. |
| Warm irrigation return water | Complete investigation to determine best management practice which will benefit the fishery. |

#### 6.5.6.2.2 Numeric TMDL and Allocations

The TMDL may also be expressed as a numeric heat load to compare with heat based waste load allocations. **Equation 6-2** is the numeric TMDL applied to Willow Creek. An example heat load calculation for heat of the summer afternoon weather and stream flow conditions near Trails End Road crossing is developed using **Equation 6-2**, **Figure 6-1** and modeling results from **Attachment B**. Two examples of how the temperature TMDL for Willow Creek equates to stream temperature and heat loads during an average summer afternoon is provided in **Table 6-26**. These examples are provided for the average summer flow of about 5cfs and provide information about each of the areas where standards are not met due to differing sources. The TMDL along with associated load and wasteload allocations are provided in kilocalories per second above water's melting point.

**Table 6-26. Willow Creek numeric TMDL, allocation and MOS example during a typical summer afternoon at river mile 4.5**

| **TMDL Component** | **Load Allocation** | | **Margin of Safety** | | |
|---|---|---|---|---|---|
| **Source Description** | Natural Sources | Human sources with all reasonable land, soil and water conservation practices in place. This includes:<br>• Well managed agricultural and suburban land use activities along the Willow Creek and tributaries that provide similar shading as reference areas<br>• Irrigation occurring with 15% efficiency savings applied to summer stream flow<br>• Study irrigation system for reducing irrigation water impact while keeping water in the stream. | Reserved for safety factor and uncertainty in analysis | = | TMDL |
| **Estimated Contribution to Temperature TMDL** | 61.0°F | 1.0°F | 0.5°F | | 62.5°F |
| **Heat Load in Kcal/Sec** | 2,262 | 78 | 38 | | 2,379 |

## 6.6 Margin of Safety and Seasonal Considerations

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. TMDL development must also 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. This section describes, in detail, considerations of seasonality and a margin of safety in the temperature TMDL development process.

The margin of safety is addressed in several ways as part of this document:

- Explicit MOSs are provided in each of the thermal TMDLs.
- Montana's water quality standards are applicable to any timeframe and any season. The temperature modeling analysis investigated temperature conditions during the heat of the summer when the temperature standards are most likely exceeded and when the most significant human caused sources are likely to heat the stream the most.
- The assessment and subsequent allocation scenarios addressed stream flow influences that affect the streams dissipative and volumetric heat capacity.
- Compliance with targets and refinement of load and wasteload allocations are all based on an adaptive management approach (**Section 6.7**) 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 westslope cutthroat and bull trout, 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.
- Temperature targets, TMDL, load and wasteload 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, including reducing the formation of anchor ice which may limit fish health.
- Thermal WLAs are based upon yearly 7Q10s, which are lower than summer time 7Q10s. The summer timeframe is stressful to the fishery, the most sensitive use. An inherent MOS for the WLAs is provided by the use of yearly 7Q10s.

## 6.7 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 processes 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 an 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 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 warming, 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 warming 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 8.2** and **8.3** provide a basic framework for reducing uncertainty and further understanding of the complex issues TMDLs undertake.

# 7.0 - Other Identified Issues or Concerns

## 7.1 Habitat Related Non-Pollutant Listings

Water quality issues are not limited to those streams where TMDLs are developed. In some cases, streams have not yet been reviewed through the DEQ assessment process and do not appear on the 303(d) list (such as Fred Burr Creek or Eightmile Creek). In other cases, streams may appear in the water quality integrated report with a non-pollutant listing such as “alteration in stream-side or littoral vegetative covers” that could be linked to a pollutant, but may not require TMDL development. These habitat related non-pollutant causes are often associated with sediment and temperature issues, or potential sediment and temperature issues. They may also be having a harmful 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 attempting to improve water quality conditions in individual streams, and the Bitterroot 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 habitat related non-pollutant listings. **Table 7-1** presents the habitat related pollution listings in the Bitterroot TPA, and highlights those streams that have an associated pollutant listing.

**Table 7-1. Waterbody segments in the Bitterroot TPA with habitat related non-pollutant listings**

| Stream Segment | Waterbody Segment ID | 2010 Probable Causes of Impairment |
|---|---|---|
| Ambrose Creek | MT76H004_120 | Physical substrate habitat alterations |
| Bass Creek | MT76H004_010 | Low flow alterations |
| Bear Creek | MT76H004_030 | Low flow alterations |
| Bitterroot River (East and West Forks to Skalkaho) | MT76H001_010 | Alteration in stream-side or littoral vegetative covers |
| Bitterroot River (Skalkaho to Eightmile)* | MT76H001_020 | Low flow alterations |
| Bitterroot River (Eightmile to mouth/ Clark Fork River)* | MT76H001_030 | Alteration in stream-side or littoral vegetative covers |
| Blodgett Creek | MT76H004_050 | Low flow alterations |
| Kootenai Creek | MT76H004_020 | Alteration in stream-side or littoral vegetative covers and Low flow alterations |
| Lick Creek* | MT76H004_170 | Alteration in stream-side or littoral vegetative covers |
| Lolo Creek (Mormon Creek to mouth/ Bitterroot River)* | MT76H005_011 | Physical substrate habitat alterations and Low flow alterations |
| Lolo Creek (Sheldon Creek to Mormon Creek)* | MT76H005_012 | Physical substrate habitat alterations |
| Lolo Creek (headwaters to Sheldon Creek)* | MT76H005_013 | Physical substrate habitat alterations |
| Lost Horse Creek | MT76H004_070 | Low flow alterations |
| Mill Creek* | MT76H004_040 | Alteration in stream-side or littoral vegetative covers and Low flow alterations |
| Miller Creek* | MT76H004_130 | Alteration in stream-side or littoral vegetative covers |
| North Channel Bear Creek | MT76H004_032 | Low flow alterations |

**Table 7-1. Waterbody segments in the Bitterroot TPA with habitat related non-pollutant listings**

| Stream Segment | Waterbody Segment ID | 2010 Probable Causes of Impairment |
|---|---|---|
| North Fork Rye Creek | MT76H004_160 | Alteration in stream-side or littoral vegetative covers |
| Rye Creek* | MT76H004_190 | Alteration in stream-side or littoral vegetative covers |
| Skalkaho Creek | MT76H004_100 | Low flow alterations |
| South Fork Lolo Creek | MT76H005_020 | Physical substrate habitat alterations and Low flow alterations |
| Sweathouse Creek | MT76H004_210 | Alteration in stream-side or littoral vegetative covers and Low flow alterations |
| Threemile Creek* | MT76H004_140 | Low flow alterations |
| Tin Cup Creek | MT76H004_080 | Alteration in stream-side or littoral vegetative covers |
| Willow Creek* | MT76H004_110 | Alteration in stream-side or littoral vegetative covers |
| * Streams listed for habitat related non-pollutants, and having associated sediment or temperature pollutant listings. | | |

## 7.2 Descriptions of Non-Pollutant Causes of Impairment

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; yet non-pollutant sources or indicators do indicate impairment. 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 a non-pollutant cause to a waterbody, and thereby provides additional insight into possible factors in need of additional investigation or remediation.

**Alteration in Stream-side or Littoral Vegetation Covers**

Alteration in stream-side 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. Such instances may be riparian vegetation removal for a road or utility corridor, or overgrazing by livestock along the stream. As a result of altering the stream-side vegetation, destabilized banks from loss of vegetative root mass could lead to over-widened stream channel conditions, and the resultant lack of canopy cover can lead to increased water temperatures.

**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 anthropogenically 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.

**Low Flow Alterations**

Streams are typically listed for low flow alterations when irrigation withdrawal management leads to base flows that are too low to support the beneficial uses designated for that stream. This could result in dry channels or extreme low flow conditions that do not support fish and aquatic life. Additionally, low flow conditions have the potential to limit sediment-transport capacity which may lead to an accumulation of fine sediments that could affect fish and aquatic life. It could also result in lower flow conditions which absorb thermal radiation more readily and increase stream temperatures, which in turn creates dissolved oxygen conditions too low to support some species of fish. It should be noted that while Montana law 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 as a probable source of impairment does not violate state or federal regulations or guidance related to stream assessment and water quality impairment determination. Subsequent to the identification of low flow alterations as a probable cause of impairment, it is up to local users, agencies, and entities to improve flows through water and land management.

## 7.3 Monitoring and BMPs for Pollution Affected Streams

Streams listed for habitat related pollution as opposed to a pollutant should not be overlooked when developing watershed management plans. Attempts should be made to collect sediment and temperature information where data is minimal and the linkage between probable cause, habitat related pollution listing, and affects to the beneficial uses are not well defined. The monitoring and restoration strategies that follow in **Section 8.0** are presented to address pollutant issues for the Bitterroot TPA streams, but are equally applicable to streams listed for the above pollution categories.

# 8.0 - Framework Water Quality Restoration and Monitoring Strategy

## 8.1 TMDL Implementation and Monitoring Framework

While certain land uses and human activities are identified as sources and causes of water quality impairment during TMDL development, the management of these activities is of more concern than the activities themselves. This document does not advocate for the removal of land and water uses to achieve water quality restoration objectives, but instead for making changes to current and future land management practices that will help improve and maintain water quality. This section discusses the framework for TMDL implementation and a monitoring strategy to help ensure successful TMDL implementation and attainment of water quality standards.

### 8.1.1 Agency and Stakeholder Coordination

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. DEQ will work with participants to use these TMDLs as a basis for developing locally-driven watershed restoration plans, administer funding specifically for 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 continue to work collaboratively with local and state agencies to achieve water quality restoration goals which will progress toward meeting TMDL targets and load reductions. Specific stakeholders and agencies that have been and will likely continue to be vital to restoration and water quality maintenance efforts include the Bitter Root Water Forum (BRWF), Lolo Watershed Group (LWG), USFS, DNRC, FWP and DEQ. Additionally, local land managers, stakeholder groups, and other state and federal agencies may be helpful in providing technical, financial or coordination assistance.

### 8.1.2 Water Quality Restoration Plan Development

A watershed restoration plan (WRP) provides a framework strategy for water quality restoration and monitoring in the Bitterroot 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:

- Implement best management practices (BMPs) to protect water conditions so that all streams in the watershed maintain good quality, with an emphasis on waters with completed TMDLs.
- Develop more detailed cost-benefit and spatial considerations for water quality improvement projects.

- Develop an approach for future BMP installments and efficiency results tracking.
- Provide information and education to reach out to stakeholders about approaches to restoration, its benefits, and funding assistance.

The Lolo Watershed Group is working on a Water Quality Restoration Plan for Lolo Creek, and is receiving financial and technical support from the DEQ under a '319 grant' to initiate WRP development. DEQ encourages collaboration among local stakeholders, interested parties, state and federal agencies in the development of the Lolo WRP and any future efforts to develop a Bitterroot TPA WRP.

### 8.1.3 Adaptive Management and Uncertainty

An adaptive management approach is recommended to manage costs as well as achieve success in meeting the water quality standards and supporting all beneficial uses. This approach works in cooperation with the monitoring strategy and allows for adjustments to the restoration goals or pollutant targets, TMDLs, and/or allocations, as necessary. These adjustments would take into account new information as it arises.

The adaptive management approach is outlined below:

- TMDLs and Allocations: The analysis presented in this document assumes that the load reductions proposed for each of the listed streams will enable the streams to meet target conditions and further assumes that meeting target conditions will ensure full support of all beneficial uses. Much of the monitoring proposed in this section of the document is intended to validate this assumption. If it looks like greater reductions in loading or improved performance is necessary to meet targets, then updated TMDL and/or allocations will be developed based on achievable reductions via application of reasonable land, soil, and water conservations practices.
- Water Quality Status: As new stressors are added to the watershed and additional data are collected, new water quality targets may need to be developed or existing targets/allocations may need to be modified. Additionally, as restoration activities are conducted in the Bitterroot TPA and target variables move towards target conditions, the impairment status of the 303(d) listed waterbodies is expected to change. An assessment of the impairment status will occur after significant restoration occurs in the watershed.

### 8.1.4 Funding and Prioritization

Funding and prioritization of restoration or water quality improvement project is integral to maintaining restoration activity and monitoring 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.

**Section 319 funding**

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. The LWG recently received 319 funding to assist with the development of the WRP. The Bitter Root Water Forum has received 319 funding to assist with nonpoint-source-pollution education and outreach.

**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 Bitterroot TPA include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats.

**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.

**Other Funding Sources**

Numerous other funding opportunities exist for addressing nonpoint source pollution. Additional information regarding funding opportunities from state agencies is contained in Montana's Nonpoint Source Management Plan (DEQ, 2007) and information regarding additional funding opportunities can be found at http://www.epa.gov/nps/funding.html.

## 8.2 Implementation Strategies and Recommendations

For each major source of human-caused pollutant loads in the Bitterroot TPA, general management recommendations are outlined below. The effect of different sources can change seasonally and be dependent on the magnitude of storm/high flow events. Therefore, restoration activities within the Bitterroot TPA should focus on all major sources for each pollutant category. Yet, restoration should begin with addressing either the sources with the biggest cost to load reduction benefit or the largest source categories found during TMDL development.

For each major source, BMPs will be most effective as part of a management strategy that focuses on critical areas within the watershed, which are those areas contributing the largest pollutant loads or are especially susceptible to disturbance. Applying BMPs for existing activities where they are currently needed is the core of TMDL implementation but only forms a part of the restoration strategy. Also important are efforts to avoid future load increases by ensuring that new activities within the watershed incorporate all appropriate BMPs, and ensuring continued implementation and maintenance of those BMPs currently in place or in practice. Restoration might also address other current pollution-causing uses and management practices. In some cases, efforts beyond implementing new BMPs may be required to address key sediment or thermal sources. In these cases, BMPs are usually identified as a first effort followed by an adaptive management approach to determine if further restoration activities are necessary to achieve water quality standards. Monitoring is also an important part of the restoration process; recommendations are outlined in **Section 8.3**.

### 8.2.1 Riparian and Floodplain Management

Riparian areas and floodplains are critical for wildlife habitat, groundwater recharge, reducing the severity of floods and upland and streambank erosion, and filtering pollutants from runoff. Therefore, enhancing and protecting riparian areas and floodplains within the watershed should be a priority of TMDL implementation in the Bitterroot TPA.

Initiatives to protect riparian areas and floodplains will help protect property, increase channel stability, and buffer waterbodies from pollutants. However, in areas with a much smaller buffer or where historical vegetation removal and development have shifted the riparian vegetation community and limited its functionality, a tiered approach for restoring stream channels and adjacent riparian vegetation should be considered that prioritizes areas for restoration based on the existing condition and potential for improvement. In non-conifer dominated areas, the restoration goals should focus on restoring natural shrub cover on streambanks to riparian vegetation target levels associated with the sediment and temperature TMDLs. Passive riparian restoration is preferable, but in areas where stream channels are unnaturally stable or streambanks are eroding excessively, active restoration approaches, such as channel design, woody debris and log vanes, bank sloping, seeding, and shrub planting may be needed. Factors influencing appropriate riparian restoration would include the severity of degradation, site-potential for various species, and the availability of local sources as transplant materials. In general, riparian plantings would promote the establishment of functioning stands of native species (grasses and willows). Wee management should also be a dynamic component of managing riparian areas.

The following recommended restoration measures would help stabilize the soil, decrease sediment reaching the streams, provide increased shade from riparian vegetation and in some cases reduce channel widths.

- Harvest and transplant locally available sod mats with dense root mass to immediately promote bank stability and capture sediments.
- Transplant mature shrubs, particularly willows (Salix sp.), to rapidly restore instream habitat and water quality by providing overhead cover and stream shading
- Seed with native graminoids (grasses and sedges) and forbs, a low cost activity where lower bank shear stresses would be unlikely to cause erosion.
- Plant willows by “sprigging” to expedite vegetative recovery; sprigging involves clipping willow shoots from nearby sources and transplanting them in the vicinity where needed.

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, “hard” approaches generally redirect channel energy and exacerbate erosion in other places. Bank armoring should be limited to areas with a demonstrated infrastructure threat. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of the upper bank, reduce stream scouring energy, and provide shading and cover habitat.

## 8.2.2 Grazing Management

Development of riparian grazing management plans should be a goal for landowners in the watershed who are not currently using a plan. Private land owners may be assisted by state, county federal, and local conservation groups to establish and implement appropriate grazing management plans. Note that riparian grazing management does not necessarily eliminate all grazing in these areas. Nevertheless, in some areas, a more restrictive management strategy may be necessary for a period in order to accelerate re-establishment of a riparian community with the most desirable species composition and structure. Grazing should be managed to provide filtering capacity via adequate groundcover, stream bank stability via mature riparian vegetation communities, and shading from mature riparian climax communities.

Grazing management includes the timing and duration of grazing, the development of multipasture systems, including riparian pastures, and the development of off-site watering areas. The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian vegetation and minimize disturbance of the stream bank and channel. The primary recommended BMPs for the Bitterroot TPA are providing off-site watering sources, limiting livestock access to streams, providing “water gaps” where livestock access to a stream is necessary, planting woody vegetation along stream banks, and establishing riparian buffers. Although passive restoration via new grazing plans or limited bank revegetation are a preferred BMPs, in some instances bank stabilization may be necessary prior to planting vegetation. Other general grazing management recommendations and BMPs to address grazing sources of pollutants and pollution can be obtained in Appendix A of Montana’s NPS Management Plan (DEQ, 2007).

### 8.2.3 Small Acreages

Small acreages are growing rapidly, and many small acreage owners own horses, cattle, or sheep. Animals grazing on small acreages can lead to overgrazing and a shortage of grass cover, leaving the soil subject to erosion and runoff to surface waters. General BMP recommendations for small acreage lots with animals include creating drylots, developing a rotational grazing system, and maintaining healthy riparian buffers. Small acreage owners should collaborate with MSU Extension Service, NRCS, conservation districts and agriculture organizations to develop management plans for their lots. Further information may be obtained from the Montana Nonpoint Source Management Plan (DEQ, 2007) or the MSU extension website at: http://www.msuextension.org/ruralliving/Index.html.

### 8.2.4 Animal Feeding Operations

Animal feeding operations (AFOs) can pose a number of risks to water quality. To minimize water quality effects from AFOs, the USDA and EPA released the Unified National Strategy for AFOs in 1999 (U.S. Department of Agriculture and U.S. Environmental Protection Agency, 1999). This plan is a written document detailing manure storage and handling systems, surface runoff control measures, mortality management, chemical handling, manure application rates, schedules to meet crop nutrient needs, land management practices, and other options for manure disposal. An AFO that meets certain specified criteria is referred to as a Concentrated Animal Feeding Operation (CAFO), and in addition may be required to obtain a Montana Pollution Discharge Elimination System (MPDES) permit as a point source. Montana’s AFO compliance strategy is based on federal law and has voluntary, as well as, regulatory components. If voluntary efforts can eliminate discharges to state waters, in some cases no direct regulation is necessary through a permit. Operators of AFOs may take advantage of effective, low cost practices to reduce potential runoff to state waters, which additionally increase property values and operation productivity. Properly installed vegetative filter strips, in conjunction with other practices to reduce waste loads 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 (U.S. Department of Agriculture and U.S. Environmental Protection Agency, 1999). Other options may include clean water diversions, roof gutters, berms, sediment traps, fencing, structures for temporary manure storage, shaping, and grading. Animal health and productivity also benefit when clean, alternative water sources are installed to prevent contamination of surface water.

Opportunities for financial and technical assistance (including comprehensive nutrient management plan development) in achieving voluntary AFO and CAFO compliance are available from conservation districts and NRCS field offices. Voluntary participation may aide in preventing a more rigid regulatory program from being implemented for Montana livestock operators in the future.

Further information may be obtained from the DEQ website at:
http://www.deq.mt.gov/wqinfo/mpdes/cafo.asp. Montana's 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 internal (Permitting Division), as well as external entities (DNRC, local watershed groups, conservation districts, MSU Extension, etc.).

### 8.2.5 Cropland

The primary strategy of the recommended cropland BMPs is to reduce sediment and nutrient 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 Bitterroot 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 filter strips and 50 percent for buffers (DEQ, 2007). 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 which will also supply shade to reduce instream temperatures. Filter strips widths along streams should be at least double the average mature canopy height to assist in providing stream shade. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in Appendix A of Montana's NPS Management Plan (DEQ, 2007).

### 8.2.6 Irrigation

Flow alteration and dewatering are commonly considered water quantity rather than water quality issues. However, changes to stream flow can have a profound effect on the ability of a stream to attenuate pollutants, especially 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 recommend flow-related recommendations and enhancements 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. Irrigation efficiency management practices in the Bitterroot TPA involve investigating how to reduce the amount of stream water diverted during July and August, while still growing crops on traditional cropland. It may be desirable to investigate irrigation practices earlier in the year that promote groundwater return during July and August. Understanding irrigation water, groundwater and surface water interactions is an important part of understanding how irrigation practices will affect stream flow during specific seasons.

Many of the irrigation practices in the Bitterroot TPA are based in flood irrigation methods. In some cases, head gates and ditches leak, which can decrease the amount of water flowing in streams. The following recommended activities would result in notable water savings:

- Install upgraded head gates for more exact control of water diversions and to minimize leakage when not in operation.
- Develop more efficient means to supply water to livestock.
- Determine necessary amounts of water to divert that would reduce over watering and improve forage quality and production.
- Redesign irrigation systems.
- Upgrade ditches (including possible lining) to increase ditch conveyance efficiency.
- Investigate field application efficiency and reduce irrigation runoff from fields.

Future studies could investigate irrigation groundwater return flow timeframes from specific areas along the Bitterroot TPA tributaries. A portion of spring and early summer flood irrigation on near-stream locations 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 were year round irrigation efficiencies could be more beneficial to preserving flow in the stream during hot summer timeframes. Preserving winter and spring base flow should also be considered during irrigation management and associated groundwater investigations.

### 8.2.7 Forestry and Timber Harvest

Timber harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (Montana State University, Extension Service, 2001) and the Montana Streamside Management Zone (SMZ) Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, road building including culvert design, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e., within 50 feet of a waterbody), the riparian protection principles behind the law should be applied to numerous land management activities (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. 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. .

The SMZ Law protects against excessive erosion and therefore is appropriate for helping meet sediment load allocations. Following the SMZ Law is a step toward meeting temperature TMDLs in this watershed, but does not provide a regulatory mechanism to fully meet the temperature TMDL shade related load allocations along forested streams. When Montana's SMZ Law was developed, meeting Montana's temperature standards through the process was not a primary consideration.

United States Forest Service (USFS) Inland Fish (INFISH) Riparian Habitat Conservation Area (RHCA) guidelines likely protect shade to a level in which the TMDL allocation would be met if they were followed throughout most of the forested portions of the watershed. This guidance includes an undisturbed 300 foot buffer on each side of fish bearing streams and 150 foot buffer on each side of non-fish bearing streams with limited exclusions and BMP guidance for timber harvest, roads, grazing, recreation and other human sources (U.S. Department of Agriculture, Forest Service, 1995).

### 8.2.8 Unpaved Road BMPs

The road sediment reductions in this document represent a gross estimation of the sediment load that would remain once appropriate road BMPs were applied at all locations, which include a reduction in contributing road length to 200-feet for each unpaved crossing and 500-feet for each parallel road segment. Achieving this reduction in sediment loading from roads may occur through a variety of methods at the discretion of local land managers and restoration specialists. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana's Nonpoint Source Management Plan (DEQ, 2007). Examples include:

- Providing adequate ditch relief up-grade of stream crossings.
- Constructing waterbars, where appropriate, and up-grade of stream crossings.
- Instead of cross pipes, using rolling dips on downhill grades with an embankment on one side to direct flow to the ditch. When installing rolling dips, ensure proper fillslope stability and sediment filtration between the road and nearby streams.
- Insloping roads along steep banks with the use of cross slopes and cross culverts.
- Outsloping low traffic roads on gently sloping terrain with the use of a cross slope.
- Using ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches.
- For maintenance, grading materials to the center of the road and avoiding removing the toe of the cutslope.
- Preventing disturbance to vulnerable slopes.
- Using topography to filter sediments; flat, vegetated areas are more effective sediment filters.
- Where possible, limit road access during wet periods when drainage features could be damaged.
- No new roads with long parallel sections within 150 feet of streams. Limit new road stream crossings to the extent practicable.

### 8.2.9 Culverts and Fish Passage

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 64% of the culverts were designed to accommodate 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 67 culverts in the watershed 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. A coarse assessment of fish passage indicated that 84 percent of the assessed culverts pose a fish passage risk at all flows. 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.

### 8.2.10 Stormwater Construction Permitting and BMPs

Construction activities disturb the soil, and if not managed properly, they can be substantial sources of sediment. Construction activity disturbing one acre or greater is required to obtain permit coverage through DEQ under the Storm Water General Permit for Construction Activities. A Stormwater Pollution Prevention Plan (SWPPP) must be developed and submitted to obtain a permit. A SWPPP identifies pollutants of concern, which is most commonly sediment, construction related sources of those pollutants, any nearby waterbodies that could be affected by construction activities, and BMPs that will be implemented to minimize erosion and discharge of pollutants to waterbodies. The SWPPP must be implemented for the duration of the project, including final stabilization of disturbed areas, which is a vegetative cover of at least 70% of the pre-disturbance level or an equivalent permanent stabilization measure. Development and implementation of a thorough SWPPP should ensure WLAs within this document are met. Additionally, because of the risk of sediment loading from construction activities disturbing 10 or more acres, EPA recently added effluent limitation guidelines, sampling requirements, and new source performance standards to control the discharge from construction sites; the changes will be incorporated into the next construction Storm Water General Permit authorization in Montana in January 2012 and the requirements will be phased in based on the area of land disturbance.

Land disturbance activities that are smaller than an acre (and exempt from permitting requirements) also have the potential to be substantial pollutant sources, and BMPs should be used to prevent and control erosion consistent with the upland erosion allocations. Potential BMPs for all construction activities include construction sequencing, permanent seeding with the aid of mulches or geotextiles, check dams, retaining walls, drain inlet protection, rock outlet protection, drainage swales, sediment basin/traps, earth dikes, erosion control structures, grassed waterways, infiltration basins, terraced slopes, tree/shrub planting, and vegetative buffer strips. The EPA support document for the construction permit requirements has extensive information about construction related BMPs, including limitations, costs, and effectiveness (EPA 2009a).

### 8.2.11 Urban Area Stormwater BMPs

Any BMPs which promote onsite or after collection infiltration, evaporation, transpiration or reuse of the initial flush stormwater should be implemented as practicable on all new or redevelopment projects. These BMPs include, but are not limited to:

- Bioretention
- Permeable pavements
- Green roofs
- Cisterns & rain barrels
- Trees & expanded tree boxes
- Reforestation & restoration
- Parking & street designs
- Water Conservation
- Drywells
- Routing water via grassy swales instead of lined systems
- Permeable underground pipe in gravel systems for areas above groundwater

- Infiltration basins
- Water reuse

EPA provides more comprehensive information about stormwater best management practices on their website at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm.

### 8.2.12 WWTPs

To ensure the WWTPs are meeting each thermal WLA, any municipality shall not increase their effluent temperature and shall discharge at rates below double their existing hourly peak flow rate, or at their design capacity hourly peak flow, whichever is greater. The WWTP flow rates associated with the target conditions are provided in **Table 6-3**. If these conditions are not met, the facility must initiate action to prove they do not heat the Bitterroot River more than 0.25°F.

If changes to a waste treatment process occur that are likely to increase the temperature of any effluent in the watershed, or if flow rates will increase above the thresholds given for the surrogate WLA approach, an effluent temperature assessment must be initiated to determine if the plant will meet the target requirement of ≤ 0.25°F temperature increase at the end of the mixing zone due to the future WWTP plant modification (**Table 6-4**). Monitoring and reporting requirements for this process are provided in **Section 8.3.1**.

### 8.2.13 Nonpoint Source Pollution Education

Because most nonpoint source pollution (NPS) is generated by individuals, a key factor in reducing NPS is increasing public awareness through education. The Bitter Root Water Forum and the Lolo Watershed Group provide educational opportunities to both students and adults through local water quality workshops and informational meetings. Continued education is key to ongoing understanding of water quality issues in the Bitterroot TPA, and to the support for implementation and restorative activities.

## 8.3 Monitoring Recommendations

The monitoring framework discussed in this section is an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach. While targets and allocations are calculated using the best available data, the data are only an estimate of a complex ecological system. The margin of safety 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. Where applicable, analytical detection limits must be below the numeric standard.

The monitoring framework 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.

The objectives for future monitoring in the Bitterroot TPA include: 1) baseline and impairment status monitoring to assess attainment of water quality targets and identify long-term trends in water quality, 2) tracking and monitoring restoration activities and evaluating the effectiveness of individual and cumulative restoration activities, and 4) refining the source assessments. Each of these objectives is discussed below for both sediment and temperature.

## 8.3.1 Baseline and Impairment Status Monitoring

Monitoring should continue to be conducted to expand knowledge of existing conditions and also collect data that can be evaluated relative to the water quality targets. Although DEQ is the lead agency for developing and conducting impairment status monitoring, other agencies or entities may collect and provide compatible data. Wherever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent with DEQ methodology so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals. The information in this section provides general guidance for future impairment status monitoring.

**Sediment**

For sediment investigation in the Bitterroot TPA, each of the streams of interest was stratified into unique reaches based on physical characteristics and anthropogenic influence. The 32 sites assessed 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.

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 it is recommended that at a minimum the following parameters be collected to allow for comparison to TMDL targets:

- Riffle Pebble Count; using Wolman Pebble Count methodology and/or 49-point grid tosses in riffles and pool tails
- Residual Pool Depth Measurements
- Greenline Assessment; NRCS methodology

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

**Temperature Ambient Stream Monitoring and Assessment**

Currently USGS monitors temperature on a continuous basis at the USGS gage near Missoula. Montana Fish Wildlife and Parks monitors continuous summer season temperatures at five sites on the Bitterroot River: near Darby, Hamilton, Bell Crossing, Florence, and Missoula. This monitoring can be used to track long term trends in stream temperatures in the Bitterroot River. Temperature monitoring on the tributaries where TMDLs are provided occurs less consistently and will likely be initiated via future TMDL review by DEQ.

The Tri-State Water Quality Council and Montana Department of Natural Resources and Conservation collected temperature and discharge data above and below an irrigation return in Threemile Creek. DEQ will incorporate this data into DEQ's assessment records.

**Temperature Wasteload Monitoring**

Three distinct conditions shall prompt temperature assessment or monitoring in effluents. First, if a WWTP initiates upgrades to their system which will likely alter effluent temperature, an engineering assessment of likely thermal alteration of the effluent must be completed and approved by DEQ prior to the upgrade. The assessment must consider if the facility upgrade would continue to achieve the 0.25°F thermal increase at the point where the effluent fully mixes with the Bitterroot River at 7Q10 during sensitive timeframes for the fishery. If the engineering assessment indicates temperature conditions at the end of the mixing zone are not met, an approach to meet the thermal conditions must be supplied to DEQ prior to any plant upgrades. DEQ shall require monitoring during the season following the upgrade.

Alternatively, if no upgrades are completed, a discharger will initiate temperature monitoring the season immediately following the permit renewal. Also, if a WWTP discharges more than double existing hourly peak flow rate or their design capacity hourly peak flow, whichever is greater, the discharger will be required to complete temperature monitoring during one season immediately following the flow exceedance or submit a report to DEQ confirming that the facility is below the 0.25°F thermal increase level at 7Q10 flows at the point where their effluent fully mixes with the Bitterroot River.

The temperature WLA monitoring and reporting will include the following procedures. Effluent temperature monitoring will be conducted using digital recording thermometers with accuracy to 0.4 ºF. Temperatures will be reported to DEQ in an excel spreadsheet by the following December for data recorded on half hour increments of time during May 1st through September15th and will include a brief summary of methods by which the data was collected. Upstream and effluent monitoring data will be used to determine if a 7-day average of the daily maximum temperatures of the effluent during the warmest week of the summer, populate a mixing equation for facility to determine the heating rate of the Bitterroot River at 7Q10 while applying the prior mentioned temperature statistic for calculations, and compare these results to those estimated in **Tables 6-3** and **6-9**. If effluent temperatures or flow rates are above those stated in **Tables 6-3** and **6-9**, the facility must demonstrate how they are (or will) conform to the heat load associated with a less than a 0.25 ºF change in the Bitterroot River at the point where each effluent is fully mixed with river water at a 7Q10 flow.

During permit renewals, monitoring and reporting requirements must be updated to include monthly maximum discharge along with monthly average discharge rates and the monitoring requirements stated in the paragraphs above. Monthly maximum discharge will be computed from at least daily discharge volume sampling, if not continuous discharge sampling.

## 8.3.2 Tracking and Monitoring Restoration Activities and Effectiveness

Restoration activities which address nonpoint sources should be tracked watershed-wide as they are implemented. Information about specific locations, spatial extent, designs, contact information, and any effectiveness evaluation should be compiled about each project as they occur.

Monitoring should be conducted prior to and after project implementation to help evaluate the effectiveness of specific practices or projects. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. At a minimum, effectiveness monitoring should address the pollutants that are targeted for each project.

Particularly for sediment, which has no numeric standard, effectiveness and reductions in loading should be evaluated using load estimate approaches applied within this document for each source category. Evaluating in-stream parameters used for sediment targets will not be practical for most projects since the sediment impacts within a stream represent cumulative impacts from many watershed scale activities.

Information about all restoration projects, along with tracking overall extent of BMP implementation, should be compiled into one location. If sufficient implementation progress is made within a watershed, DEQ will create a monitoring plan to assess target conditions and implement the monitoring. Results would be compared to targets to determine if the TMDL is achieved.

## 8.3.3 Source Assessment Refinement

In many cases, the level of detail provided by the source assessments only provides broad source categories or areas that need to reduce pollutant loads, and additional source inventory and load estimate work may be desirable. Strategies for strengthening source assessments for each of the pollutants may include:

**Sediment**

More thorough sampling or field surveys of source categories such as bank erosion or road crossings to help prioritize implementation strategies based on an assessment of a larger population of eroding banks or road crossings of concern. Culverts should be assessed for fish passage and their capacity to pass storm event flows, as culvert failure is often a source f discrete sediment loads.

Efforts to improve upon load estimates, either within a given source category or via a calibrated approach to allow improved comparison between source categories is also a possibility, but not a requirement for TMDL implementation. Improvements might include:

- a refined bank erosion retreat rate for Bitterroot River watershed streams,
- a better understanding of bank erosion effects from historical land management activities,
- improved modeling for upland erosion delivery in forested watersheds where riparian zones have recovered from SMZ law implementation,
- road erosion modeling calibration and improved consideration of load impacts from road rills and gullies, and
- evaluation of “hot spots” that simple watershed scale models may not adequately address, such as a confined animal operation adjacent to a stream.

**Temperature**

Three specific conditions could benefit from further source characterization to better optimize thermal restoration approaches. The first is further characterization of tributaries to the stream segments where TMDLs are provided within this document. Thermal monitoring of tributaries may better characterize where restoration activities should be focused within a watershed.

The second source characterization which would benefit restoration priorities entails an irrigation system assessment. This assessment should include a water use assessment (with which the adjudication process may assist) and irrigation delivery and use efficiency evaluation. Points of surface waste or ditch/stream mixing locations would be an important component of this effort. The results of an irrigation system assessment would be beneficial for guiding restoration funds to address this largest human influence upon stream temperatures.

The third source characterization which could benefit restoration priorities is monitoring of urban runoff with an approach similar to the waste load allocation (WLA) monitoring reviewed above (**Section 8.3.1**) at any locations where urban runoff from Hamilton or Missoula enters the Bitterroot River. Currently no temperature data is available for urban runoff entering the Bitterroot River.

# 9.0 – Public Participation and Response to Comments

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 Bitterroot TMDL Planning Area (TPA).

## 9.1 Participants and Roles

TMDL development for sediment impairments on tributaries of the Bitterroot River and temperature impairments on tributaries and the mainstem of the Bitterroot River occurred over a span of many years. Over the course of this project, local interest in the Bitterroot TMDLs grew, continually increasing the number of participants in the TMDL development process in the Bitterroot TPA. DEQ worked with many stakeholders to keep them apprised of project status and solicited input from TMDL advisory groups. Because TMDL development continued for a long period of time, DEQ also worked with the Bitter Root Water Forum (BRWF) to keep contact information for participants up to date throughout this project. This effort will continue through current and future TMDL development projects in the Bitterroot TPA.

Due to the large number of participants in this process, all individual participants are not named, and instead, a description of the groups of participants in the development of the sediment tributary and temperature TMDLs in the Bitterroot 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 the Bitterroot sediment tributary and temperature 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 TMDL program.

**Bitter Root Water Forum**
The Bitter Root Water Forum is a non-profit organization located in Hamilton, MT. This watershed group focuses on protecting and restoring water quality and quantity in the Bitterroot River watershed. Their mission is to help people restore, preserve, and enhance healthy waters for all users in the Bitterroot valley.

The BRWF administered a contract with DEQ to conduct tasks related to TMDL development, including data collection through third party contracting, and coordination of local stakeholder outreach activities.

The BRWF provided invaluable assistance to DEQ in identifying stakeholders and members of both the watershed and technical advisory groups for these TMDLs, and also participated on the Bitterroot TMDL Technical Advisory Group.

**Conservation Districts**

DEQ provided the Bitterroot Conservation District and the Missoula Conservation District with consultation opportunity during development of the sediment TMDLs for tributaries of the Bitterroot River and temperature TMDLs for tributaries and mainstem of the Bitterroot River. This included opportunities to provide comment during the various stages of TMDL development, and an opportunity for participation in the technical advisory group defined below.

**Bitterroot TMDL Watershed Advisory Group**

Representatives of applicable interest groups were requested to participate in the Bitterroot TMDL Watershed Advisory Group (WAG) to work with DEQ and the Bitterroot and Missoula conservation districts in an advisory capacity per Montana state law (75-5-703 and 704). DEQ requested WAG participation from the interest groups defined in MCA 75-5-704 and included local city and county representatives, livestock-oriented and farming-oriented agriculture representatives, conservation groups, watershed groups, state and federal land management agencies, and representatives of recreation and tourism interests. The WAG also included additional stakeholders, landowners, and resource professionals with an interest in maintaining and improving water quality and riparian resources, including representatives of local irrigation districts.

WAG involvement was voluntary and the level of involvement was at the discretion of the individual members. The WAG acted strictly in an advisory capacity during TMDL development and did not retain decision-making authority regarding TMDL activities. Communications with WAG members was typically conducted through email. Opportunities for review and comment were provided for WAG participants at varying stages of TMDL development, including opportunities for review of the draft TMDL document prior to the public comment period.

**Bitterroot TMDL Technical Advisory Group**

The Bitterroot TMDL Technical Advisory Group (TAG) consisted of selected resource professionals and technical advisors who possess a familiarity with water quality issues and processes in the Bitterroot TPA. Individuals included representatives from state and federal agencies, local resource professionals, and members of local government. The TAG also included members with technical knowledge of water quality modeling to provide feedback on the modeling effort for these TMDLs.

TAG members participated at their discretion and in an advisory role in the TMDL process. TAG 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 TAG feedback on project planning. Typically, draft documents were released to the TAG for review under a limited timeframe, and their comments were then compiled and evaluated. Final technical decisions regarding document modifications resided with DEQ.

**Interested Parties and General Public**

Interested parties are those persons or groups of persons with an interest in the Bitterroot TMDLs, and have chosen to be informed and/or involved in the TMDL process. DEQ maintained contact with interested parties typically through email, the DEQ wiki for TMDL development projects, and with the assistance of the Bitter Root Water Forum. The BRWF maintains a contact and distribution list of watershed stakeholders and provided avenues for information dissemination and feedback through public outreach events, watershed meetings, and emails.

DEQ's wiki for TMDL projects (http://montanatmdlflathead.pbworks.com) acts much like a website and contains TMDL project-specific pages that are maintained with current information. These pages allowed DEQ to provide the Bitterroot WAG, TAG, stakeholders, interested parties, and general public with up-to-date information about the Bitterroot TMDLs, and to post information about project schedule changes and public meetings. The wiki also provided a place for the general public to request information about the Bitterroot TMDLs and to be added to DEQ's contact list of Bitterroot TMDL interested parties.

The following information about the Bitterroot sediment tributary and temperature TMDLs was made available on the DEQ wiki:

- Maps of the Bitterroot TMDL Planning Area boundaries and impaired streams
- Information on the streams included in this project
- A detailed project schedule
- Periodic postings of project status updates
- Project contact information
- Information on the roles of the Bitterroot WAG and TAG and a list of WAG and TAG members
- Dates, times, and locations of public meetings
- Electronic copies of presentations from prior Bitterroot TMDL meetings

This information will continue to be available on DEQ's wiki during nutrient TMDL development in the Bitterroot TPA.

Though not directly involved in TMDL development, the general public plays a vital role with regard to implementation of water quality improvement actions. It is important that the general public is aware of the process and given opportunities to participate, and as such were kept informed via public meetings, the DEQ wiki, and information dissemination by the BRWF. In addition, the general public has the opportunity for review and comment of the TMDL document during the formal public comment period.

## 9.2 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 section includes DEQ's responses to all official public comments received during the public comment period.

The formal public comment period for the "Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan" was initiated on April 22, 2011 and closed on May 24, 2011. A public informational meeting and open house was held in Hamilton, MT on May 5, 2011. DEQ provided an overview of the document, answered questions, and solicited public input and comment on the TMDLs. The announcement for the meeting was distributed to the conservation districts, WAG, TAG, stakeholders and interested parties via email. Notice of the meeting was posted on the DEQ webpage and DEQ wiki, and also advertised in the following newspapers: Bitterroot Star, Missoulian, and Ravalli Republic.

One comment letter was received during the public comment period. The letter is divided into three separate questions below, and responses prepared by DEQ follow each of the questions. The original comment letter is held on file at DEQ and may be viewed upon request.

**Comment #1:** Having just seen the public notification in the Ravalli Republic this morning, I have yet to complete a review of the entire document. However, based on the executive summary and the review of the tributary TMDL it seems pretty clear to me that there are two obvious regulatory issues that would resolve most of these problems. Those are stream setbacks and proper monitoring of stream diversions for irrigation.

I appreciate that neither of these are popular political topics. But without the regulatory control of both of these problems, it is difficult to see how any alternate plan will have any significant impact.

**DEQ Response to Comment #1:** Your interpretation of approaches to restore sediment and temperature conditions in the Bitterroot River and tributaries are correct in that they should focus on managing areas near stream corridors and irrigation systems.

Streamside areas should be provided an opportunity to grow native vegetation. Native vegetation acts to hold streambank soils in place through deep rooting and it also filters pollutants when runoff from surrounding land occurs. Shrubs and trees along a stream intercept solar radiation and thus reduce stream temperature. Streamside vegetation plays an important role in reducing sediment and thermal loads to streams.

Interactions between the Bitterroot watershed's irrigation system, groundwater and stream discharge are complex. The TMDL document identifies that an irrigation system assessment should be completed to determine where irrigation efficiencies and conservation practices should be focused. Generally, the further irrigation occurs from an active stream, the more efficient it should be to help keep water in the streams. Yet, inefficient irrigation systems in strategic areas of a watershed, generally close to a stream with porous aquifers, can cool a stream via groundwater return in mid-summer, that is, if enough water volume is available to support a fishery in the stream. Warmed irrigation surface water reentering streams should always be minimized. Therefore, irrigation system monitoring would be quite useful in future irrigation related conservation efforts, if completed in a systematic and well planned fashion.

**Comment #2:** I have only lived in the Bitterroot for ten years now so it is impossible for me to know how things were. But it is easy to see where things are going. It is heartbreaking to hear from the long time locals that they would never eat a fish caught in the Bitterroot due to the pollution. It isn't going to fix itself and it is only getting worse.

**DEQ Response to Comment #2:** Generally, the more human activity in a watershed, the more likely pollutants may enter streams and lakes. Yet, Montana Fish, Wildlife and Parks (FWP) does not currently provide any fish consumption advisories in the Bitterroot watershed. Montana has further information about sport fish consumption provided at: http://meic.org/files/air-quality/mercury/MT_fish_guide.

**Comment #3:** Please make an effort to bring this issue to the public eye by whatever means you have available. Without better public awareness it will be impossible to put the proper people in office to make the needed changes.

**DEQ Response to Comment #3:** The Montana Department of Environmental Quality's (DEQ) Nonpoint Source Program encourages local governments to use and incorporate riparian buffers and setbacks into their land use planning strategies. *Montana's 2007 Nonpoint Source Management Plan* (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2007) outlines what is appropriate when considering riparian buffers into land use planning. DEQ's Nonpoint Source Program supports projects that maintain or improve instream flows and riparian restoration efforts, environmental education, as well as other water quality improvement projects through 319 Grants. However, the Nonpoint Source Program is voluntary in Montana (i.e., DEQ does not have authority to enforce action). County governments do have the authority and ability to protect water quality through regulated setbacks; however previous county efforts in the Bitterroot have failed. People who get involved and strive to make a difference by working with state agencies and local governments are a crucial piece of the land use planning process, and will have the most effective influence upon future government action.

In Ravalli County, the Bitter Root Water Forum is a lead non-governmental organization for promoting environmental restoration projects along with watershed education and outreach. The Clark Fork Coalition also works in Bitterroot on many water quality improvement projects including stream flow restoration which "concentrates on protecting and restoring streamflows in tributaries that are important for the reproduction of native fish, such as bull trout and westslope cutthroat trout, as well as for the overall health of our aquatic and terrestrial ecosystems." Visit http://brwaterforum.org and www.clarkfork.org for more information. You may want to contact these organizations if you are interested in personal involvement in education, local zoning efforts, or water quality restoration efforts.

# 10.0 - References

Andrews, E. D. and J. M. Nankervis. 1995. "Effective Discharge and the Design of Channel Maintenance Flows for Gravel-Bed Rivers: Natural and Anthropogenic Influences in Fluvial Geomorphology," in *Natural and Anthropogenic Influences in Fluvial Geomorphology: The Wolman Volume*, Costa, John E., Miller, Andrew J., Potter, Kenneth W., and Wilcock, Peter R. Geophysical Monograph Series, Ch. 10: American Geophysical Union): 151-164.

Bauer, Stephen B. and Stephen C. Ralph. 1999. Aquatic Habitat Indicators and Their Application to Water Quality Objectives Within the Clean Water Act. Seattle, WA: US Environmental Protection Agency, Region 10. Report EPA 910-R-99-014.

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

Bengeyfield, P. 2002. Unpublished Draft Analysis of Yellowstone National Park Reference Reach Data. Unpublished work.

-----. 2004. Beaverhead-Deerlodge National Forest Stream Morphology Data. Unpublished.

Bilby, R. E. and J. W. Ward. 1989. Changes in Characteristics and Function of Woody Debris With Increasing Size of Stream in Western Washington. *Transactions of the American Fisheries Society.* 118: 368-378.

Bjorn, T. C. and D. W. Reiser. 1991. "Habitat Requirements of Salmonids in Streams," in *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*, Special Publication 19 ed., (Bethesda, MD: American Fisheries Society): 83-138.

Briar, David W. and DeAnn M. Dutton. 2000. Hydrogeology and Aquifer Sensitivity of the Bitterroot Valley, Ravalli County, Montana. Helena, MT: US Geological Survey. Report Water Resources Investigations Report 99-4219, DEQ Contract # 260102.

Bryce, S. A., G. A. Lomnicky, and Philip R. Kaufmann. 2010. Protecting Sediment-Sensitive Aquatic Species in Mountain Streams Through the Application of Biologically Based Streambed Sediment Criteria. *North American Benthological Society.* 29(2): 657-672.

Buck, Fred. 1958. Water Resources Survey: Ravalli County Montana: Part I. History of Land and Water Use on Irrigated Areas and Part II. Maps Showing Irrigated Areas in Colors Designating the Sources of Supply, Helena, MT: State Engineer's Office.

Bunte, Kristin, Steven R. Abt, John P. Potyondy, and Kurt W. Swingle. 2010. Comparison of Three Pebble Count Protocols (EMAP, PIBO, and SFT) in Tow Mountain Gravel-Bed Streams. *Stream Notes.*(January 2010)

Cover, Matthew R., Christina L. May, William E. Dietrich, and Vincent H. Resh. 2008. Quantitative Linkages Among Sediment Supply, Streambed Fine Sediment, and Bethic Macroinvertebrates in Northern California Streams. *Journal of the North American Benthological Society.* 27(1): 135-149.

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

Geosyntec Consultants and Wright Water Engineers, Inc. 2008. Overview of Performance by BMP Category and Common Pollutant Type (International Stormwater Best Management Practices Database [1999-2007]). Water Environment Research Foundation; American Society of Civil Engineers; U.S.E.P.A.; Federal Highway Administration; American Public Works Association. http://www.bmpdatabase.org/Docs/Performance%20Summary%20Cut%20Sheet%20June%202008.pdf.

Irving, J. S. and T. C. Bjorn. 1984. Effects of Substrate Size Composition on Survival of Kokanee Salmon and Cutthroat Trout and Rainbow Trout Embryos. Moscow, ID: University of Idaho. Report Technical Report 84-6.

Jessup, Benjamin, Chuck Hawkins, and James B. Stribling. 2006. Biological Indicators of Stream Condition in Montana Using Macroinvertebrates. Owings Mills, MD: Tetra Tech, Inc.

Kappesser, Gary B. 2002. A Riffle Stability Index to Evaluate Sediment Loading to Streams. *Journal of the American Water Resources Association.* 38(4): 1069-1081.

Kershner, Jeffrey, Brett Roper, Nicolaas Bouwes, Richard Henderson, and Eric Archer. 2004. An Analysis of Stream Habitat Conditions in Reference and Managed Watersheds on Some Federal Lands Within the Columbia River Basin. *North American Journal of Fisheries Management.* 24: 1363-1375.

Knighton, David. 1998. Fluvial Forms and Processes: A New Perspective, New York, New York: John Wiley and Sons Inc.

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

Kondolf, G. M. 1997. Assessing Salmonid Spawning Gravel Quality. *Transactions of the American Fisheries Society.* 129: 262-281.

Lines, G and P Graham. 1988. Westslope Cutthroat Trout in Montana:Life History, Status and Management. *Montana American Fisheries Society Symposium.* 4: 53-60.

MacDonald, Lee H., Alan W. Smart, and Robert C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry on Streams in the Pacific Northwest and Alaska. Seattle, WA: U.S.Environmental Protection Agency. Report EPA 910/9-91-001.

McCullough, D and S Spalding. 2002. Multiple Lines of Evidence for Determining Upper Optimal Temperature Thresholds for Bull Trout. USFWS.

McDowell, Will and Jim Rokosch. 2005. Ambrose-Threemile Watershed Project: Watershed Assessment and Recommendations for Stream Improvements. Sandpoint, ID: Tri-State Water Quality Council.

Mebane, C. A. 2001. Testing Bioassessment Metrics: Macroinvertebrate, Sculpin, and Salmonid Responses to Stream Habitat, Sediment, and Metals. *Environmental Monitoring and Assessment.* 67(3): 293-322.

Montana Department of Environmental Quality. 2007. Montana Nonpoint Source Management Plan. Helena, MT: Montana Department of Environmental Quality.

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2007. Montana Nonpoint Source Management Plan. Helena, MT: Montana Department of Environmental Quality, Water Quality Planning Bureau, Watershed Protection Section.

Natural Resource Information System (NRIS): On-Line Interactive Map Builder.Montana State Library. 2002.

Montana State University, Extension Service. 2001. Water Quality BMPs for Montana Forests. Bozeman, MT: MSU Extension Publications.

Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. Report 77.

Overton, C. Kerry, Sherry P. Wollrab, Bruce C. Roberts, and Michael A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Relyea, C. B., G. W. Minshall, and R. J. Danehy. 2000. Stream Insects As Bioindicatores of Fine Sediment. In: Watershed 2000. Water Environment Federation Specialty Conference. Boise, ID: Idaho State University.

Riggers, B. W., A. Rosquist, R. P. Kramer, and M. Bills. 1998. An Analysis of Fish Habitat and Population Conditions in Developed and Undeveloped Watersheds on the Lolo National Forest. USDA Forest Service.

Rosgen, David L. 1994. A Classification of Natural Rivers. *Catena.* 22: 169-199.

-----. 1996. Applied River Morphology, Pagosa Springs, CO: Wildland Hydrology.

-----. 2004. River Assessment and Monitoring Field Guide, Lubrecht Forest, MT. Fort Collins, CO: Wildland Hydrology, Inc.

Ross, Clyde P., D. A. Andres, and Irving J. Witkind. 1955. Geologic Map of Montana.

Rowe, Mike, Don Essig, and Benjamin Jessup. 2003. Guide to Selection of Sediment Targets for Use in Idaho TMDLs. Pocatello, ID: Idaho Department of Environmental Quality.

Schmidt, Larry J. and John P. Potyondy. 2004. Quantifying Channel Maintenance Instream Flows: An Approach for Gravel-Bed Streams in the Western United States. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Report General Technical Report RMRS-GTR-128.

Sedell, James R., G. H. Reeves, F. R. Hauer, Jack A. Stanford, and C. P. Hawkins. 1990. Role of Refugia in Recovery From Disturbances: Modern Fragmented and Disconnected River Systems. *Environmental Management.* 14(5): 711-724.

Selong, J, Thomas A. McMahon, Alexander V. Zale, and F Barrows. 2001. Effect of Temperature on the Growth and Survival of Bull Trout, With Application of an Improved Method for Determining Thermal Tolerance in Fishes. *Trans Am Fish Soc.* 130: 1026-1037.

Shepard, B. B., Stephen A. Leathe, Thomas M. Weaver, and M. D. Enk. 1984. Monitoring Levels of Fine Sediment Within Tributaries of Flathead Lake, and Impacts of Fine Sediment on Bull Trout Recruitment. In: Wild Trout III Symposium; Yellowstone National Park, WY.

Suttle, K. B., M. E. Power, J. M. Levine, and C. McNeeley. 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmonids. *Ecological Applications.* 14(4): 969-974.

U.S. Department of Agriculture and U.S. Environmental Protection Agency. 1999. Unified National Strategy for Animal Feeding Operations. Report EPA Number 833R99900. http://www.epa.gov/npdes/pubs/finafost.pdf.

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

U.S. Environmental Protection Agency. 1999. Protocol for Developing Sediment TMDLs. Washington, D.C.: U.S. Environmental Protection Agency. Report EPA 841-B-99-004.

-----. 2009a. Development Document for Final Effluent Guidelines and Standards for the Contruction & Development Category. U.S. Environmental Protection Agency. http://water.epa.gov/scitech/wastetech/guide/construction/upload/2009_12_8_guide_construction_files_chapters.pdf.

-----. 2009b. Preliminary Data Summary of Urban Stormwater Best Management Practices. Report EPA-821-R-99-012.

Weaver, Thomas M. and J. J. Fraley. 1991. Fisheries Habitat and Fish Populations in Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program. Kalispell, MT: Flahead Basin Commission.

Wegner, Seth. 1999. A Review of the Scientific Literature on Riparian Buffers Width, Extent and Vegetation. Institute of Ecology, University of Georgia.

Wolman, M. G. 1954. A Method of Sampling Coarse River-Bed Material. *Transactions of the American Geophysical Union.* 35(6): 951-956.

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

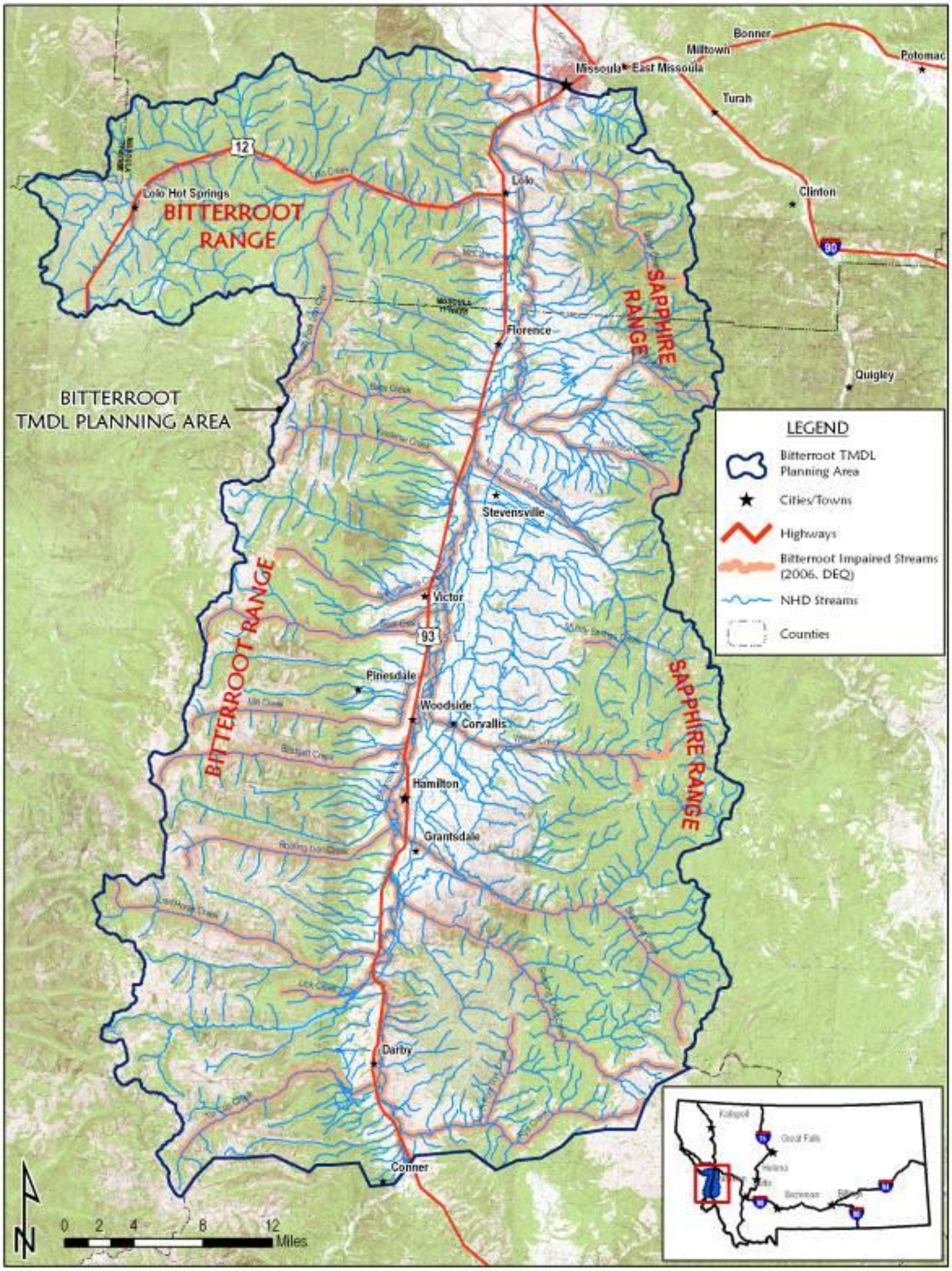
Zweig, L. D. and C. F. Rabeni. 2001. Biomonitoring for Deposited Sediment Using Benthic Invertebrates: A Test on Four Missouri Streams. *Journal of the North American Benthological Society.* 20: 643-657.

# APPENDIX A - MAPS AND FIGURES

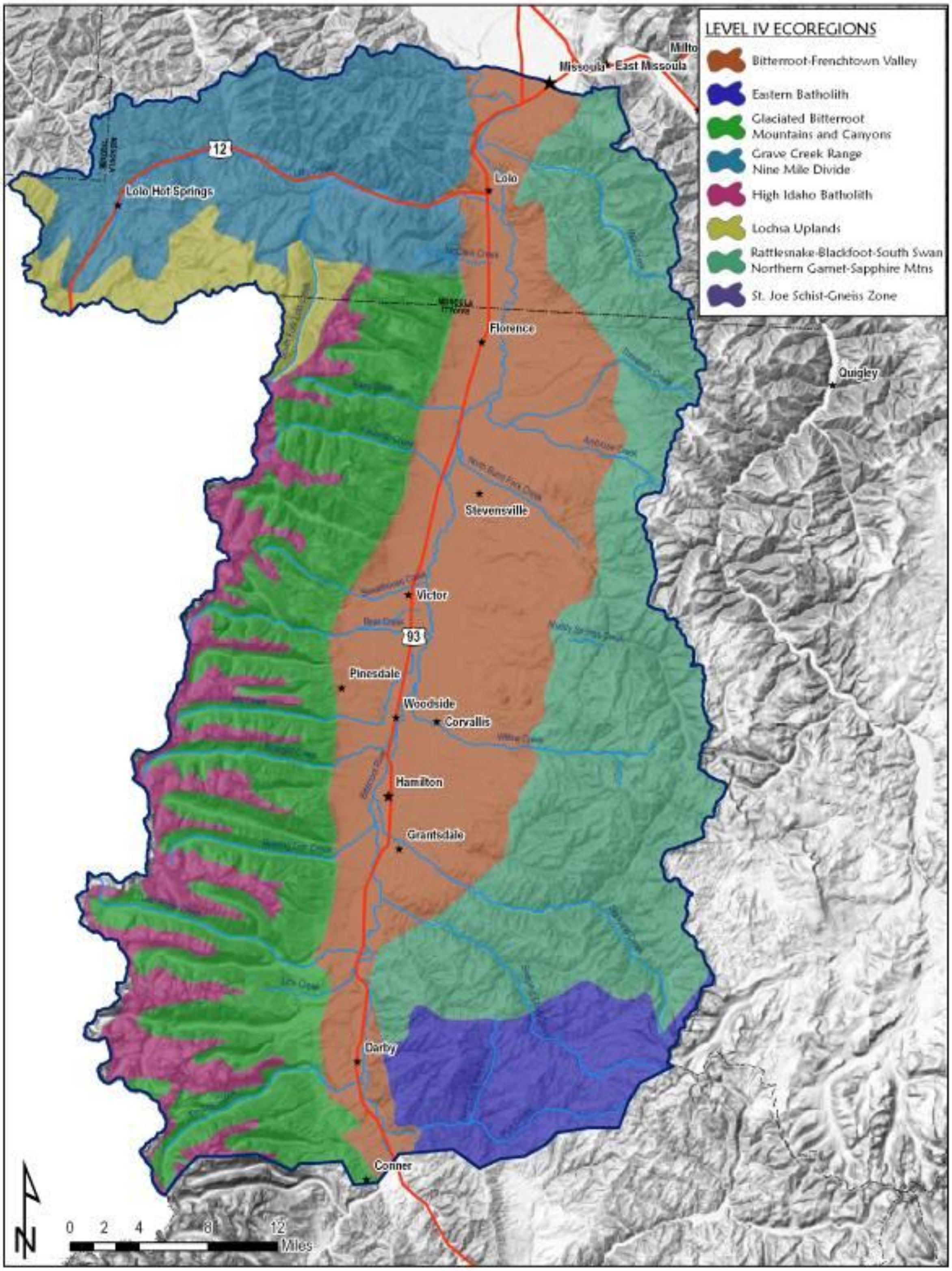
## LIST OF MAPS



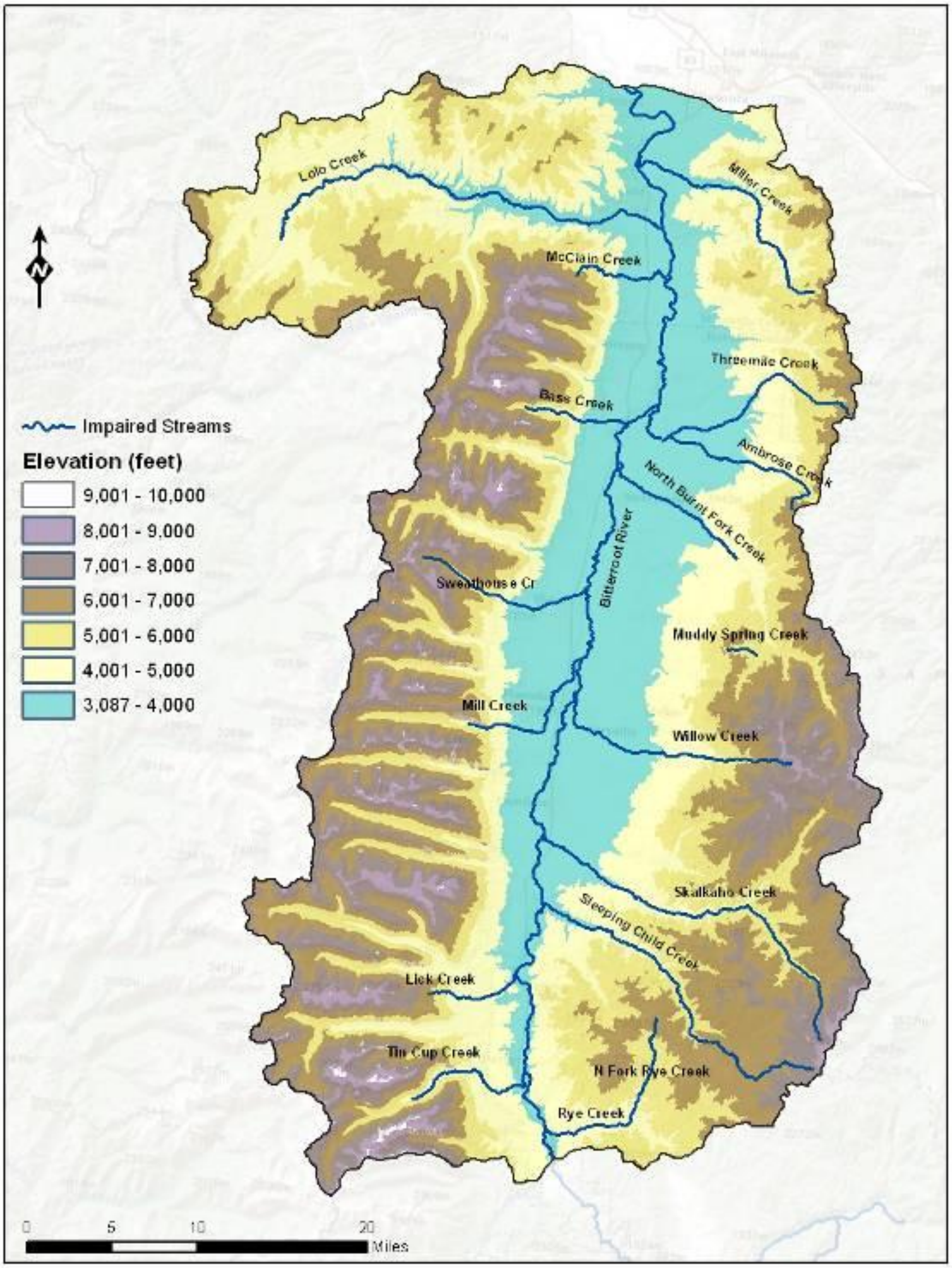
## LIST OF FIGURES



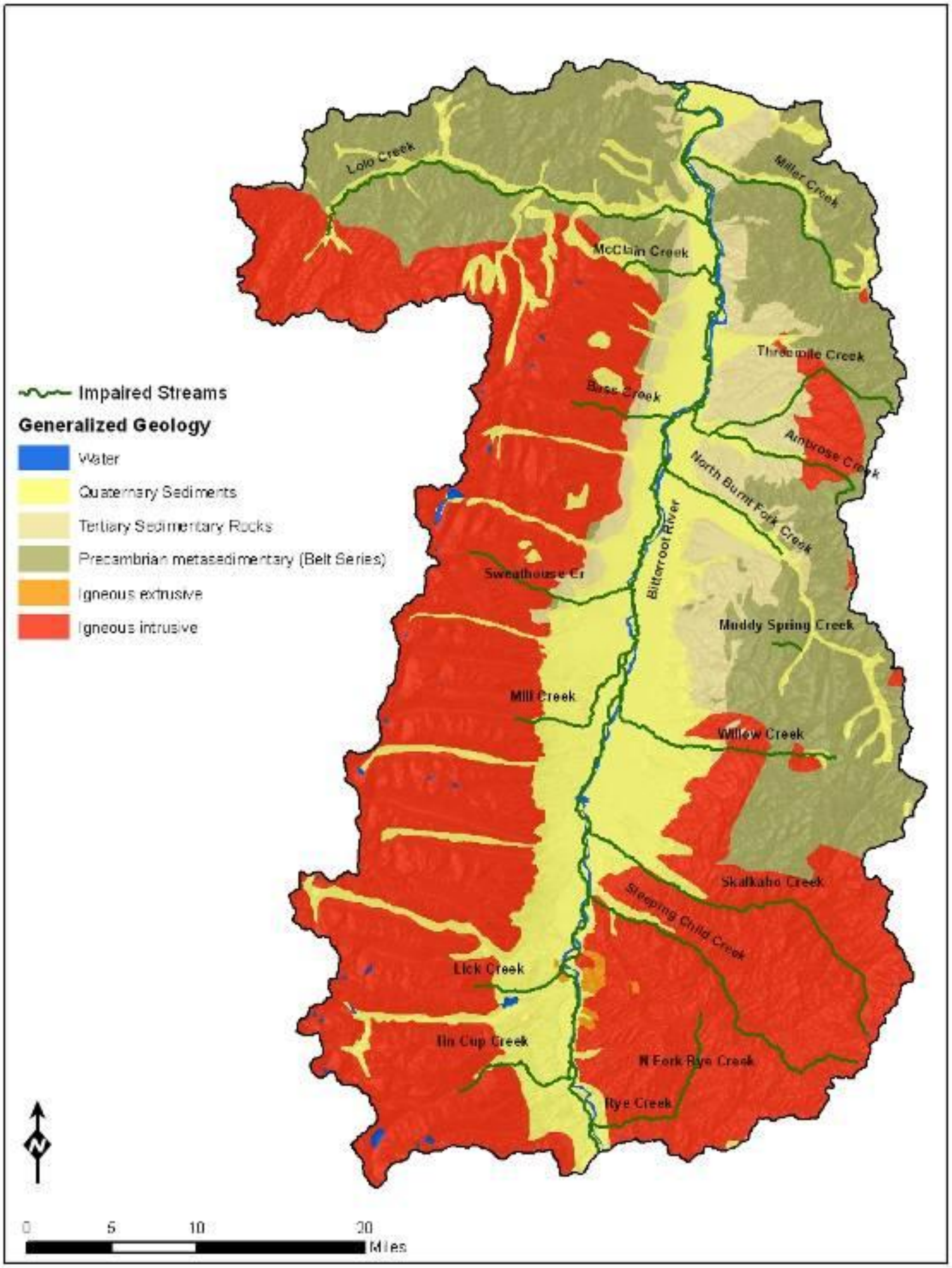

**Map A-1. Boundary of the Bitterroot TMDL Planning Area and impaired waterbodies within the planning area**



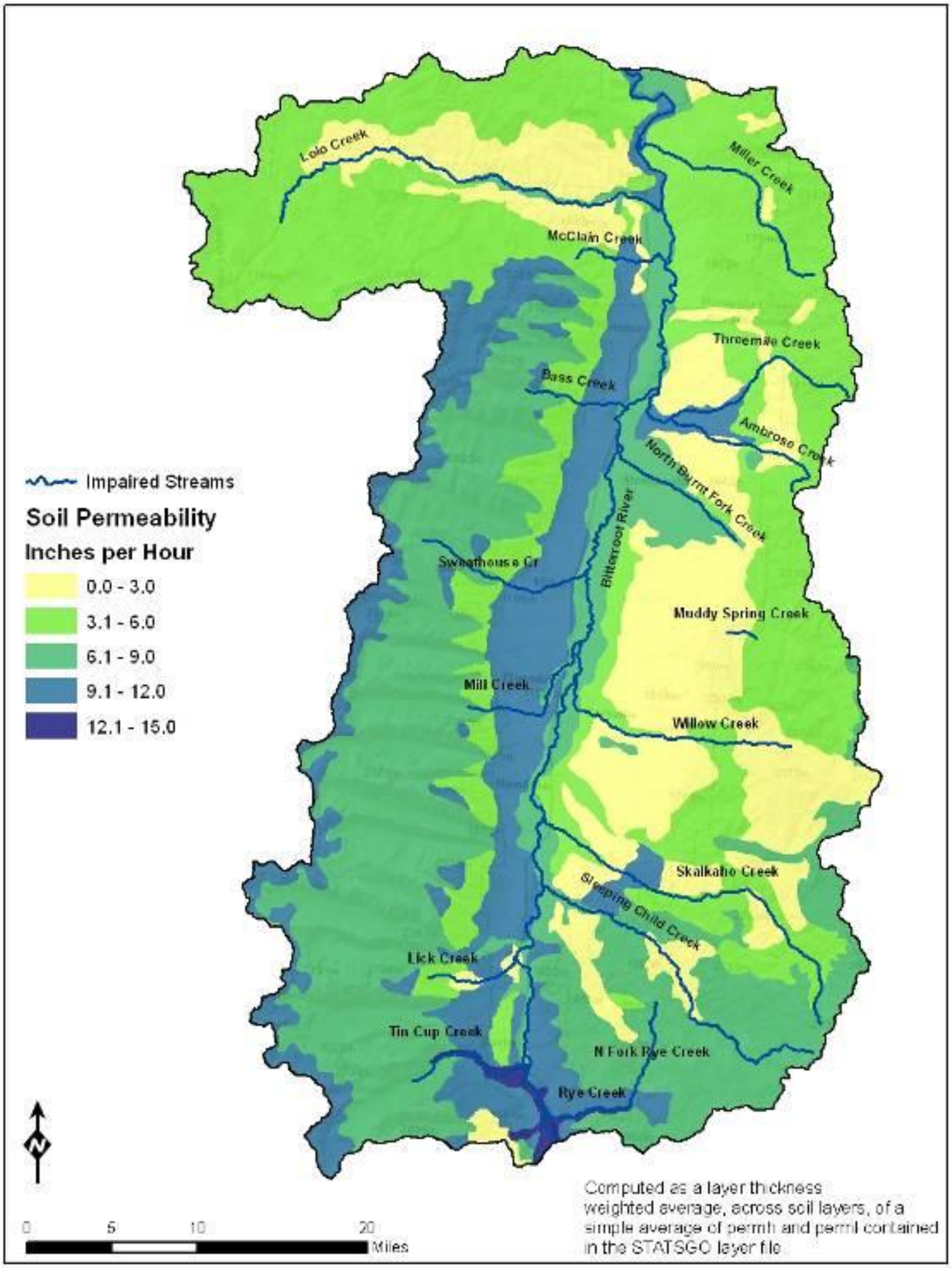

**Map A-2. Ecoregions within the Bitterroot TMDL Planning Area**



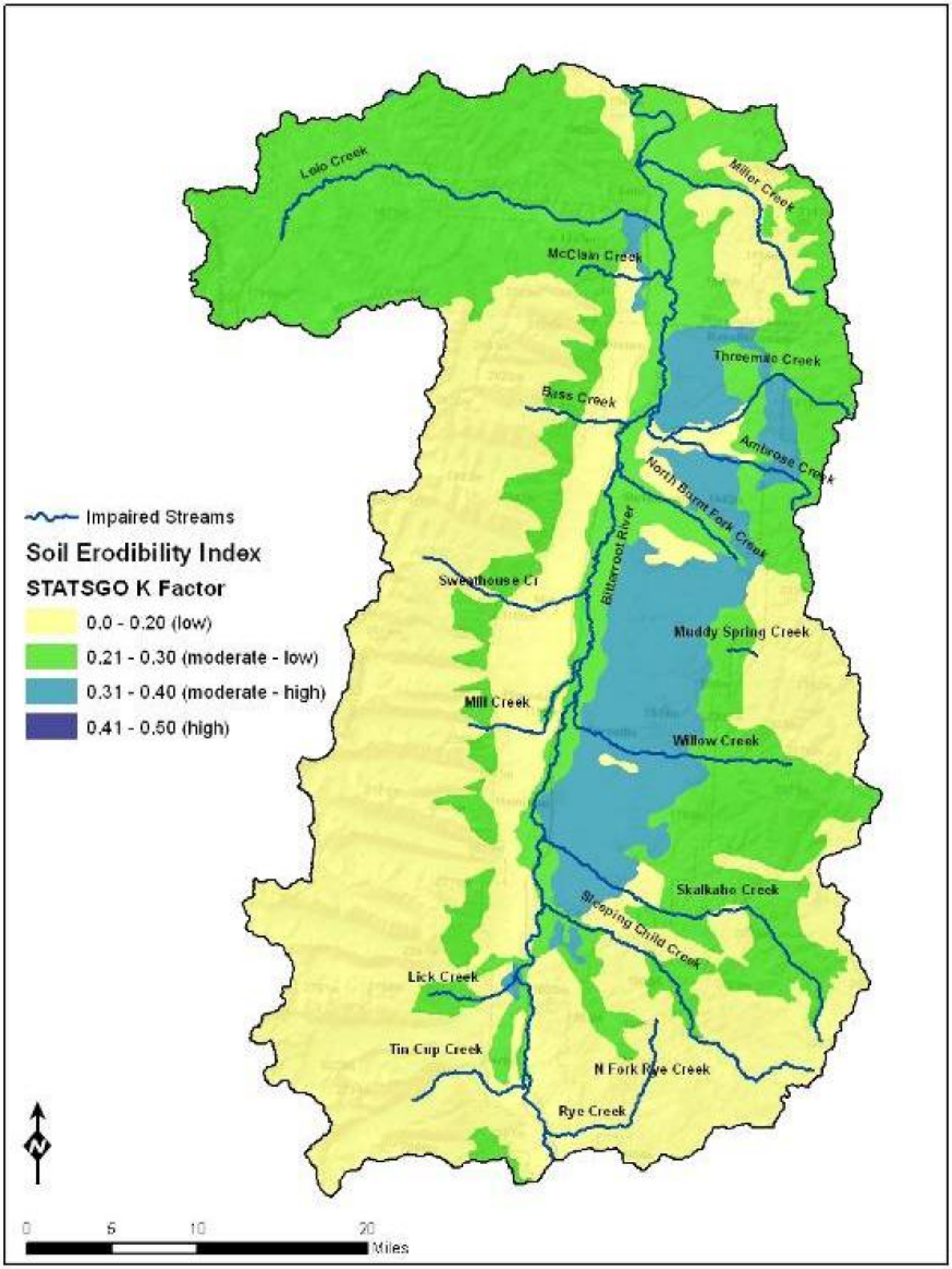

**Map A-3. Elevations in the Bitterroot TMDL Planning Area**



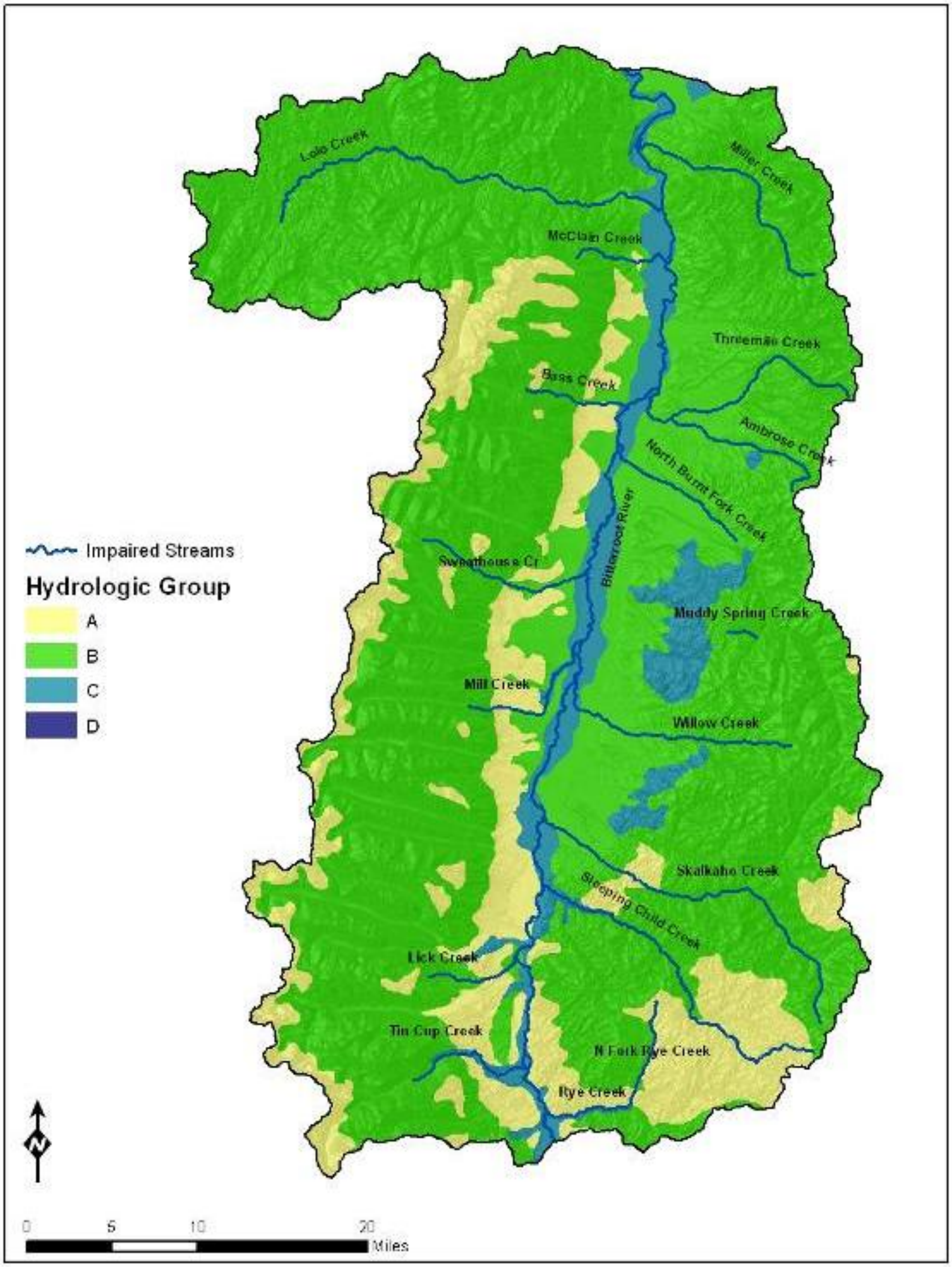

**Map A-4. Generalized geology in the Bitterroot TMDL Planning Area**



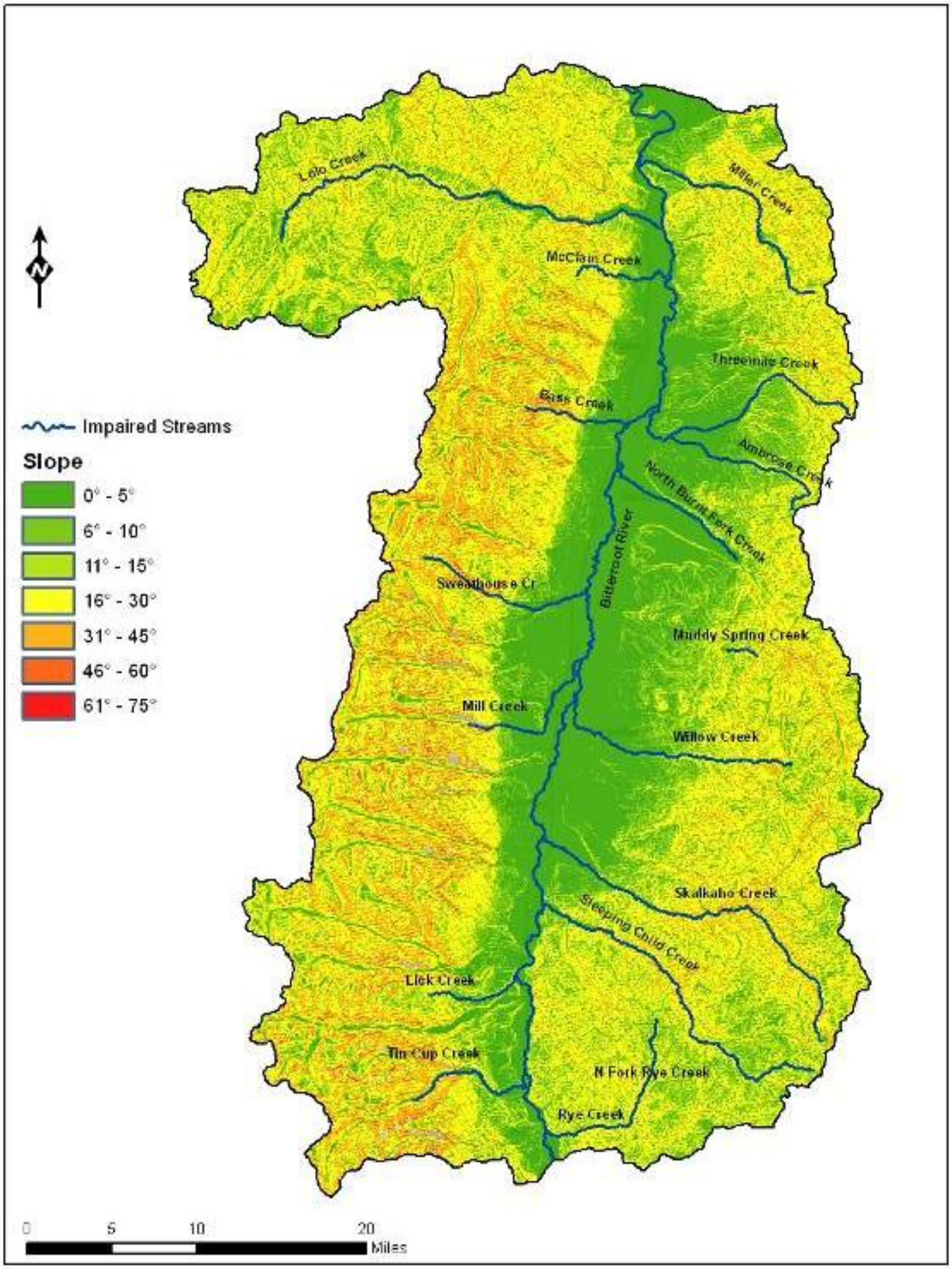

**Map A-5. Permeability of soils within the Bitterroot TMDL Planning Area**



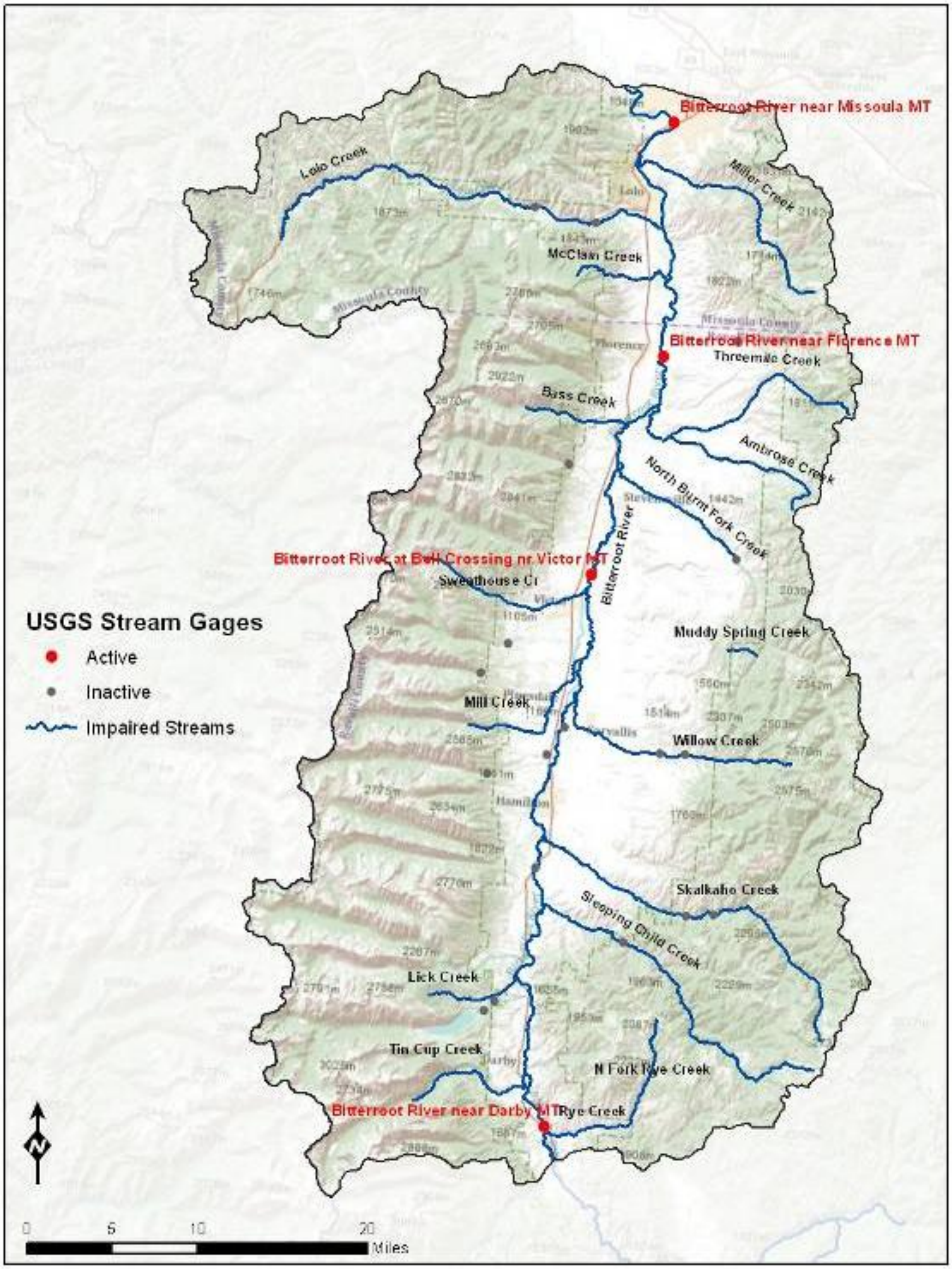

**Map A-6. Erodibility Indices (K Factors) for soils within the Bitterroot TMDL Planning Area**




**Map A-7. Hydrologic soil groups found in the Bitterroot TMDL Planning Area**.




**Map A-8. Slope ranges found within the Bitterroot TMDL Planning Area**




**Map A-9. Stream Gages found in the Bitterroot TMDL Planning Area**

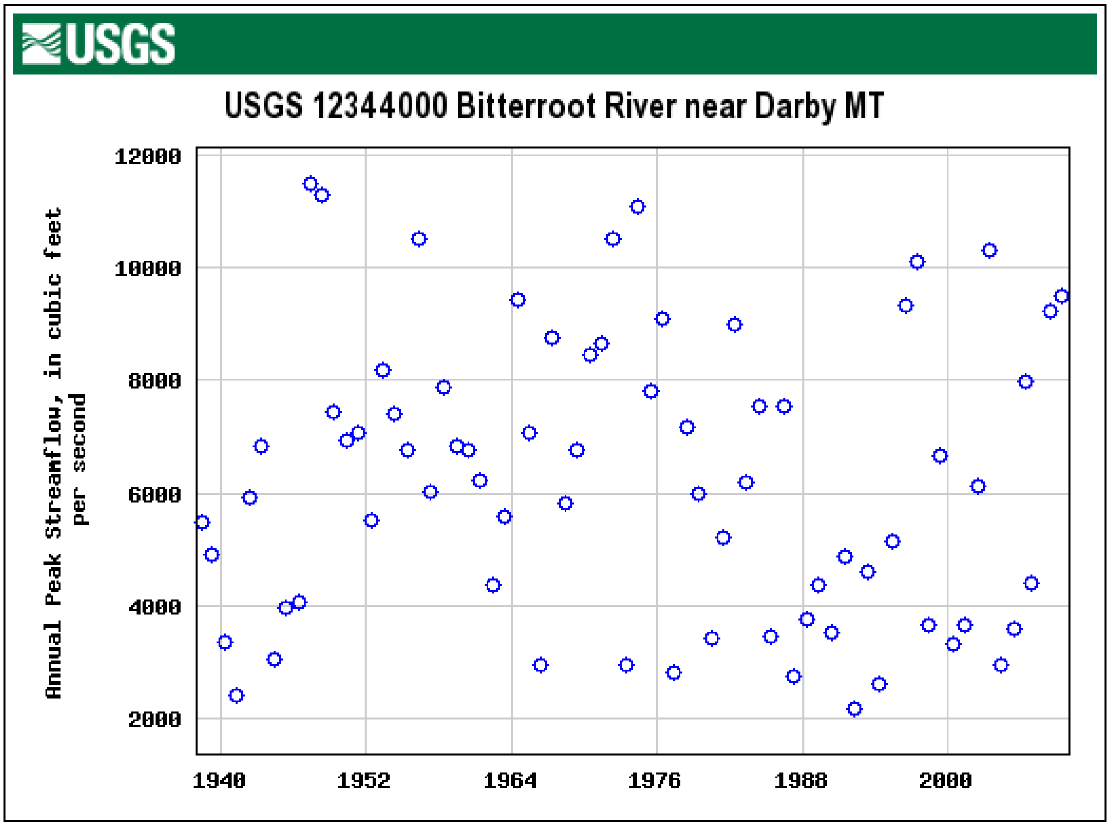



**Figure A-1. Bitterroot River annual peak streamflow near Darby, MT**

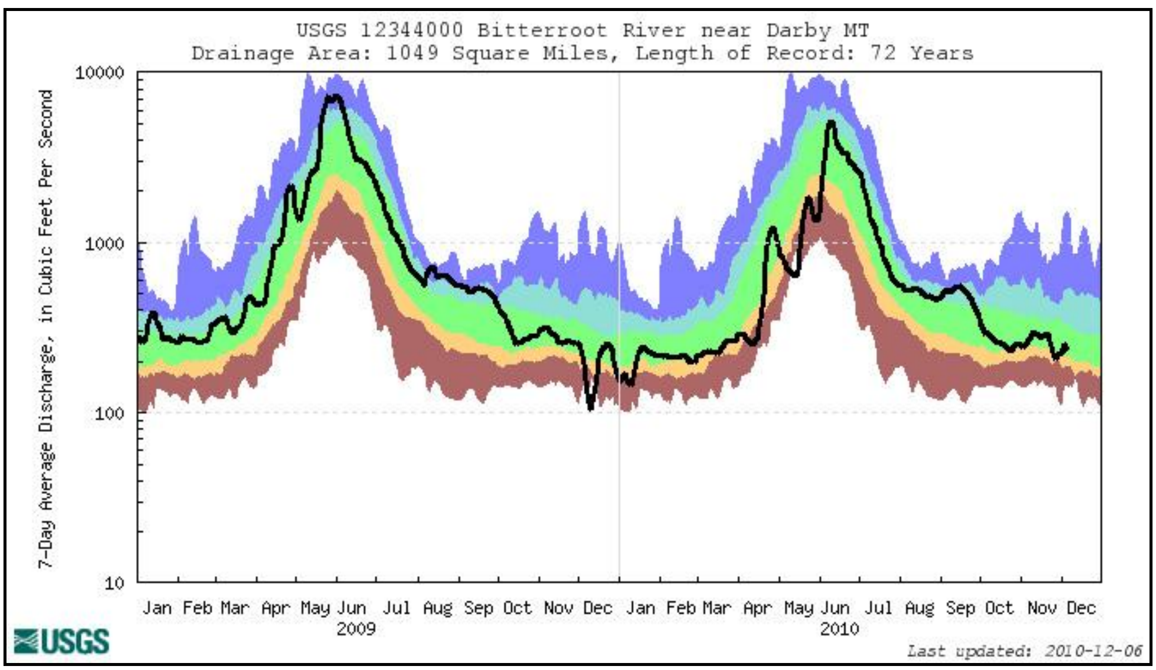



**Figure A-2. Seven day average discharge for the Bitterroot River near Darby, MT**

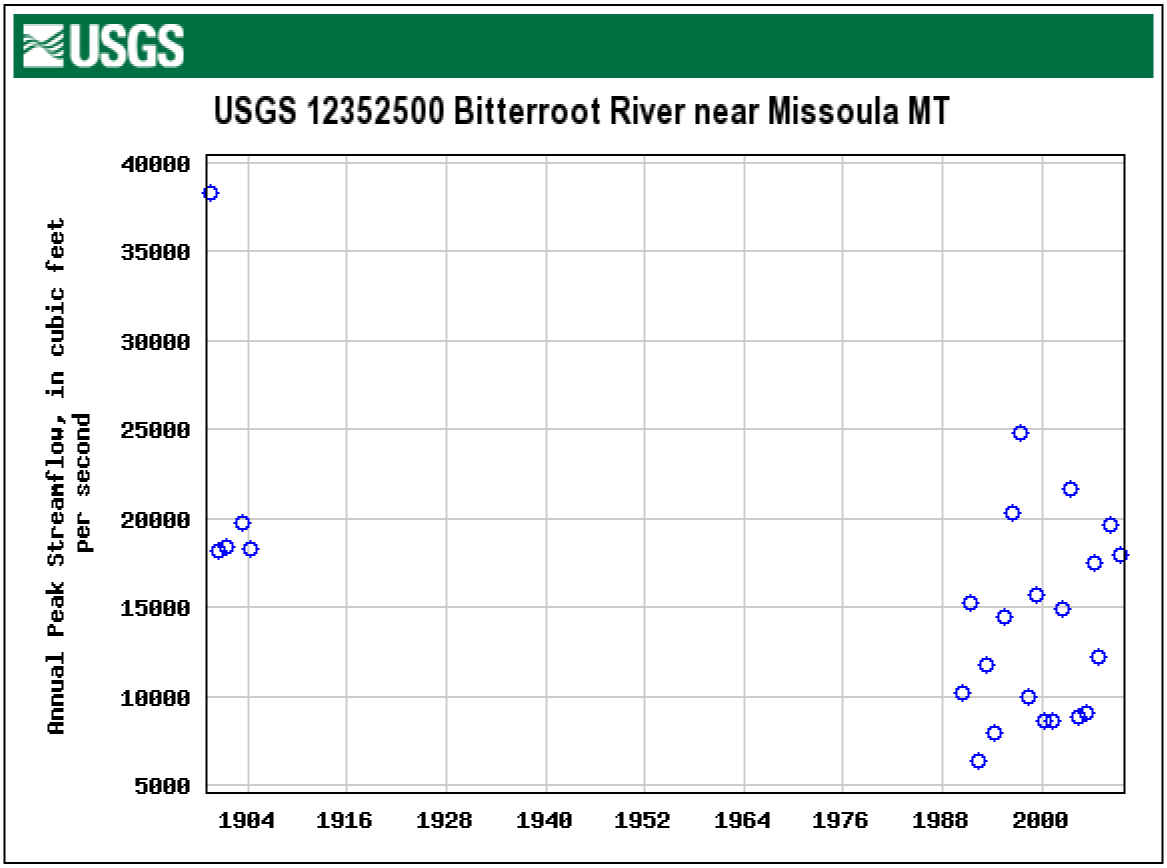



**Figure A-3. Bitterroot River annual peak streamflow near Missoula, MT**

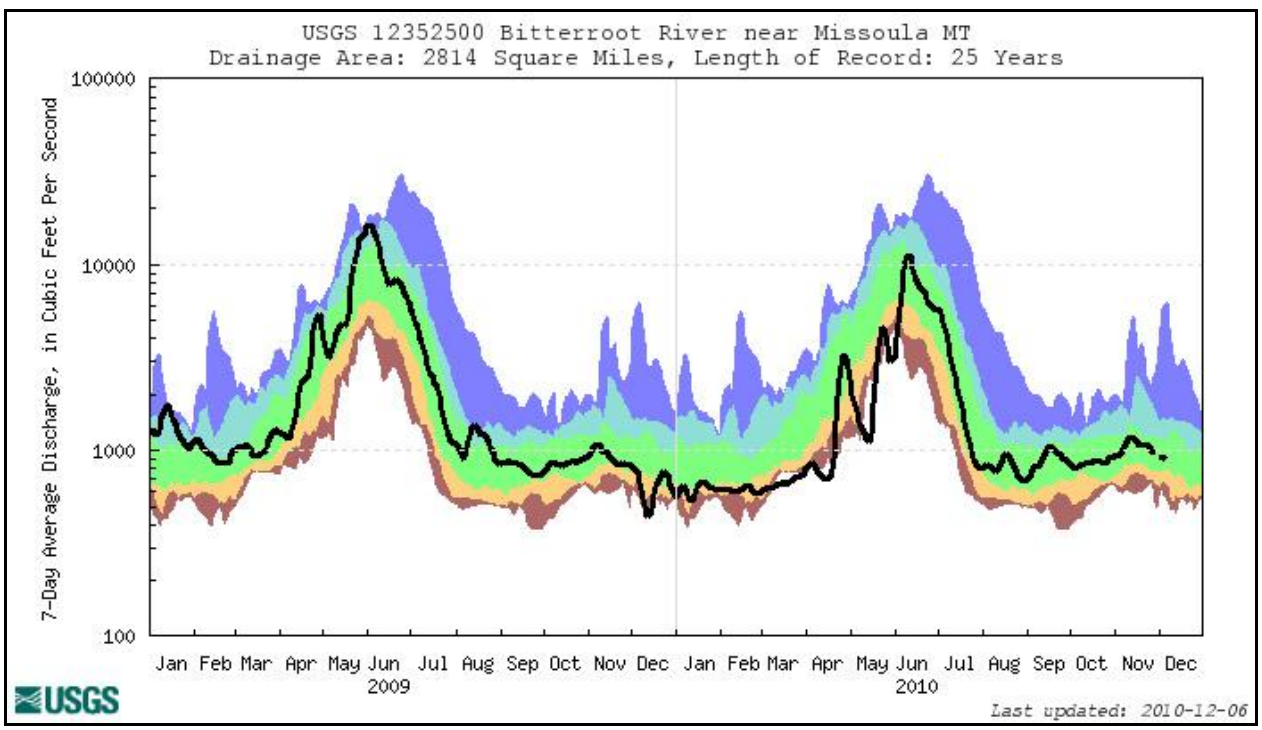
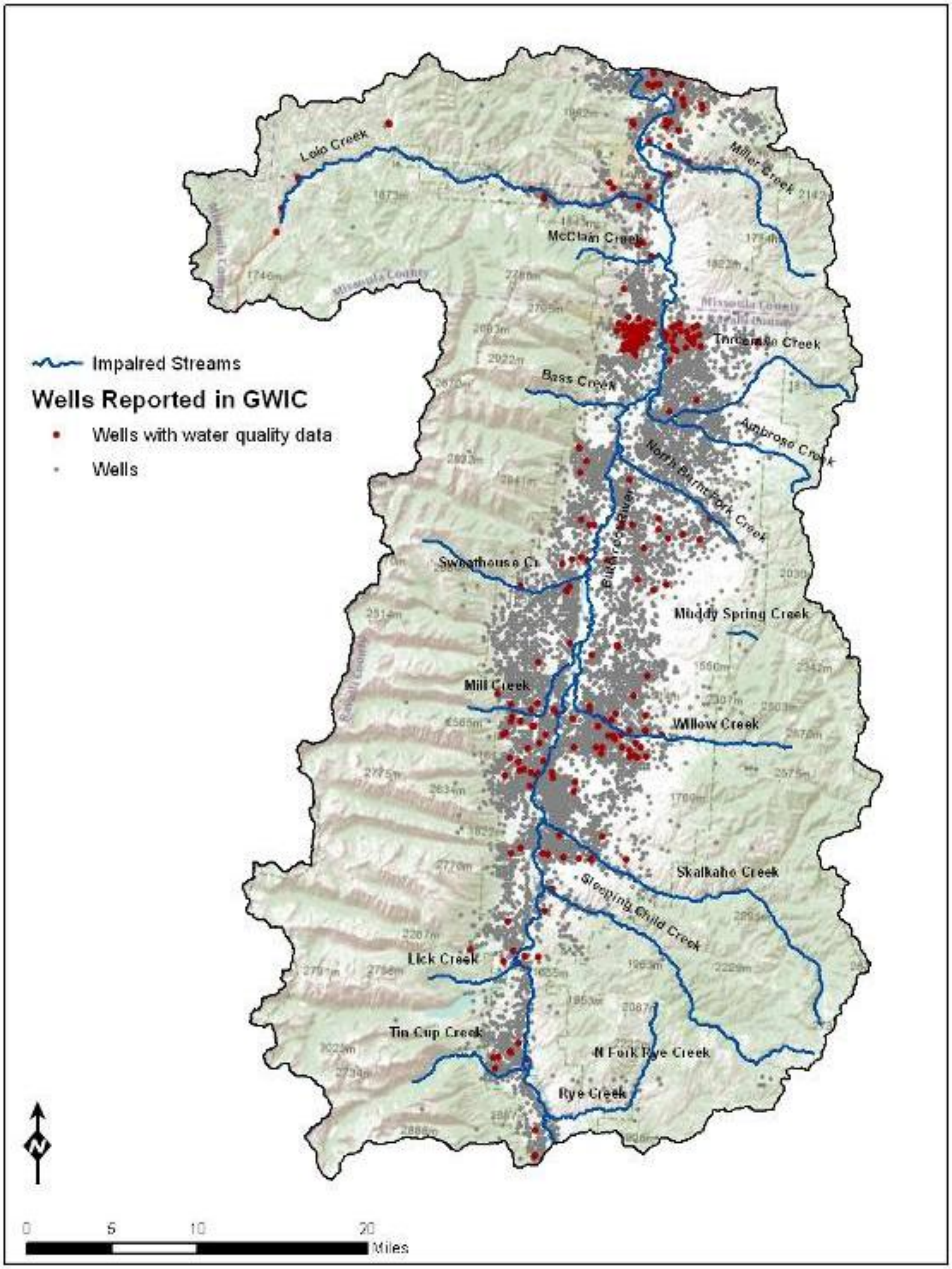
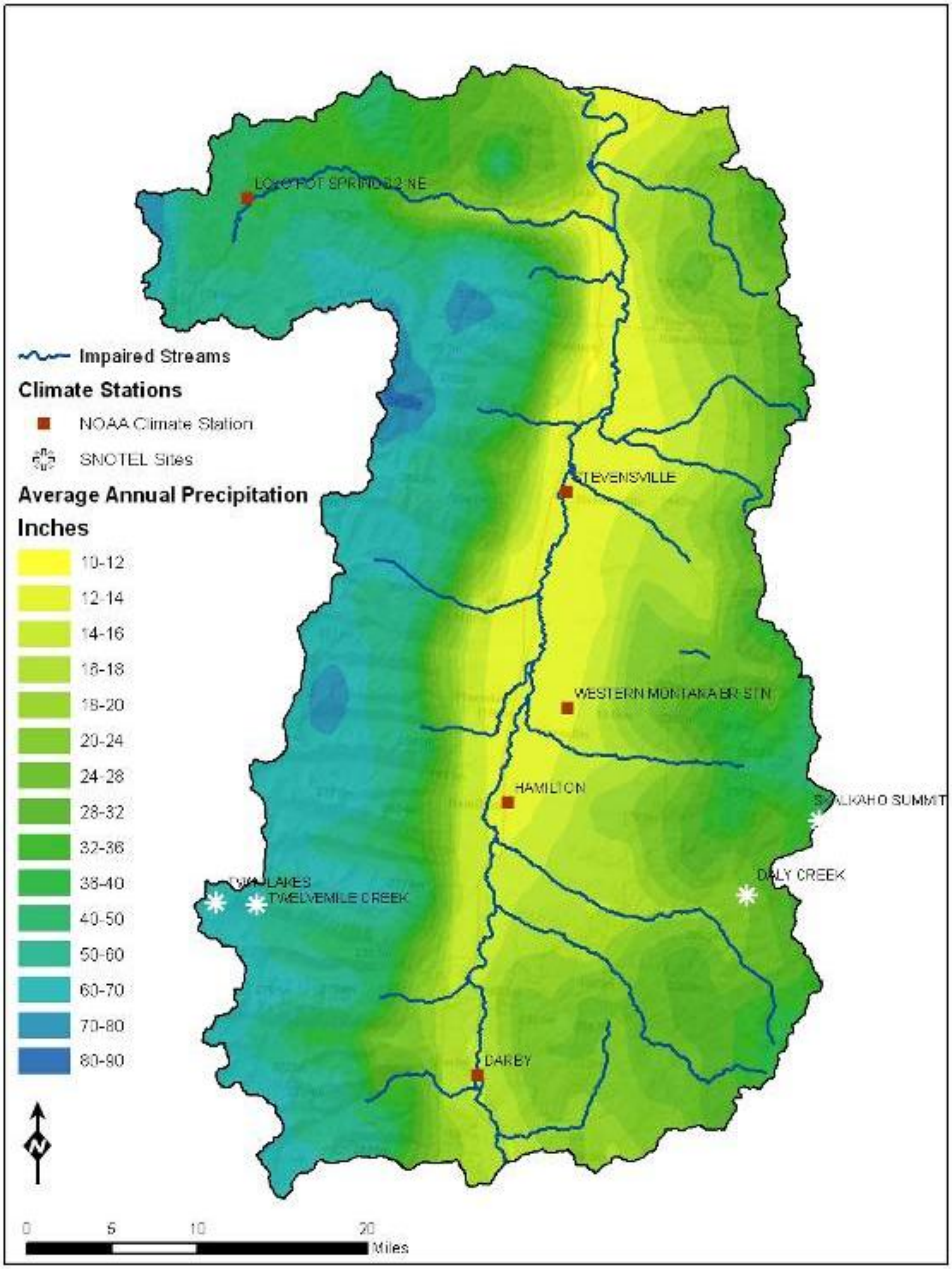


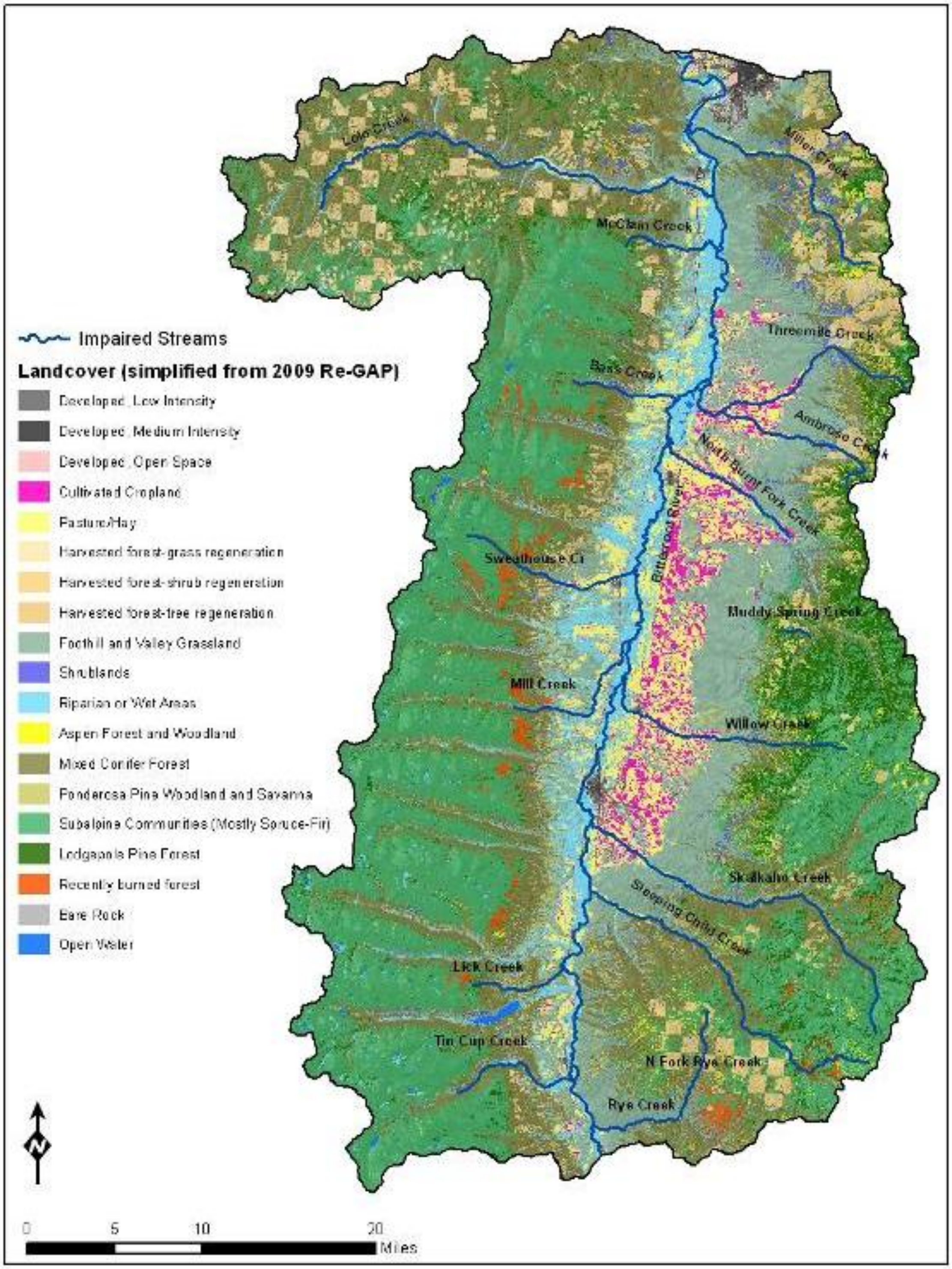

**Figure A-4. Seven day average discharge for the Bitterroot River near Missoula, MT**



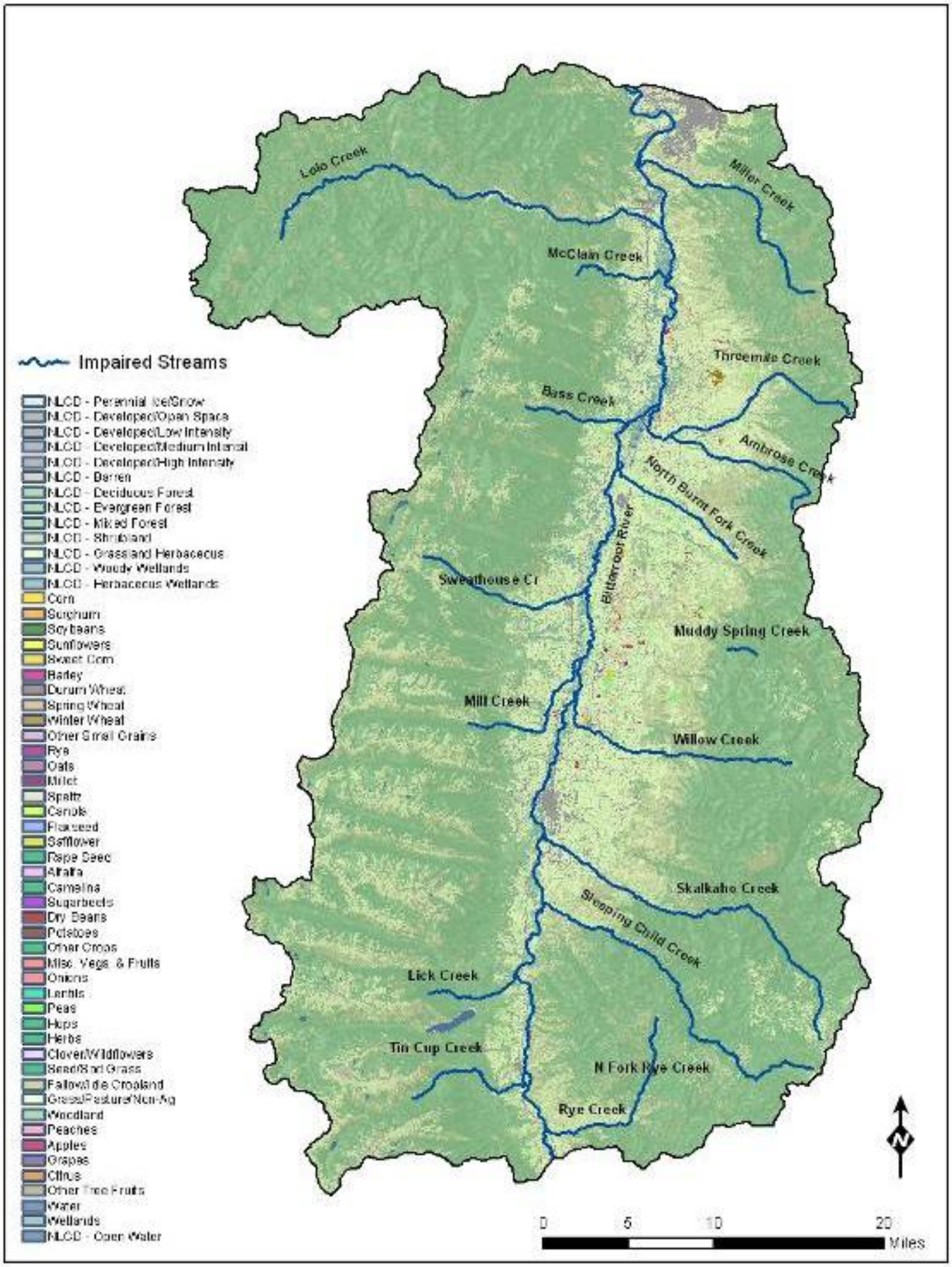

**Map A-10. Wells found in the Bitterroot TMDL Planning Area**



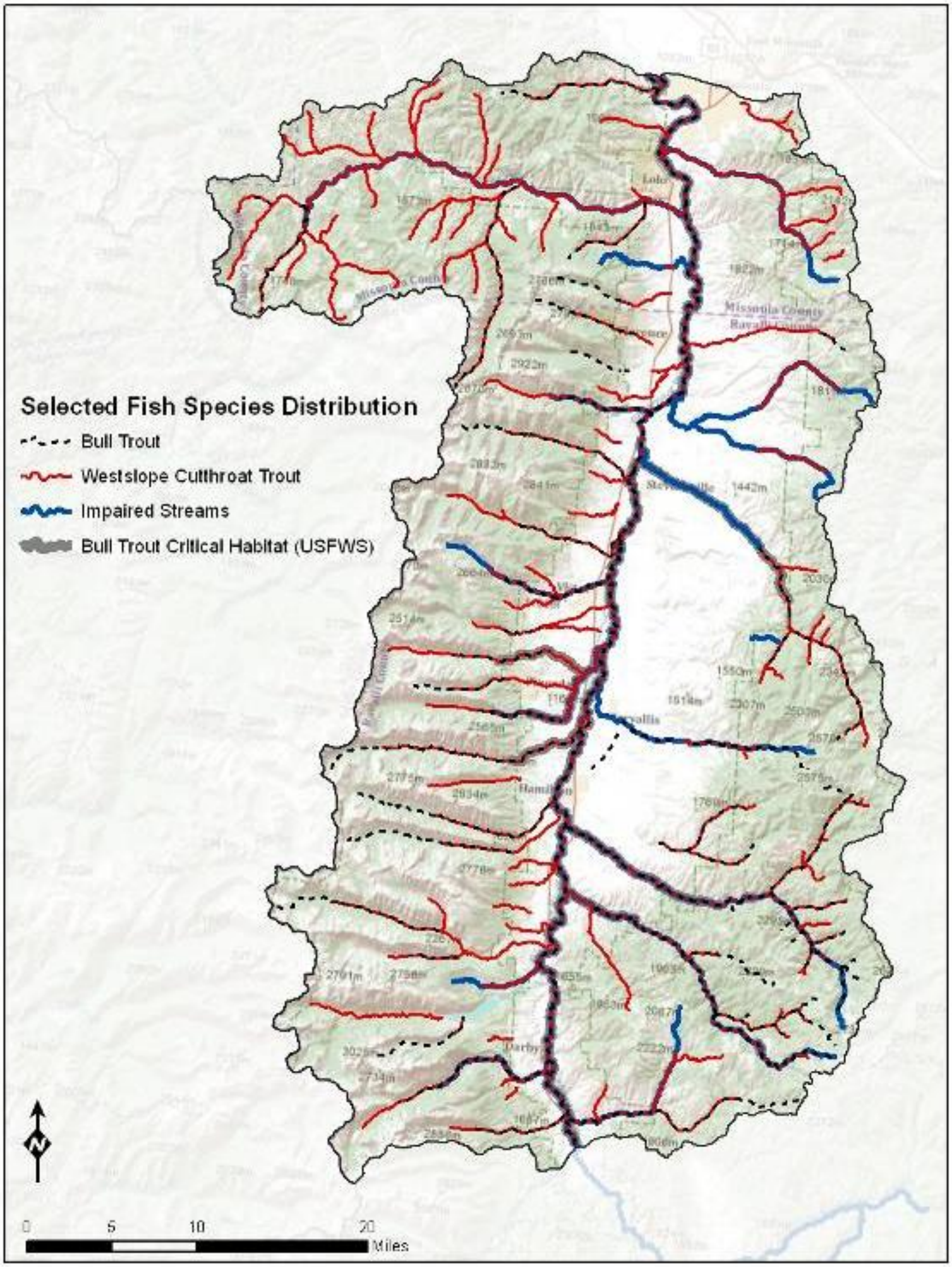

**Map A-11. Average annual precipitation in the Bitterroot TMDL Planning Area**



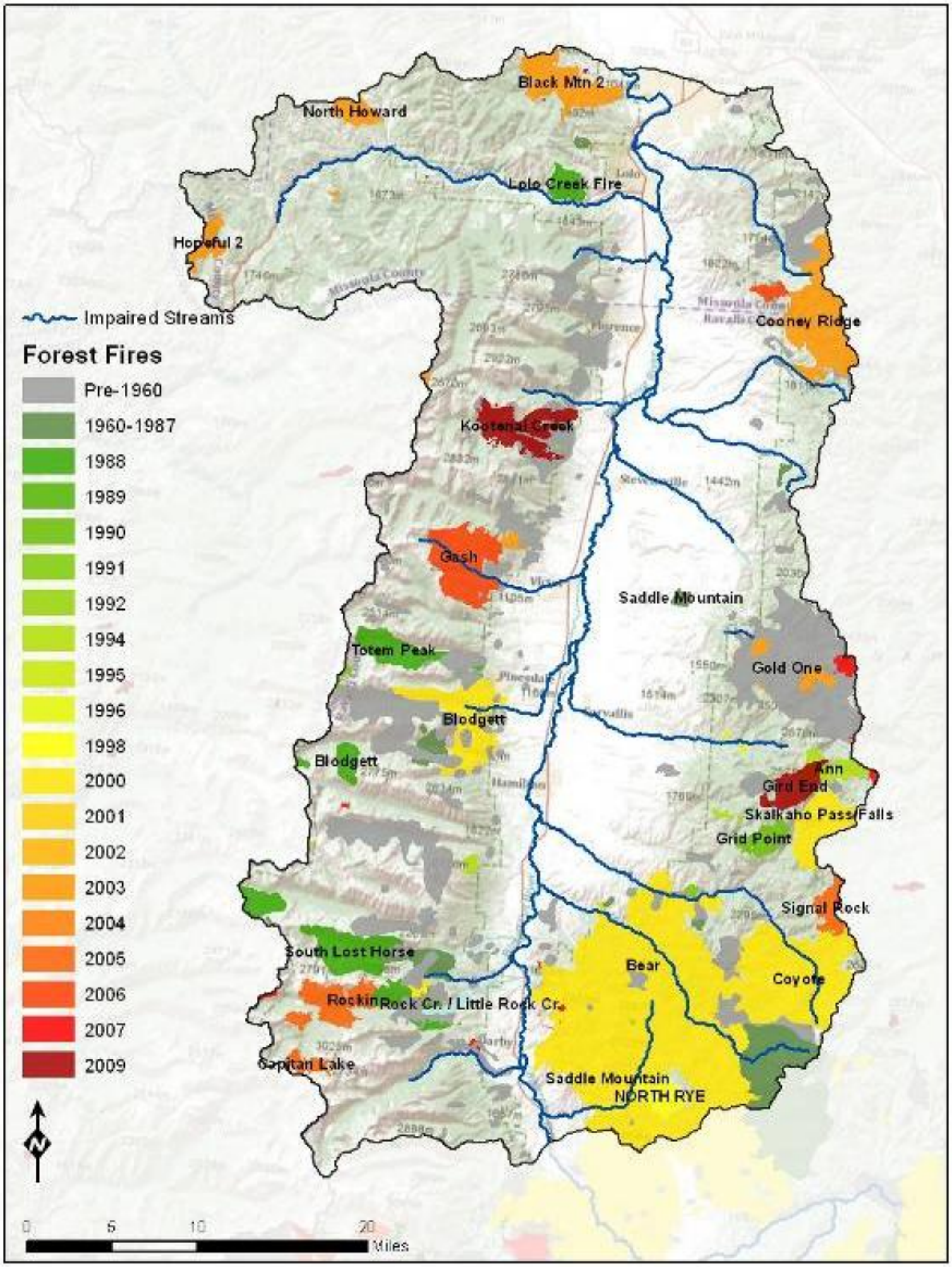

**Map A-12. Types of land cover found in the Bitterroot TMDL Planning Area**



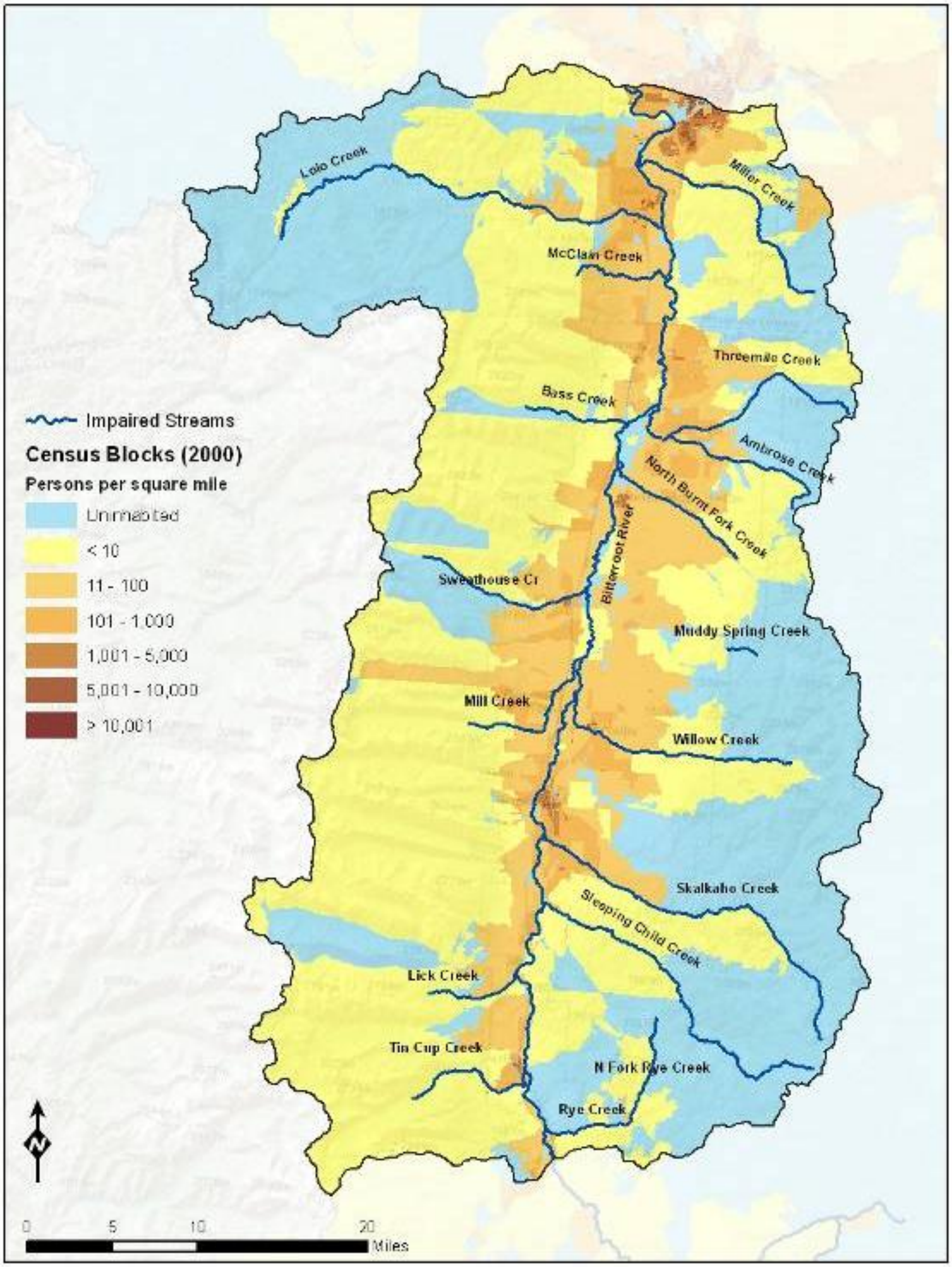

**Map A-13. Categories of land uses in the Bitterroot TMDL Planning Area**



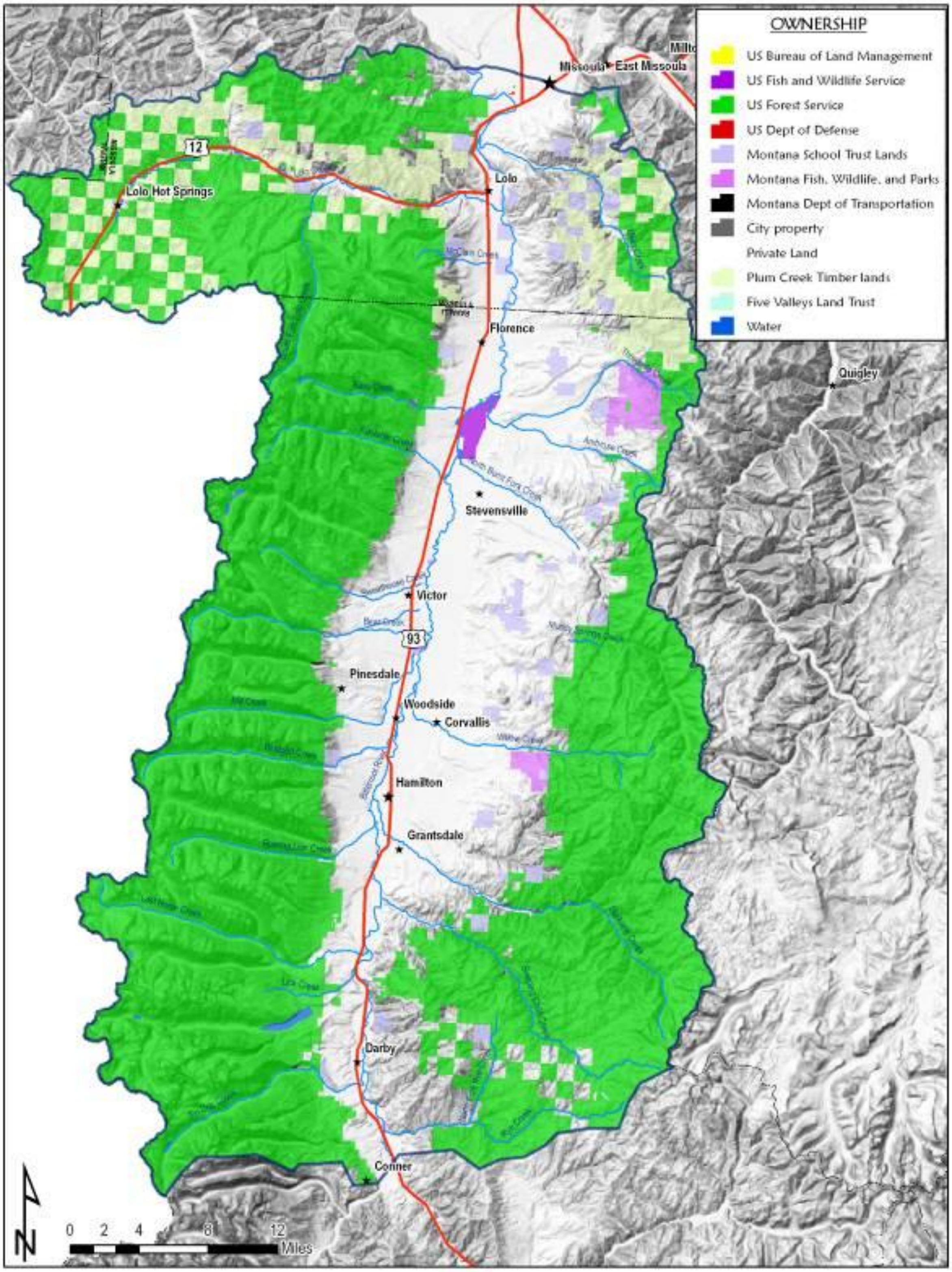

**Map A-14. Fish species distribution in the Bitterroot TMDL Planning Area**



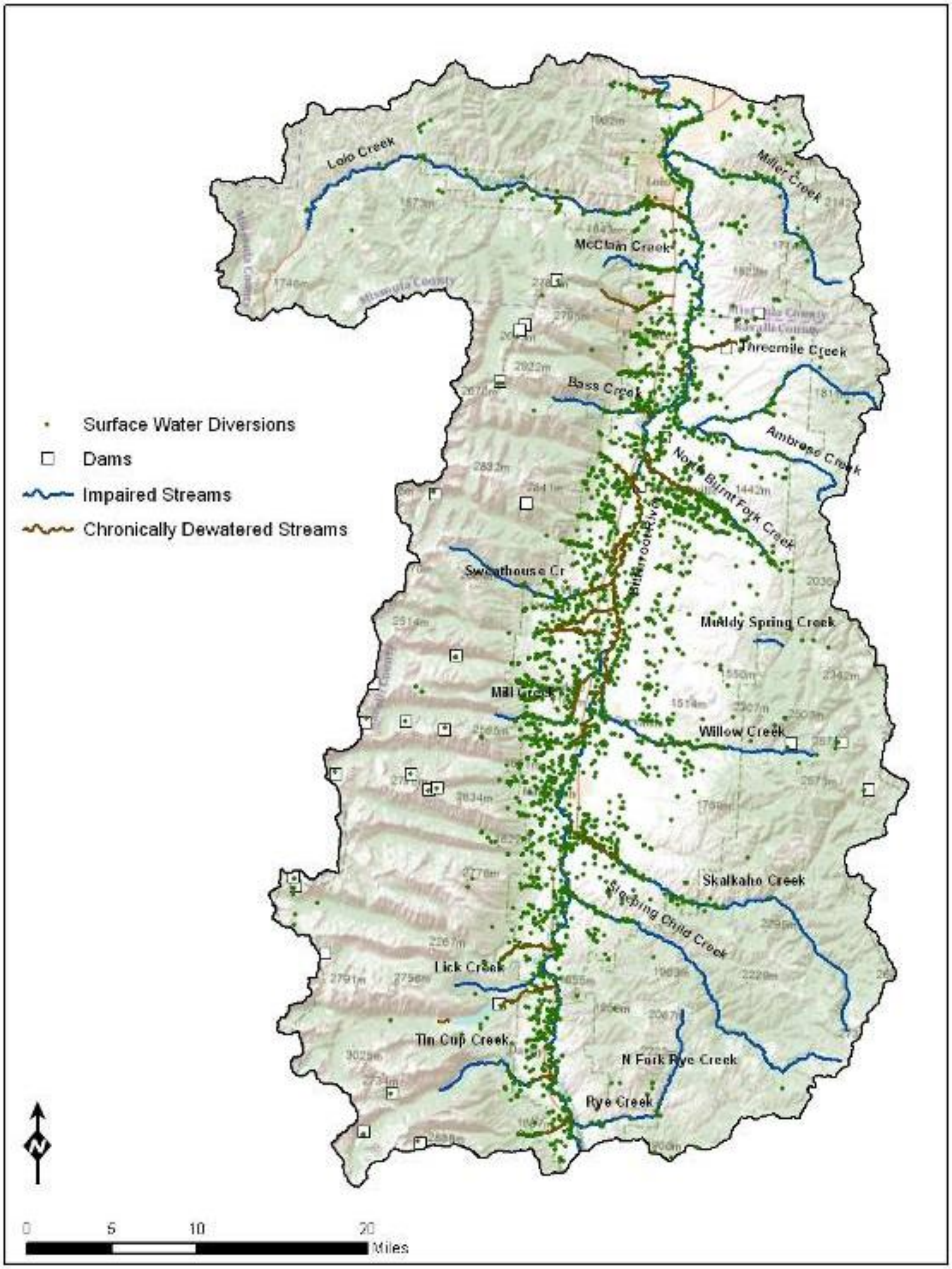

**Map A-15. History of forest fires in the Bitterroot TMDL Planning Area**



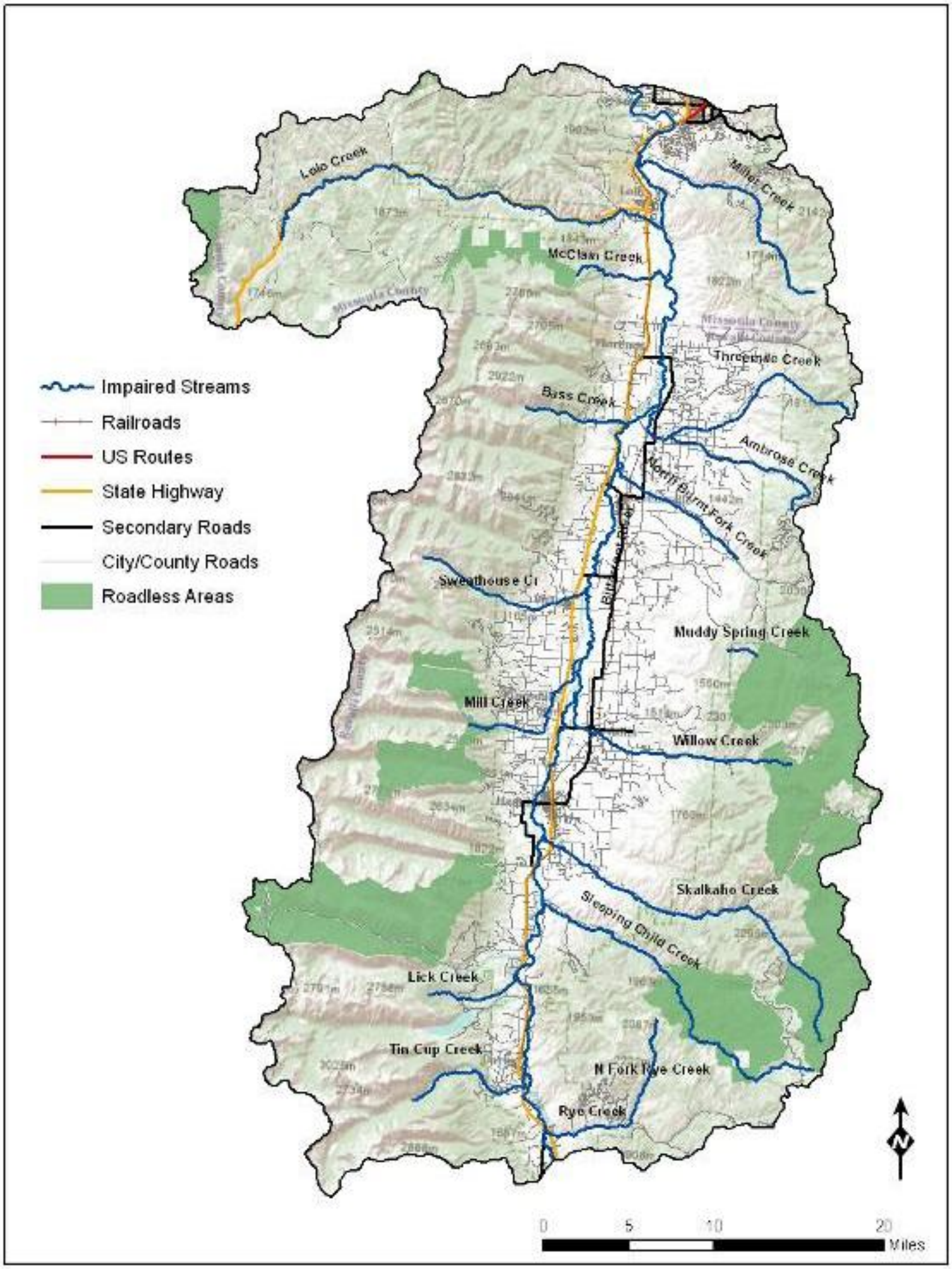

**Map A-16. 2000 Census data for the Bitterroot TMDL Planning Area**



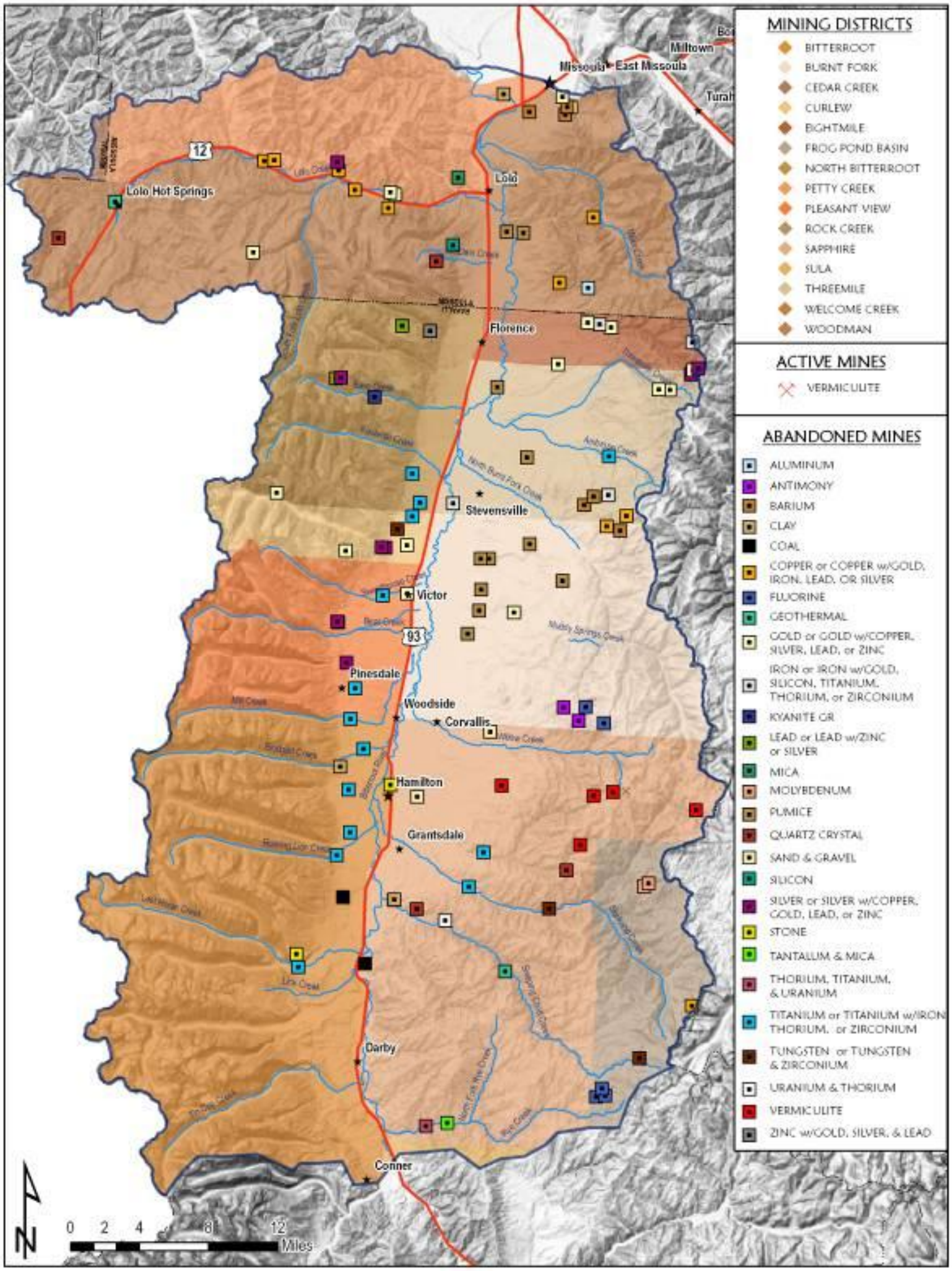

**Map A-17. Land ownership in the Bitterroot TMDL Planning Area**



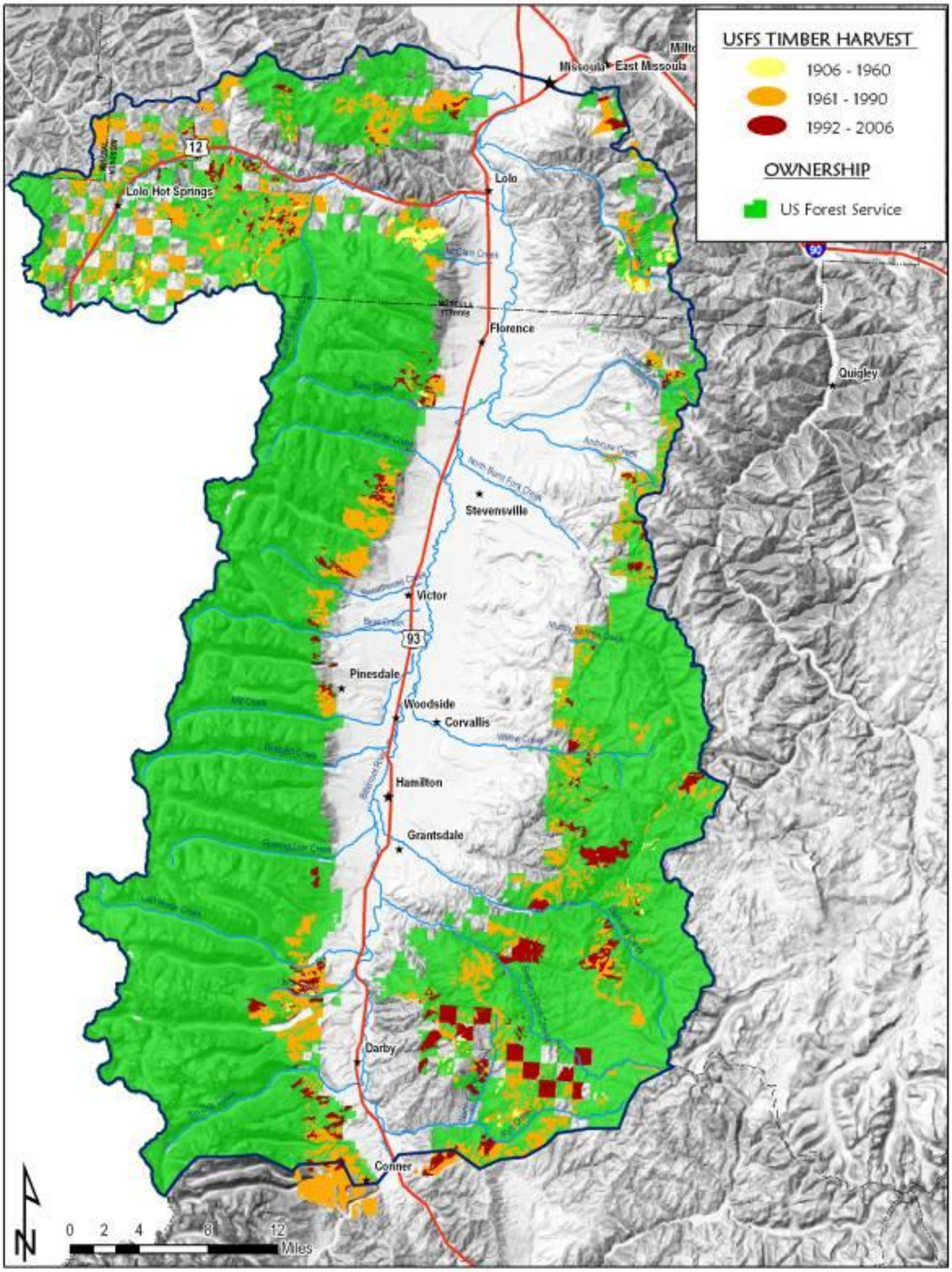

**Map A-18. Surface water diversions and locations of dams in the Bitterroot TMDL Planning Area**



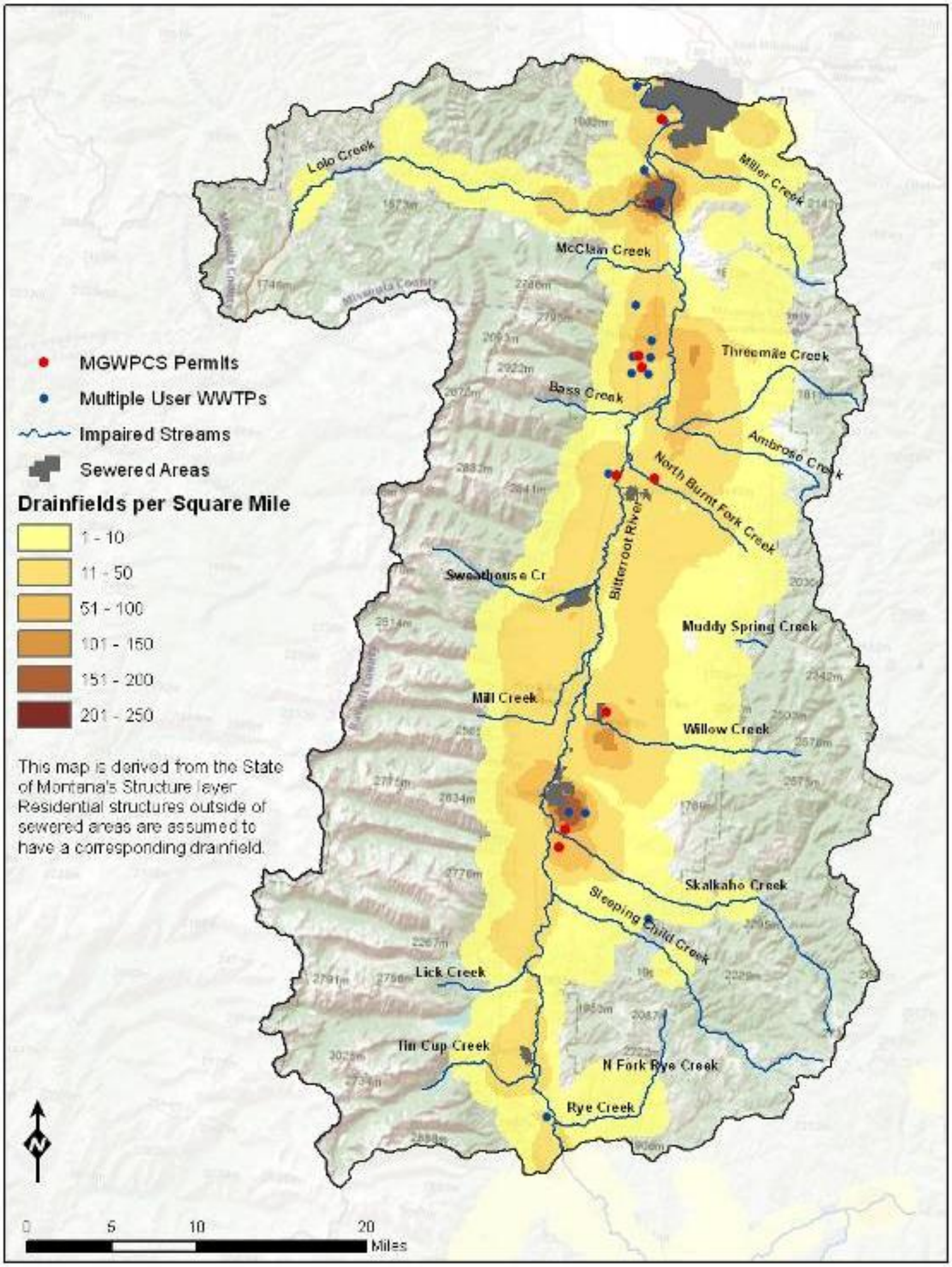

**Map A-19. Transportation networks in the Bitterroot TMDL Planning Area**



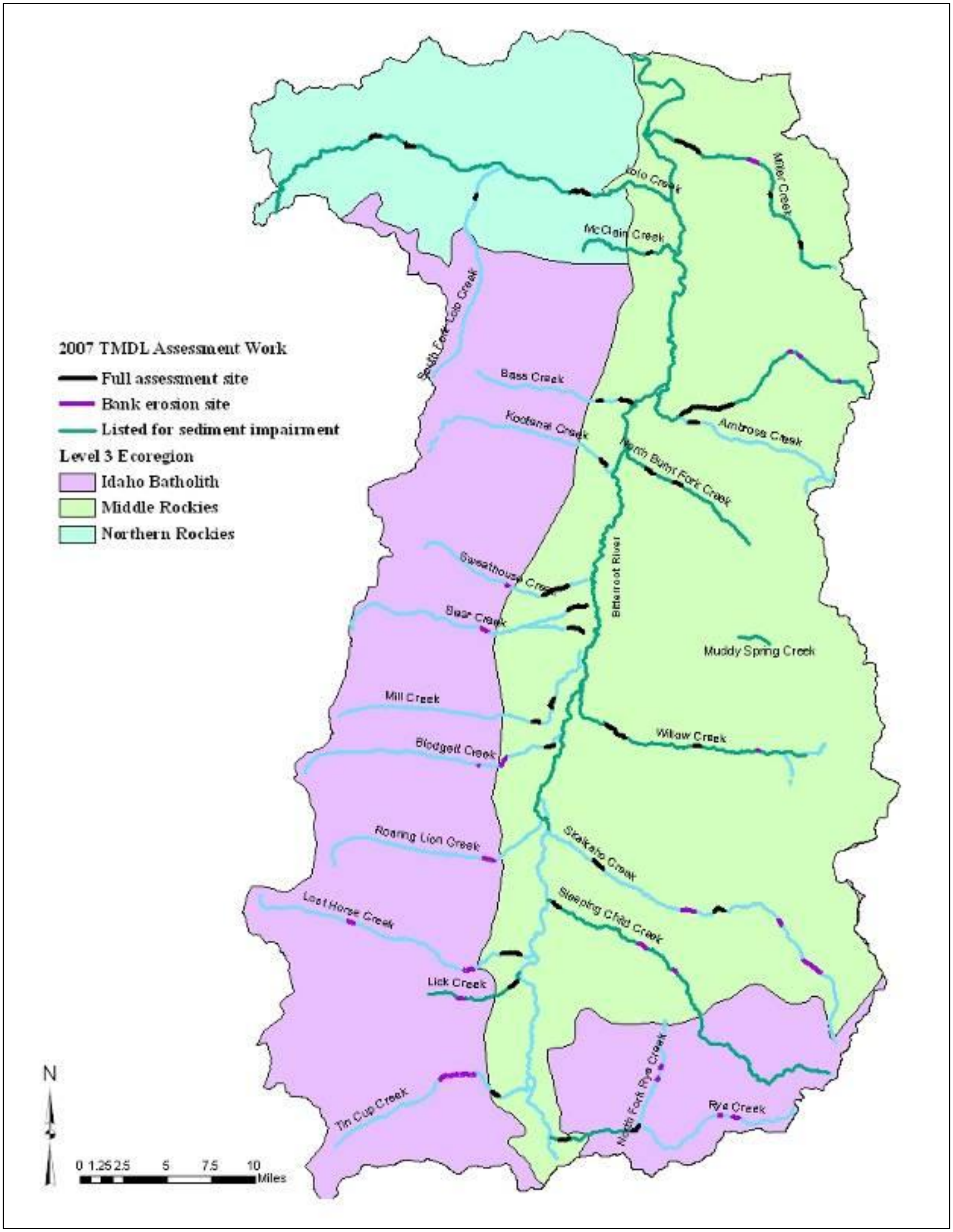

Map A-20. Locations of active and abandoned mines in the Bitterroot TMDL Planning Area



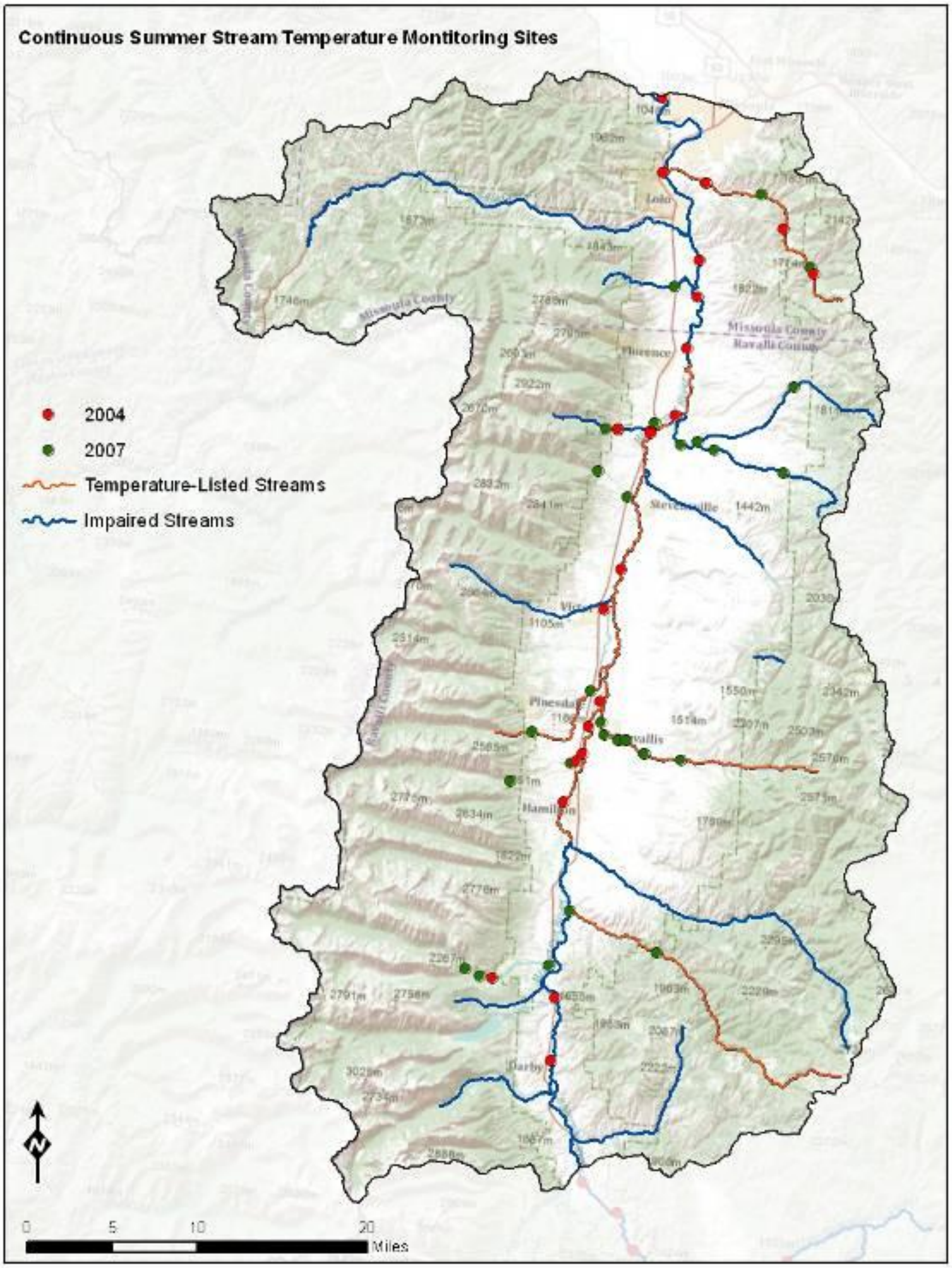

**Map A-21. Areas where timber harvests have occurred in the Bitterroot TMDL Planning Area**



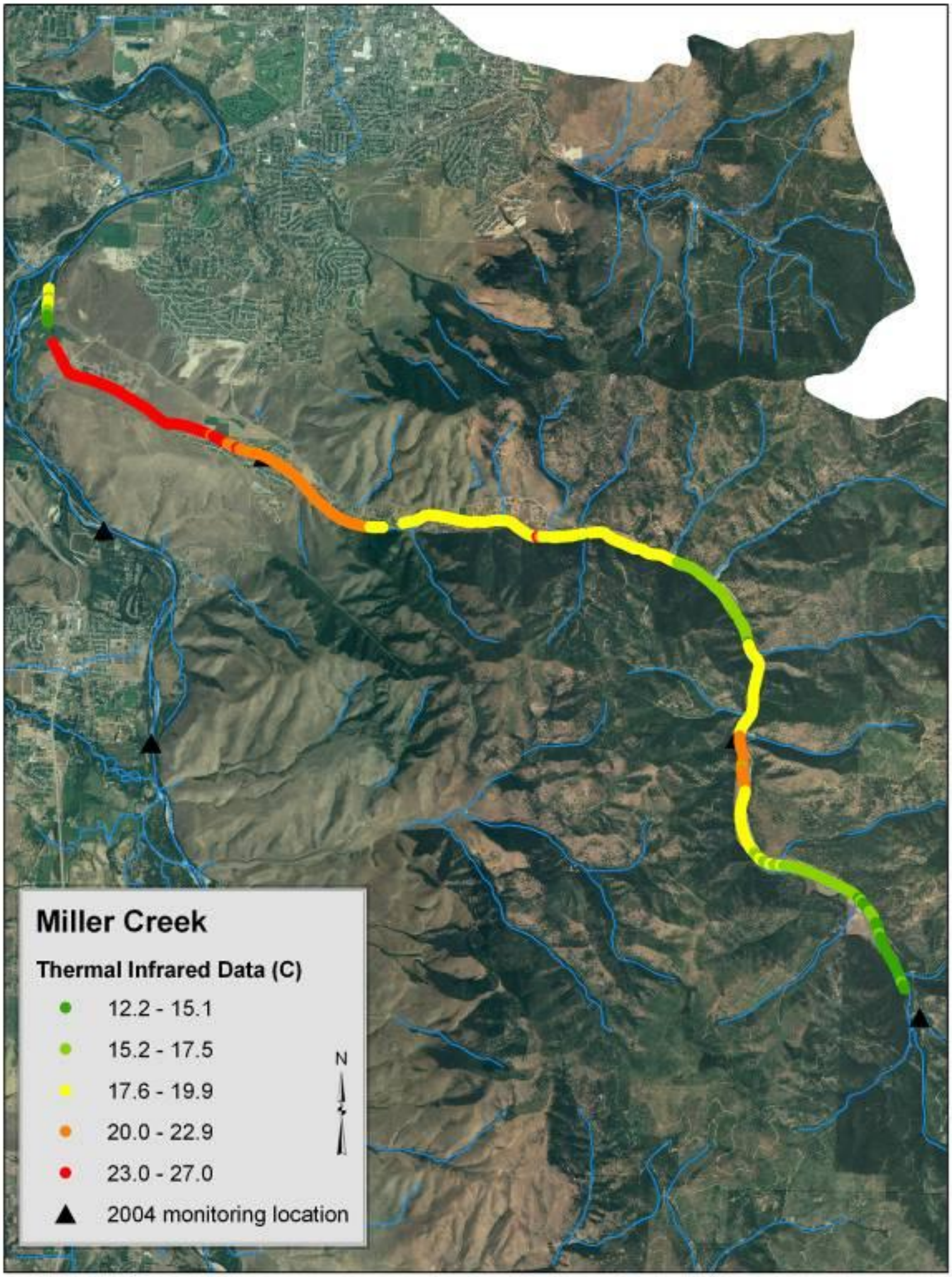

**Map A-22. Septic system density and permitted wastewater discharge locations in the Bitterroot TMDL Planning Area**



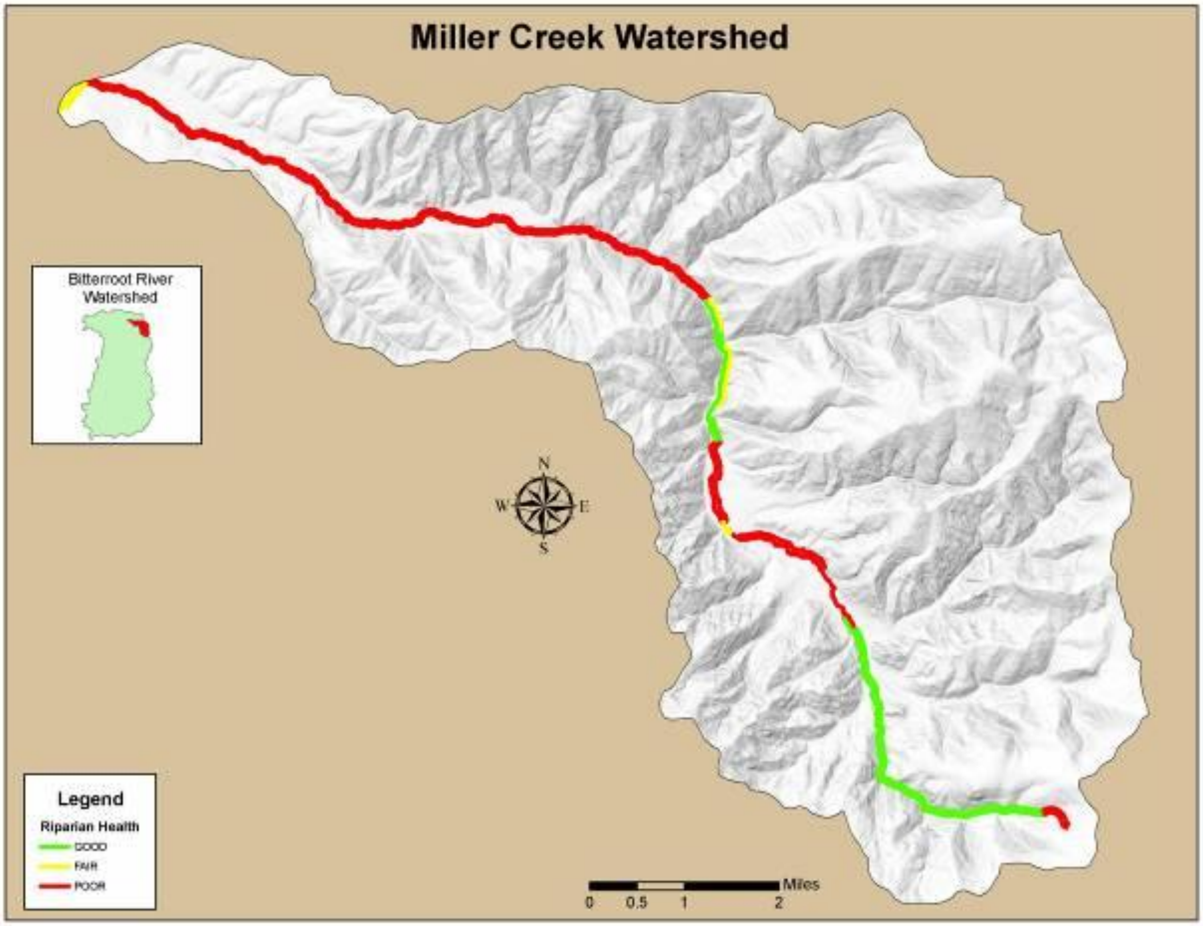

**Map A-23. Reached assessed in 2007 to assist with sediment TMDL development**



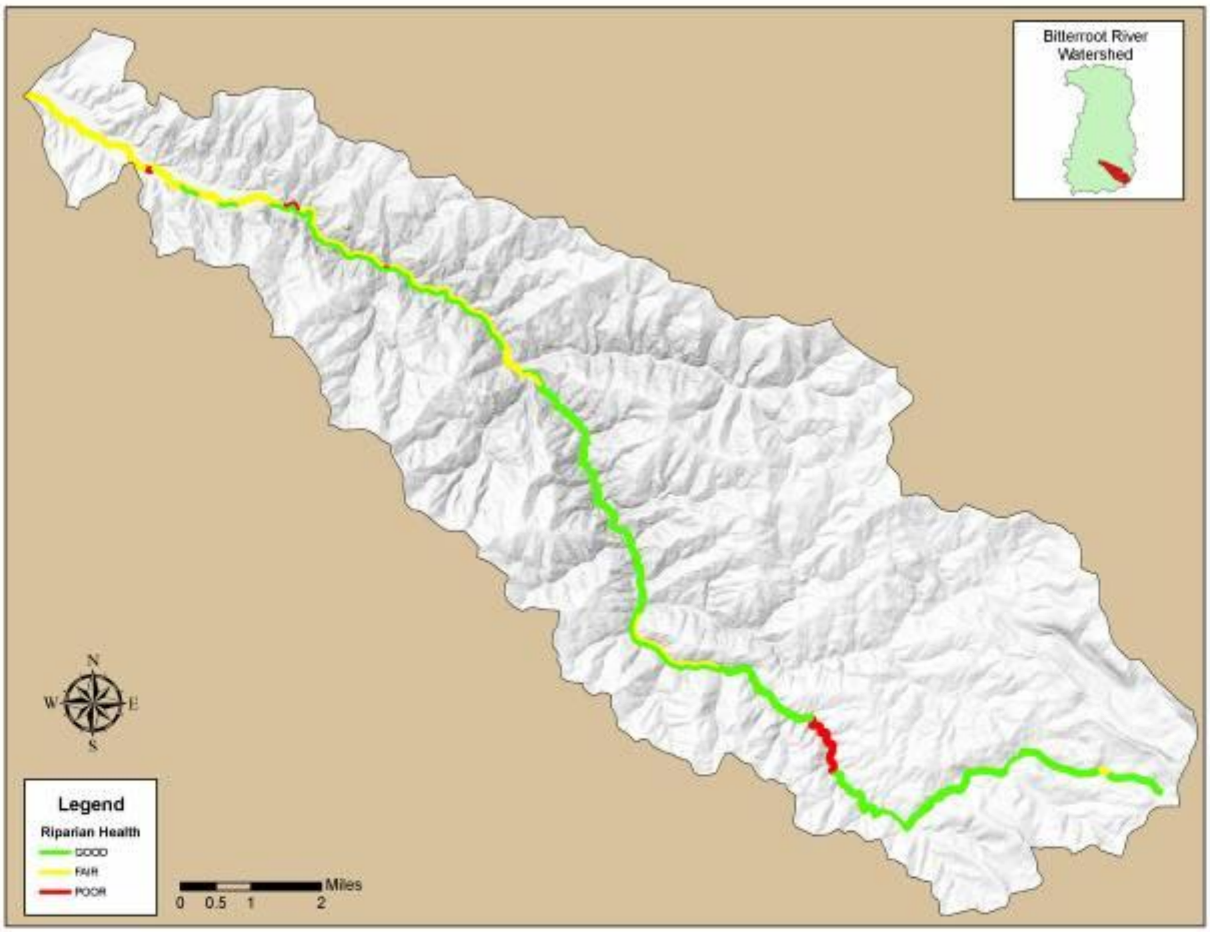

**Map A-24. 2004 and 2007 stream temperature monitoring locations in the Bitterroot TPA**



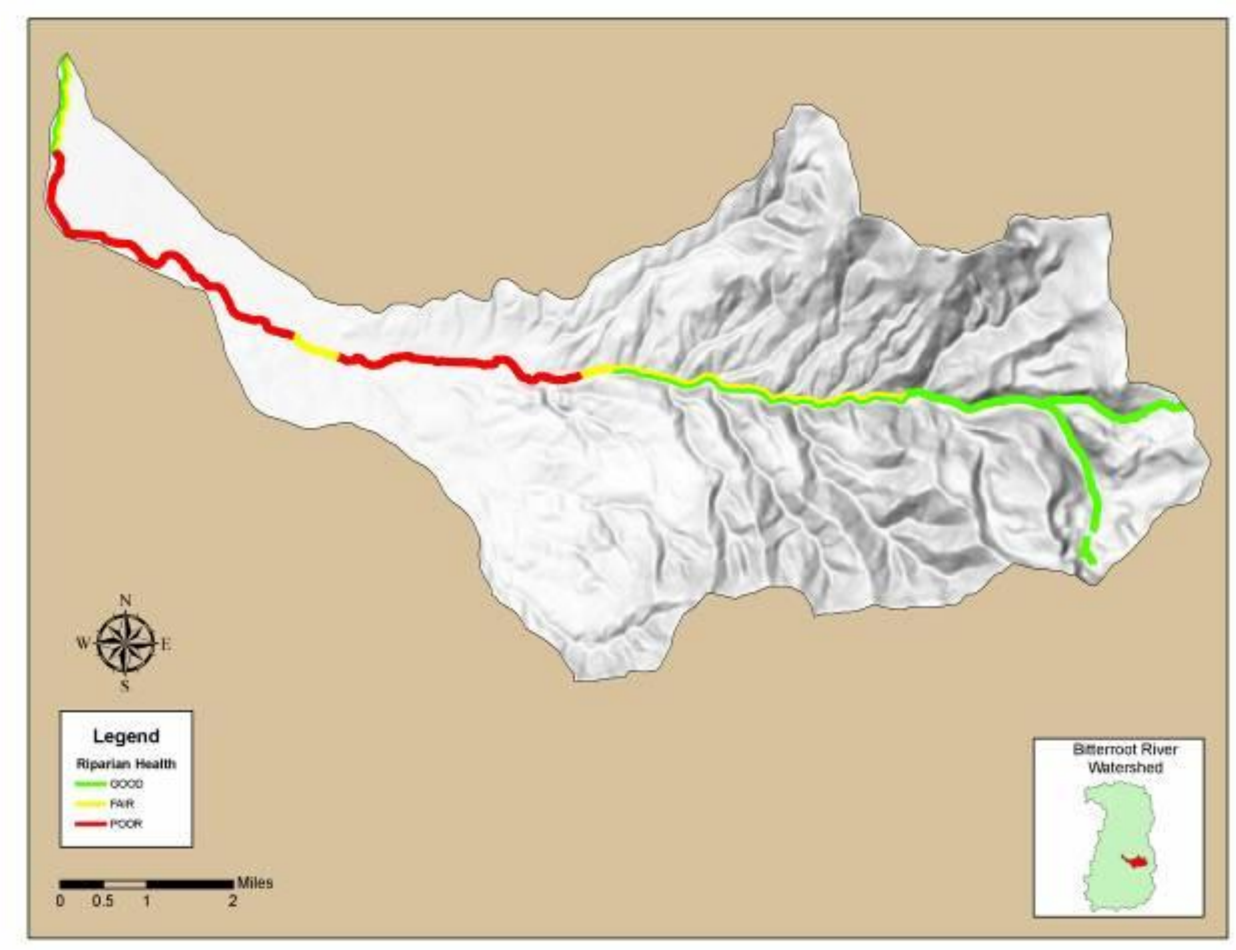

**Map A-25. Temperature monitoring locations on Miller Creek in 2004**




**Map A-26. Riparian health conditions of Miller Creek**




**Map A-27. Riparian health conditions of Sleeping Child Creek**




**Map A-28. Riparian health conditions of Willow Creek**

# APPENDIX B - BITTERROOT RIVER WATERSHED DESCRIPTION

## 2011

**Prepared for and by:**

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# B1.0 INTRODUCTION

This report describes the physical, ecological, and cultural characteristics of the Bitterroot River watershed. The characterization establishes a context for impaired waters to support total maximum daily load (TMDL) planning. The area described is known as the Bitterroot TMDL Planning Area (TPA), and is shown on **Map A-1** found in **Appendix A**.

The Montana Department of Environmental Quality (DEQ) has identified 18 impaired waterbodies (category 5) within the Bitterroot TPA: Ambrose, Bass, Lick, Lolo, McClain, Mill, Miller, Muddy Spring, North Burnt Fork, North Rye, Rye, Skalkaho, Sleeping Child, Sweathouse, Threemile, Tin Cup, and Willow Creeks and the Bitterroot River. The impairments total 303 miles of stream. The impairment listings are detailed in DEQ's Integrated 305(b)/303(d) Water Quality Report (Montana Department of Environmental Quality, 2010), and are shown on **Map A-1** found in **Appendix A**. Impairment listings are summarized in **Section 1.0** of the main document.

# B2.0 Physical Characteristics

## B2.1 Location

The TPA is located in the Pend Oreille River Basin (Accounting Unit 170102) of western Montana, and within the Bitterroot River (17010205) 4$^{th}$ code hydrologic unit. The Bitterroot River hydrologic unit is subdivided into three TMDL planning areas: Bitterroot Headwaters, Bitterroot, and Upper Lolo. This document considers only the latter two. The Upper Lolo TPA consists of the headwaters of Lolo Creek, and is the area above Lolo Hot Springs. The Bitterroot Headwaters TPA includes the watershed area south of Conner and above the confluence of the East and West Forks of the Bitterroot River, and is not addressed in this document.

The Bitterroot TPA is bounded by the Bitterroot Range to the west, the Sapphire Range to the east and the Beaverhead Range to the south. The total area is 1,210,740 acres, or approximately 1,891 square miles. Approximately 75% of the Bitterroot TPA is within Ravalli County, just under 25% in Missoula County, and a very small area is in Mineral County.

## B2.2 Ecoregions

The TPA includes 3 Level III Ecoregions: Idaho Batholith (16), Middle Rockies (17) and Northern Rockies (15). Seven Level IV Ecoregions are mapped within the Bitterroot TPA (Woods et al, 2002), as shown on **Map A-2** in Appendix A. These include: Bitterroot-Frenchtown Valley (17s), Rattlesnake-Blackfoot-South Swan-Northern Garnet-Sapphire Mountains (17x), Glaciated Bitterroot Mountains and Canyons (16e), High Idaho Batholith (16h), Eastern Batholith (16a), Lochsa Uplands (16b) and Grave Creek Range-Nine Mile Divide (15a).

## B2.3 Topography

Elevations in the Bitterroot TPA range from 3,087 - 10,157 feet above mean sea level (**Map A-3 in Appendix A**). The lowest point is the confluence with the Clark Fork River. The highest point is Trapper Peak, in the Bitterroot Range on the western margin of the TPA. The TPA geography is characterized on the west by glacially sculpted U-shaped alpine valleys draining the Bitterroot Mountains and on the east by dendritic V-shaped valleys draining the Sapphire Mountains. Slopes (discussed further below) are generally 10 to 20 percent steeper in the Bitterroot Range than in the Sapphire Range. The Bitterroot Valley is roughly 10 miles across at the widest.

## B2.4 Geology

**Map A-4** (found in **Appendix A**) provides an overview of the geology, based on the 1:500,000 scale statewide map (Ross et al., 1955). This map is generalized and does not reflect much of the current understanding of the region's geology.

### Bedrock

The bedrock of the TPA includes Precambrian metamorphic and metasedimentary rocks, Cretaceous and Tertiary igneous intrusions, and Tertiary volcanic rocks (Ross et al., 1955). Granitic rocks of the Idaho Batholith and similar igneous bodies dominate the Bitterroot Range and the Sapphire Range south of Skalkaho Creek. The distinctive slope of the range-front of the Bitterroot Mountains is a dip slope formed on the foliation in the Bitterroot mylonite zone, a 500-1,500 meter (1,640-4,920 feet) thick shear zone on the edge of the Idaho Batholith (Renard et al., 1997). Metasedimentary rocks of the Precambrian Belt Series dominate the Sapphire Range north of Skalkaho Creek and most of the Lolo Creek watershed.

**Valley Sediments**

Valley sediments are divided into Tertiary sedimentary units and younger Quaternary deposits. There are two Tertiary units: alluvial deposits of the ancestral Bitterroot River, and the Sixmile Creek Formation, representing alluvial fan deposits shed from the Bitterroot and Sapphire Ranges. The ancestral Bitterroot River deposits record source areas and drainage patterns unrelated to the current geomorphology. These deposits are well-sorted cobble, gravel and sand beds, with local interbeds of silt and clay. The Sixmile Creek Formation, however, is generally unsorted boulders and cobbles in a sandy, silty clay matrix (Briar and Dutton, 2000). North of Corvallis, the eastern margin of the valley is underlain by Tertiary sedimentary deposits. Tertiary deposits are present on the western side of the valley from Victor northwards. Valley sediments reach a thickness of 3,000 feet near Hamilton (Kendy and Tresch, 1996). Later uplift caused the Bitterroot River and tributary streams to incise these deposits, isolating them above successive alluvial plains. This same mechanism has resulted in terraces of Quaternary alluvium in the valley bottom. Glacial deposits are more limited in extent, and are primarily found in terminal moraines at the mouths of glacial valleys on the western end of the valley. In general, the moraines are larger to the south, where the elevation is higher.

## B2.5 Soils

The U.S. Geologic Survey (USGS) Water Resources Division (Schwartz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) State Soil Geographic (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. Soils analysis at a larger scale should use NRCS Soil Survey Geographic (SSURGO) data. The soil attributes considered in this characterization are permeability, erodibility and slope.

Soil permeability is reported in inches per hour (weighted average across soil unit thickness), and is shown on **Map A-5** in Appendix A. Permeability varies widely across the TPA, from 0.44 to 13.79 inches per hour. The lowest permeability soils are mapped on the eastern benches, the flanks of the Sapphire Range and the Lolo Creek subwatershed. The highest permeability soils are mapped both along the base and the crest of the Bitterroot Range.

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 shown on **Map A-6** (Appendix A), with soil units assigned to the following ranges: low (0.0-0.2), low-moderate (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 0.33 are mapped in the TPA. Nearly half (49%) of the TPA is mapped with low susceptibility soils, and another 41% is mapped with low-moderate susceptibility. Nearly all of the moderate-high susceptibility soils correspond to the Tertiary benches and the foothills of the Sapphire Range. Susceptibility to erosion exhibits a loose inverse relationship to permeability.

A hydrologic soil group is indicative of the soils potential for runoff based on water infiltration of bare, thoroughly wet soil during a long duration storm (Natural Resources Conservation Service, Soil Survey Staff, 2008). There are four hydrologic soil groups: group A soils have a high infiltration rate and a low runoff potential, group B soils have a moderate infiltration rate / moderate runoff potential, group C soils have a slow infiltration rate and a moderate-high runoff potential, and group D soils have a very slow infiltration rate and a high runoff potential (Natural Resources Conservation Service, Soil Survey Staff, 2008). **Map A-7** (Appendix A) shows that the majority (80%) of the planning area is mapped with B soil types. The C type soils are limited to the modern floodplain and some portions of the eastern benches (3%). Many of the Quaternary sediments along the front of the Bitterroot Range are mapped as A type soils.

A map of slope is provided on **Map A-8** in Appendix A. Slope is mapped as averaged over soil units, in percent. Average slopes in the Bitterroot Range are roughly 10 to 20 percent steeper than slopes in the Sapphire Range.

## B2.6 Surface Water

Within the Bitterroot TPA, the Bitterroot River flows from the confluence of the East Fork and the West Fork of the Bitterroot River, to the confluence with the Clark Fork River, a distance of approximately 84 river miles. The Bitterroot Mountains contribute nearly four times as many tributary streams as the drier Sapphire Mountains (Briar and Dutton, 2000).

**Stream Gaging Stations**

The USGS maintains four gaging stations within the TPA, as detailed below in **Table B2-1**. An additional 18 stations were formerly present in the TPA but are now inactive. The USGS gaging are also shown on **Map A-9** in Appendix A.

**Table B2-1. Stream Gages in the Bitterroot TPA**

| Name | Number | Drainage Area | Agency | Period of Record |
|---|---|---|---|---|
| Bitterroot River nr Missoula | 12352500 | 2,814 miles2 | USGS | 1898-1904; 1989- |
| Bitterroot River nr Florence | 12351200 | 2,354 miles2 | USGS | 1957- |
| Bitterroot River at Bell Crossing nr Victor MT | 12350250 | 1,963 miles2 | USGS | 1987- |
| Bitterroot River nr Darby | 12344000 | 1,049 miles2 | USGS | 1937- |

**Stream Flow**

Stream flow within the TPA generally peaks in the late spring, declines in the summer, and remains stable through the winter (Briar and Dutton, 2000).

Stream flow data is based on records from the USGS stream gages described above, and is available on the Internet from the USGS ( 2010). Flows in the Bitterroot River and its tributaries vary considerably over a calendar year. Hydrographs summarizing flows at two stations (Darby and Missoula) are provided in **Figures A-1 through A-4** in Appendix A. The hydrographs are based on weekly mean flows over 72-year and 25-year periods of record.

Monthly mean discharges in the mainstem Bitterroot River vary over an order of magnitude. Statistically, flow peaks in June and is lowest in January. Annual peak flows occur almost exclusively (>97%) in May and June.

## B2.7 Groundwater

**Hydrogeology**
Groundwater is present in both valley and bedrock aquifers. Porosity in valley aquifers is determined by the type of sediment, with coarse-grained, well-sorted sediments (*e.g*. gravel, coarse sand) having the highest porosity. Porosity in bedrock aquifers is of two types: primary (interstitial spaces between sediment grains) and secondary (void space created by dissolution or structural deformation). Recharge of the valley aquifers occurs from infiltration of precipitation, seepage from irrigation canals, stream loss, and flow out of the adjacent bedrock aquifers. Bedrock aquifers are primarily recharged by infiltration of melting snow pack (Briar and Dutton, 2000).

Due to the importance of groundwater for drinking water and irrigation, several studies have been published on the hydrogeology of the Bitterroot Valley [*e.g.* (Kendy and Tresch, 1996) (Briar and Dutton, 2000)]. In general, there are two principal aquifers: the shallow alluvial aquifer and the deeper basin-fill aquifer composed of older sedimentary deposits. These aquifers are delineated based on their differing composition and location, but they are hydraulically connected.

The average groundwater flow velocity in the bedrock is probably several orders of magnitude lower than in the valley fill sediments. Bedrock groundwater flow is complicated by variability in lithology and geologic structures. 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.

**Groundwater Quality**
Briar and Dutton (2000) reported that groundwater in the Bitterroot Valley is predominantly of a calcium-bicarbonate character.

The Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC) program monitors and samples a statewide network of wells (MBMG, 2011). As of October 2009, the GWIC database reported 18,037 wells within the TPA. Water quality data are available for 103 of those wells. 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. The locations of these data points are shown on **Map A-10** in Appendix A.

There are 145 public water supplies within the TPA, all but 2 of which use groundwater for their supply. Pinesdale and Stevensville have surface water supplies. The majority of these are small transient, non-community systems (*i.e*. that serve a dynamic population of more than 25 persons daily). There are 38 community water systems within the TPA. Water quality data are available from these utilities via the Safe Drinking Water Information System (SDWIS) State database (DEQ, 2007), although these data reflect the finished water provided to the public, not the quality of water at the source.

## B2.8 Climate

The wettest months in the TPA are May and June. Annual average precipitation ranges from 13-83 inches in the Bitterroot TPA. The Bitterroot Mountains receive considerably more precipitation than the Sapphire Range. In a water resources study of water years 1939-1958 (Swenson, 1972) the USGS calculated that runoff from the western side of the valley is greater than that from the eastern side by a factor of 4 (33.6 inches versus 7.8 inches).; **Map A-11** in Appendix A shows the distribution of average annual precipitation. The precipitation data are mapped by Oregon State University's PRISM Group, using records from National Oceanic and Atmospheric Administration (NOAA) stations (PRISM, 2010).

### Climate Stations

The National Oceanic and Atmospheric Administration currently operate five weather stations in the TPA. See **Tables B2-2 through B2-6** for climate summaries from these stations. Climate data are provided by the Western Regional Climate Center, operated by the Desert Research Institute of Reno, Nevada.

The USDA Natural Resources Conservation Service operates four Snowpack Telemetry (SNOTEL) monitoring stations within the TPA. These sites include: Skalkaho Summit (13C03S), Daly Creek (13C39S), Twin Lakes (14C08S), and Twelvemile Creek (14C13S). **Map A-11** in Appendix A shows the locations of the NOAA and SNOTEL stations, in addition to average annual precipitation.

**Table B2-2. Monthly Climate Summary: Stevensville**

Stevensville, Montana (247894) Period of Record : 8/23/1911 to 7/31/2010

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Max. Temperature (F) | 33.3 | 39.8 | 49.0 | 59.6 | 68.2 | 75.3 | 85.3 | 83.6 | 72.3 | 59.1 | 43.4 | 34.5 | 58.6 |
| Average Min. Temperature (F) | 15.2 | 19.1 | 24.6 | 30.6 | 37.4 | 44.0 | 47.3 | 45.3 | 38.3 | 30.6 | 23.3 | 17.0 | 31.1 |
| Average Total Precipitation (in.) | 1.05 | 0.83 | 0.77 | 0.83 | 1.49 | 1.62 | 0.84 | 0.92 | 1.08 | 0.87 | 1.06 | 1.08 | 12.44 |
| Average Total Snowfall (in.) | 6.8 | 5.1 | 3.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 2.6 | 5.1 | 23.9 |
| Average Snow Depth (in.) | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 |

**Table B2-3. Monthly Climate Summary: Western Ag Research Station**

Western Ag Research Station, Montana (248783) Period of Record : 4/01/1965 to 7/31/2010

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Max. Temperature (F) | 35.0 | 41.8 | 50.2 | 58.8 | 67.5 | 75.5 | 84.5 | 83.1 | 72.1 | 59.1 | 43.7 | 34.4 | 58.8 |
| Average Min. Temperature (F) | 18.1 | 21.5 | 26.5 | 31.6 | 38.4 | 45.0 | 49.3 | 47.8 | 40.5 | 32.0 | 24.2 | 17.5 | 32.7 |
| Average Total Precipitation (in.) | 0.74 | 0.49 | 0.65 | 0.96 | 1.63 | 1.57 | 0.84 | 1.06 | 1.03 | 0.73 | 0.68 | 0.71 | 11.11 |
| Average Total Snowfall (in.) | 1.9 | 1.7 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 2.3 | 7.2 |
| Average Snow Depth (in.) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table B2-4. Monthly Climate Summary: Hamilton**
Hamilton, Montana (243885) Period of Record : 6/01/1895 to 7/31/2010

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Max. Temperature (F) | 34.8 | 40.6 | 49.2 | 59.2 | 67.9 | 74.9 | 84.8 | 83.1 | 72.4 | 59.8 | 45.2 | 35.9 | 59.0 |
| Average Min. Temperature (F) | 16.7 | 20.2 | 26.3 | 32.8 | 39.6 | 45.9 | 50.4 | 48.8 | 41.5 | 33.2 | 25.0 | 18.4 | 33.2 |
| Average Total Precipitation (in.) | 0.97 | 0.79 | 0.77 | 0.87 | 1.58 | 1.68 | 0.80 | 0.86 | 1.08 | 0.90 | 1.03 | 0.98 | 12.32 |
| Average Total Snowfall (in.) | 7.4 | 5.1 | 4.0 | 0.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 3.3 | 5.2 | 26.3 |
| Average Snow Depth (in.) | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |

**Table B2-5. Monthly Climate Summary: Darby**
Darby, Montana (242221) Period of Record : 9/01/1898 to 7/31/2010

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Max. Temperature (F) | 35.7 | 41.6 | 49.1 | 58.3 | 66.9 | 74.2 | 84.4 | 82.9 | 72.4 | 60.9 | 45.4 | 37.1 | 59.1 |
| Average Min. Temperature (F) | 17.5 | 20.8 | 25.6 | 31.3 | 37.8 | 43.6 | 47.8 | 46.3 | 39.7 | 32.9 | 25.1 | 19.3 | 32.3 |
| Average Total Precipitation (in.) | 1.43 | 1.14 | 1.07 | 1.07 | 1.79 | 1.92 | 0.89 | 0.98 | 1.26 | 1.14 | 1.63 | 1.43 | 15.75 |
| Average Total Snowfall (in.) | 8.7 | 9.2 | 5.7 | 1.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 1.0 | 4.9 | 8.4 | 40.1 |
| Average Snow Depth (in.) | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 |

**Table B2-6. Monthly Climate Summary: Lolo Hot Springs 2 NE**
Lolo Hot Springs 2 NE, Montana (245146) Period of Record : 1-/01/1959 to 7/31/2010

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Max. Temperature (F) | 32.2 | 38.8 | 43.5 | 53.3 | 64.6 | 72.7 | 83.1 | 81.6 | 70.8 | 55.8 | 40.7 | 32.3 | 55.8 |
| Average Min. Temperature (F) | 13.5 | 17.1 | 19.3 | 25.7 | 31.6 | 38.4 | 40.5 | 39.7 | 32.9 | 27.2 | 22.0 | 14.9 | 26.9 |
| Average Total Precipitation (in.) | 3.43 | 1.99 | 2.07 | 1.64 | 1.92 | 2.27 | 1.14 | 1.38 | 1.44 | 1.78 | 2.42 | 2.74 | 24.22 |
| Average Total Snowfall (in.) | 32.0 | 17.4 | 13.0 | 6.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 1.5 | 10.5 | 21.9 | 103.2 |
| Average Snow Depth (in.) | 14 | 13 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 4 |

# B3.0 Ecological Parameters

## B3.1 Vegetation

The primary cover in the TPA is conifer forest. Spruce-Fir communities dominate in the Bitterroot Range. Lodgepole Pines are more common in the Sapphire Range. Land cover is shown on **Maps A-12 and A-13** in Appendix A. Data on vegetative cover is from the ReGAP project (Montana Natural Heritage Program,2009) and land use and land cover data are from the USGS National Land Cover Dataset (Homer et al.,2004).

## B3.2 Aquatic Life

Two fish species found in the TPA are of particular note. Bull trout, and to a lesser extent, westslope cutthroat trout, are viewed as an important indicator species for environmental disturbance, due to their specific requirements for spawning and rearing habitat and general sensitivity of each life history stage (Fraley and Shepard, 1989). Bull trout are designated “threatened” by the U.S. Fish and Wildlife Service (USFWS). Westslope cutthroat trout are designated “Species of Concern” by Montana Department of Fish, Wildlife and Parks (FWP). Within the TPA, the USFWS has designated 131 miles of stream as bull trout critical habitat. Critical habitat is designated in the Bitterroot River and in Blodgett, Burnt Fork, Fred Burr, Mill, Skalkaho, and Sleeping Child Creeks. Non-native brook, rainbow and brown trout are also present in the TPA.

Data on fish species distribution are developed and provided by FWP (Montana Department of Fish, Wildlife and Parks, 2010). Fish species distribution is shown on **Map A-14** in Appendix A.

## B3.3 Fires

The United States Forest Service (USFS) Region 1 office and the USFS remote sensing applications center provide data on fire locations from 1940 through 2009. Large areas of the TPA have burned within the last two decades, particularly in the Sapphire Range. The Bear and Coyote fires of 2000 burned much of the southeastern portion of the TPA, an area that includes the headwaters of Skalkaho Creek and much of the drainages of Sleeping Child and North Fork Rye Creeks. Fire history is shown in **Map A-15** in Appendix A.

# B4.0 CULTURAL PARAMETERS

## B4.1 POPULATION

An estimated 68,000 persons lived within the TPA in 2000 (NRIS, 2002). Nearly half (33,093) of that population is reported from Missoula County, which includes portions of Missoula and its southern suburbs. Some of the population is concentrated in or near the towns and unincorporated communities: Hamilton, Lolo, Stevensville, Grantsdale, Florence, Victor, Pinesdale, Darby, Corvallis and Woodside. These communities had a cumulative population of 13,584 in the 2000 census. The remaining population is distributed across the valley floor. Much of the TPA is unpopulated. Population estimates are derived from census data (United States Census Bureau, 2000), based upon the populations reported from census blocks with centroids within the TPA boundary. Census data are shown in **Map A-16** in Appendix A.

## B4.2 LAND OWNERSHIP

Land ownership data are provided by the Montana Natural Heritage Program via the Natural Resources Information System (NRIS) website ( 2010) and are shown on **Map A-17** in Appendix A and in **Table B4-1**. The dominant landholder is the USFS, which administers 57% of the Bitterroot TPA, mostly in the higher elevations. Private land is extensive. Individual private smallholdings comprise 33.5% of the Bitterroot TPA; the Plum Creek Timber Company owns another 7% of the TPA.

**Table B4-1. Land Ownership**

| Owner | Acres | Square Miles | % of Total |
|---|---|---|---|
| US Forest Service | 686,580 | 1,072.78 | 56.6% |
| Private | 406,469 | 635.11 | 33.5% |
| Plum Creek Timber Co. | 81,288 | 127.01 | 6.7% |
| Montana State Trust | 24,537 | 38.34 | 2.0% |
| Montana FWP | 8,956 | 13.99 | 0.7% |
| US FWS | 2,677 | 4.18 | 0.2% |
| Water-reserved/withdrawn by federal agency | 1,485 | 2.32 | 0.1% |
| City Government | 242 | 0.38 | <0.1% |
| US Dept of Defense | 29 | 0.05 | <0.1% |
| Montana Dept of Transportation | 13 | 0.02 | <0.1% |
| Five Valleys Land Trust | 6 | 0.01 | <0.1% |
| BLM | 5 | 0.01 | <0.1% |
| Water-navigable (MT DNRC) | 1 | 0.00 | <0.1% |

## B4.3 LAND USE AND LAND COVER

Land cover within the Bitterroot TPA is dominated by evergreen forest. Information on land use is based on the USGS National Land Cover Dataset (2000). The data are at 1:250,000 scale. Land use is illustrated on **Map A-13** (Appendix A) and **Table B4-2**.

**Table B4-2. Land Use and Land Cover**

| Land Use | Acres | Square Miles | % of Total |
|---|---|---|---|
| Evergreen Forest | 642,101 | 1,003.28 | 52.9% |
| Grassland Herbaceous | 198,789 | 310.61 | 16.4% |
| Shrubland | 150,409 | 235.01 | 12.4% |
| Pasture/Hay | 99,571 | 155.58 | 8.2% |
| Bare Rock | 55,032 | 85.99 | 4.5% |
| Small Grains | 28,574 | 44.65 | 2.4% |
| Woody Wetlands | 8,458 | 13.22 | 0.7% |
| Transitional | 6,499 | 10.15 | 0.5% |
| Water | 5,294 | 8.27 | 0.4% |
| Fallow | 4,322 | 6.75 | 0.4% |
| Emergent Herbaceous Wetlands | 4,292 | 6.71 | 0.4% |
| Commercial/Industrial/Transportation | 2,903 | 4.54 | 0.2% |
| Deciduous Forest | 2,418 | 3.78 | 0.2% |
| Low Intensity Residential | 1,904 | 2.98 | 0.2% |
| Row Crops | 919 | 1.44 | 0.1% |
| Mixed Forest | 767 | 1.20 | 0.1% |
| Urban/Recreational Grass | 424 | 0.66 | 0.03% |
| High Intensity Residential | 208 | 0.33 | 0.02% |
| Perennial Ice and Snow | 100 | 0.16 | 0.01% |

**Irrigation and Dams**

A substantial quantity of streamflow within the Bitterroot River watershed is diverted and used for irrigation throughout the valley. **Map A-18** in Appendix A shows locations of irrigation diversions and dams within the TPA, and also chronically dewatered streams.

## B4.4 Transportation Networks

Transportation networks (road and railroads) are illustrated on **Map A-19** in Appendix A.

**Roads**

The principal transportation routes in the TPA are US Highways 93 and 12. Highway 93 runs the length of the Bitterroot Valley, and Highway 12 runs along Lolo Creek. The network of unpaved roads on public and private lands will be further characterized as part of the sediment source assessment in **Section 5.0**.

**Railroads**

An active Montana Rail Link railway extends from Missoula to Darby. Information on traffic and use is not available.

## B4.5 Mining

The TPA's mining history is described in DEQ's Abandoned Mine Lands historical narratives (MDEQ,2009). Mining never became as prominent in the Bitterroot Valley as in other watersheds in western Montana. Abandoned and inactive mines are present, but at relatively low density. Placer mines were not significantly productive, and neither were subsequent lode mines. The most significant mining district within the TPA was the Woodman or Lolo district, located in the Lolo Creek subwatershed. Abandoned mine inventory locations are plotted on **Map A-20** in Appendix A. Lode mines are nearly absent in the Bitterroot Range, with the exception of the Bass Creek and Lolo Creek drainages.

## B4.6 Timber Harvest

The Bitterroot TPA contains portions of both the Bitterroot and Lolo National Forests. Within the Bitterroot portions of the national forests, a total of 3,986 timber harvests have occurred between 1906 and 2007. The total acreage harvested during this time was 88,228 acres. Timber harvests have ranged in size from a low of an acre to a high of 468 acres. **Map A-21** in Appendix A shows the majority of timber harvests have occurred in the northeastern and southwestern portions of the planning area.

Timber harvests peaked in the 1960s and 1970s. Approximately 59% (52,431 acres) of the total timber harvests within the Bitterroot TPA took place during these two decades (**Table B4-3**). Additional timber harvest may also have occurred on private lands, though no data are available for those areas.

**Table B4-3. Timber Harvest on USFS lands**

| Decade | Acreage |
|---|---|
| 1906-1910 | 242 |
| 1935 -1940 | 84 |
| 1941-1950 | 479 |
| 1951-1960 | 4,573 |
| 1961-1970 | 29,887 |
| 1971-1980 | 22,544 |
| 1981-1990 | 15,940 |
| 1991-2000 | 10,594 |
| 2001-2007 | 3,885 |

## B4.7 Wastewater

The communities of Hamilton, Lolo, Stevensville, Victor, Darby and Corvallis are sewered. Hamilton, Lolo, Stevensville and Darby systems discharge to surface water. These discharges are permitted under the Montana Pollution Discharge Elimination System (MPDES). **Table B4-4** shows the MPDES permitted facilities within the TPA, including general stormwater permits for industrial and mining activities.

The Victor wastewater treatment system consists of lagoons, and sludge is land applied at agronomic uptake rates and therefore does not need a Montana Ground Water Pollution Control System (MGWPCS) permit. The Corvallis wastewater treatment systems consist of a wetland system, aerated lagoons and infiltration ponds that discharge to groundwater and therefore is required to have an active MGWPCS permit.

As of June 2010, there are seven active or pending MGWPCS groundwater discharge permits for human waste disposal within the TPA (**Table B4-5**). These include the Corvallis wastewater treatment plant, five subdivisions (Wildflower, Falcon Estates, One Horse Estates, Hawks Landing and Grant Addition) and Peak Health & Wellness Center.

Multiple-user systems have 3-14 connections, serve fewer than 25 persons and are not regulated via the MGWPCS unless they are aerobic package plant systems, mechanical treatment plants, and nutrient removal systems, which require a high degree of operation and maintenance or systems which require monitoring pursuant to ARM 17.30.517(1)(d)(ix). The DEQ Subdivision Review Section database records 16 multiple-user wastewater treatment systems that were approved since 2000. Records are not available for earlier approvals.

Outside of the sewered communities, wastewater treatment and disposal is via septic system drainfields. DEQ estimates that the TPA includes ~18,000 residential septic systems. The estimate is based upon a GIS layer of residential structures. The highest densities are clustered south of Missoula, and around Lolo and Hamilton. Other population centers such as Grantsdale, Darby, Woodside, Victor, Stevensville, and Florence corresponded to increased density of septic systems, as compared with the "background" density of 11-50 drainfields per square mile across much of the valley. Septic system density and permitted wastewater discharge locations are shown on **Map A-22** in Appendix A.

**Table B4-4: Active MPDES Permits in the Bitterroot TMDL Planning Area**

| Permit Type | MPDES No | County | Facility | Receiving Stream |
|---|---|---|---|---|
| WWTP – Individual | MT0020028 | Ravalli | City of Hamilton WWTP | Bitterroot River |
| WWTP – Individual | MT0020168 | Missoula | Lolo WWTP | Bitterroot River |
| WWTP – Individual | MT0022713 | Ravalli | Stevensville WWTP | Bitterroot River |
| WWTP – General (sewage treatment lagoon) | MTG580011 | Ravalli | Town of Darby WWTF | Bitterroot River |
| Industrial Stormwater (Fabricated Metal) | MTR000069 | Ravalli | Selway Corporation | Flood Irrigation Ditch (Summer only) |
| Industrial Stormwater (Prefab Wood Bldgs) | MTR000260 | Ravalli | Alpine Log Homes | Bitterroot River |
| Industrial Stormwater (Used Motor Vehicle Parts) | MTR000264 | Ravalli | Truck Parts Unlimited | Bitterroot River |
| Industrial Stormwater (Airports) | MTR000399 | Ravalli | Ravalli County Airport | Gird Creek |
| Industrial Stormwater (Sawmill & Planing Mill) | MTR000406 | Ravalli | J & R Planing Inc | Tie Chute Creek |
| Mining Stormwater (Construction Sand & Gravel) | MTR300074 | Missoula | JTL Group Inc - Pattee Canyon Pit | Pattee Creek |
| Mining Stormwater (Construction Sand & Gravel) | MTR300173 | Missoula | Stan Billingsley - Billingsley Placer Mine | Lolo Creek |
| MS4* | MTR040007 | Missoula | City of Missoula | Bitterroot River* |

* Only a portion of the Missoula Municipal Separate Storm Sewer System (MS4) permit discharges within the TPA and to the Bitterroot River

**Table B4-5: Active Groundwater Permits in the Bitterroot TPA**

| MPDES No | County | Facility | Permit Status |
|---|---|---|---|
| MTX000122 | Ravalli | Corvallis County WWTF | Effective |
| MTX000142 | Ravalli | Bitterroot Land Co – Wildflower Subdivision | Effective |
| MTX000163 | Ravalli | Kearns Properties LLC – Grantsdale Addition | Effective |
| MTX000166 | Ravalli | Falcon Estates Subdivision | Effective |
| MTX000170 | Ravalli | Kootenai Creek Village | Effective |
| MTX000185 | Missoula | Bitterroot Resort WWTP | Pending |
| MTX000208 | Ravalli | One Horse Estates Sewer System | Effective |
| MTX000209 | Ravalli | Hawk's Landing Homeowners Assoc. – Community Septic System | Pending |
| MTX000213 | Missoula | Peak Health and Wellness Center | Effective |

# B5.0 REFERENCES


Briar, David W. and DeAnn M. Dutton. 2000. Hydrogeology and Aquifer Sensitivity of the Bitterroot Valley, Ravalli County, Montana. Helena, MT: US Geological Survey.

Fraley, John J. and Bradley B. Shepard. 1989. Life History, Ecology and Population Status of Migratory Bull Trout (Salvelinus Confluentus) in the Flathead Lake and River System, Montana. *Northwest Science.* 63(4): 133-143

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing. U.S. Geologic Survey.

Kendy, Eloise and Ruth E. Tresch. 1996. Geographic, Geologic, and Hydrologic Summaries of Intermontane Basins of the Northern Rocky Mountains, Montana. Helena, MT: US Geological Survey.

Montana Bureau of Mines and Geology. 2011. Groundwater Information Center. http://mbmggwic.mtech.edu/.

Montana Department of Environmental Quality. 2007. Montana Safe Drinking Water Information System. http://www.epa.gov/enviro/html/sdwis/sdwis_query.html.

-----. 2009. Abandoned Mine Information: Historical Narratives. http://www.deq.mt.gov/abandonedmines/linkdocs/default.mcpx.

-----. 2010. Montana 2010 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality, Water Quality Planning Bureau.

Montana Department of Fish, Wildlife and Parks. 2010. Fish Distribution Streams. Helena, MT: Montana Department of Fish, Wildlife and Parks. http://fwp.mt.gov/doingBusiness/reference/gisData/dataDownload.html.

Montana Natural Heritage Program. 2009. Montana Land Cover / Land Use Theme. Based on Classifications Originally Developed by the University of Idaho, Sanborn and the MNHP for the Pacific Northwest ReGAP Project. Helena, MT.

Montana State Library. 2002. Natural Resource Information System (NRIS): On-Line Interactive Map Builder. Helena, MT: Montana State Library. http://nris.state.mt.us/mapper/.

Natural Resource Information System and Montana Natural Heritage Program. 2010. Montana Land Ownership Data. Helena, MT: Montana State Library. http://mtnhp.org/stew.asp; http://nris.mt.gov/gis/bundler/.

Natural Resources Conservation Service, Soil Survey Staff. 2008. Soil Survey Geographic (SSURGO) Database for Bitterroot Valley Area, Montana. United States Department of Agriculture. http://soildatamart.nrcs.usda.gov/.

Oregon State University, PRISM Climate Group. 2010. PRISM Data. http://www.prism.oregonstate.edu/.

Renard, Kenneth G., George R. Foster, Glenn A. Weesies, Donald K. McCool, and Daniel C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE).

Ross, Clyde P., D. A. Andres, and Irving J. Witkind. 1955. Geologic Map of Montana.

Schwartz, G. E. and R. B. Alexander. 1995. Soils Data for the Conterminous United States Derived From the NRCS State Soil Geographic (STATSGO) Data Base. [Original Title: State Soil Geographic (STATSGO) Data Base for the Conterminous United States.]. USGS. http://water.usgs.gov/GIS/metadata/usgswrd/XML/ussoils.xml.

Swenson, H. A. 1972. "Chemical Quality of Water," in *Geology and Water Resources for the Bitterroot Valley, Southwestern Montana*, McMurtrey, R. G., Konizeski, Richard L., Johnson, M. V., and Bartells, J. H. U.S. Geological Survey Water-Supply Paper 1889, (Washington, DC: U.S. Govt Printing Office)

U.S. Geological Survey. 2010. USGS Current Streamflow. http://waterwatch.usgs.gov/new/index.php.

United States Census Bureau. 2000. 2000 Census Data. http://factfinder.census.gov/home/saff/main.html?_lang=en.

United States Geological Survey. 2000. National Land Cover Data for Montana, Vector Format. Montana State Library Natural Resource Information System. http://nris.mt.gov/nsdi/nris/nlcd/nlcdvector.html. Accessed 7/1/06.

Wischmeier, Walter H. and Dwight D. Smith. 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Washington, D.C.: United States Department of Agriculture. http://topsoil.nserl.purdue.edu/usle/AH_537.pdf.

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

# Appendix C - Regulatory Framework and Reference Condition Approach

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

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# C1.0 TMDL Development Requirements

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

Since 2004, EPA has requested that states combine the 303(d) list with the 305(b) report containing an assessment of Montana's water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) list also includes identification of the probable cause(s) of the water quality impairment (e.g. pollutants such as metals, nutrients, sediment, pathogens or temperature), and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each waterbody is used for consistency. The impairment status determination methodology is identified in DEQ's Water Quality Assessment Process and Methods found in Appendix A of Montana's Water Quality Integrated Report (DEQ 2006).

Under Montana state law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State law and Section 303(d) of the CWA require states to develop all necessary TMDLs for impaired or threatened waterbodies. There are no threatened waterbodies within the Bitterroot TMDL Planning Area (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 (violated). TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS. **Section 4.0** of the main document provides a description of the components of a TMDL.

To satisfy the federal CWA and Montana state law, TMDLs are developed for each waterbody-pollutant combination identified on Montana's 303(d) list of impaired or threatened waters, and are often presented within the context of a water quality restoration or protection plan. State law (Administrative Rules of Montana 75-5-703(8)) also directs Montana DEQ to "…support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing federal, state, or local regulations.

# C2.0 Applicable Water Quality Standards

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all water quality standards are met. Water quality standards form the basis for the targets described in **Sections 5.4 and 6.4**. Pollutants addressed in this framework water quality improvement plan include sediment and temperature. This section provides a summary of the applicable water quality standards for these pollutants.

## C2.1 Classification and Beneficial Uses

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

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

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

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table C2-1**. All waterbodies within the Bitterroot TPA are classified as B-1 (see **Section 3.1 and Table 3-1** in the main document for individual stream classifications).

**Table C2-1: 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. |
| **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. |

## C2.2 STANDARDS

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

**Numeric Standards**

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular DEQ-7 (DEQ 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.

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

**Narrative Standards**

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

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

## C.2.2.1 Sediment Standards

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in **Table C2-2**. 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 C2-2**).

**Table C2-2: Applicable Rules for Sediment Related Pollutants**

| Rule | Standard |
|---|---|
| 17.30.623(2) | No person may violate the following specific water quality standards for waters classified B-1: |
| 17.30.623(2)(d) | The maximum allowable increase above naturally occurring turbidity is 5 NTU for B-1 except as permitted in 75-5-318, MCA. |

**Table C2-2: Applicable Rules for Sediment Related Pollutants**

| Rule | Standard |
|---|---|
| 17.30.623(2)(f) | 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. |
| 17.30.637(1) | State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: |
| 17.30.637(1)(a) | Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines; |
| 17.30.637(1)(d) | Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life. |
| 17.30.602(19) | "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. |
| 17.30.602(25) | "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. |

### C.2.2.2 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 most of the middle segment of the Bitterroot River are likely at or greater 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 0.5°F (0.23°C).

# C3.0 Reference Conditions

## C3.1 Reference Conditions as Defined in DEQ's Standard Operating Procedure for Water Quality Assessment (2006)

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 waterbodies greatest potential for water quality given historic land use activities.

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.

Also, Montana WQS do not contain specific provisions addressing nutrients (nitrogen and phosphorous), or detrimental modifications of habitat or flow. However, these factors are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference conditions approach is used to determine if beneficial uses are supported when nutrients, flow, or habitat modifications are present.

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 presettlement 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 reference data are available and uses the secondary approach to estimate reference condition when there is no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

## C3.2 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 (Hensel 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 25$^{th}$ and 75$^{th}$ 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 C3-1** is an example boxplot type presentation of the median, 25$^{th}$ and 75$^{th}$ 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 25$^{th}$ 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 75$^{th}$ 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 (EPA 2000). 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 (DEQ 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.

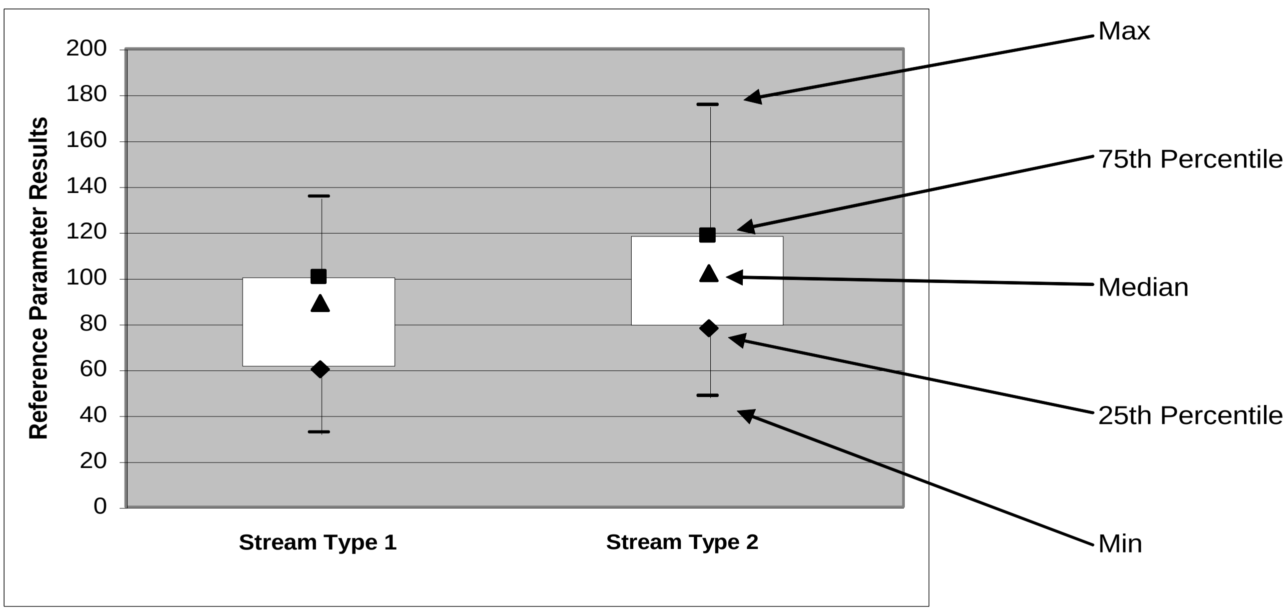


**Figure C3-1. Boxplot Example for Reference Data.**

The above 25th – 75th percentile statistical approach has several considerations:

1. It is a simple approach that is easy to apply and understand.
2. About 25 percent 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.
3. About 25 percent of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25th to 75th percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
4. 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.

5. 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 **Table C2-2**. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, cold water 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 (DEQ 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 (EPA 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 percent to 75 percent of the results from the whole data distribution represent questionable water quality. **Figure C3-2** is an example statistical distribution where higher values represent better water quality. In **Figure C3-2**, the median and $25^{th}$ percentiles represent potential target values versus the median and $75^{th}$ percentiles discussed above for regional reference distribution. Whether you use the median, the 25th 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.

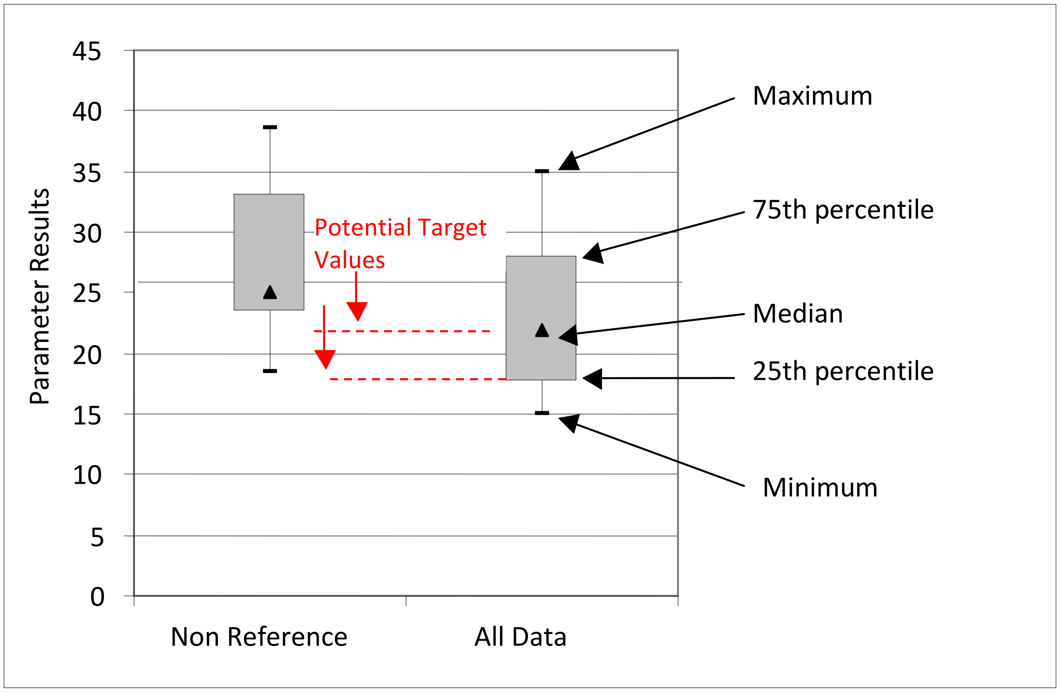


**Figure C3-2. Boxplot example for the use of all data to set targets.**

# REFERENCES

Hensel, D.R., and R.M. Hirsch. 1995. Statistical Methods in Water Resources. Studies in Environmental Science 49. Elsevier Science Publishers B.V., Amsterdam, The Netherlands.

Montana Department of Environmental Quality (DEQ). 1999. Requirements for Non-Point Sources of Pollution Impacting High-Quality and Impaired Waters. DEQ Internal Guidance. Helena, MT.

DEQ. 2004. Wadeable Streams of Montana's Hi-Line Region: An Analysis of Their Nature and Condition, with an Emphasis on Factors Affecting Aquatic Plant Communities and Recommendations to Prevent Nuisance Algae Conditions. Available at: http://www.deq.state.mt.us/wqinfo/Standards/Master_Doc_DII.pdf.

DEQ. 2006. Water Quality Assessment Process and Methods Standard Operating Procedure. Appendix A to 303(d) 2000 – 2004. WQPBWQM-001, Rev. 2, August 2006. Available at: http://www.deq.mt.gov/wqinfo/QAProgram/SOP%20WQPBWQM-001.pdf.

DEQ. 2010. Circular DEQ-7: Montana Numeric Water Quality Standards. Montana Department of Environmental Quality, Planning, Prevention, and Assistance Division – Water Quality Standards Section. Helena, Montana. August 2010. Available at: http://deq.mt.gov/wqinfo/Standards/default.mcpx.

Suplee, M. W., V. Watson, A. Varghese, and J. Cleland. 2008. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadable Streams and River. Montana Department of Environmental Quality, Helena, Montana.

United States Environmental Protection Agency (USEPA). 2000. Nutrient Criteria Technical Guidance Manual, Rivers and Steams. Washington, D.C.: United States Environmental Protection Agency, EPA-822-B00-002. Available at: http://www.epa.gov/waterscience/criteria/nutrient/guidance/rivers/

# APPENDIX D - 2007 SEDIMENT AND HABITAT DATA COLLECTION METHODS AND DATA SUMMARY – BITTERROOT TPA

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# D1.0 INTRODUCTION

This appendix includes a summary of the field protocols and results from stream channel and habitat data collected in the Bitterroot TPA during the summer of 2007 to facilitate sediment TMDL development. It is an excerpt from the Bitterroot TPA Base Parameter Report (PBS&J 2009), which is on file at DEQ and also contains site visit notes and summary statistics by monitoring site and reach type. During the field assessment, stream channel and habitat data was collected at a total of 32 monitoring sites on 23 streams (**Figure D-1**) following protocols established in *Longitudinal Field Methodology for the Assessment of Sediment and Habitat Impairments* (MTDEQ 2007a). Reach type as identified in this appendix and the Bitterroot TPA Base Parameter Report will differ from reach types in **Section 5 of the TMDL document**, as a result of ecoregion reassignment **(See Section 5.3.1.2 in the TMDL document)**; with streams originating within the Idaho Batholith ecoregion that were assessed in the 2007 DEQ field effort considered to be Idaho Batholith, and reaches located on streams that are split between Northern Rockies and Middle Rockies ecoregions assigned an ecoregion based on where the majority of the stream is located. Reach type was not modified in this appendix or the original report, and is provided without edits here to demonstrate the original sampling rationale.

## D1.1 AERIAL ASSESSMENT DATABASE

Prior to field data collection, each 303(d) listed stream segment was broken into several stream reaches based on Ecoregion, valley gradient, Strahler stream order and confinement through the use of GIS data layers and color aerial imagery. Stream reaches were delineated following the methodology outlined in *A Watershed Stratification Approach for TMDL Sediment and Habitat Impairment Verification* (MTDEQ 2007b). Stream reach data was then compiled into an Aerial Assessment Database, which included a total of 915 stream reaches on 23 stream segments in the Bitterroot TPA. With three categories of Level III Ecoregion, the Bitterroot TPA has a total of 72 possible combinations of Ecoregion, gradient, Strahler stream order and confinement. These 72 possible combinations will be referred to as "**reach types**" in this report.

*Reach Type - Unique combination of Ecoregion, gradient, Strahler stream order and confinement*

Out of the 72 possible reach types in the Bitterroot TPA, a total of 45 reach types were identified during the aerial assessment process. Sediment and habitat monitoring site assessments were performed within 11 of the 45 identified reach types.

### D1.1.1 Reach Types

A total of 11 distinct reach types were assessed in the Bitterroot TPA in 2007, with a total of 32 monitoring sites. Reach types were identified based on a unique combination of Ecoregion, valley gradient, Strahler stream order and confinement as determined through GIS analysis (**Table D-1**). Twenty-five of the monitoring sites occurred within the Middle Rockies Ecoregion, which comprised the majority of the TPA. Within the Middle Rockies, the majority of the assessments were performed at sites with valley gradients <2%, with a total of 18 sites on 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ order streams. Due to the extent of the dataset for low gradient streams in the Middle Rockies Ecoregion; data from these reach types is likely to be the most robust. Specific monitoring sites assessed in each reach type are presented in **Table D-2. Figure D-1** presents each monitoring site and Ecoregion in the Bitterroot TPA.

**Table D-1. Reach Types Assessed in the Bitterroot TPA.**

| Level III Ecoregion | Gradient | Strahler Stream Order | Confinement | Reach Type | Rosgen Stream Type (Potential) | Number of Monitoring Sites |
|---|---|---|---|---|---|---|
| Idaho Batholith | 0-<2% | 4 | U/M | IB-0-4-U/M | B3/4c | 1 |
| | | | | | | |
| | 2 to <4% | 3 | U/M | IB-2-3-U/M | B4 | 1 |
| | | | | | | |
| Middle Rockies | 0-<2% | 2 | U/M | MR-0-2-U/M | B3, B3c, C4, E4 | 3 |
| | | 3 | U/M | MR-0-3-U/M | B3c, C3, C4, E4 | 10 |
| | | 4 | U/M | MR-0-4-U/M | B3, B3c, C3, C4 | 5 |
| | | | | | | |
| | 2 to <4% | 1 | U/M | MR-2-1-U/M | B4 | 1 |
| | | 2 | U/M | MR-2-2-U/M | B3, B3c, B4, C3b, E4b | 5 |
| | | 3 | U/M | MR-2-3-U/M | B4 | 1 |
| | | | | | | |
| | >4% | 2 | U/M | MR-4-2-U/M | B4, E4b | 1 |
| | | | | | | |
| Northern Rockies | 0-<2% | 4 | U/M | NR-0-4-U/M | B4c, C3, C4 | 3 |
| | | | | | | |
| | 2 to <4% | 3 | U/M | NR-2-3-U/M | B3 | 1 |

**Table D-2. Monitoring Sites in Assessed Reach Types.**

| Level III Ecoregion | Reach Type | Reach ID |
|---|---|---|
| Idaho Batholith | IB-0-4-U/M | RYEC-28 |
| | | |
| | IB-2-3-U/M | NFRC-22 |
| | | |
| Middle Rockies | MR-0-2-U/M | KOOT-52, MILR-21, MILL-50 |
| | MR-0-3-U/M | AMBR-30, BEAR-30, LOST-43, MILR-33, NBEAR-08, NBFC-11, NBFC-15, SWEA-29, TINC-31/32, WILL-38 |
| | MR-0-4-U/M | RYEC-36, SKAL-33, SKAL-48, SLEE-43, THRE-35 |
| | | |
| | MR-2-1-U/M | MILR-11 |
| | MR-2-2-U/M | BASS-24, BASS-27, BLOD-49, LICK-19, MILL-43 |
| | MR-2-3-U/M | WILL-28 |
| | | |
| | MR-4-2-U/M | MCCL-15 |
| | | |
| Northern Rockies | NR-0-4-U/M | LOLO-26, LOLO-34, LOLO-56 |
| | | |
| | NR-2-3-U/M | SFLO-43 |

### *D1.1.1.1 Idaho Batholith*

The Idaho Batholith Ecoregion covers much of the western side of the Bitterroot TPA and included 2 monitoring sites. This Ecoregion encompasses the Bitterroot Mountains in the Selway-Bitterroot Wilderness Area on the west side of the Bitterroot River as well as the majority of the Rye Creek watershed on the east side of the Bitterroot River. No assessments were performed in this Ecoregion on the west side of the Bitterroot River since most of the area is in designated wilderness. Note that the two sites in the Rye Creek watershed are likely influenced by the large forest fires in 2000.

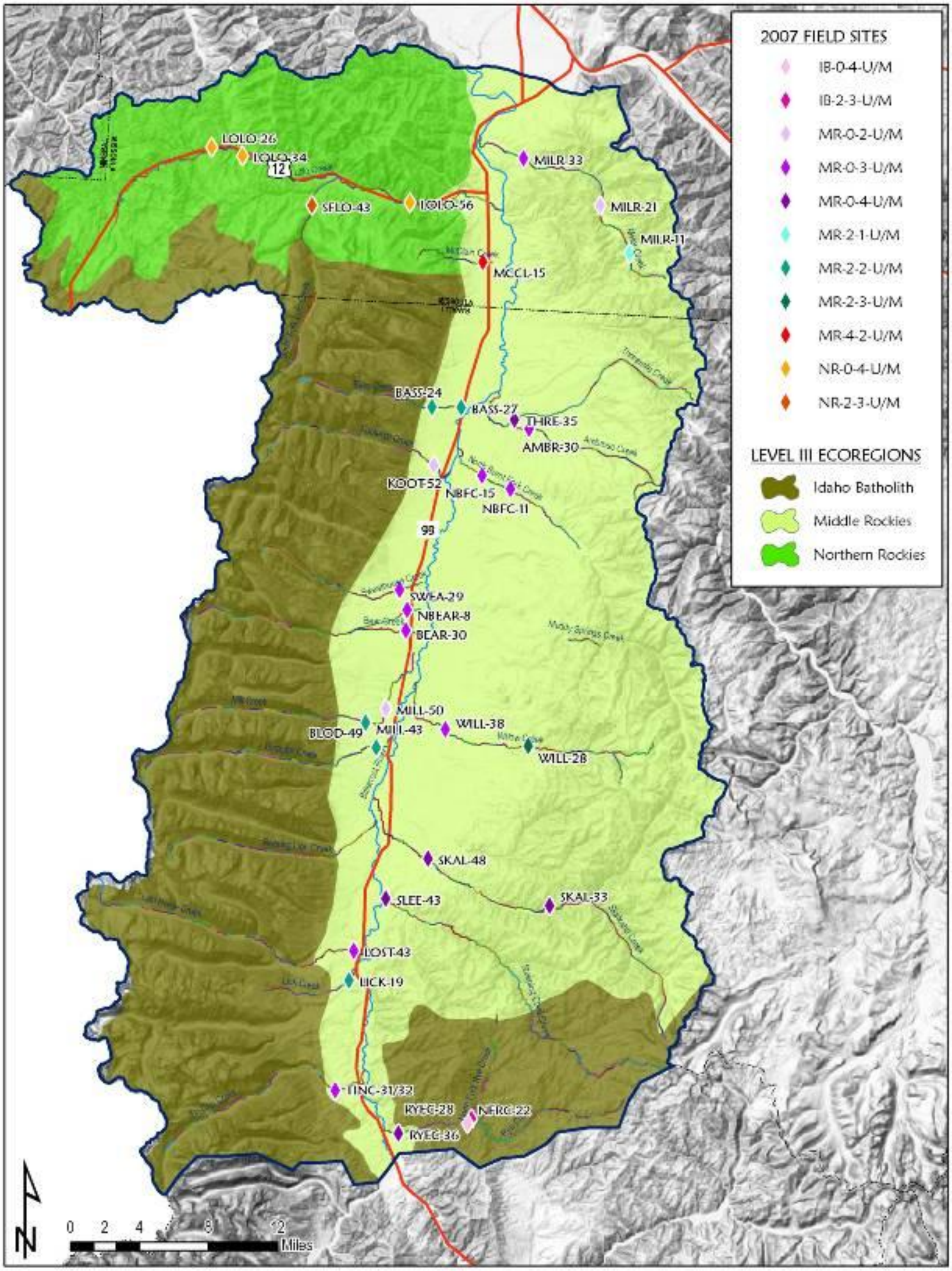
#### *D1.1.1.2 Middle Rockies*

The Middle Rockies Ecoregion includes the Sapphire Mountains on the east side of the Bitterroot River as well as valley bottom areas along the west side of the Bitterroot River. There were 25 monitoring sites in the Middle Rockies Ecoregion, the majority of which were located in low gradient valley bottom areas.

#### *D1.1.1.3 Northern Rockies*

The Northern Rockies Ecoregion covers much of the Lolo Creek watershed in the northern portion of the Bitterroot TPA and to the west of the Bitterroot River. There were 4 monitoring sites in this Ecoregion, all of which were located in the Lolo Creek watershed.

**Figure D-1. 2007 Bitterroot TPA Sediment and Habitat Monitoring Sites**



# D2.0 Field Data Collection Methodology

The following sections include descriptions for the various field methodologies that were employed for the stream assessments. The methods follow standard DEQ protocols for sediment and habitat assessments, as presented in the document, Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (MT DEQ 2007a). All field forms used in the study are standard forms used by DEQ for sediment and habitat assessments.

## D2.1 Survey Site Delineation

Stream survey sites were delineated beginning at riffle crests at the downstream ends of reaches. Survey sites were measured in the upstream direction at pre-determined lengths based on the bankfull width at the selected downstream riffle. Survey lengths of 500 feet were used for bankfull widths less than 10 feet; survey lengths of 1,000 feet were used for bankfull widths between 10 feet and 50 feet; and survey lengths of 2,000 feet were used for bankfull widths greater than 50 feet. Each survey site was divided into five equally sized study cells. The GPS locations of the downstream and upstream ends of the survey site were recorded and digital photographs were taken.

## D2.2 Field Determination of Bankfull

All members of the field crew participated in determining the bankfull elevation. 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. 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.

## D2.3 Channel Cross-sections

Channel cross-section measurements were performed at the first riffle in each cell using a line level and a measuring rod. Cross-sections were conducted in each cell containing a riffle feature. At each cross-section, depth measurements at bankfull were collected to a tenth of a foot across the channel at regular intervals. These intervals varied depending on channel width, following protocol in item 15, Section 2.3 of the Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (MT DEQ 2007a). The thalweg depth was recorded at the deepest point of the channel independent of the regularly spaced intervals. At each cross-section, GPS coordinates were recorded and photos were taken from the middle of the channel and across the channel, showing the tape across the stream.

## D2.4 Floodprone Width Measurements

The floodprone elevation was determined by multiplying the maximum depth value by two (Rosgen 1996). The floodprone 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 floodprone elevation. The total floodprone width was calculated by adding the bankfull channel width to the distances on either end of the channel to the floodprone elevation. When dense vegetation or other features prevented a direct line of tape from being strung, best professional judgment was used to determine the floodprone width.

## D2.5 Channel Bed Morphology

The length of the survey site occupied by pools and riffles was identified. Beginning from the downstream end of the survey site, the upstream and downstream stations of "dominant" riffle and pool stream features were recorded. Features were considered "dominant" when occupying over 50% of the stream width. Pools and riffles were measured from head crest or riffle crest, respectively, until the end of that feature (defined as the tail crest for pools). Stream features were identified per standard field method criteria (MT DEQ 2007a).

## D2.6 Residual Pool Depth

At each pool encountered, the maximum depth and the depth of the pool tail crest at its deepest point was measured (MT DEQ 2007a). No pool tail crest depth was recorded for dammed pools. The difference between the maximum depth and the tail crest depth is considered the residual pool depth.

## D2.7 Pool Habitat Quality

Qualitative assessments of each pool feature were undertaken, including the pool type, size, formative feature, and cover type, along with the depth of any undercut bank associated with the pool.

## D2.8 Fine Sediment in Pool Tail-outs

A measurement of the percent of fine sediment in pool tail-outs was taken using the grid toss method at the first and second scour pool of each cell. Grid toss readings were focused in those pool tail-out 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, following the methodology in Section 2.8 of Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (MT DEQ 2007a). 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 potential for spawning was recorded as Yes (Y), No (N), or Questionable (Q) at each measurement site.

## D2.9 Fine Sediment in Riffles

Using the same grid toss method as used in pools, measurements of fine sediment in riffles were performed. Grid tosses were performed before the pebble counts to avoid disturbances to fine sediments.

## D2.10 Woody Debris Quantification

The amount of large woody debris (LWD) was recorded along the entire assessment reach. Large pieces of woody debris located within the bankfull channel and which were relatively stable as to influence the channel form were counted as either single, aggregate or willow bunch. Further description of these categories is provided in Section 2.10 of Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (MT DEQ 2007a).

## D2.11 Riffle Pebble Count

One Wolman pebble count (Wolman 1954) was performed at the first riffle encountered in cells 1, 3 and 5, providing a minimum of 300 particle sizes measured within each assessment reach. Particle sizes were measured along their intermediate length axis (b-axis) and results were grouped into size categories. The pebble count was performed from bankfull to bankfull 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 Section 2.11 of Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments (MT DEQ 2007a).

## D2.12 Riffle Stability Index

In streams that had well-developed point bars, a Riffle Stability Index (RSI) evaluation was performed to determine the average size of the largest recently deposited particle. For streams in which well-developed point bars were present, a total of three RSI measurements were conducted, which consisted of intermediate axis (b-axis) measurements of 15 particles determined to be among the largest size group of recently deposited particles and which occur on over 10% of the point bar. During post-field data processing, the geometric mean of the dominant bar particle size measurements was calculated and the result was compared to the cumulative particle distribution from the riffle pebble count in an adjacent or nearby riffle.

## D2.13 Riparian Greenline Assessment

Along each monitoring site, an assessment of riparian vegetation cover was performed. Vegetation types were recorded at 10 to 20-foot intervals, depending on the bankfull channel width. The riparian greenline assessment included the general vegetation community type of the groundcover, understory and overstory on both banks. The ground cover vegetation (<1.5 feet tall) was described using the following categories: wetland, grasses or forbs, bare/disturbed ground, rock, or riprap. The understory (1.5 to 15 feet tall) and overstory (>15 feet tall) vegetation were described using the following categories: coniferous, deciduous, or mixed coniferous and deciduous. At 50-foot intervals, a riparian buffer width was estimated on either side of the bank. This width corresponded to the belt of vegetation buffering the stream from adjacent land uses.

## D2.14 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. The results of this assessment are reported in the companion document entitled Streambank Erosion Source Assessment Bitterroot TMDL Planning Area **(Appendix E)**.

## D2.15 Water Surface Slope

Water surface slope measurements were estimated using a clinometer.

## D2.16 Field Notes

At the completion of data collection at each survey site, field notes were collected by the field 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 lands-uses:

- Description of human impacts and their severity
- Description of stream channel conditions
- Description of streambank erosion conditions
- Description of riparian vegetation conditions

# D3.0 Data Summary

**Table D-3** presents sediment and habitat data for each individual reach sampled following the aforementioned assessment procedures.

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25th percentile | RYEC-28 | 14.0 | 1.4 | 13 | 21 | 4 | 5 | 0.8 | 18 | 45 | 65 | 0 |
| 75th percentile | RYEC-28 | 18.1 | 2.1 | 17 | 32 | 22 | 8 | 1.5 | | | 73 | 5 |
| minimum | RYEC-28 | 12.9 | 1.2 | 9 | 12 | 2 | 4 | 0.6 | | | 48 | 0 |
| maximum | RYEC-28 | 18.4 | 3.0 | 17 | 35 | 31 | 10 | 1.8 | | | 75 | 25 |
| median | RYEC-28 | 16.2 | 1.5 | 16 | 29 | 16 | 6 | 1.1 | | | 70 | 0 |
| mean | RYEC-28 | 15.9 | 1.8 | 14 | 26 | 15 | 7 | 1.1 | | | 66 | 6 |
| | | | | | | | | | | | | |
| 25th percentile | NFRC-22 | 14.7 | 1.3 | 10 | 20 | 13 | | 0.6 | 19 | 110 | 60 | 0 |
| 75th percentile | NFRC-22 | 15.6 | 2.5 | 19 | 29 | 26 | | 0.9 | | | 78 | 3 |
| minimum | NFRC-22 | 9.7 | 1.2 | 8 | 16 | 0 | | 0.4 | | | 58 | 0 |
| maximum | NFRC-22 | 21.9 | 2.7 | 24 | 34 | 29 | | 1.0 | | | 85 | 5 |
| median | NFRC-22 | 15.3 | 1.6 | 13 | 23 | 15 | | 0.7 | | | 75 | 0 |
| mean | NFRC-22 | 15.4 | 1.9 | 15 | 24 | 17 | | 0.7 | | | 71 | 2 |
| | | | | | | | | | | | | |
| 25th percentile | MILR-21 | 31.2 | 3.5 | 12 | 27 | 6 | 12 | 0.7 | 13 | 42 | 3 | 0 |
| 75th percentile | MILR-21 | 38.7 | 4.5 | 13 | 35 | 22 | 27 | 1.4 | | | 10 | 0 |
| minimum | MILR-21 | 14.8 | 3.5 | 11 | 25 | 4 | 0 | 0.5 | | | 0 | 0 |
| maximum | MILR-21 | 45.5 | 4.6 | 13 | 41 | 29 | 43 | 1.7 | | | 13 | 0 |
| median | MILR-21 | 31.3 | 3.9 | 13 | 30 | 14 | 19 | 1.0 | | | 8 | 0 |
| mean | MILR-21 | 32.3 | 4.0 | 12 | 32 | 15 | 20 | 1.0 | | | 7 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | AMBR-30 | 7.9 | 3.2 | 54 | 69 | 43 | 80 | 0.6 | 14 | 2 | 45 | 0 |
| 75th percentile | AMBR-30 | 10.2 | 6.7 | 61 | 80 | 71 | 100 | 0.8 | | | 55 | 0 |
| minimum | AMBR-30 | 7.7 | 2.1 | 54 | 64 | 37 | 43 | 0.5 | | | 15 | 0 |
| maximum | AMBR-30 | 13.2 | 7.3 | 67 | 86 | 84 | 100 | 0.8 | | | 65 | 5 |
| median | AMBR-30 | 8.6 | 5.0 | 54 | 74 | 51 | 93 | 0.7 | | | 50 | 0 |
| mean | AMBR-30 | 9.5 | 4.9 | 58 | 75 | 57 | 87 | 0.7 | | | 46 | 1 |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| 25th percentile | MILR-33 | 10.1 | 4.1 | 12 | 22 | 20 | | | 0 | 0 | 8 | 0 |
| 75th percentile | MILR-33 | 56.8 | 15.5 | 17 | 28 | 27 | | | | | 30 | 15 |
| minimum | MILR-33 | 10.0 | 3.7 | 9 | 16 | 12 | | | | | 8 | 0 |
| maximum | MILR-33 | 91.3 | 25.6 | 17 | 30 | 35 | | | | | 38 | 25 |
| median | MILR-33 | 48.0 | 5.1 | 16 | 27 | 22 | | | | | 18 | 15 |
| mean | MILR-33 | 43.3 | 10.8 | 14 | 24 | 24 | | | | | 20 | 11 |
| | | | | | | | | | | | | |
| 25th percentile | NBFC-11 | 23.3 | 1.6 | 9 | 10 | 0 | 1 | 1.0 | 6 | 84 | 50 | 28 |
| 75th percentile | NBFC-11 | 29.8 | 3.5 | 11 | 13 | 0 | 10 | 1.9 | | | 60 | 35 |
| minimum | NBFC-11 | 16.6 | 1.3 | 9 | 9 | 0 | 0 | 0.8 | | | 50 | 5 |
| maximum | NBFC-11 | 49.5 | 8.9 | 11 | 15 | 0 | 27 | 2.0 | | | 63 | 38 |
| median | NBFC-11 | 23.7 | 1.9 | 10 | 11 | 0 | 4 | 1.3 | | | 53 | 35 |
| mean | NBFC-11 | 28.6 | 3.4 | 10 | 12 | 0 | 8 | 1.4 | | | 55 | 28 |
| | | | | | | | | | | | | |
| 25th percentile | NBFC-15 | 14.1 | 2.6 | 13 | 16 | 0 | 0 | 0.7 | 8 | 14 | 0 | 15 |
| 75th percentile | NBFC-15 | 21.6 | 3.1 | 16 | 20 | 2 | 2 | 1.4 | | | 5 | 25 |
| minimum | NBFC-15 | 11.5 | 1.6 | 13 | 13 | 0 | 0 | 0.5 | | | 0 | 10 |
| maximum | NBFC-15 | 29.1 | 5.3 | 18 | 20 | 4 | 6 | 1.6 | | | 8 | 43 |
| median | NBFC-15 | 18.7 | 2.7 | 14 | 19 | 0 | 0 | 0.8 | | | 0 | 18 |
| mean | NBFC-15 | 19.0 | 3.1 | 15 | 18 | 1 | 1 | 1.0 | | | 3 | 22 |
| 25th percentile | WILL-38 | 16.9 | 5.5 | 24 | 33 | 12 | 29 | 0.6 | 5 | 2 | 3 | 0 |
| 75th percentile | WILL-38 | 18.5 | 6.9 | 39 | 59 | 59 | 39 | 1.0 | | | 10 | 0 |
| minimum | WILL-38 | 13.2 | 3.8 | 23 | 29 | 6 | 20 | 0.4 | | | 0 | 0 |
| maximum | WILL-38 | 19.0 | 8.5 | 52 | 80 | 100 | 41 | 1.5 | | | 15 | 0 |
| median | WILL-38 | 18.2 | 6.3 | 25 | 38 | 20 | 37 | 0.9 | | | 10 | 0 |
| mean | WILL-38 | 17.2 | 6.2 | 33 | 49 | 37 | 33 | 0.9 | | | 8 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | RYEC-36 | 12.5 | 1.2 | 20 | 25 | 4 | 12 | 1.1 | 6 | 99 | 58 | 3 |
| 75th percentile | RYEC-36 | 15.4 | 1.6 | 24 | 30 | 29 | 21 | 1.4 | | | 63 | 5 |
| minimum | RYEC-36 | 11.0 | 1.1 | 19 | 24 | 2 | 6 | 0.9 | | | 28 | 0 |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| maximum | RYEC-36 | 17.6 | 2.0 | 26 | 35 | 98 | 31 | 1.9 | | | 75 | 15 |
| median | RYEC-36 | 15.3 | 1.5 | 22 | 25 | 10 | 17 | 1.3 | | | 63 | 3 |
| mean | RYEC-36 | 14.4 | 1.5 | 22 | 28 | 27 | 17 | 1.3 | | | 57 | 5 |
| | | | | | | | | | | | | |
| 25th percentile | SKAL-33 | 23.0 | 1.8 | 3 | 5 | 2 | 2 | 0.8 | 7 | 87 | 85 | 0 |
| 75th percentile | SKAL-33 | 25.2 | 3.2 | 5 | 8 | 6 | 6 | 1.5 | | | 90 | 0 |
| minimum | SKAL-33 | 16.5 | 1.7 | 3 | 3 | 0 | 0 | 0.5 | | | 75 | 0 |
| maximum | SKAL-33 | 27.5 | 3.3 | 7 | 8 | 10 | 22 | 1.9 | | | 98 | 0 |
| median | SKAL-33 | 23.9 | 3.1 | 3 | 8 | 4 | 4 | 1.0 | | | 85 | 0 |
| mean | SKAL-33 | 23.2 | 2.6 | 4 | 6 | 4 | 6 | 1.1 | | | 87 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | SKAL-48 | 35.7 | 1.5 | 7 | 8 | 0 | 0 | 1.8 | 4 | 31 | 33 | 0 |
| 75th percentile | SKAL-48 | 41.5 | 2.8 | 11 | 14 | 2 | 2 | 3.0 | | | 55 | 5 |
| minimum | SKAL-48 | 27.4 | 1.2 | 4 | 6 | 0 | 0 | 1.3 | | | 33 | 0 |
| maximum | SKAL-48 | 42.7 | 3.1 | 14 | 17 | 4 | 27 | 3.4 | | | 73 | 8 |
| median | SKAL-48 | 41.3 | 2.0 | 9 | 11 | 0 | 2 | 2.4 | | | 45 | 0 |
| mean | SKAL-48 | 37.7 | 2.1 | 9 | 11 | 1 | 5 | 2.4 | | | 48 | 3 |
| | | | | | | | | | | | | |
| 25th percentile | SLEE-43 | 24.1 | 1.4 | 5 | 11 | 4 | | 0.8 | 4 | 37 | 43 | 0 |
| 75th percentile | SLEE-43 | 25.4 | 1.6 | 7 | 13 | 8 | | 1.8 | | | 45 | 0 |
| minimum | SLEE-43 | 17.7 | 1.1 | 4 | 11 | 2 | | 0.6 | | | 10 | 0 |
| maximum | SLEE-43 | 27.1 | 3.0 | 7 | 15 | 24 | | 3.1 | | | 48 | 8 |
| median | SLEE-43 | 24.6 | 1.6 | 7 | 11 | 6 | | 1.2 | | | 43 | 0 |
| mean | SLEE-43 | 23.8 | 1.8 | 6 | 12 | 8 | | 1.5 | | | 38 | 2 |
| | | | | | | | | | | | | |
| 25th percentile | THRE-35 | 6.7 | 1.9 | 24 | 57 | 31 | 93 | 0.6 | 14 | 26 | 58 | 18 |
| 75th percentile | THRE-35 | 7.6 | 4.1 | 33 | 63 | 78 | 100 | 1.0 | | | 70 | 28 |
| minimum | THRE-35 | 6.5 | 1.4 | 21 | 56 | 18 | 63 | 0.5 | | | 53 | 10 |
| maximum | THRE-35 | 7.9 | 4.3 | 40 | 68 | 100 | 100 | 1.5 | | | 70 | 40 |
| median | THRE-35 | 7.1 | 3.1 | 26 | 57 | 41 | 100 | 0.7 | | | 63 | 23 |
| mean | THRE-35 | 7.1 | 2.9 | 29 | 61 | 49 | 94 | 0.9 | | | 63 | 24 |
| | | | | | | | | | | | | |
| 25th | MILR-11 | 8.6 | 3.6 | 9 | 25 | 12 | 5 | 0.4 | 28 | 108 | 75 | 0 |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| percentile | | | | | | | | | | | | |
| 75th percentile | MILR-11 | 9.9 | 9.8 | 13 | 31 | 20 | 10 | 0.8 | | | 100 | 0 |
| minimum | MILR-11 | 6.2 | 3.0 | 6 | 19 | 2 | 2 | 0.4 | | | 65 | 0 |
| maximum | MILR-11 | 15.3 | 10.0 | 14 | 31 | 73 | 49 | 1.0 | | | 100 | 0 |
| median | MILR-11 | 9.8 | 5.0 | 12 | 30 | 16 | 8 | 0.6 | | | 90 | 0 |
| mean | MILR-11 | 10.0 | 6.3 | 10 | 27 | 21 | 11 | 0.6 | | | 86 | 0 |
| 25th percentile | WILL-28 | 14.4 | 2.4 | 9 | 20 | 10 | 11 | 1.0 | 13 | 332 | 88 | 0 |
| 75th percentile | WILL-28 | 14.8 | 4.3 | 12 | 22 | 16 | 30 | 1.5 | | | 93 | 0 |
| minimum | WILL-28 | 12.3 | 2.1 | 9 | 19 | 4 | 2 | 0.7 | | | 85 | 0 |
| maximum | WILL-28 | 21.4 | 8.5 | 13 | 22 | 29 | 41 | 1.7 | | | 95 | 3 |
| median | WILL-28 | 14.4 | 4.1 | 10 | 21 | 10 | 20 | 1.1 | | | 90 | 0 |
| mean | WILL-28 | 15.5 | 4.3 | 11 | 21 | 14 | 20 | 1.2 | | | 90 | 1 |
| | | | | | | | | | | | | |
| 25th percentile | KOOT-52 | 41.9 | 1.2 | 6 | 11 | 4 | 10 | 1.1 | 7 | 113 | 38 | 0 |
| 75th percentile | KOOT-52 | 45.5 | 1.4 | 10 | 16 | 12 | 15 | 1.8 | | | 58 | 0 |
| minimum | KOOT-52 | 40.1 | 1.1 | 6 | 9 | 0 | 8 | 0.6 | | | 25 | 0 |
| maximum | KOOT-52 | 47.3 | 1.5 | 13 | 18 | 67 | 18 | 3.3 | | | 58 | 0 |
| median | KOOT-52 | 43.7 | 1.3 | 6 | 13 | 10 | 12 | 1.6 | | | 43 | 0 |
| mean | KOOT-52 | 43.7 | 1.3 | 9 | 13 | 14 | 13 | 1.6 | | | 44 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | MILL-50 | 28.9 | 2.9 | 12 | 22 | 3 | 2 | 2.0 | 8 | 7 | 30 | 0 |
| 75th percentile | MILL-50 | 43.0 | 6.1 | 12 | 23 | 6 | 8 | 3.6 | | | 53 | 15 |
| minimum | MILL-50 | 21.9 | 1.3 | 11 | 22 | 0 | 0 | 1.5 | | | 10 | 0 |
| maximum | MILL-50 | 50.0 | 7.7 | 13 | 23 | 10 | 24 | 4.0 | | | 58 | 15 |
| median | MILL-50 | 36.0 | 4.5 | 12 | 22 | 5 | 4 | 2.5 | | | 35 | 3 |
| mean | MILL-50 | 36.0 | 4.5 | 12 | 22 | 5 | 7 | 2.7 | | | 37 | 7 |
| | | | | | | | | | | | | |
| 25th percentile | BEAR-30 | 25.3 | 3.9 | 14 | 18 | 2 | 4 | 1.7 | 8 | 25 | 23 | 0 |
| 75th percentile | BEAR-30 | 31.7 | 6.1 | 24 | 29 | 6 | 10 | 2.0 | | | 33 | 0 |
| minimum | BEAR-30 | 25.3 | 3.5 | 5 | 10 | 0 | 2 | 1.3 | | | 13 | 0 |
| maximum | BEAR-30 | 35.6 | 7.6 | 25 | 31 | 12 | 16 | 2.4 | | | 53 | 5 |
| median | BEAR-30 | 27.9 | 4.8 | 23 | 27 | 2 | 8 | 1.8 | | | 30 | 0 |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mean | BEAR-30 | 29.2 | 5.2 | 17 | 23 | 4 | 8 | 1.9 | | | 30 | 1 |
| | | | | | | | | | | | | |
| 25th percentile | NBEAR-08 | 15.8 | 6.0 | 7 | 11 | 0 | 4 | 1.5 | 9 | 21 | 63 | 0 |
| 75th percentile | NBEAR-08 | 23.3 | 11.1 | 9 | 19 | 6 | 6 | 1.8 | | | 83 | 3 |
| minimum | NBEAR-08 | 14.9 | 3.2 | 4 | 8 | 0 | 0 | 0.5 | | | 60 | 0 |
| maximum | NBEAR-08 | 30.0 | 13.2 | 9 | 24 | 20 | 8 | 2.2 | | | 88 | 5 |
| median | NBEAR-08 | 18.5 | 9.6 | 9 | 14 | 2 | 4 | 1.6 | | | 80 | 3 |
| mean | NBEAR-08 | 20.5 | 8.6 | 7 | 15 | 6 | 5 | 1.5 | | | 75 | 2 |
| | | | | | | | | | | | | |
| 25th percentile | LOST-43 | 115.1 | 3.0 | 7 | 11 | | 0 | 1.9 | 6 | 109 | 15 | 0 |
| 75th percentile | LOST-43 | 115.1 | 3.0 | 7 | 11 | | 4 | 3.3 | | | 53 | 0 |
| minimum | LOST-43 | 115.1 | 3.0 | 7 | 11 | | 0 | 0.9 | | | 10 | 0 |
| maximum | LOST-43 | 115.1 | 3.0 | 7 | 11 | | 8 | 3.5 | | | 58 | 0 |
| median | LOST-43 | 115.1 | 3.0 | 7 | 11 | | 0 | 2.2 | | | 18 | 0 |
| mean | LOST-43 | 115.1 | 3.0 | 7 | 11 | | 2 | 2.4 | | | 31 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | SWEA-29 | 22.8 | 2.3 | 11 | 19 | 4 | 4 | 1.2 | 8 | 19 | 3 | 10 |
| 75th percentile | SWEA-29 | 25.7 | 3.2 | 13 | 23 | 10 | 15 | 2.0 | | | 15 | 23 |
| minimum | SWEA-29 | 21.3 | 1.4 | 10 | 17 | 0 | 0 | 0.7 | | | 0 | 10 |
| maximum | SWEA-29 | 28.7 | 4.8 | 14 | 24 | 20 | 22 | 2.2 | | | 33 | 28 |
| median | SWEA-29 | 24.6 | 3.0 | 12 | 21 | 4 | 10 | 1.7 | | | 10 | 18 |
| mean | SWEA-29 | 24.6 | 2.9 | 12 | 21 | 8 | 10 | 1.6 | | | 12 | 18 |
| 25th percentile | TINC-31/32 | 26.4 | 1.9 | 1 | 2 | 0 | 0 | 1.1 | 6 | 43 | 45 | 0 |
| 75th percentile | TINC-31/32 | 31.5 | 2.9 | 2 | 4 | 2 | 15 | 1.9 | | | 45 | 3 |
| minimum | TINC-31/32 | 23.8 | 1.7 | 1 | 2 | 0 | 0 | 1.0 | | | 30 | 0 |
| maximum | TINC-31/32 | 33.6 | 3.0 | 2 | 5 | 2 | 31 | 2.4 | | | 48 | 3 |
| median | TINC-31/32 | 29.0 | 2.4 | 2 | 3 | 0 | 0 | 1.4 | | | 45 | 0 |
| mean | TINC-31/32 | 28.9 | 2.4 | 2 | 3 | 1 | 10 | 1.5 | | | 43 | 1 |
| | | | | | | | | | | | | |
| 25th percentile | BASS-24 | 15.2 | 1.8 | 3 | 7 | 0 | 2 | 0.8 | 14 | 60 | 28 | 0 |
| 75th percentile | BASS-24 | 17.9 | 2.0 | 3 | 8 | 6 | 5 | 1.4 | | | 45 | 0 |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minimum | BASS-24 | 11.5 | 1.3 | 2 | 6 | 0 | 2 | 0.4 | | | 23 | 0 |
| maximum | BASS-24 | 20.8 | 2.4 | 4 | 9 | 20 | 8 | 2.3 | | | 73 | 3 |
| median | BASS-24 | 17.9 | 1.9 | 3 | 7 | 2 | 2 | 1.1 | | | 28 | 0 |
| mean | BASS-24 | 16.7 | 1.9 | 3 | 7 | 5 | 4 | 1.1 | | | 39 | 1 |
| | | | | | | | | | | | | |
| 25th percentile | BASS-27 | 12.3 | 1.6 | 12 | 15 | 4 | 6 | 0.5 | 15 | 30 | 50 | 0 |
| 75th percentile | BASS-27 | 34.6 | 2.0 | 18 | 22 | 14 | 33 | 0.7 | | | 75 | 0 |
| minimum | BASS-27 | 9.4 | 1.6 | 7 | 11 | 4 | 4 | 0.3 | | | 28 | 0 |
| maximum | BASS-27 | 55.0 | 3.0 | 19 | 24 | 33 | 37 | 1.2 | | | 80 | 3 |
| median | BASS-27 | 14.4 | 1.9 | 16 | 19 | 12 | 22 | 0.6 | | | 68 | 0 |
| mean | BASS-27 | 25.2 | 2.0 | 14 | 18 | 14 | 20 | 0.7 | | | 60 | 1 |
| | | | | | | | | | | | | |
| 25th percentile | BLOD-49 | 26.0 | 1.4 | 3 | 8 | 0 | 6 | 1.2 | 7 | 2 | 45 | 0 |
| 75th percentile | BLOD-49 | 41.9 | 2.4 | 9 | 13 | 6 | 17 | 1.9 | | | 70 | 0 |
| minimum | BLOD-49 | 24.8 | 1.2 | 3 | 7 | 0 | 0 | 1.2 | | | 30 | 0 |
| maximum | BLOD-49 | 51.1 | 4.2 | 16 | 18 | 10 | 22 | 2.6 | | | 73 | 0 |
| median | BLOD-49 | 31.2 | 1.5 | 3 | 8 | 0 | 12 | 1.8 | | | 58 | 0 |
| mean | BLOD-49 | 35.0 | 2.1 | 7 | 11 | 3 | 12 | 1.7 | | | 55 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | LICK-19 | 7.4 | 9.6 | 18 | 34 | 10 | 2 | 0.6 | 28 | 222 | 55 | 0 |
| 75th percentile | LICK-19 | 11.3 | 16.2 | 23 | 42 | 22 | 8 | 1.0 | | | 80 | 0 |
| minimum | LICK-19 | 4.8 | 5.1 | 14 | 28 | 4 | 0 | 0.4 | | | 40 | 0 |
| maximum | LICK-19 | 20.8 | 20.2 | 24 | 44 | 63 | 16 | 1.4 | | | 95 | 0 |
| median | LICK-19 | 10.0 | 11.4 | 23 | 40 | 16 | 3 | 0.9 | | | 75 | 0 |
| mean | LICK-19 | 10.9 | 12.5 | 20 | 37 | 22 | 5 | 0.8 | | | 69 | 0 |
| | | | | | | | | | | | | |
| 25th percentile | MILL-43 | 23.6 | 6.8 | 2 | 5 | 2 | | 0.6 | 7 | 60 | 38 | 0 |
| 75th percentile | MILL-43 | 29.1 | 10.6 | 3 | 8 | 6 | | 1.0 | | | 48 | 0 |
| minimum | MILL-43 | 22.7 | 6.3 | 1 | 4 | 0 | | 0.5 | | | 33 | 0 |
| maximum | MILL-43 | 35.5 | 12.0 | 4 | 8 | 12 | | 1.7 | | | 50 | 0 |
| median | MILL-43 | 27.8 | 7.6 | 3 | 7 | 2 | | 0.6 | | | 48 | 0 |
| mean | MILL-43 | 27.7 | 8.7 | 3 | 6 | 4 | | 0.8 | | | 43 | 0 |
| | | | | | | | | | | | | |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25th percentile | MCCL-15 | 5.1 | 6.1 | 30 | 44 | 24 | 12 | 0.5 | 40 | 28 | 55 | 0 |
| 75th percentile | MCCL-15 | 6.7 | 7.2 | 39 | 52 | 47 | 45 | 0.7 | | | 75 | 10 |
| minimum | MCCL-15 | 4.6 | 3.4 | 22 | 44 | 18 | 0 | 0.4 | | | 40 | 0 |
| maximum | MCCL-15 | 11.3 | 9.8 | 40 | 60 | 84 | 82 | 0.9 | | | 75 | 15 |
| median | MCCL-15 | 5.3 | 7.0 | 38 | 45 | 45 | 29 | 0.7 | | | 60 | 5 |
| mean | MCCL-15 | 6.6 | 6.7 | 33 | 50 | 43 | 31 | 0.6 | | | 61 | 6 |
| 25th percentile | LOLO-26 | 27.6 | 1.3 | 5 | 18 | 4 | 26 | 0.8 | 3 | 9 | 50 | 0 |
| 75th percentile | LOLO-26 | 36.1 | 2.2 | 7 | 23 | 8 | 38 | 1.4 | | | 80 | 0 |
| minimum | LOLO-26 | 21.8 | 1.3 | 3 | 14 | 0 | 6 | 0.6 | | | 40 | 0 |
| maximum | LOLO-26 | 36.5 | 2.4 | 7 | 23 | 14 | 73 | 1.9 | | | 85 | 5 |
| median | LOLO-26 | 28.5 | 1.6 | 6 | 23 | 6 | 36 | 1.1 | | | 70 | 0 |
| mean | LOLO-26 | 30.1 | 1.8 | 5 | 20 | 6 | 35 | 1.2 | | | 65 | 1 |
| | | | | | | | | | | | | |
| 25th percentile | LOLO-34 | 29.1 | 2.8 | 2 | 12 | 0 | 20 | 1.5 | 2 | 31 | 75 | 5 |
| 75th percentile | LOLO-34 | 31.8 | 5.0 | 2 | 14 | 12 | 41 | 1.8 | | | 85 | 15 |
| minimum | LOLO-34 | 23.5 | 2.6 | 2 | 10 | 0 | 6 | 1.0 | | | 75 | 3 |
| maximum | LOLO-34 | 36.7 | 5.8 | 3 | 14 | 18 | 73 | 1.9 | | | 95 | 30 |
| median | LOLO-34 | 31.1 | 4.5 | 2 | 14 | 4 | 28 | 1.8 | | | 78 | 8 |
| mean | LOLO-34 | 30.4 | 4.1 | 2 | 13 | 7 | 31 | 1.6 | | | 82 | 12 |
| | | | | | | | | | | | | |
| 25th percentile | LOLO-56 | 38.9 | 3.0 | 6 | 14 | 2 | 8 | 0.9 | 3 | 18 | 73 | 13 |
| 75th percentile | LOLO-56 | 43.6 | 4.6 | 12 | 20 | 8 | 18 | 1.8 | | | 98 | 20 |
| minimum | LOLO-56 | 33.2 | 2.8 | 1 | 8 | 0 | 4 | 0.6 | | | 73 | 3 |
| maximum | LOLO-56 | 49.9 | 4.8 | 13 | 20 | 14 | 59 | 2.5 | | | 98 | 33 |
| median | LOLO-56 | 39.4 | 3.7 | 11 | 20 | 6 | 10 | 1.4 | | | 88 | 15 |
| mean | LOLO-56 | 41.0 | 3.8 | 8 | 16 | 6 | 17 | 1.4 | | | 86 | 17 |
| | | | | | | | | | | | | |
| 25th percentile | SFLO-43 | 24.4 | 1.3 | 2 | 4 | 0 | 5 | 0.6 | 5 | 37 | 55 | 0 |
| 75th percentile | SFLO-43 | 26.8 | 1.6 | 3 | 7 | 2 | 13 | 1.2 | | | 75 | 3 |
| minimum | SFLO-43 | 21.7 | 1.3 | 1 | 3 | 0 | 0 | 0.6 | | | 50 | 0 |
| maximum | SFLO-43 | 31.8 | 1.9 | 4 | 8 | 2 | 22 | 1.9 | | | 78 | 13 |

**Table D-3. Individual Assessment Reach Data 2007.**

| Statistic | Reach ID | Width / Depth Ratio | Entrenchment Ratio | Riffle Pebble Count Percent <2mm | Riffle Pebble Count Percent <6mm | Riffle Grid Toss Percent <6mm * | Pool Tail-out Grid Toss Percent <6mm * | Mean Residual Pool Depth * | Number of Pools per 1000 Feet | Total Number of LWD per 1000 Feet | Percent Understory Shrub Cover | Percent Bare/Disturbed Ground |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| median | SFLO-43 | 25.4 | 1.3 | 3 | 6 | 0 | 7 | 0.9 | | | 70 | 0 |
| mean | SFLO-43 | 26.0 | 1.5 | 3 | 6 | 1 | 9 | 1.0 | | | 66 | 3 |

* Riffle grid toss, pool tail-out grid toss and residual pool depth measurements include all data.

# D4.0 REFERENCES


MTDEQ. 2007a. Longitudinal Field Methodology for the Assessment of Sediment and Habitat Impairments. Montana Department of Environmental Quality, Helena, Montana.

MTDEQ. 2007b. A Watershed Stratification Approach for TMDL Sediment and Habitat Impairment Verification. Montana Department of Environmental Quality, Helena, Montana.

Rosgen, David L. 1994. A Classification of Natural Rivers. *Catena.* 22169-199. 1996. Applied River Morphology, Pagosa Springs, CO: Wildland Hydrology.

# APPENDIX E - 2007 STREAM BANK EROSION SOURCE ASSESSMENT – BITTERROOT TMDL PLANNING AREA

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# E1.0 Introduction

This appendix includes a summary of the field protocols and results from sediment loading due to streambank erosion along several stream segments in the Bitterroot TMDL Planning Area (TPA). It is an excerpt from the Streambank Erosion Source Assessment (PBS&J 2008), which is on file at DEQ. Sediment loads due to streambank erosion were calculated based on field data collected in 2007. Streambank erosion assessments were conducted over two monitoring timeframes, with 32 monitoring sites assessed during June/August and 23 monitoring sites assessed during October/November. Streambank erosion data collected at field monitoring sites was extrapolated to the stream reach and stream segment scales based on information in the Aerial Assessment Database, which was compiled in GIS prior to field data collection. Streambank erosion data collected in the field was also used to estimate sediment loading at the watershed scale and to assess the potential to decrease sediment inputs due to streambank erosion.

Reach type as identified in this appendix and in the Streambank Erosion Source Assessment Report will differ from reach types in **Section 5 of the TMDL document**, as a result of ecoregion reassignment **(See Section 5.3.1.2 in the TMDL document)**; with streams originating within the Idaho Batholith ecoregion that were assessed in the 2007 DEQ field effort considered to be Idaho Batholith, and reaches located on streams that are split between Northern Rockies and Middle Rockies ecoregions assigned an ecoregion based on where the majority of the stream is located. Reach type was not modified in this appendix or the original report, and is provided without edits here to demonstrate the original sampling rationale.

## E1.1 Terminology

Streambank erosion data collected at monitoring sites was extrapolated to the stream reach and stream segment scales based on similar reach characteristics as identified in the Aerial Assessment Database. Sediment load calculations were performed for monitoring sites, stream reaches and stream segments, which are defined as follows:

| | |
|---|---|
| *Monitoring Site -* | *A 500, 1000, or 2000 foot section of a reach where field monitoring was conducted* |
| *Stream Reach -* | *Subdivision of the stream segment based on Ecoregion, stream order, gradient and confinement* |
| *Stream Segment -* | *303(d) listed segment* |

Prior to field data collection, each 303(d) listed ***stream segment*** was broken into several ***stream reaches*** based on Ecoregion, gradient, Strahler stream order and confinement through the use of GIS data layers and color aerial imagery. Stream reaches were delineated following the methodology outlined in *A Watershed Stratification Approach for TMDL Sediment and Habitat Impairment Verification* (MDEQ 2007a). Stream reach data was compiled into an Aerial Assessment Database, which included a total of 915 stream reaches on 23 stream segments in the Bitterroot TPA. A subset of the stream reaches identified in the Aerial Assessment Database were assessed in the field at ***monitoring sites***, which were selected to represent conditions at the stream reach scale. At each monitoring site, eroding streambanks were assessed following protocols established in *Longitudinal Field Methodology for the Assessment of Sediment and Habitat Impairments* (MDEQ 2007b).

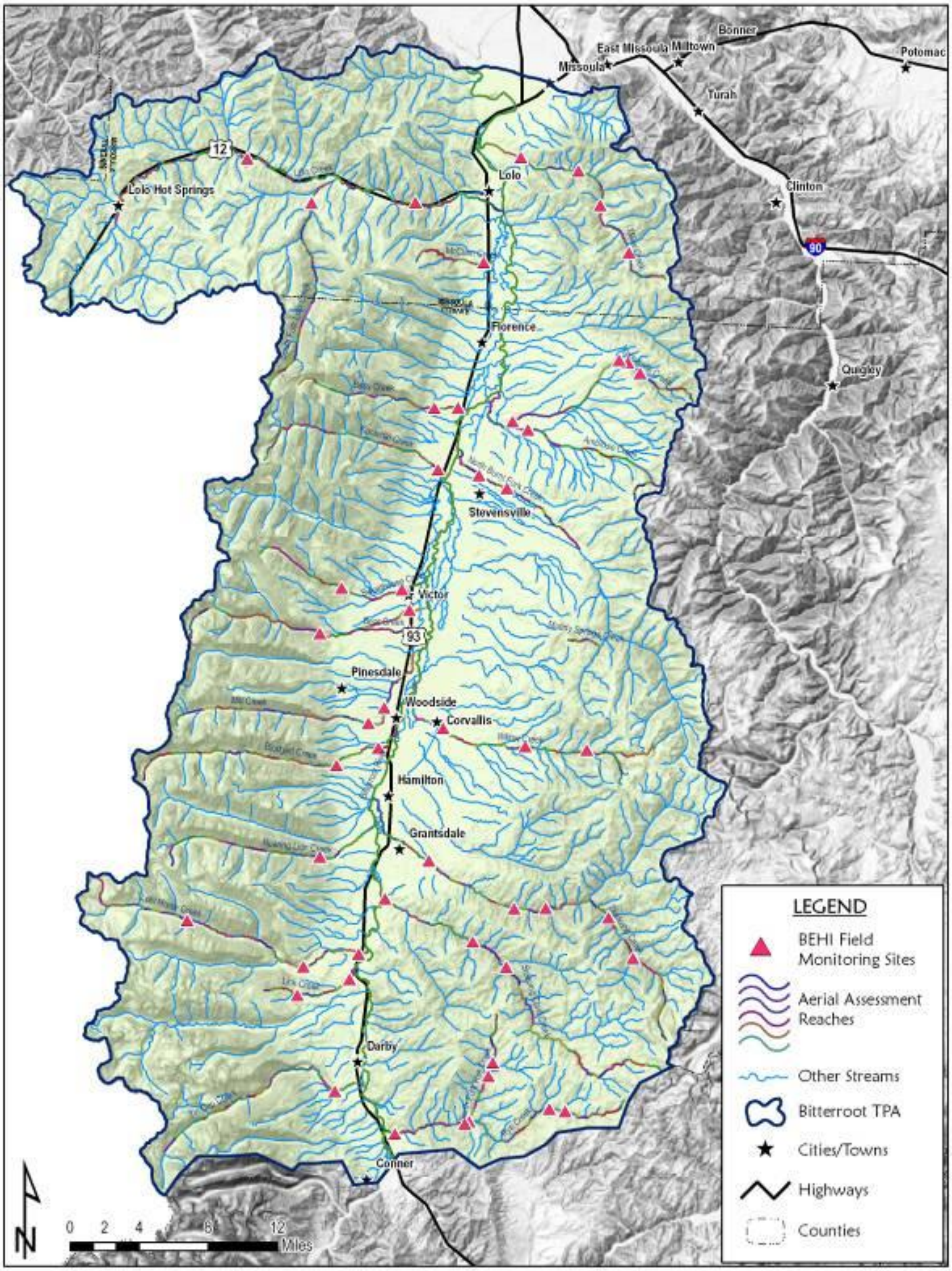
## E1.2 Sediment Impairments

In the Bitterroot TPA, twelve stream segments are listed on the 2010 303(d) List for sediment impairments including: Lick Creek, Lolo Creek (3 segments), McClain Creek, Miller Creek, Muddy Springs Creek, North Fork Burnt Creek, Rye Creek, Sleeping Child Creek, Threemile Creek, and Willow Creek.

# E2.0 Data Collection and Extrapolation Methodology

Streambank erosion assessments were performed on 191 streambanks at 55 monitoring sites in 2007. A total of 11.4 miles of stream were assessed along 23 stream segments, including: Ambrose Creek, Bass Creek, Bear Creek, North Bear Creek, Blodgett Creek, Kootenai Creek, Lick Creek, Lolo Creek, South Fork Lolo Creek, Lost Horse Creek, McClain Creek, Mill Creek, Miller Creek, North Burnt Fork Creek, Roaring Lion Creek, Rye Creek, North Fork Rye Creek, Skalkaho Creek, Sleeping Child Creek, Sweathouse Creek, Threemile Creek, Tin Cup Creek, and Willow Creek. One to five monitoring sites were assessed on each of these stream segments. Monitoring site lengths varied from 500 feet to 1,000 feet to 2,000 feet depending on the bankfull width of the stream. Monitoring site locations are presented in **Figure E-1**. Sites were chosen following the same process described in **Appendix D, Section D1.1**

**Figure E-1. Monitoring sites.**



## E2.1 STREAMBANK EROSION RATES

At each monitoring site, streambank erosion rates were assessed by performing **Bank Erosion Hazard Index (BEHI)** measurements and evaluating the **Near Bank Stress (NBS)** (Rosgen 1996, 2004). At each eroding bank, the BEHI score was determined based on the following six parameters:

- Bank height
- Bankfull height
- Root depth
- Root density
- Bank angle
- Surface protection

Evaluation of these six parameters resulted in a BEHI score, which was then rated from “very low” to “extreme”. In addition to the BEHI assessment, the Near Bank Stress was also determined at each eroding bank. Near Bank Stress was assessed by evaluating the shape of the channel at the toe of the bank and the force of the water (i.e. “stream power”) along the bank. Near Bank Stress was also rated from “very low” to “extreme”. The BEHI and NBS ratings were used to estimate the annual retreat rate of each streambank based on measured retreat rates from the Lamar River in Yellowstone National Park (Rosgen 1996) (**Table E-1**).

**Table E-1. Annual Streambank Retreat Rates (Feet/Year) (adapted from Rosgen 1996)**

| BEHI | Near Bank Stress | | | | | |
|---|---|---|---|---|---|---|
| | very low | low | moderate | high | very high | extreme |
| **very Low** | 0.002 | 0.004 | 0.009 | 0.021 | 0.050 | 0.12 |
| **low** | 0.02 | 0.04 | 0.10 | 0.24 | 0.57 | 1.37 |
| **moderate** | 0.10 | 0.17 | 0.28 | 0.47 | 0.79 | 1.33 |
| **high - very high** | 0.37 | 0.53 | 0.76 | 1.09 | 1.57 | 2.26 |
| **extreme** | 0.98 | 1.21 | 1.49 | 1.83 | 2.25 | 2.76 |

## E2.2 STREAMBANK SEDIMENT LOADS

For each eroding bank assessed in the Bitterroot TPA, the annual sediment load due to streambank erosion was determined based on the banks length, mean height, and annual retreat rate. The length and mean height were measured in the field, while the annual retreat rate was determined based on the relationship between the BEHI and NBS ratings (**Table E-1**). The annual sediment load in cubic feet was calculated from the field data and then converted into cubic yards and finally converted into tons per year based on the bulk density of streambank material. The bulk density of streambank material was assumed to average 1.3 tons/yard$^3$ as identified in *Watershed Assessment of River Stability and Sediment Supply* (WARSSS) (Rosgen 2006, EPA 2006). This process resulted in a sediment load for each eroding bank expressed in tons per year. The sediment loads for each eroding bank within a monitoring site were summed to provide an overall sediment load due to streambank erosion for each monitoring site in tons per year.

## E2.3 AERIAL ASSESSMENT DATABASE

Streambank erosion measured at 52 of the monitoring sites assessed in the field was extrapolated to the stream reach and stream segment scales based on the Aerial Assessment Database. In the field, monitoring sites were selected in areas that were representative of the overall stream condition at the stream reach scale. Stream reaches were defined in the Aerial Assessment Database prior to field work through the use of GIS data layers and color aerial imagery from 2005. Sediment loads derived from the monitoring sites were extrapolated to the stream reach scale. Sediment loads at the stream reach scale were then summed to achieve an estimate of sediment loads due to streambank erosion for each 303(d) listed stream segment.

### E2.3.1 Reach Types

Prior to field data collection, stream segments in the Bitterroot TPA were broken into stream reaches based on Ecoregion, gradient, Strahler stream order and confinement. For streambank erosion sediment load extrapolation purposes, stream reaches were grouped based on three possible categories for Ecoregion, two possible categories for confinement, three possible categories for gradient, and four possible categories for Strahler stream order (**Table E-2)**. For each of the two confinement categories, there are 12 possible slope and stream order combinations, resulting in a total of 24 possible confinement, slope and stream order combinations. With three categories of Level III Ecoregions, the Bitterroot TPA has a total of 72 possible combinations of Ecoregion, gradient, Strahler stream order and confinement. These 72 possible combinations will be referred to as "**reach types**" in this report.

*Reach Type -* *Unique combination of Ecoregion, gradient, Strahler stream order and confinement*

Out of the 72 possible reach types in the Bitterroot TPA, a total of 45 reach types were identified during the aerial assessment process. Monitoring site assessments were performed within 18 of the 45 identified reach types.

**Table E-2. Possible Level III Ecoregion, Gradient, Strahler Stream Order, and Confinement Combinations**

| Ecoregion III | Gradient | Confinement | Strahler Stream Order |
|---|---|---|---|
| Idaho Batholith | > 4% | Unconfined/Moderately Confined | 1 |
| Middle Rockies | 2 - < 4% | Confined | 2 |
| Northern Rockies | < 2% | | 3 |
| | | | 4 |

### E2.3.2 Sediment Load Extrapolation

Sediment loads due to streambank erosion were extrapolated from monitoring sites to stream reaches based on reach types as delineated in the Aerial Assessment Database. The sediment load calculated within an individual monitoring site was extrapolated directly to the stream reach in which it was located. When several monitoring sites were located within a single reach type, the mean sediment load from the monitoring sites was calculated. This mean "reach type" sediment load was then assigned to each reach of that type under the assumption that reaches with the same reach type will have the same mean annual sediment load due to streambank erosion.

Since only 18 out of the 45 identified reach types were assessed in the field, it was necessary to extrapolate the data from the 18 assessed reach types to the 27 un-assessed reach types. Out of the 27 un-assessed reach types, 9 were 1$^{st}$ order streams that were assigned a sediment load of zero due to their relatively small size, steep gradient and coarse streambank material. For the 18 stream reach types (excluding 1$^{st}$ order streams) in which no monitoring site was located, sediment loads were extrapolated from reach types exhibiting the most similarity to the un-assessed reach types. Gradient was the primary factor considered when extrapolating sediment loading data from assessed reach types to us-assessed reach types, though a detailed review of the 2005 color aerial imagery was also conducted to assure that reaches were comparable.

The process of extrapolating sediment loading data collected at monitoring sites to the stream reach scale is presented in the following sections for each of the three Level III Ecoregions in the Bitterroot TPA.

### *E2.3.2.1 Idaho Batholith Reach Types*

In the Idaho Batholith Level III Ecoregion, a total of 13 monitoring sites were assessed in the field. Monitoring sites were assessed in 7 out of the 17 reach types identified in the Idaho Batholith Level III Ecoregion. For reach types with field data, the mean sediment load due to streambank erosion was calculated. For reach types that were not assessed in the field, gradient was the primary factor considered when assigning sediment loads from reach types in which monitoring sites were located. Sediment loads from 1st order streams were assumed to be zero since their relatively small size; steep gradient and coarse streambank material generally tend to limit streambank erosion (**Table E-3)**.

**Table E-3. Idaho Batholith Reach Types and Sediment Loads**

| Ecoregion III | Gradient | Strahler Stream Order | Confinement | Stream Reach Count | Monitoring Site Count | Field Monitoring Site | Mean Sediment Load per 1000' (Tons/Year) | Justification of Load | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Idaho Batholith | > 4% | 1 | C | 9 | | | 0 | Strahler 1 | |
| Idaho Batholith | > 4% | 1 | U/M | 62 | | | 0 | Strahler 1 | |
| Idaho Batholith | > 4% | 2 | C | 31 | 1 | SWEA-18 | 0.10 | Monitoring Site | |
| Idaho Batholith | > 4% | 2 | U/M | 90 | 1 | LICK-08 | 3.90 | Monitoring Site | |
| Idaho Batholith | > 4% | 3 | C | 3 | | | 0.10 | SWEA-18 | Based on confinement |
| Idaho Batholith | > 4% | 3 | U/M | 13 | | | 3.90 | LICK-08 | Based on confinement |
| Idaho Batholith | 2 to < 4% | 1 | U/M | 5 | | | 0 | Strahler 1 | |
| Idaho Batholith | 2 to < 4% | 2 | C | 6 | | | 0.10 | SWEA-18 | Based on confinement |
| Idaho Batholith | 2 to < 4% | 2 | U/M | 71 | 3 | BLOD-35, RYEC-14, ROLI-24 | 3.93 | Monitoring Site | Average of monitoring sites |
| Idaho Batholith | 2 to < 4% | 3 | C | 7 | | | 0.10 | SWEA-18 | Based on confinement |
| Idaho Batholith | 2 to < 4% | 3 | U/M | 31 | 4 | NFRC-12, RYEC-16, LOST-33, NFRC-22 | 5.15 | Monitoring Site | Average of monitoring sites |
| Idaho Batholith | 2 to < 4% | 4 | U/M | 1 | | | 5.15 | NFRC-12, RYEC-16, LOST-33, NFRC-22 | Based on confinement |
| Idaho Batholith | < 2% | 1 | U/M | 3 | | | 0 | Strahler 1 | |

**Table E-3. Idaho Batholith Reach Types and Sediment Loads**

| Ecoregion III | Gradient | Strahler Stream Order | Confinement | Stream Reach Count | Monitoring Site Count | Field Monitoring Site | Mean Sediment Load per 1000' (Tons/Year) | Justification of Load | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Idaho Batholith | < 2% | 2 | U/M | 38 | 1 | NFRC-10 | 2.20 | Monitoring Site | |
| Idaho Batholith | < 2% | 3 | C | 2 | | | 0.10 | SWEA-18 | Based on confinement |
| Idaho Batholith | < 2% | 3 | U/M | 20 | 2 | BEAR-19, TINC-21 | 6.50 | Monitoring Site | Average of monitoring sites |
| Idaho Batholith | < 2% | 4 | U/M | 5 | 1 | RYEC-28 | 66.00 | Monitoring Site | If not adjacent to RYEC-28, use 6.5 from average of BEAR-19 & TINC-21 |

### *E2.3.2.2 Middle Rockies Reach Types*

In the Middle Rockies Level III Ecoregion, a total 36 monitoring sites were assessed in the field. Monitoring sites were assessed in 9 out of the 20 reach types identified in the Middle Rockies Level III Ecoregion. For reach types with field data, the mean sediment load due to streambank erosion was calculated. For reach types that were not assessed in the field, gradient was the primary factor considered when assigning sediment loads from reach types in which monitoring sites were located. Sediment loads from 1$^{st}$ order streams were assumed to be zero since their relatively small size; steep gradient and coarse streambank material generally tend to limit streambank erosion (**Table E-4**).

**Table E-4. Middle Rockies Reach Types and Sediment Loads**

| Ecoregion III | Gradient | Strahler Stream Order | Confinement | Stream Reach Count | Monitoring Site Count | Field Monitoring Site | Mean Sediment Load per 1000' (Tons/Year) | Justification of Load | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Middle Rockies | > 4% | 1 | C | 21 | | | 0 | Strahler 1 | |
| Middle Rockies | > 4% | 1 | U/M | 34 | | | 0 | Strahler 1 | |
| Middle Rockies | > 4% | 2 | C | 22 | 1 | THRE-21 | 4.80 | Monitoring Site | |
| Middle Rockies | > 4% | 2 | U/M | 48 | 3 | THRE-14, MCCL-15 | 8.80 | Monitoring Site | Average of monitoring sites |
| Middle Rockies | > 4% | 3 | C | 1 | | | 4.90 | THRE-21 | Based on confinement and gradient |
| Middle Rockies | > 4% | 3 | U/M | 10 | | | 6.27 | THRE-14, MCCL-15 | Based on confinement and gradient |
| Middle Rockies | > 4% | 4 | C | 2 | | | 4.90 | THRE-21 | Based on confinement and gradient |

**Table E-4. Middle Rockies Reach Types and Sediment Loads**

| Ecoregion III | Gradient | Strahler Stream Order | Confinement | Stream Reach Count | Monitoring Site Count | Field Monitoring Site | Mean Sediment Load per 1000' (Tons/Year) | Justification of Load | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Middle Rockies | 2 to < 4% | 1 | U/M | 1 | | MILR-11 | 0 | Monitoring Site | |
| Middle Rockies | 2 to < 4% | 2 | C | 4 | | | 3.75 | THRE-21 & SLEE-30 | Based on confinement |
| Middle Rockies | 2 to < 4% | 2 | U/M | 39 | 6 | BLOD-49, THRE-16, BASS-24, BASS-27, LICK-19, MILL-43 | 4.28 | Monitoring Site | Average of monitoring sites |
| Middle Rockies | 2 to < 4% | 3 | C | 1 | | | 3.75 | THRE-21 & SLEE-30 | Based on confinement |
| Middle Rockies | 2 to < 4% | 3 | U/M | 33 | 3 | SKAL-13, WILL-28, SKAL-21 | 8.53 | Monitoring Site | Average of field reaches |
| Middle Rockies | 2 to < 4% | 4 | C | 3 | | | 3.75 | THRE-21 & SLEE-30 | Based on confinement |
| Middle Rockies | 2 to < 4% | 4 | U/M | 6 | 2 | SLEE-27, SKAL-36 | 7.15 | Monitoring Site | Average of monitoring sites |
| Middle Rockies | < 2% | 2 | C | 1 | | | 2.60 | SLEE-30 | Based on confinement and gradient |
| Middle Rockies | < 2% | 2 | U/M | 35 | 3 | KOOT-52, MILL-50, MILR-21 | 19.10 | Monitoring Site | Average of KOOT-52 & MILR-21 |
| Middle Rockies | < 2% | 3 | U/M | 107 | 11 | AMBR-30, BEAR-30, MILR-28, MILR-33, NBEAR-08, NBFC-11, NBFC-15, SWEA-29, TINC-31/32, LOST-43, WILL-38 | 16.69 | Monitoring Site | Average of monitoring sites |
| Middle Rockies | <2% | 4 | C | 3 | 1 | SLEE-30 | 2.60 | Monitoring Site | |
| Middle Rockies | < 2% | 4 | U/M | 63 | 5 | SKAL-48, THRE-35, RYEC-36, SKAL-33, SLEE-44 | 14.80 | Monitoring Site | Average of monitoring sites |

### *E2.3.2.3 Northern Rockies Reach Types*

In the Northern Rockies Level III Ecoregion, a total of 4 monitoring sites were assessed in the field. Monitoring sites were assessed in 2 out of the 9 reach types identified in the Northern Rockies Level III Ecoregion. For reach types with field data, the mean sediment load due to streambank erosion was calculated. For reach types that were not assessed in the field, gradient was the primary factor considered when assigning sediment loads from reach types in which monitoring sites were located. Sediment loads from 1st order streams were assumed to be zero since their relatively small size, steep gradient and coarse streambank material generally tend to limit streambank erosion (**Table E-5**).

**Table E-5. Northern Rockies Reach Types and Sediment Loads**

| Ecoregion III | Gradient | Strahler Stream Order | Confinement | Stream Reach Count | Monitoring Ste Count | Field Monitoring Site | Mean Sediment Load per 1000' (Tons/Year) | Justification of Load | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Northern Rockies | > 4% | 1 | U/M | 2 | | | 0 | Strahler 1 | |
| Northern Rockies | > 4% | 1 | C | 1 | | | 0 | Strahler 1 | |
| Northern Rockies | > 4% | 2 | C | 6 | | | 1.20 | SFLO-43 | Closest reach |
| Northern Rockies | > 4% | 3 | C | 2 | | | 10.40 | LOLO-26, LOLO-34, LOLO-56 | Average of monitoring sites |
| Northern Rockies | 2 to < 4% | 3 | C | 1 | | | 1.20 | SFLO-43 | Closest reach |
| Northern Rockies | 2 to < 4% | 3 | U/M | 4 | 1 | SFLO-43 | 1.20 | Monitoring Site | |
| Northern Rockies | < 2% | 3 | C | 1 | | | 1.20 | SFLO-43 | Closest reach |
| Northern Rockies | < 2% | 3 | U/M | 5 | | | 10.40 | LOLO-26, LOLO-34, LOLO-56 | Average of monitoring sites |
| Northern Rockies | < 2% | 4 | U/M | 62 | 3 | LOLO-26, LOLO-34, LOLO-56 | 10.40 | Monitoring Site | Average of monitoring sites |

## E2.4 Sources of Streambank Erosion

At each eroding bank, the source of streambank erosion was evaluated based on observed anthropogenic disturbances and the surrounding land-use practices. The source of streambank instability was identified based on the following near-stream source categories:

- Transportation
- Riparian grazing
- Cropland
- Mining
- Silviculture
- Irrigation-shifts in stream energy

- Natural sources
- Other

For example, an eroding streambank in a heavily grazed area in which all the willows had been removed was assigned a source of "100% riparian grazing", while an eroding streambank due to road encroachment upstream was assigned a source of "100% transportation". Naturally eroding streambanks were considered the result of "natural sources". The "other" category was chosen when streambank erosion resulted from a source not described in the list. If multiple sources were observed, then a percent was noted for each source.

Streambank erosion sources identified along a monitoring site were extrapolated directly to the stream reach in which the monitoring site was located. For stream reaches in which no monitoring site was located, streambank erosion sources were assigned based on a review of land-use practices as observed in color aerial imagery from 2005. Streambank erosion sources at the stream segment scale were derived from the sources identified along the individual stream reaches within the stream segment. Streambank erosion sources for the stream segment's watershed were assumed to be the same as those along the stream segment and were assigned equal percentages as identified for the stream segment. A more detailed review of streambank erosion sources is provided in **Section B3**.

## E2.5 Actively and Slowly Eroding Streambanks

As discussed in the introduction, streambank erosion assessments were conducted over two monitoring timeframes: June/August and October/November. During the June/August monitoring timeframe, only "actively/visually" eroding streambanks were assessed in the field, while during the October/November monitoring timeframe, sites were assessed for both "actively/visually" eroding streambanks and for "slowly eroding/undercut/vegetated" streambanks. The bank erosion assessment methodology was refined between these two timeframes to provide for a better estimate of the "total" sediment load. However, this resulted in an underestimated sediment load for sites assessed during the June/August monitoring timeframe since "slowly eroding/undercut/vegetated" banks were not included. To "normalize" the June/August data, the average sediment load due to streambank erosion from "slowly eroding/undercut/vegetated" banks at sites from October/November was determined and added to the sites assessed during the June/August monitoring timeframe.

During the October/November monitoring timeframe, a total of 23 monitoring sites were assessed. "Slowly eroding/undercut/vegetated" banks were measured along 19 of the monitoring sites, while two sites had no bank erosion and two sites had only "actively/visually" eroding banks. Out of these 23 monitoring sites, a total of 107 "slowly eroding/undercut/vegetated" were assessed, with a mean height of 2.8 feet. Within these monitoring sites, "slowly eroding/undercut/vegetated" streambanks comprised an average of 22.7%, or 454 feet of bank per 1,000 feet of stream (2,000 feet of bank). Due to the stable nature of these streambanks, they were assigned a Bank Erosion Hazard Index (BEHI) score of low and a NBS score of very low, which results in a retreat rate of 0.02 feet per year (Rosgen 1996). Based on this retreat rate, an average sediment load of 1.2 tons/year was estimated to be derived from "slowly eroding/undercut/vegetated" per 1,000 feet of stream within the Bitterroot TPA. This value was added to monitoring sites assessed during the June/August monitoring timeframe and assigned as a natural source of sediment for extrapolation purposes.

# E3.0 Sediment Loading Due to Streambank Erosion

Sediment load calculations and estimates at the monitoring site, stream reach, stream segment and watershed scales are presented in the following sections.

## E3.1 Monitoring Site Sediment Loads

A total sediment load of 758 tons/year was attributed to eroding streambanks within the monitoring sites (**Table E-6**). Approximately 60% of the sediment load due to streambank erosion at the monitoring sites was due to anthropogenic sources, while approximately 40% was due to natural sources. Monitoring site assessments suggest that riparian grazing and cropland are the greatest anthropogenic contributors of sediment loads due to streambank erosion in the Bitterroot TPA, followed by the “other” category, which primarily describes impacts due to residential and commercial encroachment within the watershed, but also includes riprap, upstream channelization or land uses, recreation, and historical agriculture.

**Table E-6. Summary of Monitoring Site Sediment Loads**

| Source | Sediment Load (Tons/Year) | Sediment Load (Percent) |
|---|---|---|
| Transportation | 40 | 5.3 |
| Riparian Grazing | 170 | 22.4 |
| Cropland | 127 | 16.7 |
| Mining | 0 | 0 |
| Silviculture | 13 | 1.6 |
| Irrigation | 17 | 2.3 |
| Natural Sources | 306 | 40.4 |
| Other | 86 | 11.3 |
| **Total** | **758** | **100** |
| **Anthropogenic** | **452** | **59.6** |
| **Natural** | **306** | **40.4** |

Sediment loads for each monitoring site were normalized to a length of 1,000 feet for the purpose of comparison and extrapolation. Sediment loads due to streambank erosion for each monitoring site are presented in **Table E-7** in descending order, while sediment loads for each monitoring site are presented by source in **Table E-8**. Mean BEHI scores, length of eroding bank, percent of eroding bank, and the estimated potential Rosgen stream type are also presented for each monitoring site in **Table E-7**. This assessment indicates that a substantial portion of the sediment load due to streambank erosion is derived from relatively few monitoring sites, with 9 monitoring sites on 8 stream segments providing 65% (495 tons/year) of the total sediment load, including the following stream segments:

- Mill Creek (MILL-50)
- Rye Creek (RYEC-28)
- Miller Creek (MILL-28)
- Skalkaho Creek (SKAL-48)
- Sweathouse Creek (SWEA-29)
- North Burnt Fork Creek (NBFC-11, NBFC-15)
- Kootenai Creek (KOOT-52)

**Table E-7. Monitoring Site Sediment Loads due to Streambank Erosion**

| Stream Segment | ReachID | Estimated Potential Rosgen Stream Type | Mean BEHI Score | Length of Eroding Bank (feet) | Monitoring Site Length (feet) | Percent of Monitoring Site with Eroding Bank | Sediment Loading from Monitoring Site (Tons/Year) | Sediment Loading per 1000' of Stream (Tons/Year) |
|---|---|---|---|---|---|---|---|---|
| Mill | MILL-50 | C4 | 34.0 | 456 | 1000 | 22.8 | 125.3 | 125.3 |
| Rye | RYEC-28 | B3/4c | 39.4 | 298 | 1000 | 14.9 | 66.0 | 66.0 |
| Miller | MILR-28 | F4, B4c | 29.0 | 950 | 1000 | 47.5 | 39.9 | 39.9 |
| Skalkaho | SKAL-48 | C3 | 26.5 | 672 | 2000 | 16.8 | 73.2 | 36.6 |
| Sweathouse | SWEA-29 | C4 | 36.1 | 390 | 1000 | 19.5 | 35.1 | 35.1 |
| Threemile | THRE-35 | C4 | 29.5 | 511 | 1000 | 25.6 | 33.8 | 33.8 |
| North Burnt Fork | NBFC-11 | C3 | 34.0 | 337 | 1000 | 16.9 | 31.9 | 31.9 |
| Kootenai | KOOT-52 | B3,B3c | 30.6 | 681 | 2000 | 17.0 | 62.0 | 31.0 |
| North Burnt Fork | NBFC-15 | C3/4 | 35.9 | 416 | 1000 | 20.8 | 27.8 | 27.8 |
| Bear | BEAR-30 | C3 | 55.8 | 43 | 1000 | 2.2 | 18.0 | 18.0 |
| Willow | WILL-28 | B4 | 36.0 | 121 | 1000 | 6.1 | 15.0 | 15.0 |
| Lolo | LOLO-56 | C4 | 33.2 | 242 | 2000 | 6.1 | 29.0 | 14.5 |
| Lolo | LOLO-26 | B4c,C4 | 37.2 | 221 | 2000 | 5.5 | 27.0 | 13.5 |
| Threemile | THRE-16 | C4, B4c | 28.7 | 409 | 500 | 40.9 | 6.7 | 13.3 |
| Skalkaho | SKAL-36 | C3/4, C3/4/b | 30.4 | 1455 | 2000 | 36.4 | 26.6 | 13.3 |
| McClain | MCCL-15 | E4,E4b | 34.9 | 254 | 500 | 25.4 | 6.5 | 12.9 |
| North Fork Rye | NFRC-22 | B4 | 41.7 | 74 | 1000 | 3.7 | 11.2 | 11.2 |
| North Bear | NBEAR-08 | C3 | 24.4 | 119 | 1000 | 6.0 | 11.0 | 11.0 |
| Miller | MILR-33 | C4,E4 | 40.5 | 104 | 1000 | 5.2 | 10.1 | 10.1 |
| Rye | RYEC-14 | B4, C4b | 21.5 | 295 | 500 | 29.5 | 4.3 | 8.6 |
| Blodgett | BLOD-49 | B3c | 30.7 | 63 | 1000 | 3.2 | 7.6 | 7.6 |
| Miller | MILR-21 | C4,E4 | 38.1 | 66 | 1000 | 3.3 | 7.2 | 7.2 |
| Tin Cup | TINC-21 | C4, B4c | 18.3 | 2620 | 2000 | 65.5 | 14.2 | 7.1 |
| Rye | RYEC-16 | B4 | 26.7 | 330 | 1000 | 16.5 | 7.1 | 7.1 |
| Skalkaho | SKAL-21 | B3/4 | 17.2 | 1647 | 1000 | 82.4 | 6.1 | 6.1 |
| Bear | BEAR-19 | B3 | 14.3 | 1095 | 1000 | 54.8 | 5.9 | 5.9 |
| Ambrose | AMBR-30 | E4 | 37.9 | 52 | 500 | 5.2 | 2.6 | 5.2 |
| Threemile | THRE-21 | B4, B4c | 29.4 | 135 | 500 | 13.5 | 2.5 | 4.9 |
| Threemile | THRE-14 | B4, B4c | 27.8 | 217 | 500 | 21.7 | 2.4 | 4.7 |
| Skalkaho | SKAL-13 | B4, C4b | 18.0 | 882 | 1000 | 44.1 | 4.5 | 4.5 |
| Lick | LICK-08 | B4 | 16.0 | 500 | 500 | 50.0 | 1.9 | 3.8 |
| Lolo | LOLO-34 | C3/4 | 33.9 | 45 | 2000 | 1.1 | 6.4 | 3.2 |
| Sleeping Child | SLEE-30 | B3/4 | 19.9 | 190 | 1000 | 9.5 | 2.6 | 2.6 |
| Blodgett | BLOD-35 | B3 | 12.4 | 670 | 1000 | 33.5 | 2.5 | 2.5 |
| Tin Cup | TINC-31/32 | B3,B3c | 20.9 | 100 | 2000 | 2.5 | 4.4 | 2.2 |
| North Fork Rye | NFRC-10 | C4 | 19.6 | 195 | 500 | 19.5 | 1.1 | 2.2 |
| North Fork Rye | NFRC-12 | B3/4 | 17.7 | 245 | 1000 | 12.3 | 1.5 | 1.5 |
| Bass | BASS-24 | B3 | | | 1000 | | 1.2 | 1.2 |
| Bass | BASS-27 | B3c | | | 1000 | | 1.2 | 1.2 |
| Lick | LICK-19 | E4b,B4 | | | 500 | | 0.6 | 1.2 |
| Lost Horse | LOST-43 | C3,B3 | | | 2000 | | 2.4 | 1.2 |
| Mill | MILL-43 | C3b,B3 | | | 1000 | | 1.2 | 1.2 |
| Miller | MILR-11 | B4 | | | 500 | | 0.6 | 1.2 |
| Rye | RYEC-36 | C4 | | | 1000 | | 1.2 | 1.2 |
| South Fork Lolo | SFLO-43 | B3 | | | 1000 | | 1.2 | 1.2 |
| Skalkaho | SKAL-33 | B3, B3c | | | 2000 | | 2.4 | 1.2 |
| Sleeping Child | SLEE-44 | C3,B3c | | | 1000 | | 1.2 | 1.2 |
| Willow | WILL-38 | C4 | | | 1000 | | 1.2 | 1.2 |
| Sleeping Child | SLEE-27 | B3 | 13.0 | 225 | 1000 | 11.3 | 1.0 | 1.0 |
| Lost Horse | LOST-33 | B3 | 18.4 | 365 | 2000 | 9.1 | 1.6 | 0.8 |
| Roaring Lion | ROLI-24 | B3 | 15.7 | 110 | 1000 | 5.5 | 0.7 | 0.7 |
| Sweathouse | SWEA-18 | A2/3 | 12.6 | 55 | 1000 | 2.8 | 0.1 | 0.1 |
| Blodgett | BLOD-42 | A2, B2 | | 0 | 1000 | | 0.0 | 0.0 |
| Lost Horse | LOST-15 | B3 | | | 1000 | | 0.0 | 0.0 |

**Table E-8. Monitoring Site Sediment Loads from Individual Sources due to Streambank Erosion**

| Stream Segment | Reach ID | Monitoring Site Length | | Transportation Load (Tons/Year) | Riparian Grazing Load (Tons/Year) | Cropland Load (Tons/Year) | Mining Load (Tons/Year) | Silviculture Load (Tons/Year) | Irrigation Load (Tons/Year) | Natural Load (Tons/Year) | "Other" Load (Tons/Year) | Total Load |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambrose Creek | AMBR-30 | 500 | Total | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.7 | **2.6** |
| | | | Percent | 0 | 3 | 0 | 0 | 0 | 0 | 33 | 64 | |
| Bass Creek | BASS-24 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | **1.2** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Bass Creek | BASS-27 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | **1.2** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Bear Creek | BEAR-19 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.9 | 0.0 | **5.9** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Bear Creek | BEAR-30 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.6 | 8.4 | **18.0** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 53 | 47 | |
| Blodgett Creek | BLOD-35 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | **2.5** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Blodgett Creek | BLOD-42 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Blodgett Creek | BLOD-49 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 5.1 | **7.6** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 68 | |
| Kootenai Creek | KOOT-52 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 61.9 | 0.0 | **62.0** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Lick Creek | LICK-08 | 500 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 0.0 | **1.9** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Lick Creek | LICK-19 | 500 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | **0.6** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Lolo Creek | LOLO-26 | 2000 | Total | 22.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 0.0 | **27.0** |
| | | | Percent | 82 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | |
| Lolo Creek | LOLO-34 | 2000 | Total | 0.4 | 0.0 | 0.0 | 0.0 | 2.8 | 0.0 | 3.2 | 0.0 | **6.4** |
| | | | Percent | 6 | 0 | 0 | 0 | 44 | 0 | 50 | 0 | |
| Lolo Creek | LOLO-56 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.0 | 8.0 | **29.0** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 28 | |
| Lost Horse Creeek | LOST-15 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Lost Horse Creeek | LOST-33 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | **1.6** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Lost Horse Creeek | LOST-43 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 0.0 | **2.4** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| McClain Creek | MCCL-15 | 500 | Total | 0.0 | 5.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | **6.5** |
| | | | Percent | 0 | 82 | 0 | 0 | 0 | 0 | 18 | 0 | |
| Mill Creek | MILL-43 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | **1.2** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Mill Creek | MILL-50 | 1000 | Total | 0.0 | 0.0 | 91.2 | 0.0 | 0.0 | 0.0 | 30.1 | 4.0 | **125.3** |
| | | | Percent | 0 | 0 | 73 | 0 | 0 | 0 | 24 | 3 | |
| Miller Creek | MILR-11 | 500 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | **0.6** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Miller Creek | MILR-21 | 1000 | Total | 0.6 | 3.0 | 0.0 | 0.0 | 0.6 | 0.0 | 3.0 | 0.0 | **7.2** |
| | | | Percent | 8 | 42 | 0 | 0 | 8 | 0 | 42 | 0 | |
| Miller Creek | MILR-28 | 1000 | Total | 0.0 | 13.0 | 0.0 | 0.0 | 0.0 | 8.0 | 18.9 | 0.0 | **39.9** |
| | | | Percent | 0 | 33 | 0 | 0 | 0 | 20 | 47 | 0 | |
| Miller Creek | MILR-33 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 8.9 | **10.1** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 88 | |
| North Bear Creek | NBEAR-08 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.1 | 3.9 | **11.0** |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 36 | |
| North Burnt Fork Creek | NBFC-11 | 1000 | Total | 9.1 | 21.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | **31.9** |
| | | | Percent | 29 | 67 | 0 | 0 | 0 | 0 | 5 | 0 | |
| North Burnt Fork Creek | NBFC-15 | 1000 | Total | 0.0 | 24.1 | 0.0 | 0.0 | 0.0 | 2.5 | 1.2 | 0.0 | **27.8** |
| | | | Percent | 0 | 87 | 0 | 0 | 0 | 9 | 4 | 0 | |

## Table E-8. Monitoring Site Sediment Loads from Individual Sources due to Streambank Erosion

| Stream Segment | Reach ID | Monitoring Site Length | | Transportation Load (Tons/Year) | Riparian Grazing Load (Tons/Year) | Cropland Load (Tons/Year) | Mining Load (Tons/Year) | Silviculture Load (Tons/Year) | Irrigation Load (Tons/Year) | Natural Load (Tons/Year) | "Other" Load (Tons/Year) | Total Load |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Fork Rye Creek | NFRC-10 | 500 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 1.1 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| North Fork Rye Creek | NFRC-12 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 1.5 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| North Fork Rye Creek | NFRC-22 | 1000 | Total | 0.0 | 1.4 | 8.3 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 11.2 |
| | | | Percent | 0 | 12 | 74 | 0 | 0 | 0 | 13 | 0 | |
| Roaring Lion Creek | ROLI-24 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 0.7 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Rye Creek | RYEC-14 | 500 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.3 | 0.0 | 0.0 | 4.3 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 101 | 0 | 0 | |
| Rye Creek | RYEC-16 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.1 | 0.0 | 7.1 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Rye Creek | RYEC-28 | 1000 | Total | 0.0 | 23.5 | 23.5 | 0.0 | 9.0 | 0.0 | 8.7 | 0.0 | 66.0 |
| | | | Percent | 0 | 36 | 36 | 0 | 15 | 0 | 14 | 0 | |
| Rye Creek | RYEC-36 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 1.2 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Skalkaho Creek | SKAL-13 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 0.0 | 4.5 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Skalkaho Creek | SKAL-21 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.1 | 0.0 | 6.1 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Skalkaho Creek | SKAL-33 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 0.0 | 2.4 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Skalkaho Creek | SKAL-36 | 2000 | Total | 0.0 | 19.8 | 0.0 | 0.0 | 0.0 | 0.0 | 6.7 | 0.0 | 26.6 |
| | | | Percent | 0 | 75 | 0 | 0 | 0 | 0 | 25 | 0 | |
| Skalkaho Creek | SKAL-48 | 2000 | Total | 6.5 | 7.3 | 0.0 | 0.0 | 0.0 | 0.0 | 31.3 | 28.2 | 73.2 |
| | | | Percent | 9 | 10 | 0 | 0 | 0 | 0 | 43 | 39 | |
| Sleeping Child Creek | SLEE-27 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Sleeping Child Creek | SLEE-30 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 0.0 | 2.6 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Sleeping Child Creek | SLEE-44 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 1.2 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| South Fork Lolo Creek | SFLO-43 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 1.2 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Sweathouse Creek | SWEA-18 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Sweathouse Creek | SWEA-29 | 1000 | Total | 0.0 | 28.3 | 0.0 | 0.0 | 0.0 | 2.5 | 1.2 | 3.1 | 35.1 |
| | | | Percent | 0 | 81 | 0 | 0 | 0 | 7 | 3 | 9 | |
| Threemile Creek | THRE-14 | 500 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 0.0 | 2.4 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Threemile Creek | THRE-16 | 500 | Total | 1.2 | 4.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 6.6 |
| | | | Percent | 18 | 73 | 0 | 0 | 0 | 0 | 11 | 0 | |
| Threemile Creek | THRE-21 | 500 | Total | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 0.0 | 2.4 |
| | | | Percent | 4 | 4 | 0 | 0 | 0 | 0 | 92 | 0 | |
| Threemile Creek | THRE-35 | 1000 | Total | 0.0 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.3 | 14.5 | 33.8 |
| | | | Percent | 0 | 41 | 0 | 0 | 0 | 0 | 16 | 43 | |
| Tin Cup Creek | TINC-21 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.2 | 0.0 | 14.2 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Tin Cup Creek | TINC-31/32 | 2000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 0.0 | 4.4 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |
| Willow Creek | WILL-28 | 1000 | Total | 0.0 | 3.5 | 3.5 | 0.0 | 0.0 | 0.0 | 8.1 | 0.0 | 15.0 |
| | | | Percent | 0 | 23 | 23 | 0 | 0 | 0 | 54 | 0 | |
| Willow Creek | WILL-38 | 1000 | Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 1.2 |
| | | | Percent | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | |

## E3.2 Stream Reach Sediment Loads

Sediment loads calculated at the monitoring site scale were extrapolated to the stream reach scale based on the Aerial Assessment Database. First, the monitoring site sediment load was extrapolated directly to the stream reach in which it was located. Second, the mean sediment load was calculated for each stream reach type in which one or more monitoring sites were located. This mean "reach type" sediment load was then assigned to each reach of that type. Finally, for stream reach types in which no monitoring site was located, sediment loads were extrapolated from reach types exhibiting the most similarity to the un-assessed reach types (see **Tables B-3, B-4** and **B-5).** This decision was based on several factors as described in **Section B2.4**, including the information in the Aerial Assessment Database, a review of 2005 color aerial imagery in GIS, and best professional judgment based on site-specific knowledge acquired during the monitoring site assessment process. This process was performed individually for each reach, with sediment loads assigned to each observed source based on the overall estimated reach load. Data extrapolated to the stream reach scale is presented in the Streambank Erosion Database in the Streambank Erosion Source Assessment (PBS&J 2008).

## E3.3 Stream Segment Sediment Loads

Stream segment sediment loads were estimated based on the cumulative sediment load of the stream reaches within the stream segment. Sediment loads were estimated for a total of 360.9 miles along 23 stream segments. A total sediment load of 15,639 tons/year was attributed to eroding streambanks at the stream segment scale (**Table E-9**). Approximately 49% of the sediment load due to streambank erosion at the stream segment scale was due to anthropogenic sources, while approximately 51% was due to natural sources. Stream segment sediment loading estimates indicate that riparian grazing, cropland, transportation and "other" (residential and commercial encroachment) are the greatest anthropogenic contributors of sediment loads due to streambank erosion in the Bitterroot TPA. Sediment loads due to streambank erosion for each stream segment are provided for each source in **Table E-10**.

**Table E-9. Summary of Stream Segment Sediment Loads**

| Source | Sediment Load (Tons/Year) | Sediment Load (Percent) |
|---|---|---|
| Transportation | 1,268 | 8.1 |
| Riparian Grazing | 2,438 | 15.6 |
| Cropland | 1,913 | 12.2 |
| Mining | 36 | 0.2 |
| Silviculture | 78 | 0.5 |
| Irrigation | 299 | 1.9 |
| Natural Sources | 7,947 | 50.9 |
| Other | 1,661 | 10.6 |
| **Total** | **15,639** | **100** |
| **Anthropogenic** | **7,692** | **49.1** |
| **Natural** | **7,947** | **50.9** |

**Table E-10. Stream Segment Sediment Loads from Individual Sources due to Streambank Erosion**

| Stream Segment | Stream Segment Length (Miles) | Sediment Load | Sources | | | | | | | | Total Load (Tons/Year) | Total Load per Mile (Tons/Year) | Total Load per 1000 Feet (Tons/Year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Transportation | Riparian Grazing | Cropland | Mining | Silviculture | Irrigation - shifts in stream energy | Natural Sources | Other | | | |
| Ambrose Creek | 12.7 | Tons/Year | 40.5 | 107.4 | 173.4 | 0.0 | 0.0 | 0.0 | 120.5 | 44.6 | 486.4 | 38.3 | 7.3 |
| | | *Percent* | *8%* | *22%* | *36%* | *0%* | *0%* | *0%* | *25%* | *9%* | | | |
| Bass Creek | 10.0 | Tons/Year | 2.7 | 9.8 | 0.0 | 0.0 | 0.0 | 0.9 | 107.7 | 5.2 | 126.3 | 12.7 | 2.4 |
| | | *Percent* | *2%* | *8%* | *0%* | *0%* | *0%* | *1%* | *85%* | *4%* | | | |
| Bear Creek | 20.2 | Tons/Year | 27.8 | 64.1 | 0.0 | 0.0 | 0.0 | 9.2 | 563.5 | 189.8 | 854.3 | 42.2 | 8.0 |
| | | *Percent* | *3%* | *8%* | *0%* | *0%* | *0%* | *1%* | *66%* | *22%* | | | |
| Blodgett Creek | 18.7 | Tons/Year | 14.5 | 59.3 | 32.1 | 33.7 | 0.0 | 13.8 | 251.5 | 52.7 | 457.6 | 24.5 | 4.6 |
| | | *Percent* | *3%* | *13%* | *7%* | *7%* | *0%* | *3%* | *55%* | *12%* | | | |
| Kootenai Creek | 13.5 | Tons/Year | 4.9 | 25.6 | 0.8 | 0.0 | 0.0 | 16.1 | 277.0 | 59.2 | 383.5 | 28.4 | 5.4 |
| | | *Percent* | *1%* | *7%* | *0%* | *0%* | *0%* | *4%* | *72%* | *15%* | | | |
| Lick Creek | 6.4 | Tons/Year | 10.0 | 30.8 | 0.0 | 0.0 | 0.0 | 0.0 | 73.8 | 2.2 | 116.9 | 18.3 | 3.5 |
| | | *Percent* | *9%* | *26%* | *0%* | *0%* | *0%* | *0%* | *63%* | *2%* | | | |
| Lolo Creek | 31.5 | Tons/Year | 367.7 | 196.8 | 60.6 | 0.0 | 36.4 | 40.9 | 886.3 | 153.1 | 1741.7 | 55.3 | 10.5 |
| | | *Percent* | *21%* | *11%* | *3%* | *0%* | *2%* | *2%* | *51%* | *9%* | | | |
| Lost Horse Creek | 19.6 | Tons/Year | 27.8 | 23.3 | 0.0 | 0.0 | 0.0 | 7.3 | 468.5 | 4.3 | 531.2 | 27.1 | 5.1 |
| | | *Percent* | *5%* | *4%* | *0%* | *0%* | *0%* | *1%* | *88%* | *1%* | | | |
| McClain Creek | 5.4 | Tons/Year | 15.4 | 29.5 | 8.0 | 2.0 | 0.0 | 5.2 | 21.6 | 0.0 | 81.7 | 15.3 | 2.9 |
| | | *Percent* | *19%* | *36%* | *10%* | *2%* | *0%* | *6%* | *26%* | *0%* | | | |
| Mill Creek | 19.1 | Tons/Year | 23.5 | 178.2 | 527.6 | 0.0 | 0.0 | 1.0 | 495.3 | 76.4 | 1302.1 | 68.1 | 12.9 |
| | | *Percent* | *2%* | *14%* | *41%* | *0%* | *0%* | *0%* | *38%* | *6%* | | | |
| Miller Creek | 18.3 | Tons/Year | 82.9 | 201.5 | 362.4 | 0.0 | 0.7 | 30.1 | 429.5 | 249.8 | 1356.8 | 74.0 | 14.0 |
| | | *Percent* | *6%* | *15%* | *27%* | *0%* | *0%* | *2%* | *32%* | *18%* | | | |
| Muddy Springs Creek | 2.0 | Tons/Year | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| | | *Percent* | *100%* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* | | | |
| North Burnt Fork Creek | 10.9 | Tons/Year | 68.7 | 402.1 | 132.2 | 0.0 | 0.0 | 24.3 | 227.2 | 84.5 | 939.0 | 85.8 | 16.3 |
| | | *Percent* | *7%* | *43%* | *14%* | *0%* | *0%* | *3%* | *24%* | *9%* | | | |
| North Fork Rye Creek | 7.1 | Tons/Year | 11.0 | 2.7 | 12.1 | 0.0 | 1.8 | 0.0 | 63.4 | 5.0 | 95.9 | 13.5 | 2.6 |
| | | *Percent* | *11%* | *3%* | *13%* | *0%* | *2%* | *0%* | *66%* | *5%* | | | |
| Roaring Lion Creek | 15.0 | Tons/Year | 2.4 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | 277.0 | 1.3 | 285.1 | 19.0 | 3.6 |
| | | *Percent* | *1%* | *2%* | *0%* | *0%* | *0%* | *0%* | *97%* | *0%* | | | |
| Rye Creek | 17.5 | Tons/Year | 38.9 | 84.2 | 53.5 | 0.0 | 13.4 | 21.5 | 450.0 | 3.1 | 664.6 | 38.0 | 7.2 |
| | | *Percent* | *6%* | *13%* | *8%* | *0%* | *2%* | *3%* | *68%* | *0%* | | | |
| Skalkaho Creek | 27.7 | Tons/Year | 82.1 | 286.6 | 125.0 | 0.0 | 0.0 | 16.5 | 1069.9 | 148.7 | 1728.7 | 62.4 | 11.8 |
| | | *Percent* | *5%* | *17%* | *7%* | *0%* | *0%* | *1%* | *62%* | *9%* | | | |
| Sleeping Child Creek | 24.9 | Tons/Year | 22.4 | 99.5 | 66.2 | 0.0 | 25.5 | 13.6 | 417.9 | 22.3 | 667.3 | 26.8 | 5.1 |
| | | *Percent* | *3%* | *15%* | *10%* | *0%* | *4%* | *2%* | *63%* | *3%* | | | |
| South Fork Lolo Creek | 14.9 | Tons/Year | 2.2 | 10.2 | 0.0 | 0.0 | 0.0 | 0.0 | 236.0 | 0.0 | 248.4 | 16.7 | 3.2 |
| | | *Percent* | *1%* | *4%* | *0%* | *0%* | *0%* | *0%* | *95%* | *0%* | | | |
| Sweathouse Creek | 11.2 | Tons/Year | 10.3 | 320.3 | 5.5 | 0.0 | 0.0 | 30.8 | 170.8 | 80.0 | 617.6 | 55.3 | 10.5 |
| | | *Percent* | *2%* | *52%* | *1%* | *0%* | *0%* | *5%* | *28%* | *13%* | | | |
| Threemile Creek | 18.0 | Tons/Year | 357.4 | 84.2 | 214.8 | 0.0 | 0.0 | 21.1 | 471.4 | 312.5 | 1461.4 | 81.1 | 15.4 |
| | | *Percent* | *24%* | *6%* | *15%* | *0%* | *0%* | *1%* | *32%* | *21%* | | | |
| Tin Cup Creek | 16.2 | Tons/Year | 16.1 | 23.9 | 6.9 | 0.0 | 0.0 | 11.9 | 436.4 | 58.2 | 553.3 | 34.2 | 6.5 |
| | | *Percent* | *3%* | *4%* | *1%* | *0%* | *0%* | *2%* | *79%* | *11%* | | | |
| Willow Creek | 20.1 | Tons/Year | 38.8 | 193.6 | 132.1 | 0.0 | 0.0 | 34.6 | 432.0 | 108.4 | 939.4 | 46.6 | 8.8 |
| | | *Percent* | *4%* | *21%* | *14%* | *0%* | *0%* | *4%* | *46%* | *12%* | | | |

## E3.4 Watershed Sediment Loads

Watershed sediment loads were estimated for the Bitterroot TPA based on the total length of stream within the watershed. The Bitterroot TPA includes the entire Bitterroot River watershed from the confluence of the East Fork Bitterroot River and West Fork Bitterroot River downstream to the Confluence with the Clark Fork River. The Bitterroot TPA also includes the Lolo Creek watershed from the confluence of the East Fork Lolo Creek and West Fork Lolo Creek downstream to the confluence with the Bitterroot River. In addition, the Upper Lolo TPA, which extends from the headwaters downstream to the confluence of the East Fork Lolo Creek and West Fork Lolo Creek, was also included in this assessment.

Watershed sediment loads were estimated from the sum of the sediment loads at the stream segment scale combined with an estimate of sediment loads from un-assessed streams. Assessed streams include 360.9 miles of stream segments described in the Aerial Assessment Database, while un-assessed streams were identified using a modified version of the USGS National Hydrography Dataset (NHD) in which irrigation ditches were removed. The modified NHD layer indicates there are 2,397.2 miles of stream within the Bitterroot TPA. Thus, a total of 2,036.3 miles of stream were not included in the Aerial Assessment Database.

Sediment loading along the 2,036.3 miles of un-assessed streams was evaluated using the 25$^{th}$ percentile of sediment loading from the entire dataset. Based on the 25$^{th}$ percentile of the entire dataset at the stream segment scale, an annual sediment load of 18.6 tons/mile was estimated to be the average rate of streambank erosion within the Bitterroot TPA. This value is equivalent to 3.5 tons/year of sediment input from every 1,000 feet of stream. Based on the estimated sediment load of 18.6 tons per mile, eroding streambanks along the 2,036.3 un-assessed miles of stream in the Bitterroot TPA are estimated to contribute 37,875 tons of sediment per year (**Table E-11**). The total sediment load for the Bitterroot TPA is estimated at 53,514 tons/year. Sediment loads for individual watersheds are provided in **Table E-12**.

**Table E-11. Summary of Sediment Loads due to Streambank Erosion at the Watershed Scale**

| Stream Length (Miles) | Length of Stream Assessed using Aerial Imagery (Miles) | Length of Stream Un-assessed (Miles) | Estimated Sediment Load for Assessed Streams (Tons/Year) | Estimated Sediment Load for Un-assessed Streams based on Stream Segment Extrapolation (18.6 Tons/Mile/Year) | Total Sediment Load (Tons/Year) |
|---|---|---|---|---|---|
| 2,397.2 | 360.9 | 2,036.3 | 15,639 | 37,875 | 53,514 |

In addition to the 53,514 tons/year estimated for the Bitterroot TPA, which includes the Lolo Creek watershed, a sediment load of 21,059 tons/year was estimated for the Bitterroot Headwaters TPA based on an estimated sediment load of 18.6 tons/mile/year and 1,132.23 miles of stream. Thus, a total sediment load of 74,574 tons/year is estimated for the entire Bitterroot River watershed.

**Table E-12. Watershed Sediment Loads from Individual Sources due to Streambank Erosion**

| Stream Segment | Stream Segment Length (Miles) | Sediment Load | Sources: Transportation | Riparian Grazing | Cropland | Mining | Silviculture | Irrigation - shifts in stream energy | Natural Sources | Other | Total Load (Tons/Year) | Total Load per Mile (Tons/Year) | Total Load per 1000 Feet (Tons/Year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambrose Creek | 38.1 | Tons/Year | 79.9 | 211.7 | 341.9 | 0.0 | 0.0 | 0.0 | 237.6 | 87.9 | 959.0 | 25.2 | 4.8 |
| | | *Percent* | *8%* | *22%* | *36%* | *0%* | *0%* | *0%* | *25%* | *9%* | | | |
| Bass Creek | 16.1 | Tons/Year | 5.2 | 18.7 | 0.0 | 0.0 | 0.0 | 1.7 | 205.2 | 9.9 | 240.6 | 14.9 | 2.8 |
| | | *Percent* | *2%* | *8%* | *0%* | *0%* | *0%* | *1%* | *85%* | *4%* | | | |
| Bear Creek | 36.1 | Tons/Year | 36.9 | 86.6 | 0.0 | 0.0 | 0.0 | 12.4 | 758.3 | 255.9 | 1150.0 | 31.9 | 6.0 |
| | | *Percent* | *3%* | *8%* | *0%* | *0%* | *0%* | *1%* | *66%* | *22%* | | | |
| Blodgett Creek | 36.6 | Tons/Year | 24.1 | 102.8 | 53.4 | 55.9 | 0.0 | 22.9 | 435.1 | 94.9 | 791.1 | 21.6 | 4.1 |
| | | *Percent* | *3%* | *13%* | *7%* | *7%* | *0%* | *3%* | *55%* | *12%* | | | |
| Kootenai Creek | 40.5 | Tons/Year | 11.4 | 59.1 | 1.7 | 0.0 | 0.0 | 37.3 | 639.8 | 136.6 | 885.9 | 21.9 | 4.1 |
| | | *Percent* | *1%* | *7%* | *0%* | *0%* | *0%* | *4%* | *72%* | *15%* | | | |
| Lick Creek | 9.8 | Tons/Year | 15.5 | 47.5 | 0.0 | 0.0 | 0.0 | 0.0 | 113.9 | 3.4 | 180.3 | 18.4 | 3.5 |
| | | *Percent* | *9%* | *26%* | *0%* | *0%* | *0%* | *0%* | *63%* | *2%* | | | |
| Lolo Creek (including South Fork Lolo Creek) | 332.2 | Tons/Year | 1548.3 | 828.6 | 255.2 | 0.0 | 153.3 | 172.2 | 3732.2 | 644.7 | 7334.5 | 22.1 | 4.2 |
| | | *Percent* | *21%* | *11%* | *3%* | *0%* | *2%* | *2%* | *51%* | *9%* | | | |
| Lost Horse Creek | 40.7 | Tons/Year | 48.4 | 41.4 | 0.0 | 0.0 | 0.0 | 12.8 | 813.6 | 7.4 | 923.6 | 22.7 | 4.3 |
| | | *Percent* | *5%* | *4%* | *0%* | *0%* | *0%* | *1%* | *88%* | *1%* | | | |
| McClain Creek | 7.0 | Tons/Year | 21.2 | 40.5 | 11.1 | 2.7 | 0.0 | 7.1 | 29.8 | 0.0 | 112.4 | 16.1 | 3.0 |
| | | *Percent* | *19%* | *36%* | *10%* | *2%* | *0%* | *6%* | *26%* | *0%* | | | |
| Mill Creek | 71.0 | Tons/Year | 41.0 | 310.3 | 918.7 | 0.0 | 0.0 | 1.8 | 862.4 | 133.1 | 2267.2 | 31.9 | 6.0 |
| | | *Percent* | *2%* | *14%* | *41%* | *0%* | *0%* | *0%* | *38%* | *6%* | | | |
| Miller Creek | 56.9 | Tons/Year | 126.7 | 308.0 | 554.0 | 0.0 | 1.1 | 46.0 | 656.5 | 381.8 | 2074.0 | 36.4 | 6.9 |
| | | *Percent* | *6%* | *15%* | *27%* | *0%* | *0%* | *2%* | *32%* | *18%* | | | |
| Muddy Springs Creek | 2.0 | Tons/Year | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| | | *Percent* | *100%* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* | | | |
| North Burnt Fork Creek | 107.0 | Tons/Year | 199.4 | 1167.2 | 383.7 | 0.0 | 0.0 | 70.5 | 659.6 | 245.3 | 2725.7 | 25.5 | 4.8 |
| | | *Percent* | *7%* | *43%* | *14%* | *0%* | *0%* | *3%* | *24%* | *9%* | | | |
| North Fork Rye Creek | 26.8 | Tons/Year | 52.8 | 13.1 | 58.5 | 0.0 | 8.7 | 0.0 | 305.6 | 24.0 | 462.7 | 17.3 | 3.3 |
| | | *Percent* | *11%* | *3%* | *13%* | *0%* | *2%* | *0%* | *66%* | *5%* | | | |
| Roaring Lion Creek | 28.3 | Tons/Year | 4.6 | 8.1 | 0.0 | 0.0 | 0.0 | 0.0 | 516.6 | 2.4 | 531.7 | 18.8 | 3.6 |
| | | *Percent* | *1%* | *2%* | *0%* | *0%* | *0%* | *0%* | *97%* | *0%* | | | |
| Rye Creek (including North Fork Rye Creek) | 85.8 | Tons/Year | 113.4 | 245.0 | 155.6 | 0.0 | 39.1 | 62.6 | 1310.4 | 9.1 | 1935.2 | 22.6 | 4.3 |
| | | *Percent* | *6%* | *13%* | *8%* | *0%* | *2%* | *3%* | *68%* | *0%* | | | |
| Skalkaho Creek | 135.9 | Tons/Year | 177.7 | 620.2 | 270.4 | 0.0 | 0.0 | 35.6 | 2315.4 | 321.7 | 3741.1 | 27.5 | 5.2 |
| | | *Percent* | *5%* | *17%* | *7%* | *0%* | *0%* | *1%* | *62%* | *9%* | | | |
| Sleeping Child Creek | 117.4 | Tons/Year | 80.1 | 355.9 | 236.9 | 0.0 | 91.2 | 48.5 | 1495.0 | 79.6 | 2387.2 | 20.3 | 3.9 |
| | | *Percent* | *3%* | *15%* | *10%* | *0%* | *4%* | *2%* | *63%* | *3%* | | | |
| South Fork Lolo Creek | 60.1 | Tons/Year | 9.7 | 44.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1035.7 | 0.0 | 1090.0 | 18.1 | 3.4 |
| | | *Percent* | *1%* | *4%* | *0%* | *0%* | *0%* | *0%* | *95%* | *0%* | | | |
| Sweathouse Creek | 33.7 | Tons/Year | 17.2 | 537.7 | 9.3 | 0.1 | 0.0 | 51.6 | 286.7 | 134.3 | 1036.9 | 30.8 | 5.8 |
| | | *Percent* | *2%* | *52%* | *1%* | *0%* | *0%* | *5%* | *28%* | *13%* | | | |
| Threemile Creek (including Ambrose Creek) | 120.6 | Tons/Year | 824.1 | 194.1 | 495.2 | 0.0 | 0.0 | 48.6 | 1087.0 | 720.6 | 3369.6 | 27.9 | 5.3 |
| | | *Percent* | *24%* | *6%* | *15%* | *0%* | *0%* | *1%* | *32%* | *21%* | | | |
| Tin Cup Creek | 42.7 | Tons/Year | 32.5 | 48.4 | 13.9 | 0.0 | 0.0 | 24.0 | 811.7 | 115.6 | 1046.2 | 24.5 | 4.6 |
| | | *Percent* | *3%* | *5%* | *1%* | *0%* | *0%* | *2%* | *78%* | *11%* | | | |
| Willow Creek | 61.3 | Tons/Year | 70.4 | 351.4 | 239.8 | 0.0 | 0.0 | 62.7 | 784.0 | 196.8 | 1705.0 | 27.8 | 5.3 |
| | | *Percent* | *4%* | *21%* | *14%* | *0%* | *0%* | *4%* | *46%* | *12%* | | | |

# E4.0 Potential Sediment Load Reductions

This section is provided for technical guidance in determining sediment allocations for human influenced activities that cause streambank erosion. The results are only one of a number of components that will be considered during the TMDL sediment allocation process. The results are provided to determine a reasonable amount of sediment reduction to sources that influence streambank erosion. The allocation process will also consider economic feasibility of restoration from each significant source and regional BMP effectiveness studies. Determining a potential overall load reduction from streambank erosion also will help define how much sediment production from streambank erosion is likely derived from natural conditions.

## E4.1 Streambank Erosion Reduction

To estimate a potential decrease in sediment loading due to improved streambank stability, BEHI values in the existing dataset for each streambank that exceeded the “moderate” category were reduced to “moderate”. The results of this model are presented in **Table E-13** for the individual monitoring sites. Reductions calculated at the monitoring site scale were extrapolated to the stream segment scale using the Aerial Assessment Database (**Table E-14**). This reduction often resulted in a “moderate BEHI/low NBS” combination for an expected retreat rate of 0.17 feet/year. Through BMPs, the actual length and height of eroding bank could also be reduced, which would lead to further reductions in sediment loading.

**Table E-13. Monitoring Site Sediment Loads with BEHI Reduced to "Moderate"**

| Stream Segment | ReachID | Sediment Loading from Monitoring Sites (Tons/Year) | Sediment Loading from 1000' of Stream (Tons/Year) | Sediment Loading from Monitoring Sites with Moderate BEHI (Tons/Year) | Sediment Loading from 1000' of Stream with Moderate BEHI (Tons/Year) |
|---|---|---|---|---|---|
| Ambrose Creek | AMBR-30 | 2.6 | 5.2 | 1.3 | 2.5 |
| Bass Creek | BASS-24 | 1.2 | 1.2 | 1.2 | 1.2 |
| Bass Creek | BASS-27 | 1.2 | 1.2 | 1.2 | 1.2 |
| Bear Creek | BEAR-19 | 5.9 | 5.9 | 5.9 | 5.9 |
| Bear Creek | BEAR-30 | 18.0 | 18.0 | 7.1 | 7.1 |
| Blodgett Creek | BLOD-35 | 2.5 | 2.5 | 2.5 | 2.5 |
| Blodgett Creek | BLOD-42 | 0.0 | 0.0 | 0.0 | 0.0 |
| Blodgett Creek | BLOD-49 | 7.6 | 7.6 | 3.3 | 3.3 |
| Kootenai Creek | KOOT-52 | 62.0 | 31.0 | 47.1 | 23.5 |
| Lick Creek | LICK-08 | 1.9 | 3.8 | 1.9 | 3.8 |
| Lick Creek | LICK-19 | 0.6 | 1.2 | 0.6 | 1.2 |
| Lolo Creek | LOLO-26 | 27.0 | 13.5 | 10.3 | 5.2 |
| Lolo Creek | LOLO-34 | 6.4 | 3.2 | 4.5 | 2.3 |
| Lolo Creek | LOLO-56 | 29.0 | 14.5 | 10.9 | 5.5 |
| Lost Horse Creek | LOST-15 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lost Horse Creek | LOST-33 | 1.6 | 0.8 | 1.6 | 0.8 |
| Lost Horse Creek | LOST-43 | 2.4 | 1.2 | 2.4 | 1.2 |
| McClain Creek | MCCL-15 | 6.5 | 12.9 | 3.7 | 7.5 |
| Mill Creek | MILL-43 | 1.2 | 1.2 | 1.2 | 1.2 |
| Mill Creek | MILL-50 | 125.3 | 125.3 | 66.1 | 66.1 |
| Miller Creek | MILR-11 | 0.6 | 1.2 | 0.6 | 1.2 |
| Miller Creek | MILR-21 | 7.2 | 7.2 | 3.1 | 3.1 |
| Miller Creek | MILR-28 | 39.9 | 39.9 | 21.2 | 21.2 |
| Miller Creek | MILR-33 | 10.1 | 10.1 | 4.1 | 4.1 |
| North Bear Creek | NBEAR-08 | 11.0 | 11.0 | 11.0 | 11.0 |
| North Burnt Fork Creek | NBFC-11 | 31.9 | 31.9 | 12.3 | 12.3 |
| North Burnt Fork Creek | NBFC-15 | 27.8 | 27.8 | 10.4 | 10.4 |
| North Fork Rye Creek | NFRC-10 | 1.1 | 2.2 | 1.1 | 2.2 |
| North Fork Rye Creek | NFRC-12 | 1.5 | 1.5 | 1.5 | 1.5 |
| North Fork Rye Creek | NFRC-22 | 11.2 | 11.2 | 4.4 | 4.4 |
| Roaring Lion Creek | ROLI-24 | 0.7 | 0.7 | 0.7 | 0.7 |
| Rye Creek | RYEC-14 | 4.3 | 8.6 | 4.3 | 8.6 |
| Rye Creek | RYEC-16 | 7.1 | 7.1 | 7.1 | 7.1 |
| Rye Creek | RYEC-28 | 66.0 | 66.0 | 25.1 | 25.1 |
| Rye Creek | RYEC-36 | 1.2 | 1.2 | 1.2 | 1.2 |
| South Fork Lolo Creek | SFLO-43 | 1.2 | 1.2 | 1.2 | 1.2 |
| Skalkaho Creek | SKAL-13 | 4.5 | 4.5 | 4.5 | 4.5 |
| Skalkaho Creek | SKAL-21 | 6.1 | 6.1 | 6.1 | 6.1 |
| Skalkaho Creek | SKAL-33 | 2.4 | 1.2 | 2.4 | 1.2 |
| Skalkaho Creek | SKAL-36 | 26.6 | 13.3 | 22.4 | 11.2 |
| Skalkaho Creek | SKAL-48 | 73.2 | 36.6 | 62.2 | 31.1 |
| Sleeping Child Creek | SLEE-27 | 1.0 | 1.0 | 1.0 | 1.0 |
| Sleeping Child Creek | SLEE-30 | 2.6 | 2.6 | 2.6 | 2.6 |
| Sleeping Child Creek | SLEE-44 | 1.2 | 1.2 | 1.2 | 1.2 |
| Sweathouse Creek | SWEA-18 | 0.1 | 0.1 | 0.1 | 0.1 |
| Sweathouse Creek | SWEA-29 | 35.1 | 35.1 | 12.9 | 12.9 |
| Threemile Creek | THRE-14 | 2.4 | 4.7 | 2.4 | 4.7 |
| Threemile Creek | THRE-16 | 6.7 | 13.3 | 6.7 | 13.3 |
| Threemile Creek | THRE-21 | 2.5 | 4.9 | 2.5 | 4.9 |
| Threemile Creek | THRE-35 | 33.8 | 33.8 | 12.9 | 12.9 |
| Tin Cup Creek | TINC-21 | 14.2 | 7.1 | 14.2 | 7.1 |
| Tin Cup Creek | TINC-31/32 | 4.4 | 2.2 | 4.4 | 2.2 |
| Willow Creek | WILL-28 | 15.0 | 15.0 | 5.6 | 5.6 |
| Willow Creek | WILL-38 | 1.2 | 1.2 | 1.2 | 1.2 |

**Table E-14. Potential Sediment Load Reduction from Stream Segments with BEHI Reduced to "Moderate"**

| Stream Segment | Total Load (Tons/Year) | Total Load with "Moderate" BEHI (Tons/Year) | Total Load due to Anthropogenic Sources (Tons/Year) | Total Load with "Moderate" BEHI due to Anthropogenic Sources (Tons/Year) | Potential Reduction in Anthropogenic Sediment Load with "Moderate" BEHI | Percent Reduction in Anthropogenic Sediment Load with "Moderate" BEHI |
|---|---|---|---|---|---|---|
| Ambrose Creek | 486.4 | 315.8 | 365.9 | 215.9 | 150.0 | 41% |
| Bass Creek | 126.3 | 115.0 | 18.6 | 15.5 | 3.1 | 17% |
| Bear Creek | 854.3 | 531.0 | 290.8 | 158.1 | 132.7 | 46% |
| Blodgett Creek | 457.6 | 345.9 | 206.1 | 124.1 | 82.0 | 40% |
| Kootenai Creek | 383.5 | 302.8 | 106.6 | 71.0 | 35.5 | 33% |
| Lick Creek | 116.9 | 92.3 | 43.1 | 30.6 | 12.5 | 29% |
| Lolo Creek | 1741.7 | 723.6 | 855.4 | 355.8 | 499.7 | 58% |
| Lost Horse Creek | 531.2 | 412.3 | 62.6 | 37.4 | 25.2 | 40% |
| McClain Creek | 81.7 | 73.4 | 60.0 | 52.4 | 7.7 | 13% |
| Mill Creek | 1302.1 | 817.2 | 806.8 | 460.9 | 345.9 | 43% |
| Miller Creek | 1356.8 | 748.3 | 927.3 | 517.7 | 409.6 | 44% |
| Muddy Springs Creek | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 100% |
| North Burnt Fork Creek | 939.0 | 442.1 | 711.7 | 327.7 | 384.0 | 54% |
| North Fork Rye Creek | 95.9 | 72.2 | 32.6 | 19.7 | 12.9 | 40% |
| Roaring Lion Creek | 285.1 | 260.2 | 8.1 | 6.8 | 1.3 | 16% |
| Rye Creek | 664.6 | 513.1 | 214.6 | 130.5 | 84.1 | 39% |
| Skalkaho Creek | 1728.7 | 1175.5 | 658.8 | 455.6 | 203.2 | 31% |
| Sleeping Child Creek | 667.3 | 501.0 | 249.4 | 166.1 | 83.3 | 33% |
| South Fork Lolo Creek | 248.4 | 191.3 | 12.4 | 5.8 | 6.6 | 54% |
| Sweathouse Creek | 617.6 | 322.8 | 446.9 | 187.2 | 259.6 | 58% |
| Threemile Creek | 1461.4 | 776.0 | 989.9 | 478.1 | 511.8 | 52% |
| Tin Cup Creek | 553.3 | 374.9 | 116.9 | 61.0 | 55.9 | 48% |
| Willow Creek | 939.4 | 533.7 | 507.5 | 252.5 | 255.0 | 50% |

# E5.0 REFERENCES

MDEQ. 2007a. A Watershed Stratification Approach for TMDL Sediment and Habitat Impairment Verification. Montana Department of Environmental Quality, Helena, Montana.

MDEQ. 2007b. Longitudinal Field Methodology for the Assessment of Sediment and Habitat Impairments. Montana Department of Environmental Quality, Helena, Montana.

Rosgen, D. 1996 Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Rosgen, D. 2006. *Watershed Assessment of River Stability and Sediment Supply* (WARSSS). Wildland Hydrology, Fort Collins, Colorado.

U.S. Environmental Protection Agency (EPA). 2006. *Watershed Assessment of River Stability and Sediment Supply* (WARSSS). Version 1.0. Available at: http://www.epa.gov/warsss/index.htm. Site accessed March 2008.

# APPENDIX F - REGIONAL REFERENCE AND DEQ SUMMARY STATISTICS CONSIDERED FOR SEDIMENT TARGET DEVELOPMENT– BITTERROOT TPA

**Table F-1. Summary Statistics for Percent Fines via Pebble Count by Ecoregion and Gradient**

| | **PebCnt reach average by ecoregion 2mm** | | | **PebCnt reach average by ecoregion 6mm** | | | **PebCnt reach average by gradient <2mm** | | **PebCnt reach average by gradient <6mm** | | **PebCnt reach average by gradient and ecoregion, <2mm** | | | | | | **PebCnt reach average by gradient and ecoregion, <6mm** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data Source** | **Idaho Bath (16)** | **M. Rockies (17)** | **N. Rockies (15)** | **Idaho Bath (16)** | **M. Rockies (17)** | **N. Rockies (15)** | **High Gradient Average (A&B) <2mm** | **Low Gradient Average (C) <2mm** | **High Gradient Average (A&B) <6mm** | **Low Gradient Average (C) <6mm** | **Idaho Bath. High Gradient Average (A&B) <2mm** | **Idaho Bath Low Gradient Average (C) <2mm** | **Mid. Rockies High Gradient Average (A&B) <2mm** | **Mid. Rockies Low Gradient Average (C) <2mm** | **N. Rockies High Gradient Average (A&B) <2mm** | **N. Rockies Low Gradient Average (C) <2mm** | **Idaho Bath. High Gradient Average (A&B) <6mm** | **Idaho Bath Low Gradient Average (C) <6mm** | **Mid. Rockies High Gradient Average (A&B) <6mm** | **Mid. Rockies Low Gradient Average (C) <6mm** | **N. Rockies High Gradient Average (A&B) <6mm** | **N. Rockies Low Gradient Average (C) <6mm** |
| DEQ Bitt. 2007 25th Percentile (excludes E channels-except by reach type) | 5 | 10 | 4 | 10 | 14 | 15 | 3 | 7 | 6 | 13 | 3 | 7 | 6 | 10 | | 4 | 6 | 14 | 10 | 17 | | 15 |
| DEQ Bitt. 2007 Median (excludes E channels-except by reach type) | 8 | 12 | 5 | 14 | 23 | 16 | 8 | 12 | 12 | 20 | 7 | 12 | 8 | 13 | | 5 | 11 | 21 | 14 | 26 | | 16 |
| DEQ Bitt. 2007 75th percentile (excludes E channels-except by reach type) | 14 | 15 | 7 | 22 | 31 | 18 | 12 | 15 | 22 | 24 | 14 | 15 | 9 | 19 | | 7 | 18 | 23 | 17 | 36 | | 18 |
| DEQ Bitt. 2007 (n) | 16 | 10 | 3 | 16 | 10 | 3 | 12 | 17 | 12 | 17 | 9 | 7 | 2 | 8 | 0 | 3 | 9 | 7 | 2 | 8 | 0 | 3 |
| BDNF Ref. median (excludes E channels-except by reach type) | | | | | 11 | | | | 10 | 27 | | | | | | | | | 10 | 17 | | |
| BDNF Ref. 75th%ile (excludes E channels-except by reach type) | | | | | 22.5 | | | | 21 | 29 | | | | | | | | | 21 | 29 | | |
| BDNF (n) | | | | | 79 | | | | 49 | 30 | | | | | | | | | 49 | 30 | | |
| BNF Ref. median - (excludes E channels-except by reach type) | 17 | 16 | | 23 | 20 | | 20 | 19 | 19 | 30 | 17 | 19 | 16 | 24 | | | 21 | 33 | 19 | 30 | | |
| BNF Ref. 75th%ile - (excludes E channels-except by reach type) | 24 | 24 | | 33 | 29 | | 22 | 24 | 29 | 36 | 24 | 22 | 21 | 27 | | | 32 | 39 | 24 | 34 | | |
| BNF (n) | 49 | 26 | | 49 | 26 | | 92 | 15 | 92 | 15 | 42 | 7 | 21 | 4 | | | 42 | 7 | 21 | 4 | | |
| KNFLD Ref. median (excludes E channels-except by reach type) | | | 4 | | | 7 | | | | | | | | | 5 | 3 | | | | | 8 | 7 |
| KNFLD Ref 75th%tile (excludes E channels-except by reach type) | | | 7 | | | 15 | | | | | | | | | 9 | 8 | | | | | 19 | 10 |
| KNFLD (n) | | | 69 | | | 76 | | | | | | | | | 48 | 5 | | | | | 51 | 6 |

**Table F-2. Summary Statistics for Percent Fines via Pebble Count by Reach Type <2mm and <6mm**

| | **PebCnt reach average by reach type <2mm** | | | | | | | | | | **PebCnt reach average by reach type <6mm** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data Source** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** |
| DEQ Bitt. 2007 25th Percentile (excludes E channels-except by reach type) | | | | 3 | 3 | 11 | 7 | 7 | 10 | 27 | | | | 6 | 6 | 23 | 13 | 11 | 19 | 44 |
| DEQ Bitt. 2007 Median (excludes E channels-except by reach type) | | | | 8 | 4 | 13 | 12 | 8 | 12 | 33 | | | | 12 | 7 | 25 | 20 | 12 | 22 | 50 |
| DEQ Bitt. 2007 75th percentile (excludes E channels-except by reach type) | | | | 12 | 8 | 14 | 15 | 10 | 19 | 46 | | | | 22 | 12 | 26 | 24 | 14 | 30 | 63 |
| DEQ Bitt. 2007 (n) | | | | 12 | 8 | 4 | 17 | 6 | 11 | 3 | | | | 12 | 8 | 4 | 17 | 6 | 11 | 3 |
| BDNF Ref. median (excludes E channels-except by reach type) | | | | | | | | | | | 17 | - | - | 9 | 7 | 18 | 17 | 8 | 22 | 30 |
| BDNF Ref. 75th%ile (excludes E channels-except by reach type) | | | | | | | | | | | 24 | - | - | 20 | 12 | 25 | 29 | 14 | 29 | 44 |
| BDNF (n) | | | | | | | | | | | 9 | - | - | 40 | 26 | 14 | 30 | 11 | 19 | 113 |
| BNF Ref. median - (excludes E channels-except by reach type) | 19 | 15 | 21 | 11 | 11 | 17 | 19 | 9 | 21 | 30 | 25 | 18 | 30 | 14 | 14 | 20 | 30 | 12 | 31 | 39 |
| BNF Ref. 75th%ile - (excludes E channels-except by reach type) | 26 | 20 | 27 | 17 | 13 | 24 | 24 | 12 | 24 | 33 | 34 | 22 | 36 | 20 | 16 | 31 | 36 | 16 | 39 | 43 |
| BNF (n) | 61 | 19 | 39 | 70 | 43 | 25 | 19 | 5 | 14 | 2 | 61 | 19 | 39 | 70 | 43 | 25 | 19 | 5 | 14 | 2 |
| KNFLD Ref. median (excludes E channels-except by reach type) | 6 | 5 | 12 | 5 | 2 | 7 | 3 | 0 | 8 | - | 7 | 4 | 20 | 9 | 5 | 12 | 7 | 1 | 10 | 1 |
| KNFLD Ref 75th%tile (excludes E channels-except by reach type) | 8 | 6 | 12 | 10 | 4 | 13 | 8 | 0 | 12 | - | 17 | 7 | 24 | 18 | 12 | 21 | 10 | 2 | 15 | 1 |
| KNFLD (n) | 4 | 3 | 1 | 39 | 20 | 19 | 5 | 2 | 3 | - | 7 | 5 | 2 | 39 | 20 | 19 | 5 | 2 | 3 | 1 |

**Table F-3. Summary Statistics for Percent Fines via Pebble Count by Ecoregion and Reach Type <2mm**

| | PebCnt reach average Idaho Bath by reach type 2mm | | | | | | | | | | PebCnt reach average Mid Rockies by reach type 2mm | | | | | | | | | | PebCnt reach average N. Rockies by reach type 2mm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data Source** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** |
| DEQ Bitt. 2007 25th Percentile (excludes E channels-except by reach type) | | | | 3 | 3 | 14 | 7 | 6 | 12 | 20 | | | | 7 | 4 | 10 | 11 | 9.3 | 14 | 39 | | | | | | | 3.5 | | 3.5 | |
| DEQ Bitt. 2007 Median (excludes E channels-except by reach type) | | | | 7 | 3 | 15 | 12 | 7 | 12 | 20 | | | | 10 | 4 | 11 | 14 | 9.5 | 22 | 46 | | | | | | | 5 | | 5 | |
| DEQ Bitt. 2007 75th percentile (excludes E channels-except by reach type) | | | | 14 | 8 | 15 | 15 | 10 | 17 | 20 | | | | 11 | 4 | 11 | 22 | 9.8 | 30 | 52 | | | | | | | 6.5 | | 6.5 | |
| DEQ Bitt. 2007 (n) | | | | 9 | 7 | 2 | 7 | 4 | 3 | 1 | | | | 3 | 1 | 2 | 7 | 2 | 4 | 2 | | | | | | | 3 | | 3 | |
| BNF Ref. median - (excludes E channels-except by reach type) | 26 | - | 25 | 11 | 15 | 13 | 19 | 19 | 13 | 25 | 18 | 14 | 19 | 12 | 11 | 37 | 24 | - | 24 | 35 | | | | | | | | | | |
| BNF Ref. 75th%ile - (excludes E channels-except by reach type) | 30 | - | 29 | 21 | 19 | 21 | 22 | 19 | 13 | 25 | 22 | 19 | 22 | 15 | 13 | 37 | 27 | - | 27 | 35 | | | | | | | | | | |
| BNF (n) | 15 | - | 14 | 27 | 15 | 12 | 7 | 1 | 6 | 1 | 15 | 7 | 8 | 6 | 5 | 1 | 4 | - | 4 | 1 | | | | | | | | | | |
| KNFLD Ref. median (excludes E channels-except by reach type) | | | | | | | | | | | | | | | | | | | | | 6 | 5 | 12 | 5 | 2 | 6.5 | 3 | 0 | 8 | - |
| KNFLD Ref 75th%tile (excludes E channels-except by reach type) | | | | | | | | | | | | | | | | | | | | | 8.4 | 6 | 12 | 9.5 | 4.3 | 13 | 8 | 0 | 12 | - |
| KNFLD (n) | | | | | | | | | | | | | | | | | | | | | 4 | 3 | 1 | 39 | 20 | 19 | 5 | 2 | 3 | - |

**Table F-4. Summary Statistics for Percent Fines via Pebble Count by Ecoregion and Reach Type <6mm**

| | PebCnt reach average Idaho Bath by reach type 6mm | | | | | | | | | | PebCnt reach average Mid Rockies by reach type 6mm | | | | | | | | | | PebCnt reach average N. Rockies by reach type 6mm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Data Source** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** | **A** | **A3** | **A4** | **B** | **B3** | **B4** | **C** | **C3** | **C4** | **E** |
| DEQ Bitt. 2007 25th Percentile (excludes E channels-except by reach type) | | | | 6 | 6.3 | 25 | 14 | 12 | 22 | 37 | | | | 14 | 6 | 23 | 15 | 11 | 29 | 56 | | | | | | | 15 | | 15 | |
| DEQ Bitt. 2007 Median (excludes E channels-except by reach type) | | | | 11 | 7 | 25 | 21 | 14 | 22 | 37 | | | | 21 | 6 | 24 | 24 | 12 | 41 | 63 | | | | | | | 16 | | 16 | |
| DEQ Bitt. 2007 75th percentile (excludes E channels-except by reach type) | | | | 18 | 12 | 26 | 23 | 17 | 25 | 37 | | | | 24 | 6 | 26 | 41 | 12 | 52 | 69 | | | | | | | 18 | | 18 | |
| DEQ Bitt. 2007 (n) | | | | 9 | 7 | 2 | 7 | 4 | 3 | 1 | | | | 3 | 1 | 2 | 7 | 2 | 4 | 2 | | | | | | | 3 | | 3 | |
| BDNF Ref. median (excludes E channels-except by reach type) | | | | | | | | | | | 17 | - | - | 9 | 7 | 18 | 17 | 8 | 22 | 30 | | | | | | | | | | |
| BDNF Ref. 75th%ile (excludes E channels-except by reach type) | | | | | | | | | | | 24 | - | - | 20 | 12 | 25 | 29 | 14 | 29 | 44 | | | | | | | | | | |
| BDNF (n) | | | | | | | | | | | 9 | - | - | 40 | 26 | 14 | 30 | 11 | 19 | 113 | | | | | | | | | | |
| BNF Ref. median - (excludes E channels-except by reach type) | 36 | - | 35 | 15 | 15 | 16 | 33 | 20 | 36 | 31 | 22 | 16 | 10 | 15 | 14 | 41 | 30 | - | 30 | 47 | | | | | | | | | | |
| BNF Ref. 75th%ile - (excludes E channels-except by reach type) | 45 | - | 40 | 26 | 22 | 30 | 39 | 20 | 40 | 31 | 25 | 22 | 10 | 16 | 15 | 41 | 34 | - | 34 | 47 | | | | | | | | | | |
| BNF (n) | 15 | - | 14 | 27 | 15 | 12 | 7 | 1 | 6 | 1 | 15 | 7 | 8 | 6 | 5 | 1 | 4 | - | 4 | 1 | | | | | | | | | | |
| KNFLD Ref. median (excludes E channels-except by reach type) | | | | | | | | | | | | | | | | | | | | | 7 | 4 | 20 | 9 | 5 | 12 | 7 | 1 | 10 | 1 |
| KNFLD Ref 75th%tile (excludes E channels-except by reach type) | | | | | | | | | | | | | | | | | | | | | 17 | 7 | 24 | 18 | 12 | 21 | 10 | 2 | 15 | 1 |
| KNFLD (n) | | | | | | | | | | | | | | | | | | | | | 7 | 5 | 2 | 39 | 20 | 19 | 5 | 2 | 3 | 1 |

**Table F-5. Summary Statistics for Percent Fines via Grid Toss in Riffles and Pool Tails <6mm**

| | Grid reach average – Pool Tail by ecoregion <6mm | | | Grid reach average - Riffle by ecoregion <6mm | | |
|---|---|---|---|---|---|---|
| **Data Source** | **Idaho Batholith** | **Middle Rockies** | **Northern Rockies** | **Idaho Batholith** | **Middle Rockies** | **Northern Rockies** |
| DEQ Bitt. 2007 25th Percentile | 7 | 6 | 24 | 4 | 2 | 6 |
| DEQ Bitt. 2007 Median | 9 | 10 | 31 | 6 | 15 | 6 |
| DEQ Bitt. 2007 75th percentile | 12 | 20 | 33 | 14 | 23 | 7 |
| DEQ Bitt. 2007 (n) | 13 | 8 | 3 | 15 | 10 | 3 |
| PIBO Ref. 75th%ile | 25 | 16 | 16 | | | |
| PIBO Ref. median | 17 | 9 | 8 | | | |
| PIBO (n) | 23 | 64 | 29 | | | |

**Table F-6. Summary Statistics for Width to Depth Ratio.**

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | **n** | **Median** | **75th** | **25th** |
| ≤ 35’ | BNF Reference | 93 | 11 | **16** | 8 |
| | DEQ 2007 | 69 | 16 | 22 | 13 |
| > 35’ | BNF Reference | 20 | 25 | **29** | 20 |
| | DEQ 2007 | 57 | 31 | 40 | 26 |

**Table F-7. Summary statistics for residual pool depth (ft).**

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | **n** | **Median** | **75th** | **25th** |
| <20’ | KNFLD Reference | 57 | 0.8 | | 0.6 |
| | PIBO Reference | 40 | 1.0 | | 0.8 |
| | DEQ 2007 | 8 | 0.71 | 0.8 | 0.7 |
| 20-35’ | KNFLD Reference | 18 | 1.4 | | 1.2 |
| | PIBO Reference | 50 | 1.4 | | 1.1 |
| | DEQ 2007 | 11 | 1.19 | 1.5 | 1.1 |
| >35’ | PIBO Reference | 25 | 1.7 | | 1.3 |
| | DEQ 2007 | 13 | 1.5 | 1.7 | 1.2 |

**Table F-8. Summary statistics for pool frequency (pools/mile).**

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| <20' | KNFLD Reference | 57 | 114 | | 81 |
| | PIBO Reference | 40 | **84** | | 64 |
| | DEQ 2007 | 8 | 90 | 148 | 74 |
| 20-35' | KNFLD Reference | 18 | 53 | | 38 |
| | PIBO Reference | 50 | **49** | | 36 |
| | DEQ 2007 | 11 | 42 | 69 | 32 |
| >35' | PIBO Reference | 25 | **26** | | 17 |
| | DEQ 2007 | 13 | 13 | 29 | 21 |

**Table F-9. Summary statistics for for LWD frequency (LWD/mile).**

| Bankfull Width | Data Source | Summary Statistics | | | |
|---|---|---|---|---|---|
| | | n | Median | 75th | 25th |
| <20' | KNFLD Reference | 57 | 359 | | 183 |
| | PIBO Reference | 40 | 402 | | 214 |
| | DEQ 2007 | 8 | 153 | 573 | 106 |
| 20-35' | KNFLD Reference | 18 | 242 | | 92 |
| | PIBO Reference | 45 | 459 | | 293 |
| | DEQ 2007 | 11 | 222 | 380 | 106 |
| >35' | PIBO Reference | 24 | 662 | | 387 |
| | DEQ 2007 | 13 | 195 | 195 | 92 |

# APPENDIX G - UNPAVED ROAD SEDIMENT ASSESSMENT BITTERROOT TPA

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Water Quality Planning Bureau
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# G1.0 Introduction

This report presents a sediment and culvert assessment of the unpaved road network within the Bitterroot TMDL Planning Area (TPA). This assessment was performed as part of the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. Roads located near stream channels can impact stream function through degradation of riparian vegetation, channel encroachment, and sediment loading. The degree of impact is determined by a number of factors, including road type, construction specifications, drainage, soil type, topography, precipitation, and the use of Best Management Practices (BMPs). Through a combination of GIS analysis, field assessment, and modeling, estimated sediment loads were developed for unpaved road crossings and parallel road segments. Existing road conditions were modeled, as well as estimated future road conditions after the application of sediment reducing Best Management Practices (BMPs). Existing culverts were also assessed for fish passage and failure.

The majority of the Bitterroot TPA (USGS HUC ID #17010205) is located within Ravalli County, with a smaller portion in Missoula County, including the southwest corner of the City of Missoula (**Figure G6-1**). The Bitterroot TPA includes the Bitterroot River watershed downstream from the confluence of the East and West Forks near Conner, Montana, as well as the lower Lolo Creek watershed below Lolo Hot Springs. This document details the assumptions, methods, and results from the road sediment analysis for the Bitterroot TPA.

The 2010 303(d) List includes a total of 12 listed stream segments within the Bitterroot TPA that are listed for sediment. 20 stream segments, including 8 segments also listed for sediment, are listed for other habitat alterations. **Table G1-1** includes a summary of sediment impaired stream segments.

# G2.0 Data Collection

The Bitterroot Unpaved Road Sediment assessment consisted of three primary tasks: 1.) GIS Layer development and summary statistics, 2.) field assessment and sediment modeling, and 3.) sediment load calculations and allocations for sediment listed watersheds and the entire Bitterroot TPA. Additional information on assessment techniques is available in prior reporting for this project: *Task 1. Road GIS Layers and Summary Statistics* (MDEQ 2007), and *Task 2. Sampling and Analysis Plan* (MDEQ 2007).

## G2.1 Spatial Analysis

Using road layers provided by the Bitterroot National Forest (BNF), Lolo National Forest (LNF), Missoula County and Ravalli County, road crossings and parallel segments in the road network were identified and classified relative to 6th code subwatershed, land ownership, and landscape type. These classifications captured a statistically representative sample of roads within the entire watershed, based on a number of road conditions (subwatershed, road design, soil type, maintenance level, etc). Summary statistics show that there are a total of 3634 road crossings in the Bitterroot TPA, with 3357 unpaved crossings and 277 paved crossings. Landscape layers were downloaded from the EPA 2002 Level 4 Ecoregions, and were classified into Mountain, Foothill, and Valley landscape types as follows: Mountain Landscape *(Eastern Batholith , High Idaho Batholith, Glaciated Bitterroot Mountains and Canyons, Lochsa Uplands*

*Grave Creek Range-Nine Mile Divide)*; Foothills Landscape *(Bitterroot-Frenchtown Valley -without digitized valley bottom areas);* and Valley Landscape *(The valley landscape type was developed by digitizing the valley bottoms throughout the TPA using a hill-shaded Digital Elevation Map (DEM), aerial and color infrared photography, topographic maps, and land use in GIS).* There are 2336 Mountain crossings (2260 unpaved), 900 Foothill crossings (789 unpaved), and 398 Valley crossings (308 unpaved). There are 1535 road crossings on federal lands (1479 unpaved), 1567 crossings on private lands (1359 unpaved), 490 crossings on Plum Creek Timber land (479 unpaved), and 42 crossings (40 unpaved) crossings on state lands. A random subset of unpaved crossing sites was generated for field assessment based on the proportion of total crossings within each landscape type, with approximately 5% of the total unpaved crossings assessed (199 sites). Parallel road segments were identified as areas where roads encroach upon the stream channel, and total road lengths within 50-foot and 150-foot buffer zones were generated. There is a total of 141 miles of unpaved parallel road segments within 50 feet of stream channels and 341 miles within 150 feet. Statistics generated using GIS were updated in the field, as described in **Section 2.4**.

## G2.2 Field Data Collection

A total of 136 unpaved crossings and 63 parallel segments were evaluated in the field (**Figure 6-2**). Eighty nine crossings were assessed in the mountain landscape, 35 crossings were assessed in the foothill landscape, and 12 crossings were assessed in the valley landscape type. In the field, parallel segments were selected based on best professional judgment while traveling roads on which specific crossings were selected for evaluation. When a parallel reach was encountered, the reach was divided into smaller segments and assessed at pre-selected intervals to eliminate sample bias. Generally, the majority of parallel road segments are located in narrow stream valleys or canyons in foothill and mountain landscapes, where roads are constructed near streams. Forty eight parallel segments were assessed in the mountain landscape type and 15 segments were assessed in the foothill landscape type. Six of the 48 mountain parallel sites were paved. No parallel segments were encountered or assessed in the valley landscape type due to the small overall area of the valley landscape, and the observation that the majority of valley roads were paved and/or did not parallel a stream channel.

## G2.3 Sediment Assessment Methodology

The road sediment assessment was conducted using the WEPP:Road forest road erosion prediction model (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston, 1995), developed by the USDA Forest Service and other agencies, and is used to predict runoff, erosion, and sediment delivery from forest roads. The model predicts sediment yields based on specific soil, climate, ground cover, and topographic conditions. Specifically, the following model input data was collected in the field: soil type, percent rock, road surface, road design, traffic level, and specific road topographic values (road grade, road length, road width, fill grade, fill length, buffer grade, and buffer length). In addition, supplemental data was collected on vegetation condition of the buffer, evidence of erosion from the road system, and potential for fish passage and culvert failure.

Site specific climate profiles were created using data from the Western Regional Climate Center (http://www.wrcc.dri.edu). Climate stations were selected from within the Bitterroot TPA boundary that exhibited similar conditions for each specific landscape type. The Stevensville station (247894: 3380 ft elevation, 12.46-inches annual precipitation), was selected for valley sites, the Darby station (242221: 3880-feet elevation, 16.27-inches annual precipitation) was selected to model the foothill sites, and the

Lolo Hot Springs 2 NE station (245146: 4060-feet elevation, 24.95-inches annual precipitation) was used to model the mountain sites.

Generally, 30-year model simulations are adequate to obtain a reliable average erosion estimate. However, in drier climates (less than 500 mm of precipitation), 50-year or longer simulations are necessary to obtain average erosion estimates. For the Bitterroot TPA, 30-year simulations were run for mountain sites, and fifty-year simulations were run for valley and foothill sites.

Some road conditions encountered in the field are not accurately represented in the WEPP:Road design options; as a result, some adjustments were made to the model to more appropriately represent these types of roads. **Attachment B** contains a description of model or site condition adjustments, as recommended by the model author or by professional judgment.

## G2.4 Field Adjustments

Field conditions required that a number of sites be moved to different locations due to lack of access (landowner permission or road condition), lack of an existing stream channel, or inaccuracies in the road or stream GIS layers, which showed crossings which were not accurate. It was noted during field activities that some roads were classified as unpaved on the GIS layer attributes, when in fact, they were found to be paved roads upon field inspection. Also, some road crossings on parallel segments were not present upon field inspection. GIS layers often contain additional crossings when road and stream layers parallel each other close together. Records were kept in the field and edits were made to the GIS layers. Revised unpaved road network statistics were generated, which resulted in unpaved road crossings decreasing from 3357 to 3294 crossings (**Table G2-1**).

The ability to generate completely accurate road and stream crossing layers is not feasible; however, this revised tally represents a more accurate representation of existing conditions.

**Table G2-1. Total Revised Number of Unpaved Crossings**

| Landscape Type | Unpaved Road Crossings using GIS Only | Revised Unpaved Crossings After Field and Map Adjustments |
|---|---|---|
| Mountain | 2260 | 2238 |
| Foothill | 789 | 761 |
| Valley | 308 | 295 |
| **Total** | **3357** | **3294** |

Total unpaved road crossings and crossing densities were also classified by major land ownership within the TPA, with results shown in **Table G2-2**.

**Table G2-2. Unpaved Road Crossings Sorted by Major Land Ownership**

| Land Ownership / Management Unit | Number of Unpaved Crossings | Ownership Area (sq mi) | Ownership Area (%) | Crossing Density (crossings/sq mi) |
|---|---|---|---|---|
| United States Forest Service | 1471 | 1031.2 | 56.6% | 1.43 |
| State of Montana | 41 | 52.7 | 2.9% | 0.78 |
| Plum Creek Timber | 475 | 101.4 | 5.6% | 4.68 |
| Private | 1307 | 634.2 | 34.8% | 2.06 |
| Water | 0 | 2.32 | 0.1% | 0.0 |
| **Total** | **3294** | **1821.8** | **100%** | **1.81** |

USFS land contains the most unpaved road crossings, and Plum Creek Timber land has the highest density of road crossings when compared with ownership area.

## G2.5 Mean Sediment Loads from Field Assessed Sites

Field assessment data and WEPP:Road modeling results were used to develop sediment loads based on various watershed criteria. A standard statistical breakdown of loads from the unpaved road network within each sediment-listed watershed was generated using the applicable dataset of field assessed crossing and parallel sites. Mean load and contributing length, median load, maximum and minimum loads, and 25$^{th}$ and 75$^{th}$ percentile loads were calculated for unpaved road crossings within each landscape type that was the basis of the field assessment. Mean sediment loads from unpaved road crossings were estimated at 0.12 tons/year in mountain landscapes, 0.22 tons/year in the foothill landscapes, and 0.07 tons/year in the valley landscapes. A statistical summary of sediment loads for field assessed sites are included in **Table G2-3**.

**Table G2-3. Sediment Load Summary for Field Assessed Crossings by Landscape Type**

| Statistical Parameter | Mountain | Foothill | Valley | Total of Field Assessed Crossings |
|---|---|---|---|---|
| Number of Sites (n) | 89 | 35 | 12 | 136 |
| Mean Contributing Length (ft) | 241 | 369 | 326 | 283 |
| Mean Load (tons/year) | 0.12 | 0.22 | 0.07 | 0.14 |
| Median Load (tons/year) | 0.02 | 0.09 | 0.05 | 0.03 |
| Maximum Load (tons/year) | 2.42 | 1.79 | 0.28 | 2.42 |
| Minimum Load (tons/year) | 0 | 0 | 0 | 0 |
| 25th Percentile (tons/year) | 0.007 | 0.03 | 0.006 | 0.007 |
| 75th Percentile (tons/year) | 0.09 | 0.24 | 0.11 | 0.10 |

The sediment load summary shows significant differences between minimum and maximum load values, as well as between mean and median values, especially for mountain and valley landscape types. These data suggest that a small number of high sediment load crossing sites impact the average values.

Mean sediment loads were calculated for parallel road segments, and loads were then normalized to a per-mile value to account for differences in contributing road length. Mean sediment loads from unpaved parallel road segments were estimated at 2.21 tons/year/mile in mountain landscapes and 0.31 tons/year/mile in foothill landscapes. No valley parallel segments were assessed in the field due to the small overall area of the valley landscape and the majority presence of paved roads or roads that did not parallel streams. As a result, the mean sediment loads from the mountain and foothill parallel segments were averaged together to obtain an estimated sediment load of 1.26 tons/year/mile for valley parallel segments (**Table G2-4**). A summary of modeling results from field assessed sites is located in **Attachment A**.

**Table G2-4. Sediment Load Summary from Unpaved Field Assessed Parallel Sites by Landscape Type**

| Statistical Parameter | Mountain | Foothill | Valley | Total of Field Assessed Parallel Segments |
|---|---|---|---|---|
| Number of Sites (n) | 41 (1) | 15 | 0 | 56 |
| Mean Contributing Length (ft) | 1234 | 1046 | NA | 1204 |
| Mean Load (tons/year/mile) | 2.21 | 0.31 | 1.26 (2) | NA |
| Median Load (tons/year/mile) | 0.16 | 0.17 | NA | 0.17 |
| Maximum Load (tons/mile/year) | 29.1 | 1.84 | NA | 29.1 |
| Minimum Load (tons/year/mile) | 0 | 0 | NA | 0 |

(1) Paved sites removed from total (2) Average of mountain and foothill totals

The parallel segment load summary also shows significant differences between mean and median loads, and modeling results showed that a small number of high load parallel reaches impact the average values. There is also a large difference in mean sediment load between the mountain and foothill landscapes. This is likely due to a lack of suitable road construction locations in higher mountain elevations, resulting in more roads being constructed in narrow stream valleys with smaller buffer distances.

## G2.6 Extrapolation to Watershed Scale

Total unpaved road crossings and parallel road distances were further defined by land ownership and subwatershed. USGS 6th code subwatersheds were used as a basis for road sediment categorization in order to provide means for identifying the most impacted areas, and opportunities for potential restoration planning (**Figure G6-3**). Some 303(d) listed streams did not correlate with 6th code subwatershed boundaries; as a result, these watersheds were digitized and reported separately, to avoid duplication of results with the 6th code layer. The following 303(d) streams were reported separately from the 6th code subwatershed in which they are located: Lick Creek, Lower Bear Creek, McClain Creek, Muddy Spring Creek, and the North Fork of Rye Creek. A summary of unpaved road conditions by 6th code/303(d) subwatershed is included as **Table G2-5**; road crossing and parallel road distance sorted by ownership and landscape type is included in **Table G2-6** and **Table G2-7**.

The road network was also classified by major landowner and land management within the watershed, as various entities and administrative controls direct operation and maintenance of the road network. Four major landowner classifications were developed: United States Forest Service (USFS), State of Montana, Plum Creek Timber Company, and private landowners. Plum Creek Timber is the largest private landowner in the TPA, and was classified separately. Within each major land category, crossings and parallel segments were classified by landscape type. Average sediment loads developed for mountain, foothill, and valley sites were used to calculate total sediment loads for the watershed, and results are reported by these major land units within 6th code subwatersheds. Extrapolation of these results to the remainder of road crossings within the Bitterroot TPA assumes that the random subset of crossings assessed as part of this study is representative of the entire watershed.

# G3.0 Unpaved Road Network Load Analysis

Mean sediment loads from field assessed sites were used to extrapolate existing loads throughout the entire watershed. Mean loads for unpaved crossings within mountain (0.12 tons/year), foothill (0.22 tons/year), and valley (0.07 tons/year) landscape types were applied to the total number of crossings within the TPA, and further classified by 6th code HUC and land ownership. The existing total Bitterroot watershed sediment load from unpaved road crossings was estimated at 461.3 tons/year, and the total existing load from parallel road segments is estimated at 248.4 tons/year (**Table G3-1**). Detailed sediment loads for road crossings and parallel road segments classified by ownership and landscape type within each 6th code/303(d) subwatershed are included in **Table G3-2** and **Table G3-3**. Total sediment loads from the unpaved road network classified by ownership and landscape type within each 6th code/303(d) subwatershed are shown in **Table G3-4.**

**Table G3-1. Sediment Load Summary from Unpaved Road Crossings – Existing Conditions**

| Road Feature | Landscape Type | Total Number of Crossings | Mean Sediment Load (Tons/year) | Total Sediment Load (Tons/year) |
|---|---|---|---|---|
| Crossing | Mountain | 2238 | 0.12 | 268.6 |
| Crossing | Foothill | 761 | 0.22 | 167.4 |
| Crossing | Valley | 295 | 0.07 | 25.3 |
| **Total:** | | **3294** | | **461.3** |
| **Road Feature** | **Landscape Type** | **Total Parallel Distance w/in 50-feet (Mi)** | **Mean Sediment Load (Tons/year/mile)** | **Total Sediment Load (Tons/year)** |
| Parallel | Mountain | 103.6 | 2.21 | 229.0 |
| Parallel | Foothill | 29.1 | 0.31 | 9.0 |
| Parallel | Valley | 8.3 | 1.26 | 10.4 |
| **Total:** | | **141.0** | | **248.4** |
| **Total Bitterroot TPA:** | | | | **709.7** |

## G3.1 Sediment Load from Road Crossings

Road crossing results showed that the Lower Lolo Creek (34.6 tons/year), Lolo Creek-Grave Creek (23.2 tons/year), and the Bitterroot Rover-Larry Creek (20.2 tons/year) contained the three highest sediment loads from unpaved road crossings (**Table G3-2**). The total sediment load from unpaved crossings was 461.3 tons/year from a total of 3294 crossings, or an average of 0.14 tons/year/crossing across all land units. The majority of sediment load is generated from crossings on private land (216.6 tons/year), followed by USFS land (177.5 tons/year), and Plum Creek Timber land (57.1 tons/year).

## G3.2 Sediment Load from Parallel Road Segments

Parallel road segment results showed that the Lower Lolo Creek (27.2 tons/year), Lolo Creek-Grave Creek (24.2 tons/year), and Upper Rye Creek (15.1 tons/year) watersheds contained the three highest sediment loads from parallel road segments (**Table G3-3**). The total sediment load from parallel road segments was 242.8 tons/year from a total of 141 miles of road within 50-feet of streams, or an average of 1.72 tons/year/mile across all landscape types. The majority of sediment load is generated from parallel road segments on USFS land (127.4 tons/year), followed by private land (57.1 tons/year), and Plum Creek Timber land (54.1 tons/year).

The study originally intended to evaluate parallel road distances within two buffer zones (50 and 150 feet). Field observations indicated that the majority of parallel road segments did not appear to contribute significant sediment to streams unless buffer distances were very small. WEPP:Road modeling results supported these observations, as 99% of sediment load from parallel road segments occurred within 50-feet of streams (**Figure G3-1.**). Furthermore, a large majority of the load within 50-feet occurred at distances less than 20-feet.

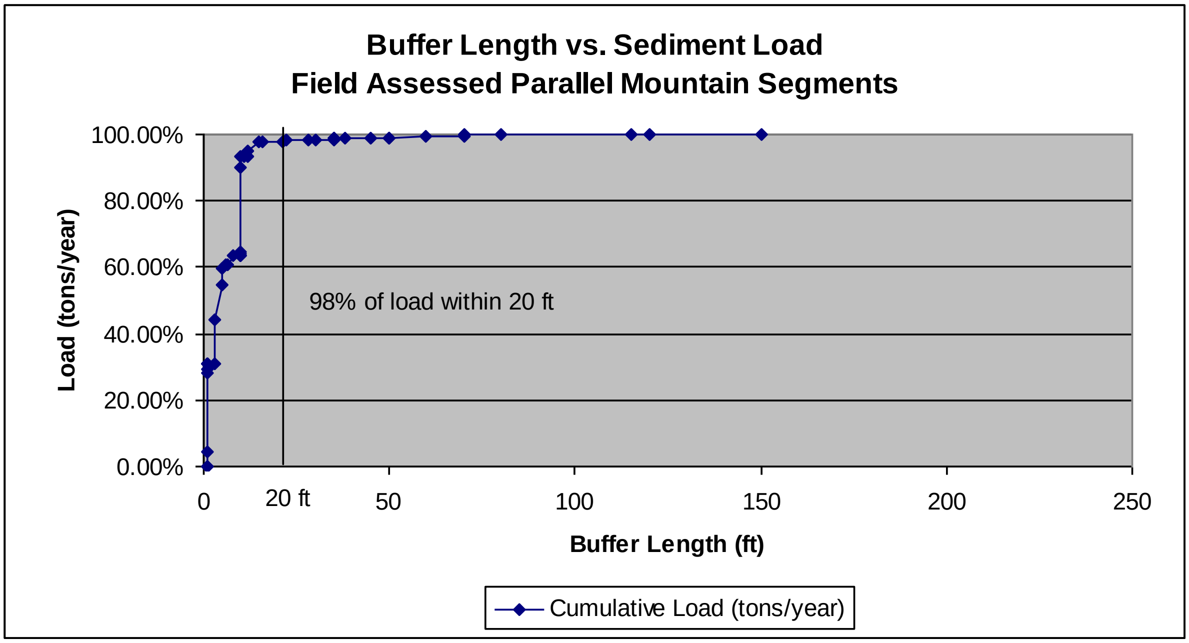


**Figure G3-1. Cumulative Parallel Sediment Load vs. Buffer Length**

**Figures G3-2** and G**3-3** show the differences noted in the field between parallel sites with small and large buffer lengths. Parallel sites with buffer lengths greater than 20 feet have a greater filtering capacity and potential for sediment removal.

**Figure G3-2. Parallel Segment BRLC-F161P – Average Buffer Distance 75 feet**

**Figure G3-3. Parallel Segment ULHC-M165P – Average Buffer Distance <10 feet**

## G3.3 Culvert Assessment

Culverts were analyzed for their ability to allow for fish passage, and for their ability to pass adequate flood flows. Of the 133 field assessed road crossing sites, field sites with bridges and decommissioned sites were removed from the dataset, along with any sites where any of the required screening data could not be accurately collected. After removing these sites from the dataset, sixty-seven (67) culverts were determined to be suitable for assessment (**Figure G6-4**).

### G3.3.1 Fish Passage

Measurements were collected at each field assessed crossing site, and these values were used to estimate if culverts represented fish passage barriers at various flow conditions. The fish passage evaluation was completed using the criteria listed in Table 1 of the document *A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on National Forests in Alaska* (USFS, September 27, 2002). The analysis uses site-specific information to classify culverts as green (passing all lifestages of salmonids), red (partial or total barrier to salmonids), or grey (needs additional analysis). Indicators used in the classification are the ratio of the culvert width to bankfull width (constriction ratio), culvert slope, and outlet drop, with large (>48-inches) and small (<48-inches) culvert groups evaluated differently. Failure of any one of the three indicators results in a red classification. Using the Alaska fish passage analysis, 56 of 67 culverts (84%) were classified as partial or total fish barriers, 8 of 67 (12%) were classified as needing additional evaluation, and only 3 of 67 culverts (4.5%) were classified as capable of passing fish at all flows and life stages (**Table G3-5A** and **Table G3-5B** ).

**Table G3-5A. Fish Passage Analysis for Selected Culverts**

| Culvert Classification or Indicator* | Definition of Indicator | Number of Culverts | Percentage of Total Culverts Assessed (n = 67) |
|---|---|---|---|
| Green (1) | High certainty of meeting juvenile fish passage at all flows | 3 | 4.5% |
| Gray (2) | Additional and more detailed analysis is required to determine juvenile fish passage ability | 8 | 12.0% |
| Red (3) | High certainty of not providing juvenile fish passage at all desired stream flows | 56 | 83.5% |

*The number in parenthesis will be used to denote the respective color in **Table 3-5B**.

Constriction ratios less than 1.0 not only indicate a potential fish passage problem, but also an increased potential for culvert failure. Fifty nine of the 67 culverts assessed (88%) have a constriction ratio less than 1.0.

## G3.3.2 Culvert Failure Potential

Each culvert with available data was evaluated to determine peak flow using USGS regression equations developed by Omang (July 1992) for un-gaged sites, and flow estimates using Manning's equation. Using the regression equations, peak discharge flows were developed for the 2-, 5-, 10-, 25-, 50-, and 100-year recurring intervals for each selected culvert. Montana is divided into eight hydrologic regions, with a unique set of equations developed for each region. The Bitterroot TPA is located in the West Region, and independent variables within these equations are drainage area (square miles) and precipitation (inches). Drainage area above each culvert was calculated using a digital elevation model (DEM) and the ArcSwat extension in GIS. The average mean annual precipitation was calculated within each drainage area from a mean precipitation layer available on NRIS (Montana Average Annual Precipitation GIS layer, 1971-2000, PRISM Group).

Using site-specific culvert information collected in the field (including material, shape, dimensions, and slope) a peak flow was also calculated using Manning's equation. Variables in Manning's equation are culvert area, hydraulic radius, slope, and roughness coefficient (based on culvert material). The peak flow calculated using Manning's equation was compared with Omang values to estimate the maximum storm event that each culvert could convey without water backup. Of the 67 culverts analyzed for fish passage, 58 were analyzed for failure potential due to the inability to collect slope measurements in the field at some locations. The number of culverts passing each specific storm event is shown in **Table G3-6**.

**Table G3-6. Percent of Culverts Passing Design Storm Events**

| Design Storm Event | Number of Culverts Passing | Number of Culverts Failing Specific Flow | Cumulative Percent Passing |
|---|---|---|---|
| Total Culverts | 58 | | 100% |
| Q2 | 51 | 7 | 88% |
| Q5 | 47 | 4 | 81% |
| Q10 | 39 | 8 | 67% |
| Q25 | 37 | 2 | 64% |
| Q50 | 36 | 1 | 62% |
| Q100 | 34 | 2 | 59% |

As peak discharge increases, so does the percentage of culverts incapable of passing the greater flows. Based on the peak flow analysis, it appears that most culverts were designed to pass the Q100 flow, as the majority of culverts (59%) passed the Q100. However, there were 21 culverts (36%) that fail to pass the Q25 design flow.

Potential road fill volume at risk for delivery in the event of a culvert failure was calculated using field measurements of the road prism over the culvert. The volumes calculated are conservative, assuming that the entire road prism above the culvert fails to bankfull width and is delivered to the stream, which will likely not always be the case. In some instances only part of the road fill may be delivered, and in other cases water may simply overtop the road and the culvert will stay intact.

It is difficult to develop specific road crossing allocations for sediment delivered in the event of a culvert failure, as there are several factors that may impact the accuracy of the data. First, peak flows generated using the USGS regression equations are subject to large standard errors that may substantially over or underestimate peak discharge. In addition, peak flows generated using Manning's equation rely heavily on culvert slope. Slope values measured during field activities were estimated using a handheld inclinometer where accessible, and visual estimates were recorded where access or use of an inclinometer was not possible. Different slope estimates may lead to variations in peak flow calculations. Second, the culvert assessment was conducted on a small subset of culverts, which may or may not be representative of the entire Bitterroot TPA. Third, it is difficult if not impossible to estimate which culverts will fail in any given year, and what percentage of at-risk fill material will be delivered to the stream. Due to these difficulties in sediment delivery estimation, specific sediment loads were not developed for each crossing.

# G4.0 Application of Best Management Practices

Sediment impacts are widespread throughout the Bitterroot TMDL Planning Area, and sediment loading from the unpaved road network is one of several sources within the watershed. Application of Best Management Practices (BMPs) on the unpaved road network will result in a decrease in sediment loading to streams. Various BMP sediment reduction scenarios were evaluated based on reductions in contributing road length, reduction in road crossing density, and combinations of the two approaches.

The selected scenario for estimating sediment load reductions was calculated by assuming a uniform reduction in contributing road length to 200-feet for each unpaved crossing and 500-feet for each parallel road segment. Load reductions from potential culvert failures will be addressed on a case-by-case basis depending on a number of evaluation factors.

Due to the extent of the unpaved road network and the resulting inability to assess it in its entirety, generalized assumptions are necessary for modeling the effects of BMPs. Restoration efforts would need to consider site-specific BMPs that, on average, would likely be represented by the modeling assumptions. Other management issues that will impact BMP scenarios are the ability to perform restoration work within the different land ownership categories.

## 4.1 Contributing Road Length Reduction Scenarios

A contributing road length reduction scenario for road crossings was selected assuming a length reduction to 200 feet (100-feet on each side of a crossing or 200-feet on one side). On crossing locations in excess of this length reduction scenario, road lengths were reduced to the corresponding post-BMP scenario of 200-feet. No changes were made to crossing locations where the contributing road length was less than the 200-foot BMP reduction scenario. The 200-foot BMP scenario was evaluated using the WEPP:Road model, so potential sediment load reductions could be estimated. Reduced mean sediment loads were then extrapolated to the entire watershed in the same manner in which the existing sediment loads were calculated. For the 200-foot BMP scenario, mean sediment loads would be reduced from 0.12 tons/year to 0.04 tons/year for mountain crossings, from 0.22 tons/year to 0.05 tons/year for foothill crossings, and from 0.07 tons/year to 0.03 tons/year for valley crossings.

A contributing road length scenario for parallel road segments was selected assuming a length reduction to 500-feet. During field assessment, an attempt was made to determine the average load of parallel road segments by collecting data at pre-selected intervals within a total parallel distance (i.e. every 0.5 miles over a 3-mile segment). This method eliminates the bias of collecting data from portions of the road that are near the stream. This approach was recommended by the model author. Field-assessed parallel road distances in excess of the selected road length reduction were reduced to the post-BMP scenario of 500-feet.

For the 500-foot BMP scenario, mean sediment loads would be reduced from 2.21 tons/year/mile to 0.88 tons/year/mile for mountain parallel segments and from 0.31 tons/year/mile to 0.25 tons/year/mile for foothill parallel segments. Since no valley parallel road segments were assessed in the field, 1.26 tons/year was used for the valley parallel road segments, which is the average of the mountain and foothill totals. The average load would be reduced from 1.26 tons/year/mile to 0.57 tons/year/mile. Estimated summary load reductions by landscape type are show in **Table G4-1**.

**Table G4-1. Estimated Sediment Load Summary – Reduce Crossing Length to 200-feet and Parallel Length to 500-feet**

| Road Feature | Landscape Type | Total Number of Sites | Mean Sediment Load (Tons/year) | Total Sediment Load (Tons/year) | Load Reduction % |
|---|---|---|---|---|---|
| Crossing | Mountain | 2238 | 0.04 | 93.5 | 65.2% |
| Crossing | Foothill | 761 | 0.05 | 40 | 76.1% |
| Crossing | Valley | 295 | 0.03 | 9.9 | 60.9% |
| **Total** | | **3294** | | **143.4** | **68.9%** |
| **Road Feature** | **Landscape Type** | **Total Parallel Distance Within 50-feet (Miles)** | **Mean Sediment Load (Tons/year/mile)** | **Total Sediment Load (Tons/year)** | **Load Reduction %** |
| Parallel | Mountain | 103.6 | 0.88 | 91.1 | 60.2% |
| Parallel | Foothill | 29.1 | 0.25 | 7.1 | 21.1% |
| Parallel | Valley | 8.3 | 0.56 | 4.7 | 54.8% |
| **Total** | | **141.0** | | **102.9** | **58.6%** |
| **Total Bitterroot TPA:** | | | | **246.3** | **65.3%** |

Total sediment load from road crossings would be reduced from 461.3 tons/year to 143.4 tons/year (68.9% reduction), assuming all sites were fully BMP'd. Total sediment load from parallel road segments would be reduced from 248.4 tons/year to 102.9 tons/year (58.6% reduction).

The most significant reduction in sediment load occurs in the mountain landscape type for both crossing and parallel segments. Estimated total sediment load reductions for crossings with a 200-foot contributing length and parallel segments with a 500-foot contributing length were also classified by 6th code HUC/303(d) watershed assuming all sites were fully BMP'd (**Table G4-2** and **Table G4-3**). Total sediment load reductions classified by subwatershed are also shown in **Table G4-4**.

## 4.2 Culvert Replacement Recommendations

USFS documentation (Inland Native Fish Strategy, Environmental Assessment, 1995) recommends that as old culverts are replaced, new culverts should be designed to pass the 100-year flow event. It is recommended that all culvert crossings in the Bitterroot TPA be upgraded to pass the Q100 flood event. It is also recommended that culvert replacements be completed in a manner that allows for full fish and Aquatic Organism Passage (AOP). Specifically, culverts would be sized with constriction ratios at 1.0 or greater, and with a goal of re-creating the stream channel through the crossing to match those channel conditions outside of the crossing influence.
The identification of priority culverts for replacement should be on the following factors:

1.) Inability to pass the Q25 design flow;
2.) Constriction ratio <0.70;
3.) Location on a perennial fish bearing stream;
4.) Fill at risk of being delivered to stream exceeds the median value of 12.2 tons/crossing

Achieving full culvert replacement will take many years to complete, and some culverts on private land may never be replaced. This will result in continued loads from culvert failures in the foreseeable future; however, continued investment in the replacement of culverts failing the above criteria will significantly reduce sediment loads over time.

## 4.3 Additional BMPs

As an alternative to or in combination with reductions in contributing road length or crossing density, other potential BMPs are available that would reduce sediment loading from the unpaved road network. Road sediment reduction strategies such as the installation of full structural BMPs at existing road crossings (drive through dips, culvert drains, settling basins, silt fence, etc), road surface improvement, reduction in road traffic levels (seasonal or permanent road closures), and timely road maintenance to reduce surface rutting are all BMPs that would lead to reduced sediment loading from the road network.

# G5.0 References

MDEQ 2007. Task 1. Road GIS & Summary Statistics, Bitterroot TPA. Prepared by Water & Environmental Technologies, PC. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

MDEQ 2007. Task 2. Sampling and Analysis Plan, Bitterroot TPA. Prepared by Water & Environmental Technologies, PC. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

MDEQ 2007. Unpaved Road Sediment Assessment, Upper Jefferson River TMDL Planning Area, Prepared by Water & Environmental Technologies, PC. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

MDEQ 2007. Unpaved Road Sediment Assessment, Yaak River TMDL Planning Area, Prepared by Water & Environmental Technologies, PC. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

MDEQ 2005. Culvert Analysis, Prospect Creek TMDL. Prepared by Lolo National Forest with Revisions by River Design Group. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Inland Native Fish Strategy, Environmental Assessment. 1995. Decision notice and finding of no significant impact. U.S. Department of Agriculture, Forest Service, Intermountain, Northern, and Pacific Northwest Regions.

U.S. Geological Survey 1992. Analysis of the Magnitude and Frequency of Floods and the Peak Flow Gauging Network in Montana, R.J. Omang. Water Resources Investigations Report 92-4048.

USDA Forest Service 1999. FS WEPP - Forest Service Interfaces for the Water Erosion Prediction Project Computer Model. Rocky Mountain Research Station and San Dimas Technology and Development Center.

Elliott, William J, PE, PhD, Team Leader, Rocky Mountain Research Station, Moscow, ID - personal communication.

## G6.0 Figures

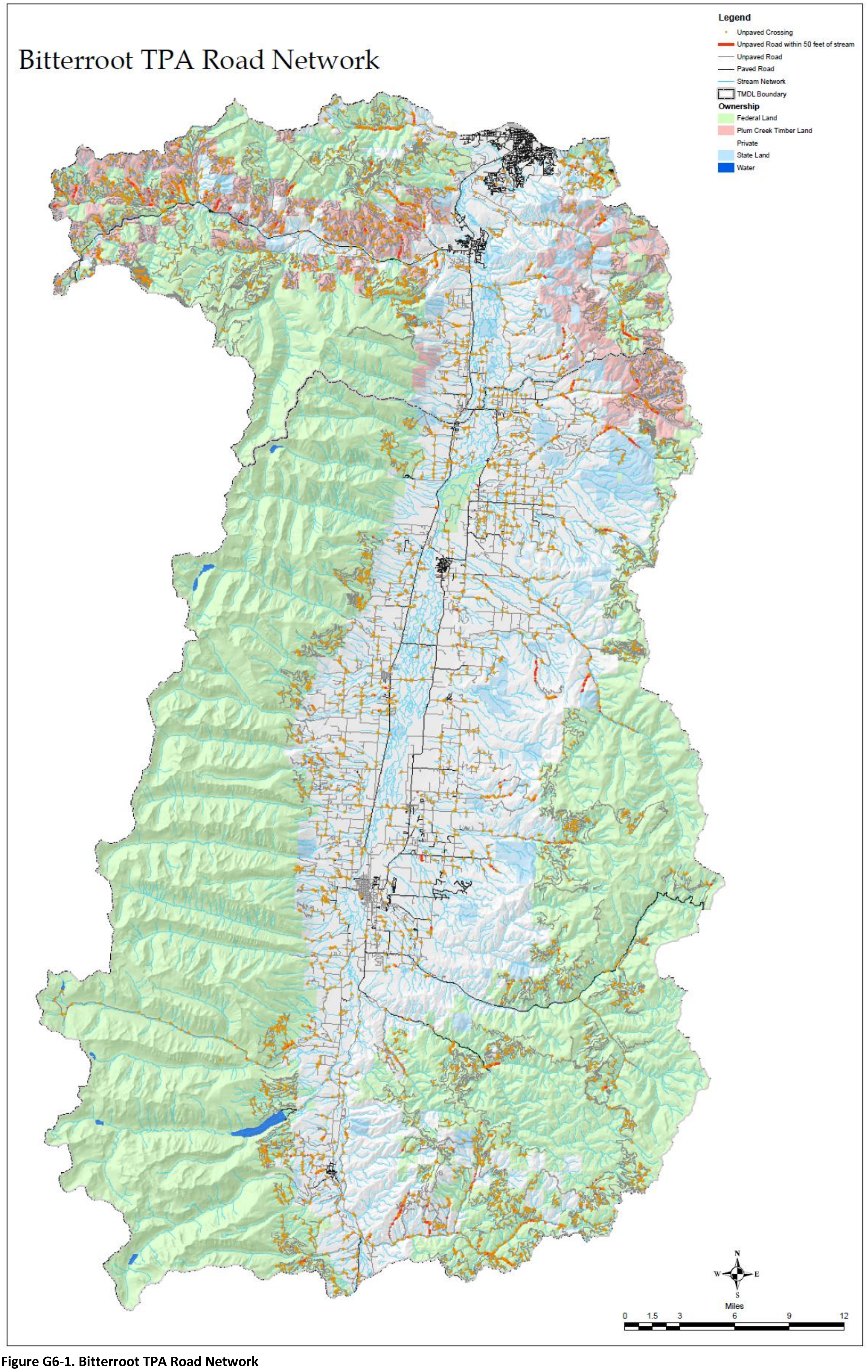


**Figure G6-1. Bitterroot TPA Road Network**

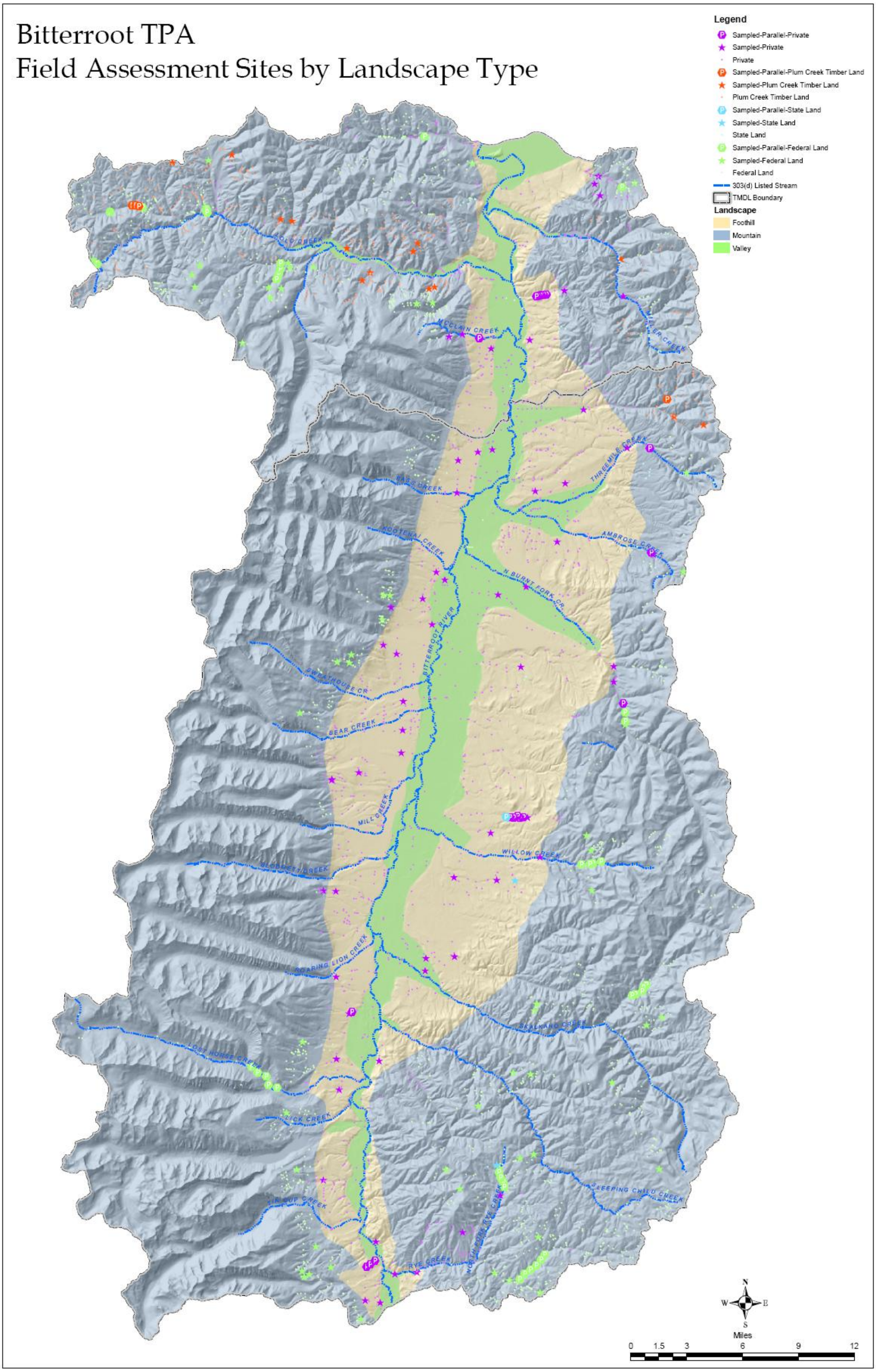


**Figure G6-2. Bitterroot TPA Field Assessment Sites by Landscape Type.**


**Figure G6-3. Bitterroot TPA Field Assessment Sites by 6th Code HUC/303(d) Stream.**

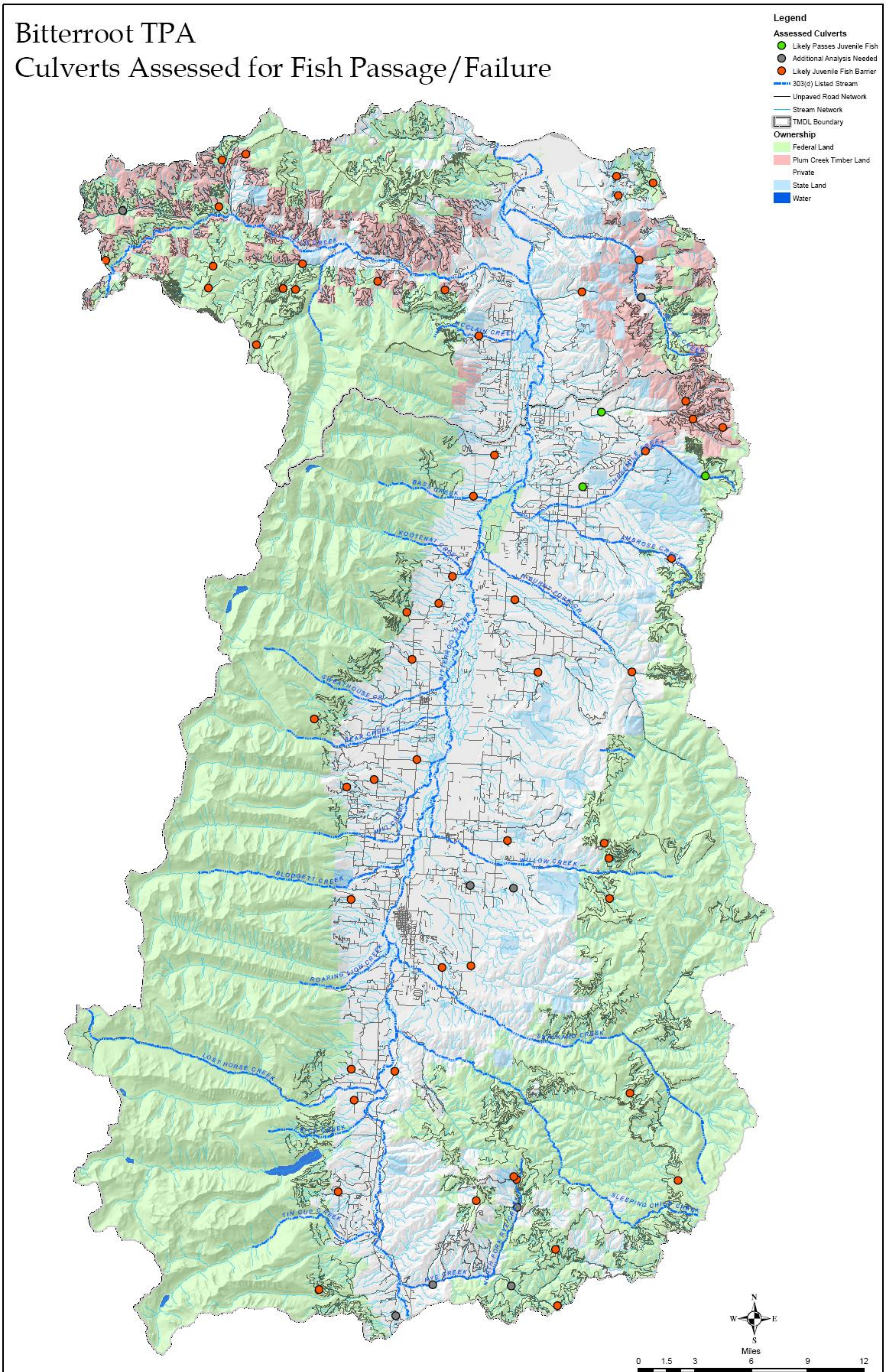


**Figure G6-4. Bitterroot TPA Culverts Assessed for Fish Passage/Failure.**

# G7.0 TABLES

**Table G1-1. 2010 303(d) Listed Stream Segments – Bitterroot TPA**

| Waterbody | Waterbody Segment ID | 2010 Impairment Listing |
|---|---|---|
| AMBROSE CREEK | MT76H004_120 | Other habitat alterations |
| BASS CREEK | MT76H004_010 | Other habitat alterations |
| BEAR CREEK | MT76H004_030 | Other habitat alterations |
| BLODGETT CREEK | MT76H004_050 | Other habitat alterations |
| KOOTENAI CREEK | MT76H004_020 | Other habitat alterations |
| LICK CREEK | MT76H004_170 | Sediment/Siltation, Other habitat alterations |
| LOLO CREEK | MT76H005_013 | Sediment/Siltation, Other habitat alterations |
| LOLO CREEK | MT76H005_011 | Sediment/Siltation, Other habitat alterations |
| LOLO CREEK | MT76H005_012 | Sediment/Siltation, Other habitat alterations |
| LOST HORSE CREEK | MT76H004_070 | Other habitat alterations |
| McCLAIN CREEK | MT76H004_150 | Sedimentation/Siltation |
| MILL CREEK | MT76H004_040 | Other habitat alterations |
| MILLER CREEK | MT76H004_130 | Sediment/Siltation, Other habitat alterations |
| MUDDY SPRING CREEK | MT76H004_180 | Sedimentation/Siltation |
| NORTH BURNT FORK CREEK | MT76H004_200 | Bottom Deposits |
| NORTH FORK RYE CREEK | MT76H004_160 | Other habitat alterations |
| RYE CREEK | MT76H004_190 | Sediment/Siltation, Other habitat alterations |
| SKALKAHO CREEK | MT76H004_100 | Other habitat alterations |
| SLEEPING CHILD CREEK | MT76H004_090 | Sedimentation/Siltation |
| SOUTH FORK LOLO CREEK | MT76H005_020 | Other habitat alterations |
| SWEATHOUSE CREEK | MT76H004_210 | Other habitat alterations |
| THREEMILE CREEK | MT76H004_140 | Sediment/Siltation, Other habitat alterations |
| TIN CUP CREEK | MT76H004_080 | Other habitat alterations |
| WILLOW CREEK | MT76H004_110 | Sediment/Siltation, Other habitat alterations |

**Table G2-5. Unpaved Road Summary by 6th Code HUC/303(d) Watershed**

| Subwatershed | Unpaved Crossings | Unpaved Roads (miles) | Stream Length (miles) | Unpaved Roads w/in 50ft (miles) | Unpaved Roads w/in 100ft (miles) | Area (sq miles) | Crossing Density (#/sq mi) | Road Density (mi/sq mi) |
|---|---|---|---|---|---|---|---|---|
| Ambrose Creek | 59 | 64.19 | 59.72 | 2.40 | 7.56 | 20.70 | 2.85 | 3.10 |
| Bass Creek | 12 | 6.32 | 31.72 | 0.25 | 0.53 | 14.45 | 0.83 | 0.44 |
| Bear Creek | 10 | 11.86 | 32.72 | 0.50 | 1.12 | 27.91 | 0.36 | 0.43 |
| Big Creek | 1 | 5.55 | 54.33 | 0.02 | 0.04 | 35.11 | 0.03 | 0.16 |
| Bitterroot River-Birch Creek | 91 | 106.19 | 138.57 | 3.66 | 9.06 | 59.61 | 1.53 | 1.78 |
| Lower Bear Creek | 8 | 5.49 | 8.92 | 0.18 | 0.50 | 1.96 | 4.09 | 2.81 |
| Bitterroot River-Canyon Creek | 21 | 30.39 | 39.76 | 0.51 | 1.55 | 15.56 | 1.35 | 1.95 |
| Bitterroot River-Chaffin Creek | 46 | 51.68 | 40.79 | 1.79 | 4.18 | 20.20 | 2.28 | 2.56 |
| Bitterroot River-Darby | 120 | 97.33 | 129.45 | 4.68 | 12.49 | 48.29 | 2.48 | 2.02 |
| Bitterroot River-Hayes Creek | 147 | 119.23 | 121.27 | 6.50 | 13.74 | 49.67 | 2.96 | 2.40 |
| Bitterroot River-Larry Creek | 121 | 105.09 | 160.89 | 3.89 | 8.39 | 50.49 | 2.40 | 2.08 |
| Bitterroot River-Lick Creek | 73 | 74.75 | 104.74 | 2.07 | 5.40 | 44.61 | 1.64 | 1.68 |
| Lick Creek | 27 | 25.24 | 23.84 | 0.98 | 2.45 | 8.53 | 3.17 | 2.96 |
| Bitterroot River-North Woodchuck Creek | 86 | 72.69 | 139.60 | 4.54 | 11.96 | 47.40 | 1.81 | 1.53 |
| McClain Creek | 44 | 41.11 | 29.38 | 1.56 | 3.27 | 8.94 | 4.92 | 4.60 |
| Bitterroot River-Spooner Creek | 65 | 69.33 | 111.88 | 1.65 | 4.63 | 39.08 | 1.66 | 1.77 |
| Bitterroot River-Woodside | 71 | 122.50 | 125.74 | 2.45 | 6.08 | 51.54 | 1.38 | 2.38 |
| Blodgett Creek | 4 | 6.00 | 37.66 | 0.10 | 0.26 | 28.35 | 0.14 | 0.21 |
| Burnt Fork Bitterroot River-Stevensville | 53 | 70.53 | 93.89 | 2.01 | 5.60 | 32.99 | 1.61 | 2.14 |
| Daly Creek | 30 | 48.18 | 68.91 | 1.01 | 2.94 | 37.38 | 0.80 | 1.29 |
| Divide Creek | 16 | 15.17 | 46.88 | 0.38 | 0.93 | 17.82 | 0.90 | 0.85 |
| Eightmile Creek | 78 | 127.51 | 53.58 | 5.00 | 13.84 | 27.62 | 2.82 | 4.62 |
| Fred Burr Creek | 14 | 14.21 | 35.94 | 0.39 | 0.84 | 24.00 | 0.58 | 0.59 |
| Gird Creek | 20 | 36.69 | 73.61 | 0.71 | 1.62 | 32.36 | 0.62 | 1.13 |
| Howard Creek | 101 | 125.00 | 49.38 | 6.38 | 16.18 | 19.35 | 5.22 | 6.46 |
| Kootenai Creek | 7 | 5.61 | 66.61 | 0.27 | 0.51 | 31.49 | 0.22 | 0.18 |
| Little Sleeping Child Creek | 27 | 32.71 | 37.64 | 1.12 | 3.72 | 15.51 | 1.74 | 2.11 |
| Lolo Creek-Grave Creek | 194 | 246.74 | 130.57 | 11.28 | 25.12 | 55.76 | 3.48 | 4.42 |
| Lost Horse Creek | 13 | 14.84 | 47.14 | 0.48 | 1.66 | 43.41 | 0.30 | 0.34 |
| South Lost Horse Creek | 31 | 27.81 | 43.43 | 1.43 | 2.33 | 31.17 | 0.99 | 0.89 |
| Lower Burnt Fork Bitterroot River | 41 | 59.34 | 61.29 | 2.34 | 5.40 | 31.31 | 1.31 | 1.90 |

**Table G2-5. Unpaved Road Summary by 6th Code HUC/303(d) Watershed**

| Subwatershed | Unpaved Crossings | Unpaved Roads (miles) | Stream Length (miles) | Unpaved Roads w/in 50ft (miles) | Unpaved Roads w/in 100ft (miles) | Area (sq miles) | Crossing Density (#/sq mi) | Road Density (mi/sq mi) |
|---|---|---|---|---|---|---|---|---|
| Muddy Spring Creek | 1 | 5.57 | 2.61 | 0.02 | 0.03 | 1.71 | 0.58 | 3.25 |
| Lower Lolo Creek | 295 | 220.98 | 129.45 | 12.85 | 24.24 | 49.65 | 5.94 | 4.45 |
| Upper Lolo Creek | 91 | 126.34 | 53.30 | 4.13 | 9.25 | 21.99 | 4.14 | 5.75 |
| South Fork Lolo Creek | 29 | 55.40 | 61.40 | 0.92 | 2.96 | 38.82 | 0.75 | 1.43 |
| Lower Rye Creek | 60 | 51.49 | 42.27 | 4.35 | 10.19 | 16.09 | 3.73 | 3.20 |
| Upper Rye Creek | 151 | 121.30 | 78.27 | 7.01 | 16.10 | 28.50 | 5.30 | 4.26 |
| North Fork Rye Creek | 65 | 67.51 | 46.82 | 2.69 | 6.79 | 18.37 | 3.54 | 3.67 |
| Lower Skalkaho Creek | 18 | 19.73 | 47.47 | 0.74 | 1.63 | 16.34 | 1.10 | 1.21 |
| Middle Skalkaho Creek | 27 | 36.62 | 41.64 | 1.22 | 2.37 | 18.38 | 1.47 | 1.99 |
| Upper Skalkaho Creek | 46 | 66.51 | 101.08 | 1.44 | 4.93 | 45.27 | 1.02 | 1.47 |
| Lower Sleeping Child Creek | 44 | 47.62 | 48.32 | 1.82 | 3.66 | 20.57 | 2.14 | 2.32 |
| Middle Sleeping Child Creek | 25 | 45.31 | 58.40 | 1.14 | 2.17 | 22.43 | 1.11 | 2.02 |
| Upper Sleeping Child Creek | 51 | 51.03 | 39.83 | 1.73 | 3.95 | 15.44 | 3.30 | 3.31 |
| McCalla Creek | 56 | 43.18 | 47.46 | 1.59 | 3.46 | 17.10 | 3.28 | 2.53 |
| Mill Creek | 58 | 58.09 | 75.53 | 1.72 | 4.51 | 39.98 | 1.45 | 1.45 |
| Miller Creek | 118 | 167.55 | 106.74 | 5.82 | 14.16 | 47.83 | 2.47 | 3.50 |
| O'Brien Creek | 99 | 104.74 | 61.90 | 4.99 | 9.74 | 25.33 | 3.91 | 4.13 |
| Roaring Lion Creek | 5 | 3.15 | 43.97 | 0.13 | 0.24 | 25.14 | 0.20 | 0.13 |
| Rock Creek | 7 | 16.35 | 64.82 | 0.15 | 0.49 | 57.29 | 0.12 | 0.29 |
| Sawtooth Creek | 22 | 14.06 | 69.73 | 0.59 | 1.28 | 30.38 | 0.72 | 0.46 |
| Swan Creek | 30 | 29.75 | 71.74 | 0.75 | 2.04 | 28.63 | 1.05 | 1.04 |
| Sweathouse Creek | 50 | 63.32 | 56.36 | 1.37 | 3.47 | 28.52 | 1.75 | 2.22 |
| Sweeney Creek | 19 | 13.95 | 36.36 | 0.56 | 1.27 | 19.00 | 1.00 | 0.73 |
| Threemile Creek | 97 | 126.46 | 136.93 | 4.37 | 12.96 | 51.87 | 1.87 | 2.44 |
| Tin Cup Creek | 29 | 19.62 | 60.69 | 0.77 | 1.63 | 42.23 | 0.69 | 0.46 |
| Upper Burnt Fork Bitterroot River | 19 | 19.61 | 72.01 | 0.55 | 1.90 | 40.03 | 0.47 | 0.49 |
| West Fork Butte Creek | 50 | 98.92 | 35.52 | 1.53 | 5.88 | 17.86 | 2.80 | 5.54 |
| Willoughby Creek | 35 | 38.37 | 53.11 | 2.45 | 5.48 | 20.73 | 1.69 | 1.85 |
| Willow Creek | 66 | 95.10 | 94.04 | 3.02 | 8.90 | 42.33 | 1.56 | 2.25 |
| **Total** | **3294** | **3666.92** | **4037.60** | **140.98** | **339.56** | **1820.41** | **1.81** | **2.01** |

Bear Creek and Sweathouse Creek HUC_12 layers were cross-labeled. They have been corrected in this spreadsheet.

**Table G2-6. Unpaved Road Crossings by Ownership and Landscape Type by 6th Code HUC/303(d) Subwatershed**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subwatershed** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Crossings** |
| Ambrose Creek | 0 | 2 | 20 | 0 | 0 | 0 | 18 | 17 | 2 | 0 | 0 | 0 | 59 |
| Bass Creek | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 12 |
| Bear Creek | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 10 |
| Big Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Bitterroot River-Birch Creek | 0 | 0 | 6 | 0 | 0 | 0 | 14 | 66 | 4 | 0 | 1 | 0 | 91 |
| Bitterroot River-Canyon Creek | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 9 | 0 | 0 | 0 | 0 | 21 |
| Bitterroot River-Chaffin Creek | 0 | 1 | 32 | 0 | 0 | 0 | 4 | 9 | 0 | 0 | 0 | 0 | 46 |
| Bitterroot River-Darby | 0 | 0 | 55 | 0 | 0 | 0 | 14 | 50 | 1 | 0 | 0 | 0 | 120 |
| Bitterroot River-Hayes Creek | 0 | 1 | 66 | 0 | 0 | 10 | 5 | 25 | 30 | 0 | 0 | 10 | 147 |
| Bitterroot River-Larry Creek | 1 | 3 | 10 | 0 | 0 | 0 | 35 | 72 | 0 | 0 | 0 | 0 | 121 |
| Bitterroot River-Lick Creek | 0 | 3 | 18 | 0 | 0 | 0 | 12 | 36 | 4 | 0 | 0 | 0 | 73 |
| Bitterroot River-North Woodchuck Creek | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 42 | 18 | 5 | 1 | 3 | 86 |
| Bitterroot River-Spooner Creek | 0 | 1 | 19 | 0 | 0 | 0 | 15 | 28 | 2 | 0 | 0 | 0 | 65 |
| Bitterroot River-Woodside | 0 | 0 | 2 | 0 | 0 | 0 | 15 | 48 | 6 | 0 | 0 | 0 | 71 |
| Blodgett Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 4 |
| Burnt Fork Bitterroot River-Stevensville | 3 | 0 | 5 | 0 | 0 | 0 | 39 | 6 | 0 | 0 | 0 | 0 | 53 |
| Daly Creek | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| Divide Creek | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| Eightmile Creek | 0 | 0 | 0 | 0 | 0 | 52 | 5 | 14 | 7 | 0 | 0 | 0 | 78 |
| Fred Burr Creek | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 4 | 0 | 0 | 0 | 14 |
| Gird Creek | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 20 |
| Howard Creek | 0 | 0 | 47 | 0 | 0 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 101 |
| Kootenai Creek | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 7 |
| Lick Creek | 0 | 0 | 25 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 27 |
| Little Sleeping Child Creek | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 27 |
| Lolo Creek-Grave Creek | 0 | 0 | 64 | 0 | 0 | 111 | 1 | 0 | 16 | 0 | 0 | 2 | 194 |
| Lost Horse Creek | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| Lower Bear Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 8 |
| Lower Burnt Fork Bitterroot River | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 3 | 7 | 0 | 0 | 1 | 41 |
| Lower Lolo Creek | 0 | 0 | 91 | 0 | 0 | 147 | 20 | 2 | 35 | 0 | 0 | 0 | 295 |
| Lower Rye Creek | 0 | 0 | 10 | 0 | 0 | 0 | 2 | 6 | 42 | 0 | 0 | 0 | 60 |
| Lower Skalkaho Creek | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 9 | 0 | 0 | 0 | 0 | 18 |
| Lower Sleeping Child Creek | 0 | 0 | 39 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 44 |
| McCalla Creek | 0 | 0 | 34 | 0 | 0 | 0 | 4 | 17 | 1 | 0 | 0 | 0 | 56 |
| McClain Creek | 0 | 0 | 16 | 0 | 0 | 0 | 3 | 15 | 10 | 0 | 0 | 0 | 44 |
| Middle Skalkaho Creek | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 |
| Middle Sleeping Child Creek | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| Mill Creek | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 48 | 3 | 0 | 0 | 0 | 58 |
| Miller Creek | 0 | 0 | 44 | 0 | 0 | 39 | 5 | 1 | 23 | 0 | 0 | 6 | 118 |
| Muddy Spring Creek | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| North Fork Rye Creek | 0 | 0 | 57 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 2 | 65 |
| O'Brien Creek | 0 | 0 | 64 | 0 | 0 | 2 | 2 | 2 | 29 | 0 | 0 | 0 | 99 |
| Roaring Lion Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 |
| Rock Creek | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 7 |
| Sawtooth Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 4 | 0 | 0 | 0 | 22 |
| South Fork Lolo Creek | 0 | 0 | 18 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| South Lost Horse Creek | 0 | 1 | 25 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 31 |

**Table G2-6. Unpaved Road Crossings by Ownership and Landscape Type by 6th Code HUC/303(d) Subwatershed**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subwatershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Crossings |
| Swan Creek | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 22 | 1 | 0 | 0 | 0 | 30 |
| Sweathouse Creek | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 50 |
| Sweeney Creek | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 19 |
| Threemile Creek | 0 | 0 | 25 | 0 | 1 | 2 | 15 | 47 | 2 | 0 | 0 | 5 | 97 |
| Tin Cup Creek | 0 | 0 | 22 | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 29 |
| Upper Burnt Fork Bitterroot River | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 |
| Upper Lolo Creek | 0 | 0 | 54 | 0 | 0 | 36 | 0 | 0 | 1 | 0 | 0 | 0 | 91 |
| Upper Rye Creek | 0 | 0 | 150 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 151 |
| Upper Skalkaho Creek | 0 | 0 | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 |
| Upper Sleeping Child Creek | 0 | 0 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51 |
| West Fork Butte Creek | 0 | 0 | 40 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| Willoughby Creek | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 24 | 5 | 0 | 4 | 0 | 35 |
| Willow Creek | 0 | 0 | 38 | 0 | 0 | 0 | 5 | 19 | 3 | 0 | 1 | 0 | 66 |
| **Total** | **4** | **12** | **1455** | **0** | **1** | **474** | **286** | **741** | **280** | **5** | **7** | **29** | **3294** |

**Table G2-7. Detailed Length of Parallel Road Segments Within 50-Feet of Streams by 6th Code HUC/303(d) Subwatershed**

| Ownership | Federal Land | | | Plum Creek Timber Land | | | Private Land | | | State Land | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subwatershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | (miles) |
| Ambrose Creek | 0.00 | 0.34 | 0.95 | 0.00 | 0.00 | 0.00 | 0.42 | 0.57 | 0.12 | 0.00 | 0.00 | 0.00 | 2.40 |
| Bass Creek | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |
| Bear Creek | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 |
| Big Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Bitterroot River-Birch Creek | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.44 | 2.72 | 0.28 | 0.00 | 0.05 | 0.00 | 3.66 |
| Bitterroot River-Canyon Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 |
| Bitterroot River-Chaffin Creek | 0.00 | 0.03 | 1.26 | 0.00 | 0.00 | 0.00 | 0.18 | 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 1.79 |
| Bitterroot River-Darby | 0.00 | 0.00 | 1.87 | 0.00 | 0.00 | 0.00 | 0.37 | 2.26 | 0.18 | 0.00 | 0.00 | 0.00 | 4.68 |
| Bitterroot River-Hayes Creek | 0.00 | 0.02 | 3.24 | 0.00 | 0.00 | 0.37 | 0.14 | 0.82 | 1.38 | 0.00 | 0.00 | 0.52 | 6.50 |
| Bitterroot River-Larry Creek | 0.10 | 0.07 | 0.24 | 0.00 | 0.00 | 0.00 | 0.93 | 2.54 | 0.00 | 0.00 | 0.00 | 0.00 | 3.89 |
| Bitterroot River-Lick Creek | 0.00 | 0.12 | 0.45 | 0.00 | 0.00 | 0.00 | 0.26 | 1.13 | 0.11 | 0.00 | 0.00 | 0.00 | 2.07 |
| Bitterroot River-North Woodchuck Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.49 | 2.04 | 1.66 | 0.11 | 0.03 | 0.19 | 4.54 |
| Bitterroot River-Spooner Creek | 0.00 | 0.02 | 0.43 | 0.00 | 0.00 | 0.00 | 0.37 | 0.78 | 0.05 | 0.00 | 0.00 | 0.00 | 1.65 |
| Bitterroot River-Woodside | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.33 | 1.95 | 0.14 | 0.00 | 0.00 | 0.00 | 2.45 |
| Blodgett Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| Burnt Fork Bitterroot River-Stevensville | 0.08 | 0.00 | 0.19 | 0.00 | 0.00 | 0.00 | 1.40 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 2.01 |
| Daly Creek | 0.00 | 0.00 | 1.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 |
| Divide Creek | 0.00 | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 |
| Eightmile Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.51 | 0.13 | 1.07 | 0.30 | 0.00 | 0.00 | 0.00 | 5.00 |
| Fred Burr Creek | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.12 | 0.00 | 0.00 | 0.00 | 0.39 |
| Gird Creek | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Howard Creek | 0.00 | 0.00 | 2.51 | 0.00 | 0.00 | 3.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.38 |
| Kootenai Creek | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 |
| Lick Creek | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.98 |
| Little Sleeping Child Creek | 0.00 | 0.00 | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 0.00 | 0.00 | 0.00 | 1.12 |
| Lolo Creek-Grave Creek | 0.00 | 0.00 | 4.07 | 0.00 | 0.00 | 6.35 | 0.09 | 0.00 | 0.68 | 0.00 | 0.00 | 0.08 | 11.28 |
| Lost Horse Creek | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 |
| Lower Bear Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 |
| Lower Burnt Fork Bitterroot River | 0.00 | 0.00 | 1.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.91 | 0.00 | 0.00 | 0.13 | 2.34 |

**Table G2-7. Detailed Length of Parallel Road Segments Within 50-Feet of Streams by 6th Code HUC/303(d) Subwatershed**

| Ownership | Federal Land | | | Plum Creek Timber Land | | | Private Land | | | State Land | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subwatershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | (miles) |
| Lower Lolo Creek | 0.00 | 0.00 | 3.02 | 0.00 | 0.00 | 6.88 | 0.48 | 0.04 | 2.42 | 0.00 | 0.00 | 0.00 | 12.85 |
| Lower Rye Creek | 0.00 | 0.00 | 0.29 | 0.00 | 0.00 | 0.00 | 0.05 | 0.27 | 3.74 | 0.00 | 0.00 | 0.00 | 4.35 |
| Lower Skalkaho Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.74 |
| Lower Sleeping Child Creek | 0.00 | 0.00 | 1.69 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.09 | 0.00 | 0.00 | 0.00 | 1.82 |
| McCalla Creek | 0.00 | 0.00 | 0.87 | 0.00 | 0.00 | 0.00 | 0.09 | 0.55 | 0.09 | 0.00 | 0.00 | 0.00 | 1.59 |
| McClain Creek | 0.00 | 0.00 | 0.68 | 0.00 | 0.00 | 0.00 | 0.12 | 0.48 | 0.29 | 0.00 | 0.00 | 0.00 | 1.56 |
| Middle Skalkaho Creek | 0.00 | 0.00 | 1.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22 |
| Middle Sleeping Child Creek | 0.00 | 0.00 | 1.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 |
| Mill Creek | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 1.39 | 0.12 | 0.00 | 0.00 | 0.00 | 1.72 |
| Miller Creek | 0.00 | 0.00 | 2.50 | 0.00 | 0.00 | 1.46 | 0.12 | 0.02 | 1.49 | 0.00 | 0.00 | 0.23 | 5.82 |
| Muddy Spring Creek | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| North Fork Rye Creek | 0.00 | 0.00 | 2.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.08 | 2.69 |
| O'Brien Creek | 0.00 | 0.00 | 3.21 | 0.00 | 0.00 | 0.05 | 0.10 | 0.12 | 1.51 | 0.00 | 0.00 | 0.00 | 4.99 |
| Roaring Lion Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 |
| Rock Creek | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.06 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| Sawtooth Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.13 | 0.00 | 0.00 | 0.00 | 0.59 |
| South Fork Lolo Creek | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 |
| South Lost Horse Creek | 0.00 | 0.02 | 1.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.04 | 0.00 | 0.00 | 0.00 | 1.43 |
| Swan Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.58 | 0.02 | 0.00 | 0.00 | 0.00 | 0.75 |
| Sweathouse Creek | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 | 0.00 | 0.00 | 0.00 | 0.00 | 1.37 |
| Sweeney Creek | 0.00 | 0.00 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.56 |
| Threemile Creek | 0.00 | 0.00 | 1.17 | 0.00 | 0.14 | 0.23 | 0.47 | 1.60 | 0.16 | 0.00 | 0.00 | 0.60 | 4.37 |
| Tin Cup Creek | 0.00 | 0.00 | 0.52 | 0.00 | 0.00 | 0.00 | 0.02 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 |
| Upper Burnt Fork Bitterroot River | 0.00 | 0.00 | 0.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 |
| Upper Lolo Creek | 0.00 | 0.00 | 2.49 | 0.00 | 0.00 | 1.62 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 4.13 |
| Upper Rye Creek | 0.00 | 0.00 | 6.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 7.01 |
| Upper Skalkaho Creek | 0.00 | 0.00 | 1.44 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44 |
| Upper Sleeping Child Creek | 0.00 | 0.00 | 1.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.73 |
| West Fork Butte Creek | 0.00 | 0.00 | 1.17 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.53 |
| Willoughby Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 1.77 | 0.49 | 0.00 | 0.13 | 0.00 | 2.45 |
| Willow Creek | 0.00 | 0.00 | 1.86 | 0.00 | 0.00 | 0.00 | 0.10 | 0.83 | 0.23 | 0.00 | 0.00 | 0.00 | 3.02 |
| **Total** | **0.18** | **0.62** | **58.89** | **0.00** | **0.14** | **25.07** | **8.00** | **28.09** | **17.85** | **0.11** | **0.21** | **1.82** | **140.98** |

**Table G3-2. Detailed Sediment Load From Unpaved Road Crossings by 6th Code HUC/303(d) Subwatershed – Existing Conditions**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load (t/y) |
| Ambrose Creek | 0 | 0.44 | 2.4 | 0 | 0 | 0 | 1.26 | 3.74 | 0.24 | 0 | 0 | 0 | 8.08 |
| Bass Creek | 0 | 0 | 0.96 | 0 | 0 | 0 | 0 | 0.88 | 0 | 0 | 0 | 0 | 1.84 |
| Bear Creek | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 | 1.7 |
| Big Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.22 | 0 | 0 | 0 | 0 | 0.22 |
| Bitterroot River-Birch Creek | 0 | 0 | 0.72 | 0 | 0 | 0 | 0.98 | 14.52 | 0.48 | 0 | 0.22 | 0 | 16.92 |
| Bitterroot River-Canyon Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0.84 | 1.98 | 0 | 0 | 0 | 0 | 2.82 |
| Bitterroot River-Chaffin Creek | 0 | 0.22 | 3.84 | 0 | 0 | 0 | 0.28 | 1.98 | 0 | 0 | 0 | 0 | 6.32 |
| Bitterroot River-Darby | 0 | 0 | 6.6 | 0 | 0 | 0 | 0.98 | 11 | 0.12 | 0 | 0 | 0 | 18.7 |
| Bitterroot River-Hayes Creek | 0 | 0.22 | 7.92 | 0 | 0 | 1.2 | 0.35 | 5.5 | 3.6 | 0 | 0 | 1.2 | 19.99 |
| Bitterroot River-Larry Creek | 0.07 | 0.66 | 1.2 | 0 | 0 | 0 | 2.45 | 15.84 | 0 | 0 | 0 | 0 | 20.22 |
| Bitterroot River-Lick Creek | 0 | 0.66 | 2.16 | 0 | 0 | 0 | 0.84 | 7.92 | 0.48 | 0 | 0 | 0 | 12.06 |
| Bitterroot River-North Woodchuck Creek | 0 | 0 | 0 | 0 | 0 | 0 | 1.19 | 9.24 | 2.16 | 5 | 0.22 | 0.36 | 18.17 |
| Bitterroot River-Spooner Creek | 0 | 0.22 | 2.28 | 0 | 0 | 0 | 1.05 | 6.16 | 0.24 | 0 | 0 | 0 | 9.95 |
| Bitterroot River-Woodside | 0 | 0 | 0.24 | 0 | 0 | 0 | 1.05 | 10.56 | 0.72 | 0 | 0 | 0 | 12.57 |
| Blodgett Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.88 | 0 | 0 | 0 | 0 | 0.88 |
| Burnt Fork Bitterroot River-Stevensville | 0.21 | 0 | 0.6 | 0 | 0 | 0 | 2.73 | 1.32 | 0 | 0 | 0 | 0 | 4.86 |
| Daly Creek | 0 | 0 | 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.6 |
| Divide Creek | 0 | 0 | 1.92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.92 |
| Eightmile Creek | 0 | 0 | 0 | 0 | 0 | 6.24 | 0.35 | 3.08 | 0.84 | 0 | 0 | 0 | 10.51 |
| Fred Burr Creek | 0 | 0 | 0.12 | 0 | 0 | 0 | 0 | 1.98 | 0.48 | 0 | 0 | 0 | 2.58 |
| Gird Creek | 0 | 0 | 1.8 | 0 | 0 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 | 2.9 |
| Howard Creek | 0 | 0 | 5.64 | 0 | 0 | 6.48 | 0 | 0 | 0 | 0 | 0 | 0 | 12.12 |
| Kootenai Creek | 0 | 0 | 0.24 | 0 | 0 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 | 1.34 |
| Lick Creek | 0 | 0 | 3 | 0 | 0 | 0 | 0.07 | 0.22 | 0 | 0 | 0 | 0 | 3.29 |
| Little Sleeping Child Creek | 0 | 0 | 2.04 | 0 | 0 | 0 | 0 | 0 | 1.2 | 0 | 0 | 0 | 3.24 |
| Lolo Creek-Grave Creek | 0 | 0 | 7.68 | 0 | 0 | 13.32 | 0.07 | 0 | 1.92 | 0 | 0 | 0.24 | 23.23 |
| Lost Horse Creek | 0 | 0 | 1.56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.56 |
| Lower Bear Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.76 | 0 | 0 | 0 | 0 | 1.76 |
| Lower Burnt Fork Bitterroot River | 0 | 0 | 3.6 | 0 | 0 | 0 | 0 | 0.66 | 0.84 | 0 | 0 | 0.12 | 5.22 |
| Lower Lolo Creek | 0 | 0 | 10.92 | 0 | 0 | 17.64 | 1.4 | 0.44 | 4.2 | 0 | 0 | 0 | 34.6 |
| Lower Rye Creek | 0 | 0 | 1.2 | 0 | 0 | 0 | 0.14 | 1.32 | 5.04 | 0 | 0 | 0 | 7.7 |
| Lower Skalkaho Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0.63 | 1.98 | 0 | 0 | 0 | 0 | 2.61 |
| Lower Sleeping Child Creek | 0 | 0 | 4.68 | 0 | 0 | 0 | 0.07 | 0.66 | 0.12 | 0 | 0 | 0 | 5.53 |
| McCalla Creek | 0 | 0 | 4.08 | 0 | 0 | 0 | 0.28 | 3.74 | 0.12 | 0 | 0 | 0 | 8.22 |
| McClain Creek | 0 | 0 | 1.92 | 0 | 0 | 0 | 0.21 | 3.3 | 1.2 | 0 | 0 | 0 | 6.63 |
| Middle Skalkaho Creek | 0 | 0 | 3.24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.24 |
| Middle Sleeping Child Creek | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Mill Creek | 0 | 0 | 0.84 | 0 | 0 | 0 | 0 | 10.56 | 0.36 | 0 | 0 | 0 | 11.76 |
| Miller Creek | 0 | 0 | 5.28 | 0 | 0 | 4.68 | 0.35 | 0.22 | 2.76 | 0 | 0 | 0.72 | 14.01 |
| Muddy Spring Creek | 0 | 0 | 0.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.12 |
| North Fork Rye Creek | 0 | 0 | 6.84 | 0 | 0 | 0 | 0 | 0 | 0.72 | 0 | 0 | 0.24 | 7.8 |
| O'Brien Creek | 0 | 0 | 7.68 | 0 | 0 | 0.24 | 0.14 | 0.44 | 3.48 | 0 | 0 | 0 | 11.98 |
| Roaring Lion Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 | 1.1 |
| Rock Creek | 0 | 0 | 0.36 | 0 | 0 | 0 | 0.21 | 0.22 | 0 | 0 | 0 | 0 | 0.79 |
| Sawtooth Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.96 | 0.48 | 0 | 0 | 0 | 4.44 |

**Table G3-2. Detailed Sediment Load From Unpaved Road Crossings by 6th Code HUC/303(d) Subwatershed – Existing Conditions**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load (t/y) |
| South Fork Lolo Creek | 0 | 0 | 2.16 | 0 | 0 | 1.32 | 0 | 0 | 0 | 0 | 0 | 0 | 3.48 |
| South Lost Horse Creek | 0 | 0.22 | 3 | 0 | 0 | 0 | 0 | 0.66 | 0.24 | 0 | 0 | 0 | 4.12 |
| Swan Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0.49 | 4.84 | 0.12 | 0 | 0 | 0 | 5.45 |
| Sweathouse Creek | 0 | 0 | 3.6 | 0 | 0 | 0 | 0 | 4.4 | 0 | 0 | 0 | 0 | 8 |
| Sweeney Creek | 0 | 0 | 1.56 | 0 | 0 | 0 | 0 | 1.32 | 0 | 0 | 0 | 0 | 2.88 |
| Threemile Creek | 0 | 0 | 3 | 0 | 0.22 | 0.24 | 1.05 | 10.34 | 0.24 | 0 | 0 | 0.6 | 15.69 |
| Tin Cup Creek | 0 | 0 | 2.64 | 0 | 0 | 0 | 0.07 | 1.32 | 0 | 0 | 0 | 0 | 4.03 |
| Upper Burnt Fork Bitterroot River | 0 | 0 | 2.28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.28 |
| Upper Lolo Creek | 0 | 0 | 6.48 | 0 | 0 | 4.32 | 0 | 0 | 0.12 | 0 | 0 | 0 | 10.92 |
| Upper Rye Creek | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0.12 | 0 | 0 | 0 | 18.12 |
| Upper Skalkaho Creek | 0 | 0 | 5.52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.52 |
| Upper Sleeping Child Creek | 0 | 0 | 6.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.12 |
| West Fork Butte Creek | 0 | 0 | 4.8 | 0 | 0 | 1.2 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| Willoughby Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0.14 | 5.28 | 0.6 | 0 | 0.88 | 0 | 6.9 |
| Willow Creek | 0 | 0 | 4.56 | 0 | 0 | 0 | 0.35 | 4.18 | 0.36 | 0 | 0.22 | 0 | 9.67 |
| **Total** | **0.28** | **2.64** | **174.6** | **0** | **0.22** | **56.88** | **20.02** | **163.02** | **33.6** | **5** | **1.54** | **3.48** | **461.28** |

**Table G3-3. Detailed Sediment Load from Unpaved Parallel Road Segments 6th Code by HUC/303(d) Subwatershed – Existing Conditions**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load |
| Ambrose Creek | 0.00 | 0.10 | 2.10 | 0.00 | 0.00 | 0.00 | 0.53 | 0.18 | 0.27 | 0.00 | 0.00 | 0.00 | 3.18 |
| Bass Creek | 0.00 | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 |
| Bear Creek | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 |
| Big Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Bitterroot River-Birch Creek | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 | 0.56 | 0.84 | 0.61 | 0.00 | 0.02 | 0.00 | 2.40 |
| Bitterroot River-Canyon Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 |
| Bitterroot River-Chaffin Creek | 0.00 | 0.01 | 2.79 | 0.00 | 0.00 | 0.00 | 0.22 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 3.12 |
| Bitterroot River-Darby | 0.00 | 0.00 | 4.14 | 0.00 | 0.00 | 0.00 | 0.46 | 0.70 | 0.39 | 0.00 | 0.00 | 0.00 | 5.69 |
| Bitterroot River-Hayes Creek | 0.00 | 0.01 | 7.16 | 0.00 | 0.00 | 0.82 | 0.18 | 0.25 | 3.06 | 0.00 | 0.00 | 1.15 | 12.63 |
| Bitterroot River-Larry Creek | 0.13 | 0.02 | 0.54 | 0.00 | 0.00 | 0.00 | 1.18 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 2.65 |
| Bitterroot River-Lick Creek | 0.00 | 0.04 | 0.99 | 0.00 | 0.00 | 0.00 | 0.33 | 0.35 | 0.25 | 0.00 | 0.00 | 0.00 | 1.95 |
| Bitterroot River-North Woodchuck Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.62 | 0.63 | 3.66 | 0.13 | 0.01 | 0.41 | 5.53 |
| Bitterroot River-Spooner Creek | 0.00 | 0.01 | 0.94 | 0.00 | 0.00 | 0.00 | 0.47 | 0.24 | 0.10 | 0.00 | 0.00 | 0.00 | 1.76 |
| Bitterroot River-Woodside | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.41 | 0.60 | 0.30 | 0.00 | 0.00 | 0.00 | 1.41 |
| Blodgett Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| Burnt Fork Bitterroot River-Stevensville | 0.10 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 1.77 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 2.38 |
| Daly Creek | 0.00 | 0.00 | 2.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.23 |
| Divide Creek | 0.00 | 0.00 | 0.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 |
| Eightmile Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.75 | 0.16 | 0.33 | 0.66 | 0.00 | 0.00 | 0.00 | 8.90 |
| Fred Burr Creek | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.26 | 0.00 | 0.00 | 0.00 | 0.40 |
| Gird Creek | 0.00 | 0.00 | 1.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29 |
| Howard Creek | 0.00 | 0.00 | 5.55 | 0.00 | 0.00 | 8.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 14.11 |
| Kootenai Creek | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 |
| Lick Creek | 0.00 | 0.00 | 2.06 | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 2.10 |
| Little Sleeping Child Creek | 0.00 | 0.00 | 1.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 | 0.00 | 2.47 |

**Table G3-3. Detailed Sediment Load from Unpaved Parallel Road Segments 6th Code by HUC/303(d) Subwatershed – Existing Conditions**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Watershed** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Load** |
| Lolo Creek-Grave Creek | 0.00 | 0.00 | 8.99 | 0.00 | 0.00 | 14.04 | 0.12 | 0.00 | 1.51 | 0.00 | 0.00 | 0.17 | 24.83 |
| Lost Horse Creek | 0.00 | 0.00 | 1.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.07 |
| Lower Bear Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| Lower Burnt Fork Bitterroot River | 0.00 | 0.00 | 2.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 2.01 | 0.00 | 0.00 | 0.30 | 4.82 |
| Lower Lolo Creek | 0.00 | 0.00 | 6.68 | 0.00 | 0.00 | 15.20 | 0.61 | 0.01 | 5.36 | 0.00 | 0.00 | 0.00 | 27.86 |
| Lower Rye Creek | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 | 0.00 | 0.06 | 0.08 | 8.28 | 0.00 | 0.00 | 0.00 | 9.06 |
| Lower Skalkaho Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 |
| Lower Sleeping Child Creek | 0.00 | 0.00 | 3.73 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.20 | 0.00 | 0.00 | 0.00 | 3.96 |
| McCalla Creek | 0.00 | 0.00 | 1.92 | 0.00 | 0.00 | 0.00 | 0.11 | 0.17 | 0.20 | 0.00 | 0.00 | 0.00 | 2.40 |
| McClain Creek | 0.00 | 0.00 | 1.49 | 0.00 | 0.00 | 0.00 | 0.16 | 0.15 | 0.64 | 0.00 | 0.00 | 0.00 | 2.43 |
| Middle Skalkaho Creek | 0.00 | 0.00 | 2.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.69 |
| Middle Sleeping Child Creek | 0.00 | 0.00 | 2.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.51 |
| Mill Creek | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 | 0.26 | 0.00 | 0.00 | 0.00 | 1.16 |
| Miller Creek | 0.00 | 0.00 | 5.52 | 0.00 | 0.00 | 3.22 | 0.16 | 0.01 | 3.29 | 0.00 | 0.00 | 0.50 | 12.70 |
| Muddy Spring Creek | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| North Fork Rye Creek | 0.00 | 0.00 | 5.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 0.00 | 0.00 | 0.17 | 5.95 |
| O'Brien Creek | 0.00 | 0.00 | 7.10 | 0.00 | 0.00 | 0.10 | 0.13 | 0.04 | 3.35 | 0.00 | 0.00 | 0.00 | 10.72 |
| Roaring Lion Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| Rock Creek | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.07 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 |
| Sawtooth Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.30 | 0.00 | 0.00 | 0.00 | 0.44 |
| South Fork Lolo Creek | 0.00 | 0.00 | 1.27 | 0.00 | 0.00 | 0.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.04 |
| South Lost Horse Creek | 0.00 | 0.01 | 2.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.10 | 0.00 | 0.00 | 0.00 | 2.99 |
| Swan Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.18 | 0.05 | 0.00 | 0.00 | 0.00 | 0.41 |
| Sweathouse Creek | 0.00 | 0.00 | 1.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 |
| Sweeney Creek | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.81 |
| Threemile Creek | 0.00 | 0.00 | 2.58 | 0.00 | 0.04 | 0.50 | 0.59 | 0.50 | 0.36 | 0.00 | 0.00 | 1.33 | 5.89 |
| Tin Cup Creek | 0.00 | 0.00 | 1.16 | 0.00 | 0.00 | 0.00 | 0.03 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26 |
| Upper Burnt Fork Bitterroot River | 0.00 | 0.00 | 1.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22 |
| Upper Lolo Creek | 0.00 | 0.00 | 5.51 | 0.00 | 0.00 | 3.57 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 9.14 |
| Upper Rye Creek | 0.00 | 0.00 | 15.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 15.49 |
| Upper Skalkaho Creek | 0.00 | 0.00 | 3.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.19 |
| Upper Sleeping Child Creek | 0.00 | 0.00 | 3.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.81 |
| West Fork Butte Creek | 0.00 | 0.00 | 2.59 | 0.00 | 0.00 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.38 |
| Willoughby Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.55 | 1.07 | 0.00 | 0.04 | 0.00 | 1.74 |
| Willow Creek | 0.00 | 0.00 | 4.11 | 0.00 | 0.00 | 0.00 | 0.13 | 0.26 | 0.52 | 0.00 | 0.00 | 0.00 | 5.01 |
| **Total** | **0.23** | **0.19** | **130.14** | **0.00** | **0.04** | **55.40** | **10.07** | **8.68** | **39.45** | **0.13** | **0.07** | **4.03** | **248.44** |

**Table G3-4. Total Sediment Load from Unpaved Road Network by 6th Code HUC/303(d) Subwatershed – Existing Conditions**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load (t/y) |
| Ambrose Creek | 0.00 | 0.54 | 4.50 | 0.00 | 0.00 | 0.00 | 1.79 | 3.92 | 0.51 | 0.00 | 0.00 | 0.00 | 11.26 |
| Bass Creek | 0.00 | 0.00 | 1.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.90 | 0.00 | 0.00 | 0.00 | 0.00 | 2.25 |
| Bear Creek | 0.00 | 0.00 | 0.90 | 0.00 | 0.00 | 0.00 | 0.00 | 1.21 | 0.00 | 0.00 | 0.00 | 0.00 | 2.11 |
| Big Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 |
| Bitterroot River-Birch Creek | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 1.54 | 15.36 | 1.09 | 0.00 | 0.24 | 0.00 | 19.32 |
| Bitterroot River-Canyon Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.23 | 2.04 | 0.00 | 0.00 | 0.00 | 0.00 | 3.27 |
| Bitterroot River-Chaffin Creek | 0.00 | 0.23 | 6.63 | 0.00 | 0.00 | 0.00 | 0.50 | 2.08 | 0.00 | 0.00 | 0.00 | 0.00 | 9.44 |
| Bitterroot River-Darby | 0.00 | 0.00 | 10.74 | 0.00 | 0.00 | 0.00 | 1.44 | 11.70 | 0.51 | 0.00 | 0.00 | 0.00 | 24.39 |
| Bitterroot River-Hayes Creek | 0.00 | 0.23 | 15.08 | 0.00 | 0.00 | 2.02 | 0.53 | 5.75 | 6.66 | 0.00 | 0.00 | 2.35 | 32.62 |
| Bitterroot River-Larry Creek | 0.20 | 0.68 | 1.74 | 0.00 | 0.00 | 0.00 | 3.63 | 16.63 | 0.00 | 0.00 | 0.00 | 0.00 | 22.87 |
| Bitterroot River-Lick Creek | 0.00 | 0.70 | 3.15 | 0.00 | 0.00 | 0.00 | 1.17 | 8.27 | 0.73 | 0.00 | 0.00 | 0.00 | 14.01 |
| Bitterroot River-North Woodchuck Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 1.81 | 9.87 | 5.82 | 5.13 | 0.23 | 0.77 | 23.70 |
| Bitterroot River-Spooner Creek | 0.00 | 0.23 | 3.22 | 0.00 | 0.00 | 0.00 | 1.52 | 6.40 | 0.34 | 0.00 | 0.00 | 0.00 | 11.71 |
| Bitterroot River-Woodside | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 1.46 | 11.16 | 1.02 | 0.00 | 0.00 | 0.00 | 13.98 |
| Blodgett Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 |
| Burnt Fork Bitterroot River-Stevensville | 0.31 | 0.00 | 1.01 | 0.00 | 0.00 | 0.00 | 4.50 | 1.43 | 0.00 | 0.00 | 0.00 | 0.00 | 7.24 |
| Daly Creek | 0.00 | 0.00 | 5.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.83 |
| Divide Creek | 0.00 | 0.00 | 2.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.77 |
| Eightmile Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.99 | 0.51 | 3.41 | 1.50 | 0.00 | 0.00 | 0.00 | 19.41 |
| Fred Burr Creek | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 2.06 | 0.74 | 0.00 | 0.00 | 0.00 | 2.98 |
| Gird Creek | 0.00 | 0.00 | 3.05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.15 | 0.00 | 0.00 | 0.00 | 0.00 | 4.19 |
| Howard Creek | 0.00 | 0.00 | 11.19 | 0.00 | 0.00 | 15.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 26.23 |
| Kootenai Creek | 0.00 | 0.00 | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 1.16 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60 |
| Lick Creek | 0.00 | 0.00 | 5.06 | 0.00 | 0.00 | 0.00 | 0.11 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 5.39 |
| Little Sleeping Child Creek | 0.00 | 0.00 | 3.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 0.00 | 0.00 | 0.00 | 5.71 |
| Lolo Creek-Grave Creek | 0.00 | 0.00 | 16.67 | 0.00 | 0.00 | 27.36 | 0.19 | 0.00 | 3.43 | 0.00 | 0.00 | 0.41 | 48.06 |
| Lost Horse Creek | 0.00 | 0.00 | 2.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.63 |
| Lower Bear Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.82 | 0.00 | 0.00 | 0.00 | 0.00 | 1.82 |
| Lower Burnt Fork Bitterroot River | 0.00 | 0.00 | 6.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 2.85 | 0.00 | 0.00 | 0.42 | 10.04 |
| Lower Lolo Creek | 0.00 | 0.00 | 17.60 | 0.00 | 0.00 | 32.84 | 2.01 | 0.45 | 9.56 | 0.00 | 0.00 | 0.00 | 62.46 |
| Lower Rye Creek | 0.00 | 0.00 | 1.85 | 0.00 | 0.00 | 0.00 | 0.20 | 1.40 | 13.32 | 0.00 | 0.00 | 0.00 | 16.76 |
| Lower Skalkaho Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 2.14 | 0.00 | 0.00 | 0.00 | 0.00 | 3.06 |
| Lower Sleeping Child Creek | 0.00 | 0.00 | 8.41 | 0.00 | 0.00 | 0.00 | 0.09 | 0.67 | 0.32 | 0.00 | 0.00 | 0.00 | 9.49 |
| McCalla Creek | 0.00 | 0.00 | 6.00 | 0.00 | 0.00 | 0.00 | 0.39 | 3.91 | 0.32 | 0.00 | 0.00 | 0.00 | 10.62 |
| McClain Creek | 0.00 | 0.00 | 3.41 | 0.00 | 0.00 | 0.00 | 0.37 | 3.45 | 1.84 | 0.00 | 0.00 | 0.00 | 9.06 |
| Middle Skalkaho Creek | 0.00 | 0.00 | 5.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.93 |
| Middle Sleeping Child Creek | 0.00 | 0.00 | 5.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.51 |
| Mill Creek | 0.00 | 0.00 | 1.32 | 0.00 | 0.00 | 0.00 | 0.00 | 10.99 | 0.62 | 0.00 | 0.00 | 0.00 | 12.92 |
| Miller Creek | 0.00 | 0.00 | 10.80 | 0.00 | 0.00 | 7.90 | 0.51 | 0.23 | 6.05 | 0.00 | 0.00 | 1.22 | 26.71 |
| Muddy Spring Creek | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 |
| North Fork Rye Creek | 0.00 | 0.00 | 11.90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44 | 0.00 | 0.00 | 0.41 | 13.75 |

**Table G3-4. Total Sediment Load from Unpaved Road Network by 6th Code HUC/303(d) Subwatershed – Existing Conditions**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Watershed** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Load (t/y)** |
| O'Brien Creek | 0.00 | 0.00 | 14.78 | 0.00 | 0.00 | 0.34 | 0.27 | 0.48 | 6.83 | 0.00 | 0.00 | 0.00 | 22.70 |
| Roaring Lion Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 |
| Rock Creek | 0.00 | 0.00 | 0.51 | 0.00 | 0.00 | 0.00 | 0.28 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 1.02 |
| Sawtooth Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.10 | 0.78 | 0.00 | 0.00 | 0.00 | 4.88 |
| South Fork Lolo Creek | 0.00 | 0.00 | 3.43 | 0.00 | 0.00 | 2.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.52 |
| South Lost Horse Creek | 0.00 | 0.23 | 5.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.68 | 0.34 | 0.00 | 0.00 | 0.00 | 7.11 |
| Swan Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 5.02 | 0.17 | 0.00 | 0.00 | 0.00 | 5.86 |
| Sweathouse Creek | 0.00 | 0.00 | 5.43 | 0.00 | 0.00 | 0.00 | 0.00 | 4.57 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 |
| Sweeney Creek | 0.00 | 0.00 | 2.30 | 0.00 | 0.00 | 0.00 | 0.00 | 1.39 | 0.00 | 0.00 | 0.00 | 0.00 | 3.69 |
| Threemile Creek | 0.00 | 0.00 | 5.58 | 0.00 | 0.26 | 0.74 | 1.64 | 10.84 | 0.60 | 0.00 | 0.00 | 1.93 | 21.58 |
| Tin Cup Creek | 0.00 | 0.00 | 3.80 | 0.00 | 0.00 | 0.00 | 0.10 | 1.39 | 0.00 | 0.00 | 0.00 | 0.00 | 5.29 |
| Upper Burnt Fork Bitterroot River | 0.00 | 0.00 | 3.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.50 |
| Upper Lolo Creek | 0.00 | 0.00 | 11.99 | 0.00 | 0.00 | 7.89 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 20.06 |
| Upper Rye Creek | 0.00 | 0.00 | 33.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 0.00 | 33.61 |
| Upper Skalkaho Creek | 0.00 | 0.00 | 8.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.71 |
| Upper Sleeping Child Creek | 0.00 | 0.00 | 9.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.93 |
| West Fork Butte Creek | 0.00 | 0.00 | 7.39 | 0.00 | 0.00 | 1.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.38 |
| Willoughby Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 5.83 | 1.67 | 0.00 | 0.92 | 0.00 | 8.64 |
| Willow Creek | 0.00 | 0.00 | 8.67 | 0.00 | 0.00 | 0.00 | 0.48 | 4.44 | 0.88 | 0.00 | 0.22 | 0.00 | 14.68 |
| **Total** | **0.51** | **2.83** | **304.74** | **0.00** | **0.26** | **112.28** | **30.09** | **171.70** | **73.05** | **5.13** | **1.61** | **7.51** | **709.72** |

**Table G3-5B. Fish Passage Analysis for Selected Road Crossings Using Alaska Region Criteria**

| Location ID | Structure Type | Culvert Dimensions (ft) | Width (ft) | Culvert slope (%) | Bankfull width (ft) | Culvert/BF ratio | Fill Height (ft) | Fill Width (ft) | Fill Length (ft) | Fill Volume (CY) | Outlet Perch (inches) | Final Classification (# of failures) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRHC-M1 | Round CMP | 1 | 1.0 | 0 (1) | 2 | 0.50 (3) | 2 | 5 | 16 | 0.74 | 0 (1) | 1 (3) |
| BRHC-M2 | Round CMP | 2.5 | 2.5 | 4 (3 | 4 | 0.63 (2) | 4 | 11 | 22 | 6.52 | 2 (2) | 1 (3) |
| BRHC-M4 | Round CMP | 2 | 2.0 | 10 (3) | 2 | 1.00 (1) | 5 | 60 | 16 | 22.22 | N/A | 1 (3) |
| MC-M8 | Round CMP | 3.5 | 3.5 | | 7.5 | 0.47 (3) | 4.5 | 25 | 9 | 31.25 | 11 (3) | 2 (3) |
| MC-M9 | Squash CMP | 3.0 x 2.0 | 3.0 | | 4 | 0.75 (2) | 3 | 43 | 10 | 19.11 | 0 (1) | (2) |
| BRNWC-M12 | Round CMP | 3 | 3.0 | | 3.5 | 0.9 (1) | 7 | 30 | 12 | 27.22 | 6 (3) | 1 (3) |
| EMC-M16 | Squash CMP | W-3.5, H-2.5 | 3.5 | | 2 | 1.8 (1) | 5.5 | 33 | 11 | 13.44 | 16 (3) | 1 (3) |
| EMC-M17 | Round CMP | 2 | 2.0 | | 4 | 0.5 (3) | 35 | 64 | 30 | 331.85 | 6 (3) | 2 (3) |
| TMC-F19 | Round CMP | 24"-D | 2.0 | 0 (1) | 2 | 1.0 (1) | 3 | 30 | 10 | 6.67 | 0 (1) | (1) |
| TMC-M20 | Squash CMP | H-2.33, W-3.5 | 3.5 | 0 (1) | 4 | 0.9 (1) | 1 | 18 | 10 | 2.67 | 0 (1) | (1) |
| TMC-F22 | Round CMP | 3.0-CMP, 2.75-Dry | 3.0 | 1 (2) | 9 | 0.3 (3) | 2.5 | 25 | 11 | 20.83 | 1 (2) | 1 (3) |
| AC-M25 | Round CMP | 3 | 3.0 | 5 (3) | 7 | 0.4 (3) | 3 | 45 | 15 | 35.00 | 5 (3) | 3 (3) |
| BFBRS-V28 | Round CMP | 3 | 3.0 | 2 (3) | 6 | 0.5 (3) | 2 | 34 | 12 | 15.11 | 0 (1) | 2 (3) |
| BRSC-F37 | Round CMP | 1.5 | 1.5 | 1 (2) | 3 | 0.5 (3) | 4 | 10 | 28 | 4.44 | 0 (1) | 1 (3) |
| LLC-M46 | Round CMP | 1.5 | 1.5 | 3 (3) | 4 | 0.4 (3) | 4 | 8 | 35 | 4.74 | 0 (1) | 2 (3) |
| ULC-M48 | Round CMP | 3 | 3.0 | 5 (3) | 4.5 | 0.7 (2) | 2 | 8 | 26 | 2.67 | 12 (3) | 2 (3) |
| HC-M49 | Squash CMP | 3.0 X 4.5 | 3.0 | 1 (2) | 4 | 1.1 (1) | 2.5 | 7 | 40 | 2.59 | 0 (1) | (2) |
| ULC-M56 | Round CMP | 2 | 2.0 | 27 (3) | 3 | 0.7 (2) | 5 | 9 | 32 | 5.00 | N/A | 1 (3) |
| WFBC-M58 | Round CMP | 2.5 | 2.5 | 10 (3) | 5 | 0.5 (3) | 3.5 | 7 | 32 | 4.54 | 4 (2) | 2 (3) |
| LCGC-M59 | Round CMP | 1.5 | 1.5 | 3 (3) | 3 | 0.5 (3) | 5 | 8 | 42 | 4.44 | 0 (1) | 2 (3) |
| SFLC-M65 | Round CMP | 3 | 3.0 | 2 (3) | 6 | 0.5 (3) | 3 | 8 | 30 | 5.33 | 1 (2) | 2 (3) |
| SFLC-M67 | Round CMP | 2.5 | 2.5 | 3 (3) | 2 | 1.3 (1) | 3 | 10 | 35 | 2.22 | 1 (2) | 1 (3) |
| WFBC-M68 | Round CMP | 2.5 | 2.5 | 2 (3) | 7 | 0.4 (3) | 3.5 | 10 | 60 | 9.07 | 32 (3) | 3 (3) |
| LCGC-M77 | Culvert CMP | 1.5 | 1.5 | 2 (3) | 4 | 0.4 (3) | 1 | 6 | 16 | 0.89 | 7 (3) | 3 (3) |
| LCGC-M79 | Round CMP | 3 | 3.0 | 3 (3) | 10 | 0.3 (3) | 9.75 | 15 | 50 | 54.17 | 10 (3) | 3 (3) |
| LBFBR-M86 | Steel CMP/DS- concrete | 1.5 | 1.5 | 3 (3) | 5 | 0.3 (3) | 7 | 10 | 60 | 12.96 | 0 (1) | 2 (3) |
| BC-M87 | Steel CMP | 3 | 3.0 | 17 (3) | 6 | 0.5 (3) | 2.5 | 22 | 28 | 12.22 | 15 (3) | 3 (3) |
| MC-F88 | Steel CMP | 2 | 2.0 | 2 (3) | 3 | 0.7 (2) | 1 | 6 | 19 | 0.67 | 0 (1) | 1 (3) |
| MC-F89 | Steel CMP | 2 | 2.0 | 4 (3) | 8 | 0.3 (3) | 3.5 | 12 | 38 | 12.44 | 10 (3) | 3 (3) |
| MC-F89a | Steel CMP | 1 | 1.0 | 4 (3) | 3 | 0.3 (3) | 3.5 | 6 | 38 | 2.33 | 0 (1) | 2 (3) |
| BRBC-F90 | Squash CMP | 2 X 1.5 | 2.0 | 2 (3) | 5 | 0.4 (3) | 2.5 | 9 | 32 | 4.17 | 0 (1) | 2 (3) |
| BRLiC-F94 | Steel CMP | 1.5 | 1.5 | 2 (3) | 12 | 0.1 (3) | 2.5 | 23 | 35 | 25.56 | 0 (1) | 2 (3) |
| WC-M97 | Steel CMP | 2 | 2.0 | 7 (3) | 7 | 0.3 (3) | 4.5 | 18 | 31 | 21.00 | 0 (1) | 2 (3) |
| BRBC-F102 | Steel CMP | 2 | 2.0 | 1 (2) | 15 | 0.1 (3) | 5 | 21 | 15 | 58.33 | 0 (1) | 1 (3) |
| BRW-F105 | Steel CMP | 3 | 3.0 | 2 (3) | 14 | 0.2 (3) | 8 | 21 | 32 | 87.11 | 0 (1) | 2 (3) |
| BRCC-V114 | Steel CMP | 1.5 | 1.5 | 2 (3) | 5 | 0.3 (3) | 2 | 8 | 34 | 2.96 | 0 (1) | 2 (3) |
| LRC-M115 | Plastic CMP | 3 | 3.0 | 15 (3) | 10 | 0.3 (3) | 8 | 17 | 36 | 50.37 | 0 (1) | 2 (3) |
| URC-M116 | Round CMP | 1.5 | 1.5 | 2 (3) | 5 | 0.3 (3) | 4.5 | 10 | 25 | 8.33 | 0 (1) | 2 (3) |
| URC-M123 | Plastic CMP | 3 | 3.0 | 3 (3) | 4 | 0.8 (2) | 3 | 10 | 39 | 4.44 | 0 (1) | 1 (3) |
| LRC-M128 | Round CMP | 1.5 | 1.5 | 2 (3) | 6 | 0.3 (3) | 2.5 | 7 | 25 | 3.89 | Blocked (3) | 3 (3) |
| BRCC-V137 | Round CMP | 1.5 | 1.5 | 1 (2) | 2.5 | 0.6 (2) | 1 | 2 | 20 | 0.19 | 0 (1) | (2) |
| BRCC-M141 | Round CMP | 1.5 | 1.5 | 10 (3) | 3 | 0.5 (3) | 10 | 10 | 24 | 11.11 | 0 (1) | 2 (3) |
| LRC-F143 | Squash CMP | 2 x 3 | 3.0 | 1 (2) | 4 | 0.8 (2) | 1 | 6 | 30 | 0.89 | 0 (1) | (2) |
| BRD-F145 | Round CMP | 3 | 3.0 | 1 (2) | 6 | 0.5 (3) | 2 | 6 | 18 | 2.67 | 0 (1) | 1 (3) |
| LRC-M146 | Plastic CMP | 3 | 2.8 | 4 (3) | 3.5 | 0.8 (1) | 4.5 | 6 | 30 | 3.50 | 6 (3) | 2 (3) |
| USC-M158 | Round CMP | 3 | 3.0 | 5 (3) | 3 | 1.0 (1) | 3 | 5 | 32 | 1.67 | - | 1 (3) |

**Table G3-5B. Fish Passage Analysis for Selected Road Crossings Using Alaska Region Criteria**

| Location ID | Structure Type | Culvert Dimensions (ft) | Width (ft) | Culvert slope (%) | Bankfull width (ft) | Culvert/BF ratio | Fill Height (ft) | Fill Width (ft) | Fill Length (ft) | Fill Volume (CY) | Outlet Perch (inches) | Final Classification (# of failures) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DIVC-M159 | Squash CMP | 4-W, 4.33-H | 4.0 | 5 [3] | 10 | 0.4 [3] | 2 | 10 | 30 | 7.41 | 4 [2] | 2 [3] |
| BRW-F168 | Squash CMP | 2.5W, 3.5H | 2.5 | | 3 | 0.8 [1] | - | - | - | | 18 [3] | 1 [3] |
| WC-M170 | Round CMP | 3 | 3.0 | 10 [3] | 5 | 0.6 [2] | 10 | 6 | 30 | 11.11 | - | 1 [3] |
| WC-M171 | Round CMP | 4H, 3W | 3.0 | 10 [3] | 6 | 0.5 [3] | - | - | - | | 12 [3] | 3 [3] |
| BRNWC-M174 | Round CMP | 2 | 2.0 | 6 [3] | 5 | 0.4 [3] | 1 | 8 | 15 | 1.48 | 1.5 [2] | 2 [3] |
| BRLiC-F186 | Round CMP | 1 | 1.0 | 3 [3] | 16 | 0.8 [2] | 13 | 39 | 70 | 300.44 | 0 [1] | 1 [3] |
| BRLiC-F187 | Round CMP | 2 | 2.0 | 2 [3] | 20 | 0.1 [3] | 5.5 | 18 | 33 | 73.33 | 0 [1] | 2 [3] |
| BRW-F188 | Plastic CMP | 2 | 2.0 | 1 [2] | 18 | 1.3 [1] | 1 | 22 | 80 | 14.67 | 3 [2] | [2] |
| McC-F189 | Round CMP | 1.5 | 1.5 | 2 [3] | 5 | 0.3 [3] | 1.5 | 10 | 29 | 2.78 | 0 [1] | 2 [3] |
| McC-F190 | 2-Squashed CMPs | 2.5 x 3.0 | 3.0 | 2 [3] | 12 | 0.3 [3] | 1 | 21 | 34 | 9.33 | 4.5 [3] | 3 [3] |
| LLC-M191 | Round CMP | 3 | 3.0 | 6 [3] | 11 | 0.3 [3] | 7 | 14 | 35 | 39.93 | 0 [1] | 2 [3] |
| BC-F192 | Concrete | 2 | 2.0 | 1 [2] | 8 | 0.3 [3] | 3 | 11 | 20 | 9.78 | 0 [1] | 1 [3] |
| **For Sites with >48" span - Assumed Most Conservative Case Using >1X3 Spiral Configurations** | | | | | | | | | | | | |
| EMC-V15 | Round CMP | 5 | 5.0 | 0 [1] | 6 | 0.8 [1] | 6 | 58 | 10 | 77.33 | 0 [1] | [1] |
| EMC-M18 | Squash CMP | W-5.0, H-2.5 | 5.0 | 10 [3] | 8.5 | 0.6 [2] | 9.5 | 381 | 12 | 1139.47 | 0 [1] | 1 [3] |
| MC-M35 | Round CMP | 7 | 7.0 | 8 [3] | 9 | 0.8 [1] | 10 | 20 | 35 | 66.67 | 18 [3] | 2 [3] |
| WFBC-M64 | Squash CMP | 4.0H x 6.7W | 6.7 | 3 [3] | 10 | 0.7 [2] | 4.5 | 20 | 71 | 33.33 | 0 [1] | 1 [3] |
| LBFBR-M85 | Steel CMP 3- Culverts | Squashed 7 X 4.5 | 7.0 | 2 [2] | 38 | 0.2 [3] | 0.75 | 40 | 24 | 42.22 | 0 [1] | 1 [3] |
| URC-M125 | Squash CMP | 6 x 9 | 9.0 | 2 [2] | 13 | 0.7 [2] | 11 | 37 | 46 | 195.96 | 0 [1] | [2] |
| LRC-M127 | Round CMP | 5 | 5.0 | 0 [1] | 7 | 0.7 [2] | 4 | 16 | 25 | 16.59 | - | [2] |
| BRD-F160 | Concrete Flume | 5 | 5.0 | 2 [2] | 3 | 1.7 [1] | - | - | - | | - | [2] |
| SC-F194 | Round CMP | 7 X 22 | 22.0 | 1 [2] | 40 | 0.2 [3] | Concrete | | | | | 1 [3] |

[1] High certainty of meeting juvenile fish passage at all flows, [2] Additional and more detailed analysis is required to determine juvenile fish passage ability, [3] High certainty of not providing juvenile fish passage at all desired stream flows
CMP = Corrugated Metal Pipe

**Table G4-2. Estimated Sediment Load from Unpaved Road Crossings – Reduce Length to 200-feet**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load (t/y) |
| Ambrose Creek | 0.00 | 0.11 | 0.84 | 0.00 | 0.00 | 0.00 | 0.60 | 0.89 | 0.08 | 0.00 | 0.00 | 0.00 | 2.52 |
| Bass Creek | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.54 |
| Bear Creek | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 |
| Big Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| Bitterroot River-Birch Creek | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.47 | 3.47 | 0.17 | 0.00 | 0.05 | 0.00 | 4.41 |
| Bitterroot River-Canyon Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.88 |
| Bitterroot River-Chaffin Creek | 0.00 | 0.05 | 1.34 | 0.00 | 0.00 | 0.00 | 0.13 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 |
| Bitterroot River-Darby | 0.00 | 0.00 | 2.30 | 0.00 | 0.00 | 0.00 | 0.47 | 2.63 | 0.04 | 0.00 | 0.00 | 0.00 | 5.44 |
| Bitterroot River-Hayes Creek | 0.00 | 0.05 | 2.76 | 0.00 | 0.00 | 0.42 | 0.17 | 1.31 | 1.25 | 0.00 | 0.00 | 0.42 | 6.38 |
| Bitterroot River-Larry Creek | 0.03 | 0.16 | 0.42 | 0.00 | 0.00 | 0.00 | 1.18 | 3.78 | 0.00 | 0.00 | 0.00 | 0.00 | 5.57 |
| Bitterroot River-Lick Creek | 0.00 | 0.16 | 0.75 | 0.00 | 0.00 | 0.00 | 0.40 | 1.89 | 0.17 | 0.00 | 0.00 | 0.00 | 3.37 |
| Bitterroot River-North Woodchuck Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 2.21 | 0.75 | 0.17 | 0.05 | 0.13 | 3.87 |
| Bitterroot River-Spooner Creek | 0.00 | 0.05 | 0.79 | 0.00 | 0.00 | 0.00 | 0.50 | 1.47 | 0.08 | 0.00 | 0.00 | 0.00 | 2.90 |
| Bitterroot River-Woodside | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.50 | 2.52 | 0.25 | 0.00 | 0.00 | 0.00 | 3.36 |
| Blodgett Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Burnt Fork Bitterroot River-Stevensville | 0.10 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 1.31 | 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 1.94 |
| Daly Creek | 0.00 | 0.00 | 1.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.25 |

**Table G4-2. Estimated Sediment Load from Unpaved Road Crossings – Reduce Length to 200-feet**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load (t/y) |
| Divide Creek | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 |
| Eightmile Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.17 | 0.17 | 0.74 | 0.29 | 0.00 | 0.00 | 0.00 | 3.37 |
| Fred Burr Creek | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.17 | 0.00 | 0.00 | 0.00 | 0.68 |
| Gird Creek | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 |
| Howard Creek | 0.00 | 0.00 | 1.96 | 0.00 | 0.00 | 2.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.22 |
| Kootenai Creek | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 |
| Lick Creek | 0.00 | 0.00 | 1.05 | 0.00 | 0.00 | 0.00 | 0.03 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13 |
| Little Sleeping Child Creek | 0.00 | 0.00 | 0.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 1.13 |
| Lolo Creek-Grave Creek | 0.00 | 0.00 | 2.68 | 0.00 | 0.00 | 4.64 | 0.03 | 0.00 | 0.67 | 0.00 | 0.00 | 0.08 | 8.10 |
| Lost Horse Creek | 0.00 | 0.00 | 0.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.54 |
| Lower Bear Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 |
| Lower Burnt Fork Bitterroot River | 0.00 | 0.00 | 1.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.29 | 0.00 | 0.00 | 0.04 | 1.75 |
| Lower Lolo Creek | 0.00 | 0.00 | 3.80 | 0.00 | 0.00 | 6.14 | 0.67 | 0.11 | 1.46 | 0.00 | 0.00 | 0.00 | 12.19 |
| Lower Rye Creek | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 0.07 | 0.32 | 1.76 | 0.00 | 0.00 | 0.00 | 2.56 |
| Lower Skalkaho Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 |
| Lower Sleeping Child Creek | 0.00 | 0.00 | 1.63 | 0.00 | 0.00 | 0.00 | 0.03 | 0.16 | 0.04 | 0.00 | 0.00 | 0.00 | 1.86 |
| McCalla Creek | 0.00 | 0.00 | 1.42 | 0.00 | 0.00 | 0.00 | 0.13 | 0.89 | 0.04 | 0.00 | 0.00 | 0.00 | 2.49 |
| McClain Creek | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.10 | 0.79 | 0.42 | 0.00 | 0.00 | 0.00 | 1.98 |
| Middle Skalkaho Creek | 0.00 | 0.00 | 1.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13 |
| Middle Sleeping Child Creek | 0.00 | 0.00 | 1.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 |
| Mill Creek | 0.00 | 0.00 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 2.52 | 0.13 | 0.00 | 0.00 | 0.00 | 2.94 |
| Miller Creek | 0.00 | 0.00 | 1.84 | 0.00 | 0.00 | 1.63 | 0.17 | 0.05 | 0.96 | 0.00 | 0.00 | 0.25 | 4.90 |
| Muddy Spring Creek | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| North Fork Rye Creek | 0.00 | 0.00 | 2.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.08 | 2.72 |
| O'Brien Creek | 0.00 | 0.00 | 2.68 | 0.00 | 0.00 | 0.08 | 0.07 | 0.11 | 1.21 | 0.00 | 0.00 | 0.00 | 4.14 |
| Roaring Lion Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 |
| Rock Creek | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.10 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 |
| Sawtooth Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.17 | 0.00 | 0.00 | 0.00 | 1.11 |
| South Fork Lolo Creek | 0.00 | 0.00 | 0.75 | 0.00 | 0.00 | 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.21 |
| South Lost Horse Creek | 0.00 | 0.05 | 1.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.08 | 0.00 | 0.00 | 0.00 | 1.34 |
| Swan Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 1.16 | 0.04 | 0.00 | 0.00 | 0.00 | 1.43 |
| Sweathouse Creek | 0.00 | 0.00 | 1.25 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 0.00 | 0.00 | 0.00 | 0.00 | 2.30 |
| Sweeney Creek | 0.00 | 0.00 | 0.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 |
| Threemile Creek | 0.00 | 0.00 | 1.05 | 0.00 | 0.05 | 0.08 | 0.50 | 2.47 | 0.08 | 0.00 | 0.00 | 0.21 | 4.45 |
| Tin Cup Creek | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.03 | 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 1.27 |
| Upper Burnt Fork Bitterroot River | 0.00 | 0.00 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.79 |
| Upper Lolo Creek | 0.00 | 0.00 | 2.26 | 0.00 | 0.00 | 1.50 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 3.80 |
| Upper Rye Creek | 0.00 | 0.00 | 6.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 6.31 |
| Upper Skalkaho Creek | 0.00 | 0.00 | 1.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.92 |
| Upper Sleeping Child Creek | 0.00 | 0.00 | 2.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.13 |
| West Fork Butte Creek | 0.00 | 0.00 | 1.67 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.09 |
| Willoughby Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 1.26 | 0.21 | 0.00 | 0.21 | 0.00 | 1.75 |
| Willow Creek | 0.00 | 0.00 | 1.59 | 0.00 | 0.00 | 0.00 | 0.17 | 1.00 | 0.13 | 0.00 | 0.05 | 0.00 | 2.93 |
| **Total** | **0.13** | **0.63** | **60.82** | **0.00** | **0.05** | **19.81** | **9.61** | **38.90** | **11.70** | **0.17** | **0.37** | **1.21** | **143.41** |

**Table G4-3. Estimated Sediment Load from Unpaved Parallel Road Segments – Reduce Length to 500-feet**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Valley | Foothill | Mountain | Load |
| Ambrose Creek | 0.00 | 0.08 | 0.83 | 0.00 | 0.00 | 0.00 | 0.24 | 0.14 | 0.11 | 0.00 | 0.00 | 0.00 | 1.40 |
| Bass Creek | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 |
| Bear Creek | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Big Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bitterroot River-Birch Creek | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.25 | 0.67 | 0.24 | 0.00 | 0.01 | 0.00 | 1.33 |
| Bitterroot River-Canyon Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 |
| Bitterroot River-Chaffin Creek | 0.00 | 0.01 | 1.11 | 0.00 | 0.00 | 0.00 | 0.10 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.30 |
| Bitterroot River-Darby | 0.00 | 0.00 | 1.65 | 0.00 | 0.00 | 0.00 | 0.21 | 0.56 | 0.15 | 0.00 | 0.00 | 0.00 | 2.57 |
| Bitterroot River-Hayes Creek | 0.00 | 0.00 | 2.85 | 0.00 | 0.00 | 0.33 | 0.08 | 0.20 | 1.22 | 0.00 | 0.00 | 0.46 | 5.14 |
| Bitterroot River-Larry Creek | 0.06 | 0.02 | 0.21 | 0.00 | 0.00 | 0.00 | 0.53 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44 |
| Bitterroot River-Lick Creek | 0.00 | 0.03 | 0.39 | 0.00 | 0.00 | 0.00 | 0.15 | 0.28 | 0.10 | 0.00 | 0.00 | 0.00 | 0.95 |
| Bitterroot River-North Woodchuck Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.28 | 0.50 | 1.46 | 0.06 | 0.01 | 0.16 | 2.49 |
| Bitterroot River-Spooner Creek | 0.00 | 0.01 | 0.38 | 0.00 | 0.00 | 0.00 | 0.21 | 0.19 | 0.04 | 0.00 | 0.00 | 0.00 | 0.82 |
| Bitterroot River-Woodside | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.19 | 0.48 | 0.12 | 0.00 | 0.00 | 0.00 | 0.82 |
| Blodgett Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Burnt Fork Bitterroot River-Stevensville | 0.04 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.79 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 |
| Daly Creek | 0.00 | 0.00 | 0.89 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 |
| Divide Creek | 0.00 | 0.00 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 |
| Eightmile Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.08 | 0.07 | 0.26 | 0.26 | 0.00 | 0.00 | 0.00 | 3.68 |
| Fred Burr Creek | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.10 | 0.00 | 0.00 | 0.00 | 0.19 |
| Gird Creek | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 |
| Howard Creek | 0.00 | 0.00 | 2.21 | 0.00 | 0.00 | 3.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.61 |
| Kootenai Creek | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 |
| Lick Creek | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.84 |
| Little Sleeping Child Creek | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.52 | 0.00 | 0.00 | 0.00 | 0.98 |
| Lolo Creek-Grave Creek | 0.00 | 0.00 | 3.58 | 0.00 | 0.00 | 5.59 | 0.05 | 0.00 | 0.60 | 0.00 | 0.00 | 0.07 | 9.88 |
| Lost Horse Creek | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 |
| Lower Bear Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| Lower Burnt Fork Bitterroot River | 0.00 | 0.00 | 0.98 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.80 | 0.00 | 0.00 | 0.12 | 1.94 |
| Lower Lolo Creek | 0.00 | 0.00 | 2.66 | 0.00 | 0.00 | 6.05 | 0.27 | 0.01 | 2.13 | 0.00 | 0.00 | 0.00 | 11.12 |
| Lower Rye Creek | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.00 | 0.03 | 0.07 | 3.29 | 0.00 | 0.00 | 0.00 | 3.64 |
| Lower Skalkaho Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 |
| Lower Sleeping Child Creek | 0.00 | 0.00 | 1.48 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 1.58 |
| McCalla Creek | 0.00 | 0.00 | 0.76 | 0.00 | 0.00 | 0.00 | 0.05 | 0.13 | 0.08 | 0.00 | 0.00 | 0.00 | 1.03 |
| McClain Creek | 0.00 | 0.00 | 0.59 | 0.00 | 0.00 | 0.00 | 0.07 | 0.12 | 0.25 | 0.00 | 0.00 | 0.00 | 1.03 |
| Middle Skalkaho Creek | 0.00 | 0.00 | 1.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.07 |
| Middle Sleeping Child Creek | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| Mill Creek | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.10 | 0.00 | 0.00 | 0.00 | 0.64 |
| Miller Creek | 0.00 | 0.00 | 2.19 | 0.00 | 0.00 | 1.28 | 0.07 | 0.01 | 1.31 | 0.00 | 0.00 | 0.20 | 5.06 |
| Muddy Spring Creek | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| North Fork Rye Creek | 0.00 | 0.00 | 2.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 | 0.00 | 0.00 | 0.07 | 2.37 |
| O'Brien Creek | 0.00 | 0.00 | 2.83 | 0.00 | 0.00 | 0.04 | 0.06 | 0.03 | 1.33 | 0.00 | 0.00 | 0.00 | 4.28 |
| Roaring Lion Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Rock Creek | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| Sawtooth Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.12 | 0.00 | 0.00 | 0.00 | 0.23 |

**Table G4-3. Estimated Sediment Load from Unpaved Parallel Road Segments – Reduce Length to 500-feet**

| Ownership | Federal Land | | | Plum Creek Timber | | | Private | | | State | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Watershed** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Valley** | **Foothill** | **Mountain** | **Load** |
| South Fork Lolo Creek | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.81 |
| South Lost Horse Creek | 0.00 | 0.01 | 1.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.04 | 0.00 | 0.00 | 0.00 | 1.20 |
| Swan Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.14 | 0.02 | 0.00 | 0.00 | 0.00 | 0.24 |
| Sweathouse Creek | 0.00 | 0.00 | 0.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 |
| Sweeney Creek | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 |
| Threemile Creek | 0.00 | 0.00 | 1.03 | 0.00 | 0.04 | 0.20 | 0.26 | 0.40 | 0.14 | 0.00 | 0.00 | 0.53 | 2.59 |
| Tin Cup Creek | 0.00 | 0.00 | 0.46 | 0.00 | 0.00 | 0.00 | 0.01 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 |
| Upper Burnt Fork Bitterroot River | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 |
| Upper Lolo Creek | 0.00 | 0.00 | 2.19 | 0.00 | 0.00 | 1.42 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 3.63 |
| Upper Rye Creek | 0.00 | 0.00 | 6.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 6.16 |
| Upper Skalkaho Creek | 0.00 | 0.00 | 1.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.27 |
| Upper Sleeping Child Creek | 0.00 | 0.00 | 1.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.52 |
| West Fork Butte Creek | 0.00 | 0.00 | 1.03 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.35 |
| Willoughby Creek | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.44 | 0.43 | 0.00 | 0.03 | 0.00 | 0.93 |
| Willow Creek | 0.00 | 0.00 | 1.63 | 0.00 | 0.00 | 0.00 | 0.06 | 0.20 | 0.21 | 0.00 | 0.00 | 0.00 | 2.10 |
| **Total** | **0.10** | **0.15** | **51.76** | **0.00** | **0.04** | **22.04** | **4.50** | **6.94** | **15.69** | **0.06** | **0.05** | **1.60** | **102.93** |

**Table G4-4. Total Sediment Load Reductions from Unpaved Road Network: 200-feet Crossing BMP and 500-feet Parallel BMP**

| Watershed | Total Sediment Load From Unpaved Roads Existing Conditions (tons/year) | Total Sediment Load After 200-ft Crossing and 500 ft Parallel Road Length BMPs (tons/year) | Percent Reduction in Load After 200-ft Crossing and 500 ft Parallel Road Length BMPs (tons/year) |
|---|---|---|---|
| Ambrose Creek | 11.26 | 3.92 | 65.14% |
| Bass Creek | 2.25 | 0.72 | 68.13% |
| Bear Creek | 2.11 | 0.68 | 67.77% |
| Big Creek | 0.23 | 0.06 | 74.68% |
| Bitterroot River-Birch Creek | 19.32 | 5.73 | 70.33% |
| Bitterroot River-Canyon Creek | 3.27 | 1.10 | 66.38% |
| Bitterroot River-Chaffin Creek | 9.44 | 3.29 | 65.12% |
| Bitterroot River-Darby | 24.39 | 8.00 | 67.19% |
| Bitterroot River-Hayes Creek | 32.62 | 11.52 | 64.69% |
| Bitterroot River-Larry Creek | 22.87 | 7.01 | 69.36% |
| Bitterroot River-Lick Creek | 14.01 | 4.32 | 69.18% |
| Bitterroot River-North Woodchuck Creek | 23.70 | 6.37 | 73.13% |
| Bitterroot River-Spooner Creek | 11.71 | 3.73 | 68.17% |
| Bitterroot River-Woodside | 13.98 | 4.18 | 70.09% |
| Blodgett Creek | 0.92 | 0.24 | 74.18% |
| Burnt Fork Bitterroot River-Stevensville | 7.24 | 3.02 | 58.34% |
| Daly Creek | 5.83 | 2.14 | 63.28% |
| Divide Creek | 2.77 | 1.01 | 63.65% |
| Eightmile Creek | 19.41 | 7.05 | 63.68% |
| Fred Burr Creek | 2.98 | 0.87 | 70.77% |
| Gird Creek | 4.19 | 1.42 | 66.09% |
| Howard Creek | 26.23 | 9.83 | 62.51% |
| Kootenai Creek | 1.60 | 0.47 | 70.54% |
| Lick Creek | 5.39 | 1.97 | 63.43% |
| Little Sleeping Child Creek | 5.71 | 2.11 | 63.03% |
| Lolo Creek-Grave Creek | 48.06 | 17.98 | 62.58% |
| Lost Horse Creek | 2.63 | 0.97 | 63.16% |
| Lower Bear Creek | 1.82 | 0.47 | 74.38% |
| Lower Burnt Fork Bitterroot River | 10.04 | 3.69 | 63.29% |
| Lower Lolo Creek | 62.46 | 23.30 | 62.69% |
| Lower Rye Creek | 16.76 | 6.20 | 63.04% |

**Table G4-4. Total Sediment Load Reductions from Unpaved Road Network: 200-feet Crossing BMP and 500-feet Parallel BMP**

| Watershed | Total Sediment Load From Unpaved Roads Existing Conditions (tons/year) | Total Sediment Load After 200-ft Crossing and 500 ft Parallel Road Length BMPs (tons/year) | Percent Reduction in Load After 200-ft Crossing and 500 ft Parallel Road Length BMPs (tons/year) |
|---|---|---|---|
| Lower Skalkaho Creek | 3.06 | 1.03 | 66.30% |
| Lower Sleeping Child Creek | 9.49 | 3.44 | 63.73% |
| McCalla Creek | 10.62 | 3.52 | 66.88% |
| McClain Creek | 9.06 | 3.01 | 66.79% |
| Middle Skalkaho Creek | 5.93 | 2.20 | 62.93% |
| Middle Sleeping Child Creek | 5.51 | 2.04 | 62.92% |
| Mill Creek | 12.92 | 3.57 | 72.35% |
| Miller Creek | 26.71 | 9.96 | 62.70% |
| Muddy Spring Creek | 0.16 | 0.06 | 63.97% |
| North Fork Rye Creek | 13.75 | 5.09 | 63.03% |
| O'Brien Creek | 22.70 | 8.43 | 62.87% |
| Roaring Lion Creek | 1.14 | 0.30 | 74.13% |
| Rock Creek | 1.02 | 0.38 | 63.03% |
| Sawtooth Creek | 4.88 | 1.34 | 72.46% |
| South Fork Lolo Creek | 5.52 | 2.02 | 63.34% |
| South Lost Horse Creek | 7.11 | 2.54 | 64.30% |
| Swan Creek | 5.86 | 1.68 | 71.40% |
| Sweathouse Creek | 10.00 | 3.17 | 68.33% |
| Sweeney Creek | 3.69 | 1.21 | 67.26% |
| Threemile Creek | 21.58 | 7.04 | 67.40% |
| Tin Cup Creek | 5.29 | 1.80 | 66.00% |
| Upper Burnt Fork Bitterroot River | 3.50 | 1.28 | 63.45% |
| Upper Lolo Creek | 20.06 | 7.44 | 62.92% |
| Upper Rye Creek | 33.61 | 12.47 | 62.89% |
| Upper Skalkaho Creek | 8.71 | 3.19 | 63.36% |
| Upper Sleeping Child Creek | 9.93 | 3.65 | 63.27% |
| West Fork Butte Creek | 9.38 | 3.44 | 63.39% |
| Willoughby Creek | 8.64 | 2.68 | 69.01% |
| Willow Creek | 14.68 | 5.03 | 65.71% |
| **Total** | **709.72** | **246.35** | **65.29%** |

# ATTACHMENT A - WEPP:ROAD MODELING RESULTS FOR FIELD ASSESSED ROAD CROSSINGS

**Table A-1. WEPP:Road Modeling Results From Field Assessed Crossings – Valley Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Valley Crossings** | | | | | | | | | | | | | | | | | |
| EMC-V15 | Stevensville | Sandy loam | 50 | Insloped, bare ditch | graveled high | 3 | 828 | 24 | 84 | 2 | 0.3 | 1 | 80 | 0.2 | 0 | 301 | 306 |
| BFBRS-V27 | Stevensville | Sandy loam | 50 | Insloped, bare ditch | graveled high | 0.5 | 35 | 20 | 25 | 8 | 0.3 | 1 | 5 | 0.1 | 0 | 9 | 5 |
| BFBRS-V28 | Stevensville | Silty Loam | 50 | Outsloped, rutted | graveled high | 0.5 | 264 | 20 | 58 | 7 | 0.3 | 1 | 2 | 0.3 | 0 | 84 | 90 |
| BRSC-V31 | Stevensville | Silty Loam | 50 | Insloped, vegetated or rocked ditch | graveled low | 5 | 330 | 20.5 | 100 | 5.5 | 0.3 | 1 | 10 | 0.4 | 0 | 131 | 117 |
| BFBRS-V32 | Stevensville | Silty Loam | 50 | Insloped, bare ditch | graveled high | 1.5 | 64 | 10 | 70 | 11 | 0.3 | 1 | 25 | 0.2 | 0 | 18 | 13 |
| BRCC-V113 | Stevensville | Silty Loam | 50 | Insloped, bare ditch | graveled high | 0.5 | 419 | 24 | 120 | 8 | 0.3 | 1 | 10 | 0.3 | 0 | 227 | 202 |
| BRCC-V114 | Stevensville | Silty Loam | 50 | Insloped, vegetated or rocked ditch | graveled high | 1 | 700 | 34 | 27 | 6 | 0.3 | 1 | 10 | 0.3 | 0 | 234 | 246 |
| BRCC-V137 | Stevensville | Silty Loam | 50 | Insloped, bare ditch | graveled high | 2 | 120 | 18 | 20 | 1 | 0.3 | 1 | 5 | 0.4 | 0 | 55 | 42 |
| LRC-V142 | Stevensville | Silty Loam | 50 | Insloped, bare ditch | graveled high | 7 | 322 | 22 | 10 | 1 | 0.3 | 1 | 15 | 0.5 | 0 | 611 | 551 |
| BRD-V144 | Stevensville | Sandy loam | 50 | Insloped, bare ditch | graveled high | 2 | 700 | 13 | 87 | 4 | 0.3 | 1 | 40 | 0.2 | 0 | 101 | 116 |
| BRLC-V195 | Stevensville | Sandy loam | 50 | Outsloped, rutted | graveled low | 0.3 | 10 | 10 | 28 | 15 | 0.3 | 1 | 60 | 0 | 0 | 0 | 0 |
| **Valley Results** | | | | | | | **326** | | | | | | | | | **Mean (t/yr)** | **0.07** |
| | | | | | | | | | | | | | | **25th** | **0.006** | **Median** | **0.05** |
| | | | | | | | | | | | | | | **75th** | **0.11** | **Maximum** | **0.28** |
| | | | | | | | | | | | | | | | | **Minimum** | **0.00** |

**Table A-2. WEPP:Road Modeling Results From Field Assessed Crossings – Mountain Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mountain Crossings** | | | | | | | | | | | | | | | | | |
| BRHC-M1 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 1.5 | 384 | 16 | 40 | 2 | 0.3 | 1 | 25 | 1.6 | 3.1 | 101 | 80 |
| BRHC-M1 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 8 | 137 | 16 | 40 | 2 | 0.3 | 1 | 25 | | | | |
| BRHC-M2 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 7 | 490 | 18 | 120 | 4 | 0.3 | 1 | 60 | 0.1 | 0 | 341 | 313 |
| BRHC-M3 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 5 | 520 | 13 | 100 | 8 | 0.3 | 1 | 50 | 1.8 | 2.7 | 3675 | 2730 |
| BRHC-M4 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 3 | 250 | 14 | 100 | 10 | 0.3 | 1 | 30 | 0.7 | 1.1 | 245 | 186 |
| BRHC-M7 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 6 | 626 | 22 | 100 | 35 | 0.3 | 1 | 75 | 0.1 | 0 | 200 | 184 |
| MC-M8 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 0.5 | 40 | 10 | 70 | 5 | 0.3 | 1 | 50 | 0.1 | 0 | 1 | 1 |
| MC-M9 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | graveled high | 2 | 470 | 12 | 45 | 4 | 0.3 | 1 | 50 | 0.2 | 0 | 76 | 72 |
| MC-M9 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 2 | 470 | 12 | 45 | 4 | 0.3 | 1 | 50 | | | | |
| BRNWC-M11 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 6 | 463 | 10 | 84 | 38 | 0.3 | 1 | 25 | 0.5 | 0.6 | 428 | 353 |
| BRNWC-M12 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 5 | 575 | 17.5 | 50 | 7 | 0.3 | 1 | 15 | 0.3 | 0 | 596 | 545 |
| EMC-M16 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 5 | 483 | 11 | 58 | 5 | 5 | 20 | 40 | 0.3 | 0.6 | 432 | 203 |
| EMC-M17 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native low | 4 | 200 | 12 | 120 | 12 | 0.3 | 1 | 90 | 1.1 | 1.5 | 324 | 200 |
| EMC-M18 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 7 | 630 | 12 | 47 | 4 | 0.3 | 30 | 80 | 0 | 0 | 83 | 19 |
| TMC-M20 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 0.5 | 130 | 10 | 45 | 3 | 0.3 | 1 | 5 | 0.5 | 0.8 | 9 | 6 |
| AC-M24 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 2 | 175 | 15 | 65 | 17 | 0.3 | 1 | 25 | 0.4 | 0.4 | 89 | 72 |
| AC-M25 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native high | 8 | 116 | 19 | 62 | 8 | 0.3 | 1 | 20 | 0.5 | 0.5 | 126 | 83 |
| LLC-M29 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 3 | 79 | 14 | 58 | 10 | 0.3 | 1 | 10 | 0.1 | 0 | 10 | 1 |

**Table A-2. WEPP:Road Modeling Results From Field Assessed Crossings – Mountain Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mountain Crossings** | | | | | | | | | | | | | | | | | |
| LLC-M30 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 6 | 138 | 14.5 | 90 | 18 | 0.3 | 1 | 20 | 0.1 | 0 | 37 | 12 |
| LLC-M30 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 2 | 120 | 14.5 | 90 | 18 | 0.3 | 1 | 20 | | | | |
| MC-M33 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 9 | 60 | 16 | 70 | 13 | 0.3 | 1 | 10 | 0.2 | 0 | 14 | 11 |
| MC-M33 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 2.5 | 78 | 16 | 70 | 13 | 0.3 | 1 | 10 | | | | |
| MC-M34 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 8 | 234 | 13 | 120 | 20 | 0.3 | 1 | 35 | 0.2 | 0.1 | 91 | 80 |
| MC-M35 | Lolo Hot Springs | Sandy Loam | 30 | Insloped, bare ditch | native low | 4 | 357 | 19 | 120 | 19 | 0.3 | 1 | 40 | 0.2 | 0.1 | 219 | 194 |
| BRSC-M36 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native low | 7 | 166 | 17 | 100 | 20 | 0.3 | 1 | 25 | 0.1 | 0 | 16 | 14 |
| BC-M39 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 7 | 300 | 22 | 150 | 10 | 0.3 | 1 | 25 | 0.1 | 0 | 111 | 74 |
| BRSC-M40 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 8.5 | 400 | 19 | 82 | 9 | 0.3 | 1 | 25 | 0.8 | 1.5 | 950 | 714 |
| BC-M41 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native none | 1.5 | 16 | 17 | 70 | 10 | 0.3 | 1 | 25 | 0 | 0 | 3 | 0 |
| LLC-M44 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 8 | 435 | 16 | 70 | 25 | 0.3 | 1 | 60 | 2.1 | 3 | 6223 | 4,846 |
| LLC-M44 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 5 | 435 | 16 | 46 | 25 | 0.3 | 1 | 40 | | | | |
| LLC-M45 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 5 | 540 | 14 | 90 | 35 | 0.3 | 1 | 40 | 0.8 | 1.2 | 2553 | 2068 |
| LLC-M46 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 3 | 117 | 9 | 82 | 15 | 0.3 | 1 | 35 | 0.2 | 0.2 | 22 | 19 |
| LLC-M46 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 1 | 130 | 9 | 82 | 15 | 0.3 | 1 | 35 | | | | |
| LLC-M47 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native low | 1 | 112 | 14.5 | 58 | 28 | 0.3 | 1 | 70 | 0.1 | 0 | 11 | 6 |
| ULC-M48 | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 8 | 97 | 13 | 100 | 10 | 0.3 | 1 | 30 | 0.4 | 0 | 52 | 44 |
| ULC-M48 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | graveled high | 8 | 50 | 13 | 100 | 10 | 0.3 | 1 | 30 | | | | |
| HC-M49 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 1 | 67 | 20 | 51 | 9 | 0.3 | 1 | 35 | 0.1 | 0 | 14 | 5 |
| ULC-M56 | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | native high | 9 | 154 | 16 | 70 | 12 | 0.3 | 1 | 25 | 0.2 | 0.1 | 59 | 56 |
| ULC-M57 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native none | 4 | 40 | 24 | 83 | 30 | 0.3 | 1 | 40 | 0.1 | 0 | 6 | 2 |
| WFBC-M58 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 3 | 188 | 20 | 81 | 12 | 0.3 | 1 | 10 | 0.3 | 0.7 | 35 | 19 |
| LCGC-M59 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 9 | 314 | 16 | 53 | 12 | 0.3 | 1 | 20 | 0.7 | 1.4 | 337 | 212 |
| LCGC-M59 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 7 | 45 | 16 | 53 | 12 | 0.3 | 1 | 20 | | | | |
| WFBC-M64 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native none | 5 | 469 | 27.5 | 70 | 22 | 0.3 | 1 | 20 | 0.38 | 0.04 | 993.96 | 793 |
| WFBC-M64_2 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 10 | 540 | 12 | 70 | 22 | 0.3 | 1 | 20 | | | | |
| SFLC-M65 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 0.3 | 48 | 10 | 100 | 15 | 0.3 | 1 | 45 | 0 | 0.1 | 0 | 0 |
| WFBC-M66 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 1 | 30 | 12 | 0.3 | 1 | 0.3 | 1 | 0 | 0.1 | 0.2 | 3 | 1 |
| SFLC-M67 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native high | 3 | 240 | 12 | 120 | 11 | 0.3 | 1 | 25 | 0.7 | 0.9 | 579 | 211 |
| SFLC-M67 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native high | 6 | 780 | 12 | 120 | 11 | 0.3 | 1 | 25 | | | | |
| WFBC-M68 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 6 | 654 | 22 | 79 | 20 | 0.3 | 1 | 20 | 0.3 | 0 | 368 | 340 |
| WFBC-M73 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 7 | 394 | 12 | 100 | 11 | 0.3 | 1 | 50 | 1.6 | 2.7 | 434 | 323 |
| SFLC-M74 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 4 | 153 | 24 | 80 | 24 | 0.3 | 1 | 60 | 0.2 | 0.1 | 39 | 39 |
| LCGC-M75 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native none | 4 | 462 | 19 | 83 | 20 | 0.3 | 1 | 85 | 0.1 | 0.1 | 102 | 15 |
| LCGC-M76 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 2 | 84 | 14 | 83 | 13 | 0.3 | 40 | 25 | 0.2 | 0.1 | 101 | 22 |
| LCGC-M76 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 10 | 45 | 15 | 83 | 13 | 0.3 | 1 | 25 | | | | |
| LCGC-M77 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 3 | 76 | 7 | 70 | 7 | 0.3 | 1 | 40 | 0.5 | 0.6 | 9 | 6 |
| NFHC-M78 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 7 | 58 | 12 | 70 | 28 | 0.3 | 1 | 60 | 0.3 | 0.1 | 31 | 20 |
| LCGC-M79 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 1 | 184 | 11 | 47 | 20 | 0.3 | 1 | 75 | 1.4 | 1.3 | 128 | 92 |
| LCGC-M79 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native low | 2 | 103 | 11.5 | 70 | 22 | 0.3 | 1 | 60 | | | | |

**Table A-2. WEPP:Road Modeling Results From Field Assessed Crossings – Mountain Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mountain Crossings** | | | | | | | | | | | | | | | | | |
| LBFBR-M80 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 1 | 58 | 12 | 58 | 13 | 0.3 | 1 | 40 | 0.3 | 0.2 | 9 | 6 |
| LBFBR-M84 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 0.3 | 3 | 17 | 31 | 12 | 0.3 | 1 | 70 | 0 | 0 | 0 | 0 |
| LBFBR-M85 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 1 | 47 | 16 | 70 | 7 | 0.3 | 1 | 60 | 0.1 | 0 | 2 | 2 |
| LBFBR-M86 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 3 | 264 | 13 | 70 | 13 | 0.3 | 1 | 25 | 1.4 | 1.4 | 177 | 136 |
| LBFBR-M86 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 1 | 243 | 18 | 0.3 | 1 | 0.3 | 1 | 25 | | | | |
| LBFBR-M86 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | graveled low | 9 | 118 | 9 | 0.3 | 1 | 0.3 | 1 | 25 | | | | |
| LBFBR-M86 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 8 | 130 | 8.5 | 0.3 | 1 | 0.3 | 1 | 25 | | | | |
| BC-M87 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 9 | 140 | 14 | 70 | 17 | 0.3 | 1 | 75 | 0.1 | 0 | 18 | 18 |
| BRLiC-M91 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native high | 2 | 52 | 14 | 80 | 19 | 0.3 | 1 | 35 | 0.1 | 0 | 23 | 4 |
| BRLiC-M92 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 5 | 180 | 10 | 70 | 12 | 0.3 | 1 | 25 | 0.4 | 0.8 | 35 | 21 |
| BRD-M93 | Lolo Hot Springs | Loam | 30 | Outsloped, rutted | native low | 3 | 175 | 15 | 100 | 14 | 0.3 | 1 | 10 | 0.5 | 0.5 | 82 | 58 |
| BRW-M96 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 8 | 491 | 24 | 80 | 8 | 0.3 | 1 | 20 | 0.3 | 0.1 | 741 | 668 |
| WC-M97 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native high | 3.5 | 182 | 18 | 120 | 8 | 0.3 | 1 | 80 | 0.6 | 0.2 | 225 | 76 |
| WC-M97_2 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native high | 4 | 170 | 18 | 120 | 8 | 0.3 | 1 | 80 | | | | |
| LRC-M106 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 3 | 258 | 15 | 60 | 12 | 0.3 | 1 | 10 | 0.5 | 0.7 | 82 | 64 |
| MSCC-M111 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 6 | 108 | 14 | 80 | 13 | 0.3 | 1 | 40 | 0.8 | 1.2 | 33 | 14 |
| MSCC-M111 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 4 | 90 | 14 | 80 | 13 | 0.3 | 1 | 40 | | | | |
| LSCC-M112 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 6 | 195 | 19 | 120 | 11 | 0.3 | 1 | 35 | 0.2 | 0.1 | 49 | 27 |
| LRC-M115 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 6 | 198 | 25 | 100 | 18 | 0.3 | 1 | 65 | 0.1 | 0 | 91 | 87 |
| URC-M116 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 1 | 266 | 9 | 55 | 12 | 0.3 | 1 | 20 | 0.5 | 1 | 20 | 11 |
| URC-M123 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 8.5 | 203 | 25 | 85 | 8 | 0.3 | 1 | 30 | 2.3 | 3.7 | 3367 | 2402 |
| URC-M123 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native high | 8.5 | 185 | 25 | 85 | 8 | 0.3 | 1 | 30 | | | | |
| URC-M123 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 8.5 | 252 | 25 | 85 | 8 | 0.3 | 1 | 30 | | | | |
| URC-M124 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native high | 9 | 283 | 17 | 80 | 7 | 0.3 | 1 | 10 | 0.7 | 1.1 | 571 | 450 |
| URC-M125 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native high | 1 | 88 | 25 | 83 | 23 | 0.3 | 1 | 10 | 0 | 0 | 62 | 11 |
| LRC-M126 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 4 | 160 | 18 | 95 | 19 | 0.3 | 1 | 50 | 0.5 | 0.2 | 237 | 201 |
| LRC-M126 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 7 | 808 | 18 | 95 | 19 | 0.3 | 1 | 50 | | | | |
| LRC-M127 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 5 | 183 | 10 | 60 | 13 | 0.3 | 1 | 45 | 0.7 | 1.4 | 42 | 24 |
| LRC-M128 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native low | 3.5 | 247 | 15 | 75 | 7 | 0.3 | 1 | 10 | 0.6 | 1 | 83 | 60 |
| USCC-M129 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native low | 3 | 160 | 17.5 | 55 | 6 | 0.3 | 1 | 10 | 0.5 | 0.7 | 40 | 27 |
| BRCC-M138 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native low | 2 | 255 | 14 | 84 | 8 | 0.3 | 1 | 5 | 0 | 0 | 10 | 4 |
| BRCC-M139 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 8 | 510 | 16 | 100 | 10 | 0.3 | 1 | 25 | 0.2 | 0.1 | 222 | 202 |
| BRD-M140 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native none | 6 | 50 | 10 | 0.3 | 1 | 0.3 | 1 | 30 | 0.4 | 0.9 | 7 | 2 |
| BRCC-M141 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 3 | 383 | 16 | 120 | 20 | 0.3 | 1 | 10 | 0.1 | 0.1 | 61 | 54 |
| LRC-M146 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | graveled low | 8 | 105 | 22 | 70 | 8 | 0.3 | 1 | 10 | 0.1 | 0 | 27 | 16 |
| BRD-M147 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 3 | 160 | 10 | 36 | 2 | 0.3 | 1 | 5 | 0.1 | 0.1 | 5 | 4 |

**Table A-2. WEPP:Road Modeling Results From Field Assessed Crossings – Mountain Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mountain Crossings** | | | | | | | | | | | | | | | | | |
| LSCC-M148 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 5 | 216 | 14 | 46 | 3 | 0.3 | 1 | 10 | 0.1 | 0.1 | 19 | 17 |
| MSC-M149 | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native low | 5 | 90 | 14 | 84 | 15 | 0.3 | 1 | 5 | 0.8 | 1.1 | 168 | 127 |
| MSC-M149 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 5 | 275 | 14 | 84 | 7 | 0.3 | 1 | 5 | | | | |
| MSC-M150 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 6 | 200 | 10 | 60 | 20 | 0.3 | 1 | 25 | 0.5 | 0.5 | 74 | 59 |
| DC-M151 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 5 | 700 | 16 | 65 | 3 | 0.3 | 1 | 10 | 0.8 | 1.6 | 834 | 715 |
| USC-M152 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 4 | 180 | 15 | 82 | 5 | 0.3 | 1 | 20 | 0.6 | 1.1 | 58 | 43 |
| USC-M158 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 6 | 540 | 16 | 58 | 10 | 0.3 | 1 | 5 | 0.7 | 1.2 | 656 | 527 |
| DIVC-M159 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 3 | 330 | 16 | 84 | 7.5 | 0.3 | 1 | 10 | 0.3 | 0 | 53 | 46 |
| WC-M170 | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | native low | 6 | 250 | 19 | 75 | 14 | 0.3 | 1 | 25 | 0.2 | 0.1 | 61 | 62 |
| WC-M171 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled low | 7.5 | 405 | 14 | 70 | 35 | 0.3 | 1 | 15 | 0.2 | 0 | 141 | 146 |
| LLC-M172 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 1.5 | 121 | 16 | 80 | 24 | 0.3 | 1 | 30 | 0.4 | 0.4 | 59 | 36 |
| LLC-M172 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 1.5 | 107 | 16 | 80 | 24 | 0.3 | 1 | 30 | | | | |
| LLC-M173 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 3 | 166 | 18 | 82 | 18 | 0.3 | 1 | 55 | 0.2 | 0.1 | 26 | 17 |
| BRNWC-M174 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 10 | 150 | 9.5 | 40 | 3 | 0.3 | 1 | 20 | 0.7 | 1.3 | 62 | 42 |
| TCC-M181 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 2 | 178 | 13 | 76 | 17 | 0.3 | 1 | 20 | 0.4 | 0.4 | 53 | 38 |
| BRD-M182 (US) | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native low | 1 | 57 | 21 | 82 | 26 | 0.3 | 1 | 20 | 0.9 | 1.7 | 79 | 46 |
| BRD-M182 (DS) | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native low | 6 | 238 | 21.5 | 0.3 | 1 | 0.3 | 1 | 25 | | | | |
| LLC-M191 | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | native none | 5 | 190 | 14 | 95 | 14 | 0.3 | 1 | 45 | 0.1 | 0.1 | 32 | 4 |
| **Mountain Results** | | | | | | | **240.57** | | | | | | | | | **Mean (t/yr)** | **0.12** |
| | | | | | | | | | | | | | | **25th** | **0.007** | **Median** | **0.02** |
| | | | | | | | | | | | | | | **75th** | **0.09** | **Maximum** | **2.42** |
| | | | | | | | | | | | | | | | | **Minimum** | **0.00** |

**Table A-3. WEPP:Road Modeling Results From Field Assessed Crossings – Foothill Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Foothill Crossings** | | | | | | | | | | | | | | | | | |
| BRNWC-F14 | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | native low | 7 | 415 | 12 | 58 | 4 | 0.3 | 1 | 35 | 2.5 | 0.8 | 300 | 253 |
| BRNWC-F14 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 7 | 175 | 10 | 58 | 4 | 0.3 | 1 | 35 | | | | |
| TMC-F19 | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 1 | 454 | 16 | 119 | 4 | 0.3 | 1 | 10 | 0.1 | 0 | 104 | 25 |
| TMC-F22 | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 8 | 1000 | 12 | 100 | 4 | 1 | 5 | 10 | 0 | 0 | 331 | 18 |
| TMC-F22 (2) | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 8 | 50 | 12 | 100 | 4 | 1 | 5 | 10 | | | | |
| BRLC-F23 (1) | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 1 | 284 | 21 | 84 | 6 | 0.3 | 1 | 20 | 0.2 | 0 | 189 | 60 |
| BRLC-F23 (2) | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 2 | 370 | 21 | 84 | 6 | 0.3 | 1 | 20 | | | | |
| TMC-F26 | Darby | Sandy Loam | 50 | Outsloped, rutted | graveled high | 1 | 483 | 20 | 84 | 11 | 0.3 | 1 | 5 | 0.2 | 0 | 42 | 72 |
| BRSC-F37 | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 4 | 312 | 20.5 | 70 | 10.5 | 0.3 | 1 | 20 | 0.5 | 0 | 365 | 304 |
| BRSC-F37 | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 0.5 | 156 | 20.5 | 70 | 10.5 | 0.3 | 1 | 20 | | | | |
| BRSC-F38 | Darby | Silty Loam | 50 | Outsloped, unrutted | graveled high | 7 | 935 | 13 | 150 | 7 | 0.3 | 1 | 35 | 0.1 | 0 | 353 | 136 |
| BRBC-F42 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 7 | 330 | 10 | 58 | 13 | 0.3 | 1 | 25 | 1.4 | 0.3 | 236 | 197 |
| BRBC-F42 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 1 | 150 | 10 | 58 | 13 | 0.3 | 1 | 25 | | | | |
| BRBC-F43 | Darby | Sandy Loam | 50 | Insloped, bare ditch | graveled high | 0.5 | 240 | 24 | 25 | 14 | 0.3 | 1 | 50 | 0.1 | 0 | 20 | 23 |

**Table A-3. WEPP:Road Modeling Results From Field Assessed Crossings – Foothill Crossings**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MC-F88 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 11 | 259 | 12 | 70 | 4.5 | 0.3 | 1 | 30 | 1.9 | 0.5 | 298 | 238 |
| MC-F88 | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | native low | 4 | 119 | 12 | 70 | 4.5 | 0.3 | 1 | 30 | | | | |
| MC-F89 | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 3 | 125 | 14 | 47 | 14 | 0.3 | 1 | 20 | 0.7 | 0.2 | 375 | 258 |
| MC-F89 | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | native high | 2 | 551 | 14 | 47 | 14 | 0.3 | 1 | 20 | | | | |
| MC-F89A | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | native high | 7 | 836 | 14 | 70 | 8 | 0.3 | 1 | 20 | 1.1 | 0.3 | 2368 | 2162 |
| BRBC-F90 | Darby | Silty Loam | 50 | Outsloped, rutted | graveled high | 2 | 512 | 24 | 58 | 8 | 0.3 | 1 | 20 | 0.3 | 0 | 196 | 199 |
| BRLiC-F94 | Darby | Silty Loam | 50 | Outsloped, unrutted | graveled high | 3 | 410 | 26 | 100 | 5 | 0.3 | 1 | 20 | 0.1 | 0 | 297 | 101 |
| BRLiC-F95 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 7 | 320 | 15 | 90 | 15 | 0.3 | 1 | 45 | 2.2 | 0.6 | 719 | 582 |
| BRLiC-F95 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 5 | 115 | 15 | 90 | 15 | 0.3 | 1 | 45 | | | | |
| BRBC-F102 (1) | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 3 | 175 | 21 | 70 | 12 | 0.3 | 1 | 35 | 0.2 | 0 | 236 | 117 |
| BRBC-F102 (2) | Darby | Sandy Loam | 50 | Outsloped, unrutted | graveled high | 6 | 500 | 21 | 70 | 12 | 0.3 | 1 | 35 | | | | |
| BRBC-F103 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 4 | 79 | 31 | 90 | 17 | 0.3 | 1 | 60 | 2.7 | 0.8 | 4196 | 3,578 |
| BRBC-F103 | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 7 | 581 | 31 | 90 | 17 | 0.3 | 1 | 60 | | | | |
| BRBC-F103 Driveway | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 12 | 570 | 11 | 0.3 | 1 | 0.3 | 1 | 0 | 1.2 | 0.3 | 783 | 657 |
| WC-F104 | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 4.5 | 107 | 13 | 70 | 23 | 0.3 | 1 | 40 | 0.1 | 0 | 64 | 12 |
| BRW-F105 | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | graveled high | 1.5 | 176 | 24 | 79 | 14 | 0.3 | 1 | 20 | 0.2 | 0 | 88 | 65 |
| BRCC-F136 | Darby | Sandy Loam | 50 | Outsloped, rutted | native low | 5 | 207 | 12 | 56 | 8 | 0.3 | 1 | 10 | 0.1 | 0 | 19 | 16 |
| LRC-F143 | Darby | Sandy Loam | 50 | Insloped, bare ditch | graveled high | 1 | 100 | 29 | 150 | 1 | 0.3 | 1 | 20 | 0.3 | 0 | 25 | 22 |
| BRD-F145 | Darby | Sandy Loam | 50 | Outsloped, unrutted | native low | 5 | 153 | 12 | 56 | 3 | 0.3 | 1 | 10 | 0 | 0 | 7 | 3 |
| BRD-F160 | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 5 | 60 | 42 | 56 | 30 | 0.3 | 1 | 25 | 0.1 | 0 | 82 | 48 |
| BRLC-F162 | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 1 | 110 | 24 | 150 | 1 | 0.3 | 1 | 5 | 0.3 | 0 | 48 | 33 |
| BRW-F168 | Darby | Silty Loam | 50 | Outsloped, unrutted | graveled high | 4 | 1000 | 29 | 140 | 100 | 0.3 | 1 | 5 | 0 | 0 | 950 | 502 |
| WC-F169 | Darby | Silty Loam | 50 | Outsloped, unrutted | graveled high | 6 | 400 | 16 | 75 | 6 | 0.3 | 1 | 15 | 0.1 | 0 | 224 | 68 |
| BRLiC-F186 (DS) | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | native high | 5 | 900 | 24 | 0.3 | 1 | 0.3 | 1 | 20 | | | | |
| BRLiC-F186 (US) | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 4 | 175 | 23.5 | 75 | 19 | 0.3 | 1 | 20 | 1.2 | 0.3 | 2,235 | 1,810 |
| BRLiC-F187 | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 8 | 315 | 24 | 100 | 12 | 0.3 | 1 | 20 | 0.2 | 0 | 530 | 194 |
| BRW-F188 | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 5 | 450 | 21.5 | 15 | 19 | 0.3 | 1 | 40 | 0.3 | 0 | 438 | 383 |
| BRW-F188 | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 3 | 210 | 21.5 | 15 | 19 | 0.3 | 1 | 40 | | | | |
| McC-F189 | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | graveled high | 7 | 660 | 34 | 85 | 7 | 0.3 | 1 | 25 | 0.4 | 0 | 1439 | 1334 |
| McC-F190 | Darby | Silty Loam | 50 | Insloped, vegetated or rocked ditch | graveled high | 3 | 450 | 29 | 120 | 4 | 0.3 | 1 | 30 | 0.3 | 0 | 216 | 189 |
| BC-F192 | Darby | Sandy Loam | 50 | Insloped, bare ditch | graveled high | 4 | 437 | 30 | 150 | 4 | 0.3 | 1 | 15 | 0.3 | 0 | 520 | 473 |
| BRLC-F193 | Darby | Sandy Loam | 50 | Insloped, vegetated or rocked ditch | graveled high | 6 | 970 | 26 | 110 | 5 | 0.3 | 1 | 15 | 0.3 | 0 | 1048 | 989 |
| SC-F194 | Darby | Sandy Loam | 50 | Insloped, bare ditch | graveled high | 2 | 212 | 25 | 50 | 14 | 0.3 | 1 | 45 | 0.2 | 0 | 42 | 59 |
| | | | | | | | | | | | | | | | | **Mean (t/yr)** | **0.22** |
| **Foothill Results** | | | | | | | **369.1** | | | | | | | **25th** | **0.030** | **Median** | **0.09** |
| | | | | | | | | | | | | | | **75th** | **0.24** | **Maximum** | **1.79** |
| | | | | | | | | | | | | | | | | **Minimum** | **0.00** |

**Table A-4. WEPP:Road Modeling Results From Field Assessed Crossings – Total Crossing Data**

| Total Crossing Data | Road length (ft) | | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|
| | 283.36 | | | | **Mean (t/yr)** | **0.14** |
| | | | **25th** | **0.007** | **Median** | **0.03** |
| | | | **75th** | **0.10** | **Maximum** | **2.42** |
| | | | | | **Minimum** | **0.00** |

**Table A-5. WEPP: Road Modeling Results From Field Assessed Parallel Segments – Foothill Parallel**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Foothill Parallel** | | | | | | | | | | | | | | | | | |
| BRNWC-F13P | Darby | Silty Loam | 50 | Outsloped, rutted | graveled high | 6 | 1000 | 14.5 | 0.3 | 1 | 0.3 | 45 | 25 | 0 | 0 | 1688 | 46 |
| BRBC-F131P | Darby | Silty Loam | 50 | Outsloped, unrutted | native low | 9 | 1000 | 16.5 | 100 | 10 | 5 | 20 | 45 | 0 | 0 | 410 | 0 |
| BRBC-F132P | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 5 | 1000 | 20 | 95 | 19 | 0.3 | 1 | 25 | 1.6 | 0.4 | 1696 | 737 |
| BRBC-F133P | Darby | Silty Loam | 50 | Outsloped, unrutted | native low | 8 | 1000 | 18 | 100 | 12 | 0.3 | 1 | 70 | 0.8 | 0.2 | 406 | 163 |
| BRBC-F134P | Darby | Silty Loam | 50 | Outsloped, unrutted | native low | 5 | 1000 | 18 | 0.3 | 1 | 8 | 25 | 45 | 0 | 0 | 250 | 0 |
| BRBC-F135P | Darby | Silty Loam | 50 | Insloped, bare ditch | native low | 5 | 1000 | 25 | 0.3 | 1 | 6 | 450 | 45 | 0 | 0 | 2580 | 0 |
| BRLC-F161P | Darby | Silty Loam | 50 | Insloped, bare ditch | graveled high | 2 | 750 | 27 | 65 | 6 | 27 | 75 | 5 | 0 | 0 | 806 | 170 |
| BRNWC-F176P | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 6 | 528 | 12 | 90 | 30 | 6 | 60 | 20 | 0 | 0 | 797 | 60 |
| BRNWC-F177P | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 4 | 528 | 13 | 1 | 120 | 6 | 50 | 20 | 0 | 0 | 209 | 10 |
| BRNWC-F178P | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 4 | 528 | 13 | 1 | 120 | 75 | 35 | 20 | 0 | 0 | 211 | 33 |
| BRNWC-F179P | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 4 | 528 | 13 | 1 | 60 | 75 | 40 | 20 | 0 | 0 | 229 | 62 |
| BRNWC-F180P | Darby | Silty Loam | 50 | Outsloped, rutted | native low | 3 | 528 | 12 | 2 | 21 | 17 | 180 | 20 | 0 | 0 | 152 | 1 |
| BRD-F183P | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 9 | 1000 | 19 | 85 | 9 | 0.5 | 2 | 25 | 0.2 | 0 | 2328 | 260 |
| BRD-F184P | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 9 | 1000 | 21 | 58 | 18 | 0.3 | 1 | 25 | 0.4 | 0 | 2580 | 386 |
| BRD-F185P | Darby | Silty Loam | 50 | Outsloped, unrutted | native high | 9 | 1000 | 24 | 110 | 12 | 1 | 10 | 25 | 0 | 0 | 3394 | 58 |
| Foothill Results | | | | | | | | | | | Mean | 66.33 | | | | **Mean (t/yr)** | **0.07** |
| | | | | | | | | | | | Median | 35 | | **25th** | **0.003** | **Median** | **0.03** |
| | | | | | | | | | | | | | | **75th** | **0.08** | **Maximum** | **0.37** |
| | | | | | | | | | | | | | | | | **Minimum** | **0.00** |

**Table A-6. WEPP: Road Modeling Results From Field Assessed Parallel Segments – Mountain Parallel**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mountain Parallel** | | | | | | | | | | | | | | | | | |
| BRHC-M4P | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 2 | 290 | 7 | 75 | 75 | 10 | 10 | 30 | 0.1 | 0.1 | 270 | 119 |
| BRHC-M4P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 2 | 290 | 7 | 75 | 75 | 10 | 10 | 30 | 0.1 | 0.1 | 136 | 86 |
| BRHC-M5P | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 5 | 998 | 23 | 44 | 3 | 15 | 5 | 20 | 0.7 | 1.6 | 13978 | 10995 |
| OC-M6P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 4 | 196 | 10 | 34 | 4 | 20 | 30 | 30 | 0.1 | 0 | 39 | 12 |
| EMC-M16P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 5 | 240 | 11 | 84 | 10 | 10 | 10 | 40 | 0.3 | 0.5 | 164 | 86 |
| TMC-M21P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 7 | 400 | 10 | 84 | 12 | 10 | 11 | 10 | 0.1 | 0 | 349 | 182 |
| END M21P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | graveled high | 7 | 400 | 10 | 58 | 3 | 8 | 10 | 10 | 0.1 | 0 | 339 | 188 |
| AC-M25P | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 8 | 240 | 16 | 58 | 22 | 2 | 6.5 | 30 | 0.3 | 0.3 | 1220 | 272 |
| AC-M25 Pt END | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 8 | 368 | 16 | 84 | 21 | 1 | 10 | 30 | 0.3 | 0.4 | 3225 | 518 |
| ULC-M48P | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, rutted | graveled high | 10 | 291 | 18 | 80 | 11 | 2 | 3 | 70 | 0.2 | 0 | 316 | 261 |
| HC-M51P | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 2 | 1000 | 15 | 120 | 21 | 1 | 10 | 60 | 0 | 0 | 292 | 0 |
| HC-M52P | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 6 | 1000 | 15 | 120 | 30 | 1 | 12 | 60 | 0 | 0 | 428 | 6 |
| HC-M53P | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 5 | 1000 | 18 | 150 | 10 | 0.5 | 70 | 0 | 0 | 0 | 180 | 0 |
| HC-M54P | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 5 | 1000 | 20 | 150 | 12 | 0.3 | 50 | 60 | 0 | 0 | 514 | 0 |
| HC-M55P | Lolo Hot Springs | Sandy Loam | 30 | Outsloped, unrutted | native high | 6 | 1000 | 24 | 46 | 16 | 1 | 35 | 35 | 0 | 0 | 446 | 0 |
| LCGC-M61P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 8 | 500 | 13 | 45 | 30 | 0.3 | 1 | 30 | 0.5 | 1.2 | 154 | 104 |
| LCGC-M62P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 9 | 500 | 12 | 70 | 10 | 1 | 50 | 30 | 0.1 | 0.1 | 199 | 26 |
| LCGC-M63P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native none | 8 | 500 | 12 | 65 | 20 | 0.3 | 1 | 30 | 0.7 | 1.5 | 142 | 84 |
| WFBC-M70Pt- 1 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 9 | 1000 | 35 | 90 | 40 | 0.3 | 1 | 40 | 0.4 | 0 | 4552 | 2,142 |
| WFBC-M71Pt- 2 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 10 | 1000 | 35 | 100 | 83 | 0.3 | 70 | 40 | 0 | 0 | 6222 | 310 |
| WFBC-M72Pt- 3 | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 11 | 1000 | 36 | 100 | 54 | 1 | 750 | 50 | 0 | 0 | 4470 | 0 |
| LBFBR-M81P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 2.5 | 1000 | 13 | 0.3 | 1 | 1 | 21 | 0 | 0.4 | 0.8 | 598 | 86 |
| LBFBR-M82P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 2 | 1000 | 12 | 46 | 27 | 0.3 | 28 | 80 | 0.8 | 1.4 | 1358 | 87 |
| LBFBR-M83P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 1.5 | 1000 | 11 | 30 | 28 | 0.3 | 200 | 60 | 0 | 0 | 300 | 0 |
| WC-M98P | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | native high | 9 | 1000 | 15 | 82 | 9 | 7 | 10 | 80 | 2.6 | 4.4 | 85406 | 13,792 |
| WC-M99P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native high | 9 | 1000 | 28 | 150 | 18 | 0.3 | 1 | 15 | 1.6 | 3 | 29650 | 12,381 |
| WC-M100P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native high | 9 | 1000 | 28 | 0.3 | 1 | 1 | 150 | 20 | 0 | 0 | 72462 | 84 |
| WC-M101P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | native high | 8 | 1000 | 14 | 8 | 44 | 1 | 10 | 20 | 0.6 | 1.2 | 9460 | 1,792 |
| LRC-M107P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | graveled high | 8.5 | 1000 | 25 | 82 | 43 | 0.5 | 8 | 25 | 0.2 | 0 | 3900 | 1,296 |
| LRC-M108P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | graveled high | 13 | 1000 | 20 | 60 | 27 | 6 | 80 | 40 | 0 | 0 | 1494 | 0 |
| LRC-M109P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | graveled high | 10 | 1000 | 20 | 150 | 19 | 0.3 | 1 | 30 | 0.2 | 0 | 1346 | 415 |
| LRC-M110P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | graveled high | 10 | 1000 | 30 | 80 | 10 | 6 | 120 | 50 | 0 | 0 | 1366 | 0 |
| URC-M118P | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | native high | 5 | 1000 | 19 | 100 | 13 | 1 | 12 | 50 | 0.8 | 0.4 | 2620 | 330 |
| URC-M119P | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | native high | 4 | 1000 | 20 | 100 | 11 | 1 | 38 | 25 | 0 | 0 | 736 | 33 |

**Table A-6. WEPP: Road Modeling Results From Field Assessed Parallel Segments – Mountain Parallel**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mountain Parallel** | | | | | | | | | | | | | | | | | |
| URC-M120P | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | native low | 5 | 1000 | 17 | 110 | 16 | 1 | 6 | 55 | 1.2 | 0.8 | 1440 | 234 |
| URC-M121P | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | native low | 3 | 1000 | 18.5 | 120 | 12 | 1 | 115 | 55 | 0 | 0 | 980 | 3 |
| URC-M122P | Lolo Hot Springs | Sandy Loam | 30 | Insloped, vegetated or rocked ditch | native high | 4 | 1000 | 17 | 120 | 9 | 1 | 22 | 45 | 0.4 | 0.4 | 1228 | 99 |
| LLHC-M163P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 2 | 633 | 18 | 70 | 7 | 18 | 60 | 40 | 0.1 | 0.2 | 316 | 162 |
| ULHC-M164P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | native low | 0.3 | 1000 | 12 | 0.3 | 1 | 0.3 | 1 | 40 | 2.4 | 6.8 | 0 | 0 |
| ULHC-M165P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | graveled low | 0.3 | 500 | 16 | 90 | 20 | 0.3 | 1 | 40 | 0.1 | 0 | 33 | 20 |
| ULHC-M166P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | graveled low | 2 | 1000 | 14 | 75 | 4 | 7 | 45 | 20 | 0 | 0 | 106 | 0 |
| ULHC-M167P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, unrutted | graveled low | 3 | 450 | 16 | 60 | 7 | 45 | 16 | 40 | 0 | 0 | 33 | 9 |
| Mountain Results | | | | | | | | | | | Mean | 50.01 | | | | **Mean (t/yr)** | **0.55** |
| | | | | | | | | | | | Median | 11.5 | | **25th** | **0.002** | **Median** | **0.04** |
| | | | | | | | | | | | | | | **75th** | **0.13** | **Maximum** | **6.90** |
| | | | | | | | | | | | | | | | | **Minimum** | **0.00** |

**Table A-7. WEPP: Road Modeling Results From Field Assessed Parallel Segments – Mountain Parallel**

| Comment | Climate | Soil | Years | Design | Surface, traffic | Road grad (%) | Road length (ft) | Road width (ft) | Fill grad (%) | Fill length (ft) | Buff grad (%) | Buff length (ft) | Rock cont (%) | Average annual rain runoff (in) | Average annual snow runoff (in) | Average annual sediment leaving road (lb/yr) | Average annual sediment leaving buffer (lb/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Paved Segments** | | | | | | | | | | | | | | | | | |
| DC-M153P | Lolo Hot Springs | Silty Loam | 30 | Insloped, bare ditch | paved high | 2 | 1000 | 14.5 | 0.3 | 1 | 5 | 35 | 10 | 0.4 | 0.8 | 1182 | 217 |
| DC-M153P | Lolo Hot Springs | Silty Loam | 30 | Outsloped, rutted | paved high | 2 | 1000 | 14.5 | 0.3 | 1 | 5 | 35 | 10 | 0.4 | 0.8 | 0 | 0 |
| DC-M154P | Lolo Hot Springs | Silty Loam | 30 | Insloped, veg/rck ditch | paved high | 4 | 1000 | 25 | 100 | 7 | 0.3 | 1 | 20 | 3.6 | 6.4 | 2328 | 902 |
| DC-M155P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | paved high | 4 | 1000 | 26 | 142 | 12 | 9 | 15 | 20 | 1.2 | 2 | 6280 | 1,418 |
| DC-M156P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | paved high | 5 | 1000 | 23 | 150 | 9 | 5 | 3 | 20 | 6.4 | 11.6 | 15832 | 3,240 |
| DC-M157P | Lolo Hot Springs | Silty Loam | 30 | Insloped, vegetated or rocked ditch | paved high | 5 | 1000 | 24 | 150 | 20 | 5 | 5 | 20 | 1.8 | 2.8 | 9210 | 2,453 |

# ATTACHMENT B - WEPP:ROAD MODEL ADJUSTMENTS

**WEPP:Road Model Adjustments**

Heavily vegetated road conditions are not properly represented in the standard WEPP:Road assumption. As a result, William J. Elliott, author of the model, was consulted to determine how best to represent these roads within the confines of the model.

There are three traffic scenarios available in the model. For roads where vegetation has grown up on the edges, the no traffic scenario is most appropriate as this scenario grows a limited amount of vegetation on the road. It uses the same plant growth for the road that the high traffic used for the fillslope. The following table explains the model assumptions for the three traffic scenarios:

| Traffic | High | Low | None |
|---|---|---|---|
| Erodibility | 100% | 25% | 25% |
| Hydraulic Conductivity | 100% | 100% | 100% |
| Vegetation on Road Surface | 0 | 0 | 50% |
| Vegetation on fill | 50% | 50% | 100% Forested |
| Buffer | Forested | Forested | Forested |

Based on conversations with Dr. Elliott, it was not appropriate to use the forest buffer to describe the road as the hydraulic conductivity of the soil would be too high. However, the hydraulic conductivity of the fillslope would be reasonable to use to describe the road surface for a fully forested scenario. This means, for the fully vegetated/forested road surface scenario, minimize the road segment length, put the remainder of the road surface length and gradient into the fillslope box, and minimize the buffer length and gradient at stream crossings.

**Parallel Road Adjustments**

The WEPP:Road model has a maximum contributing road length of 1000-feet. According to Dr. Elliott, it is rare that the contributing road length ever exceeds this distance. As a result, any field assessed parallel road segment in excess of this distance was reduced to 1000-feet for modeling purposes.

**Road Crossing Model Adjustments**

Some road crossing locations had contributing road length on each side of the crossing, and road conditions were significantly different on each side. In these situations, each road segment was modeled separately and the two segments were then summed to get the total sediment load for the crossing. Also, some crossing locations were located at the convergence of two or more roads, with all roads contributing to sediment load at the crossing. In these cases, road segments were modeled separately and then summed to get the total sediment load for the crossing.

# ATTACHMENT C - FIELD ASSESSMENT SITE LOCATION DATA

| SITE ID | X | Y | Z |
|---|---|---|---|
| BRHC-M1 | -113.9284 | 46.8249 | 4067.0440 |
| BRHC-M2 | -113.9697 | 46.8286 | 3587.6109 |
| BRHC-M3 | -113.9737 | 46.8226 | 3926.1821 |
| BRHC-M4 | -113.9666 | 46.8139 | 4363.2244 |
| BRHC-M4P | -113.9666 | 46.8139 | 4363.2244 |
| BRHC-M5P | -113.9426 | 46.8212 | 3902.1949 |
| OC-M6P | -114.1697 | 46.8519 | 3572.7234 |
| BRHC-M7 | -114.1138 | 46.8331 | 3417.0020 |
| MC-M8 | -113.9391 | 46.7652 | 3899.7287 |
| MC-M9 | -113.9342 | 46.7364 | 4055.4354 |
| BRNWC-V10 | -114.0799 | 46.6898 | 3186.3648 |
| BRNWC-M11 | -114.1286 | 46.6972 | 4527.9715 |
| BRNWC-M12 | -114.1136 | 46.6996 | 3854.7910 |
| BRNWC-F13P | -114.0942 | 46.6971 | 3502.2369 |
| BRNWC-F14 | -114.0370 | 46.6982 | 3339.3114 |
| EMC-V15 | -113.9715 | 46.6465 | 3730.8809 |
| EMC-M16P | -113.8781 | 46.6581 | 4539.9977 |
| EMC-M16 | -113.8780 | 46.6586 | 4542.6677 |
| EMC-M17 | -113.8350 | 46.6399 | 5913.8228 |
| EMC-M18 | -113.8690 | 46.6451 | 4506.6116 |
| TMC-F19 | -113.9877 | 46.5881 | 3663.9019 |
| TMC-M20 | -113.8514 | 46.6018 | 5066.0863 |
| TMC-M21P | -113.8942 | 46.6192 | 4428.3041 |
| TMC-M21P End | -113.8942 | 46.6192 | 4428.3041 |
| TMC-F22 | -113.9201 | 46.6184 | 4102.2546 |
| BRLC-F23 | -114.0209 | 46.5808 | 3447.7218 |
| AC-M24 | -113.8487 | 46.5246 | 6078.3009 |
| AC-M25P | -113.8862 | 46.5380 | 4651.6834 |
| AC-M25 | -113.8840 | 46.5369 | 4668.5246 |
| AC-M25P-End | -113.8840 | 46.5369 | 4668.5246 |
| TMC-F26 | -113.9928 | 46.5423 | 3533.8914 |
| BFBRS-V27 | -114.0248 | 46.5060 | 3637.7349 |
| BFBRS-V28 | -114.0561 | 46.4983 | 3514.9354 |
| LLC-M29 | -114.2219 | 46.7434 | 3774.8563 |
| LLC-M30 | -114.2501 | 46.7611 | 3698.7917 |
| BRSC-V31 | -114.1285 | 46.4723 | 3327.3829 |
| BFBRS-V32 | -114.1169 | 46.5077 | 3284.1207 |
| MC-M33 | -114.1779 | 46.4929 | 4746.5450 |
| MC-M34 | -114.1850 | 46.4929 | 5278.5190 |
| MC-M35 | -114.1758 | 46.4836 | 4083.0705 |
| BRSC-M36 | -114.1846 | 46.4737 | 4541.0797 |
| BRSC-F37 | -114.1666 | 46.4478 | 3494.6637 |
| BRSC-F38 | -114.1821 | 46.4540 | 3788.6309 |
| BC-M39 | -114.2326 | 46.4388 | 5404.0912 |

| SITE ID | X | Y | Z |
|---|---|---|---|
| BRSC-M40 | -114.2174 | 46.4450 | 5542.9482 |
| BC-M41 | -114.2189 | 46.4386 | 4976.6057 |
| BRBC-F42 | -114.1557 | 46.4111 | 3441.6011 |
| BRBC-F43 | -114.1543 | 46.3887 | 3483.1795 |
| LLC-M44 | -114.1674 | 46.7213 | 5448.2877 |
| LLC-M45 | -114.1495 | 46.7228 | 5124.8898 |
| LLC-M46 | -114.1544 | 46.7334 | 3993.9928 |
| LLC-M47 | -114.1481 | 46.7351 | 4110.7198 |
| ULC-M48P | -114.5319 | 46.7367 | 4178.0463 |
| ULC-M48 | -114.5363 | 46.7401 | 4272.0820 |
| HC-M49 | -114.5209 | 46.7790 | 4437.0226 |
| HC-M51P | -114.4964 | 46.7840 | 4228.9278 |
| HC-M52P | -114.4924 | 46.7842 | 4212.7284 |
| HC-M53P | -114.4885 | 46.7837 | 4177.9498 |
| HC-M54P | -114.4845 | 46.7829 | 4124.1316 |
| HC-M55P | -114.4923 | 46.7841 | 4208.2241 |
| ULC-M56 | -114.4157 | 46.7407 | 5492.8448 |
| ULC-M57 | -114.4238 | 46.7331 | 5620.6992 |
| WFBC-M58 | -114.3359 | 46.7269 | 4564.4600 |
| LCGC-M59 | -114.4133 | 46.7868 | 3990.1414 |
| LCGC-M61P | -114.4118 | 46.7836 | 3910.1916 |
| LCGC-M62P | -114.4112 | 46.7824 | 3879.6060 |
| LCGC-M63P | -114.4109 | 46.7818 | 3836.4692 |
| WFBC-M64 | -114.3156 | 46.7469 | 3845.0158 |
| SFLC-M65 | -114.3616 | 46.6825 | 5852.9301 |
| WFBC-M66 | -114.3331 | 46.7191 | 5168.8150 |
| SFLC-M67 | -114.3217 | 46.7268 | 4769.9462 |
| WFBC-M68 | -114.4194 | 46.7237 | 5814.1752 |
| WFBC-M70P | -114.3255 | 46.7377 | 4277.7651 |
| WFBC-M71P | -114.3241 | 46.7417 | 4158.4173 |
| WFBC-M72P | -114.3242 | 46.7461 | 4017.0020 |
| WFBC-M73 | -114.3130 | 46.7431 | 4100.6998 |
| SFLC-M74 | -114.2866 | 46.7449 | 3903.2270 |
| LCGC-M75 | -114.3271 | 46.7807 | 4203.8990 |
| LCGC-M76 | -114.3140 | 46.7796 | 3820.7736 |
| LCGC-M77 | -114.4130 | 46.8230 | 4201.7763 |
| NFHC-M78 | -114.4536 | 46.8195 | 5077.6352 |
| LCGC-M79 | -114.3869 | 46.8285 | 4515.6099 |
| LBFBR-M80 | -113.9041 | 46.4030 | 4780.6542 |
| LBFBR-M81P | -113.9044 | 46.4055 | 4760.0971 |
| LBFBR-M82P | -113.9053 | 46.4124 | 4736.2356 |
| LBFBR-M83P | -113.9080 | 46.4192 | 4650.5577 |
| LBFBR-M84 | -113.9200 | 46.4357 | 4515.1319 |
| LBFBR-M85 | -113.9212 | 46.4479 | 4413.8018 |
| LBFBR-M86 | -114.0256 | 46.4434 | 3743.7352 |
| BC-M87 | -114.2715 | 46.3973 | 5951.7556 |
| MC-F88 | -114.2009 | 46.3535 | 3859.3238 |

| SITE ID | X | Y | Z |
|---|---|---|---|
| MC-F89 | -114.2308 | 46.3466 | 4127.2936 |
| MC-F89A | -114.2308 | 46.3466 | 4127.2936 |
| BRBC-F90 | -114.1546 | 46.3709 | 3484.5827 |
| BRLiC-M91 | -114.2457 | 46.1415 | 5361.9026 |
| BRLiC-M92 | -114.2589 | 46.0854 | 4688.7339 |
| BRD-M93 | -114.2438 | 46.0416 | 4806.0007 |
| BRLiC-F94 | -114.2016 | 46.1059 | 3881.4964 |
| BRLiC-F95 | -114.2125 | 46.1936 | 4097.8491 |
| BRW-M96 | -114.2328 | 46.2601 | 4403.4163 |
| WC-M97 | -113.9409 | 46.3150 | 6102.1880 |
| WC-M98P | -113.9230 | 46.2952 | 5434.5030 |
| WC-M99P | -113.9321 | 46.2936 | 5172.6339 |
| WC-M100P | -113.9354 | 46.2929 | 5106.8402 |
| WC-M101P | -113.9449 | 46.2921 | 4903.0482 |
| BRBC-F102 | -114.0488 | 46.3126 | 3758.2080 |
| BRBC-F103 | -114.0084 | 46.3265 | 4445.5253 |
| BRBC-F103 Driveway | -114.0084 | 46.3265 | 4445.5253 |
| WC-F104 | -114.0182 | 46.2765 | 4204.0676 |
| BRW-F105 | -114.0813 | 46.2147 | 3905.5791 |
| LRC-M106 | -113.9948 | 46.0607 | 6448.8540 |
| LRC-M107P | -114.0175 | 46.0488 | 5527.0942 |
| LRC-M108P | -114.0152 | 46.0447 | 5441.3763 |
| LRC-M109P | -114.0118 | 46.0413 | 5280.3205 |
| LRC-M110P | -114.0105 | 46.0375 | 5230.6693 |
| MSCC-M111 | -113.9884 | 46.1267 | 5887.3871 |
| LSCC-M112 | -114.0082 | 46.1269 | 5244.2205 |
| BRCC-V113 | -114.1131 | 46.2023 | 3755.2802 |
| BRCC-V114 | -114.1130 | 46.2120 | 3718.2284 |
| LRC-M115 | -114.0169 | 46.0522 | 5613.8527 |
| URC-M116 | -113.9693 | 46.0003 | 6100.2366 |
| URC-M118P | -113.9649 | 45.9827 | 5042.4259 |
| URC-M119P | -113.9695 | 45.9779 | 4959.8901 |
| URC-M120P | -113.9759 | 45.9744 | 4880.8094 |
| URC-M121P | -113.9822 | 45.9709 | 4787.0535 |
| URC-M122P | -113.9873 | 45.9664 | 4697.0302 |
| URC-M123 | -113.9639 | 45.9571 | 5198.2556 |
| URC-M124 | -113.9991 | 45.9650 | 4629.6693 |
| URC-M125 | -114.0161 | 45.9702 | 4443.7576 |
| LRC-M126 | -114.0541 | 46.0006 | 5190.6339 |
| LRC-M127 | -114.0143 | 46.0309 | 5057.4154 |
| LRC-M128 | -114.0602 | 46.0343 | 6398.1880 |
| USCC-M129 | -113.9799 | 46.0643 | 6166.0660 |
| BRBC-F131P | -114.0170 | 46.3256 | 4289.7001 |
| BRBC-F132P | -114.0198 | 46.3269 | 4230.4003 |
| BRBC-F133P | -114.0240 | 46.3256 | 4166.0653 |
| BRBC-F134P | -114.0281 | 46.3255 | 4098.6142 |
| BRBC-F135P | -114.0324 | 46.3256 | 4068.5404 |

| SITE ID | X | Y | Z |
|---|---|---|---|
| BRCC-F136 | -114.1583 | 45.9429 | 4239.5345 |
| BRCC-V137 | -114.1415 | 45.9420 | 4014.9301 |
| BRCC-M138 | -114.1620 | 45.9284 | 4571.3133 |
| BRCC-M139 | -114.2226 | 45.9606 | 5057.3081 |
| BRD-M140 | -114.2308 | 45.9629 | 5444.9098 |
| BRCC-M141 | -114.2279 | 45.9586 | 5322.0249 |
| LRC-V142 | -114.1271 | 45.9649 | 3998.6467 |
| LRC-F143 | -114.1027 | 45.9675 | 4047.6581 |
| BRD-V144 | -114.1506 | 45.9892 | 3938.9367 |
| BRD-F145 | -114.2132 | 46.0347 | 4087.5758 |
| LRC-M146 | -114.0203 | 46.0544 | 5690.5860 |
| BRD-M147 | -114.0770 | 46.0484 | 5826.2740 |
| LSCC-M148 | -114.0450 | 46.0997 | 5728.5965 |
| MSC-M149 | -113.9858 | 46.1815 | 5474.0404 |
| MSC-M150 | -113.9883 | 46.1763 | 5329.6555 |
| DC-M151 | -113.8449 | 46.1767 | 6178.3927 |
| USC-M152 | -113.8616 | 46.1700 | 5989.5066 |
| DC-M153P | -113.8645 | 46.2013 | 5256.2579 |
| DC-M154P | -113.8673 | 46.1990 | 5219.5226 |
| DC-M155P | -113.8689 | 46.1961 | 5152.9528 |
| DC-M156P | -113.8760 | 46.1933 | 5041.1211 |
| DC-M157P | -113.8798 | 46.1924 | 5020.1148 |
| USC-M158 | -113.8968 | 46.1236 | 6369.8396 |
| DC-M159 | -113.8384 | 46.0585 | 6973.4141 |
| BRD-F160 | -114.0871 | 46.2763 | 3676.2408 |
| BRLC-F161P | -114.1924 | 46.1669 | 3759.9974 |
| BRLC-F162 | -114.1955 | 46.1653 | 3772.5902 |
| LLHC-M163P | -114.2712 | 46.1043 | 4257.1637 |
| ULHC-M164P | -114.2810 | 46.1062 | 4282.2185 |
| ULHC-M165P | -114.2840 | 46.1128 | 4368.3494 |
| ULHC-M166P | -114.2939 | 46.1152 | 4359.2339 |
| ULHC-M167P | -114.3013 | 46.1194 | 4393.2389 |
| BRW-F168 | -114.2186 | 46.2601 | 4047.4200 |
| WC-F169 | -113.9920 | 46.2961 | 4269.7211 |
| WC-M170 | -113.9350 | 46.3035 | 5816.8635 |
| WC-M171 | -113.9316 | 46.2725 | 5813.0919 |
| LLC-M172 | -114.1704 | 46.7684 | 4638.7936 |
| LLC-M173 | -114.1748 | 46.7620 | 4793.0955 |
| BRNWC-M174 | -114.0009 | 46.7381 | 3745.9455 |
| BRNWC-F176P | -114.0242 | 46.7339 | 3511.8891 |
| BRNWC-F177P | -114.0268 | 46.7336 | 3476.0830 |
| BRNWC-F178P | -114.0284 | 46.7332 | 3461.2953 |
| BRNWC-F179P | -114.0306 | 46.7327 | 3428.4662 |
| BRNWC-F180P | -114.0322 | 46.7323 | 3408.9938 |
| TCC-M181 | -114.2170 | 45.9826 | 4518.1234 |
| BRD-M182 | -114.1988 | 45.9672 | 4555.8310 |
| BRD-F183P | -114.1590 | 45.9691 | 4194.0427 |

| SITE ID | X | Y | Z |
|---|---|---|---|
| BRD-F184P | -114.1553 | 45.9713 | 4119.3461 |
| BRD-F185P | -114.1501 | 45.9743 | 3991.6844 |
| BRLiC-F186 | -114.1587 | 46.1301 | 3840.1722 |
| BRLiC-F187 | -114.2069 | 46.1297 | 3952.5118 |
| BRW-F188 | -114.0389 | 46.2762 | 3992.7822 |
| McC-F189 | -114.1407 | 46.4920 | 3403.4938 |
| McC-F190 | -114.1272 | 46.5133 | 3333.3333 |
| LLC-M191 | -114.2305 | 46.7370 | 4080.8661 |
| BC-F192 | -114.1092 | 46.5760 | 3378.1959 |
| BRLC-F193 | -114.1098 | 46.6013 | 3390.3396 |
| SC-F194 | -114.0884 | 46.6086 | 3264.4357 |
| BRLC-V195 | -114.0721 | 46.6112 | 3218.5039 |

# APPENDIX H - SEDIMENT LOAD ESTIMATES AND BMP SCENARIO REDUCTIONS FOR THE BITTERROOT

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# H1.0 Upland Sediment

Nonpoint source pollution is pollution that originates over many varied and diffuse sources, as opposed to pollution delivered directly from a specific point or outlet, such as an end of pipe. Typically, this type of pollution is carried to streams and lakes through erosion via surface water (in the form of rainfall or snowmelt), ground water, or wind. It is often difficult to accurately quantify pollutant loads from the landscape when so much variability may exist across a watershed with regard to weather, vegetation, land use practices, soil types, geology, riparian condition, etc. However, while many complex processes are intertwined that determine this load, models with varying levels of complexity can be employed to represent the landscape and simulate the processes that occur that allow us to reasonably estimate sediment loads, identify where on the landscape those loads are coming from, and suggest how those loads could be reduced.

In the Bitterroot TPA, three main categories of pollution sources for sediment have been identified: sediment from roads, sediment from bank erosion, and sediment from upland sources. A model is used to determine sediment from upland sources, and refers to the sediment from the landscape that is delivered to the stream via overland runoff from rainfall and snowmelt.

# H2.0 Quantifying Sediment from Upland Sources Using SWAT

## H2.1 Model Development

The tool used in the Bitterroot TPA to determine the sediment loads from upland sources is the hydrologic simulation model known as SWAT (Soil and Water Assessment Tool). SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. It incorporates hydrologic, climactic, and water chemistry data with detailed land cover/land use and topography information to predict pollutant loading for seasonal and annual time frames.

A SWAT model for the Bitterroot, currently underway for evaluation of sediment and nutrient loads, is being used to represent the typical land uses and associated conditions affecting sediment production. The workings of the model are detailed as part of an initial calibration report (Van Liew, unpublished), however, finalization of this tool will be complete as it is refined as part of the nutrient TMDL. Even in its initial form, the tool is useful for estimation of landscape sediment yields. Because the model and associated sedimentation results are only preliminary, a simplified approach was implemented for the TMDL analysis. This consisted of the following:

1. Use of the preliminary SWAT model for estimating existing condition baseline upland sediment sources for impaired tributaries in the Bitterroot watershed.
2. Subsequent scenario analysis outside of the model, where loads from the preliminary SWAT model are multiplied by a literature based BMP efficiency to establish the load reductions for the TMDL.

An initial existing condition scenario was used that incorporated some basic assumptions regarding land use management practices to estimate current existing loads. Changes were then made to parameters in the model to represent potential land use management practice improvements and thereby estimate the sediment loads that could be expected if those practices were adopted.

To simulate pollutant loading at the watershed scale, SWAT first partitions a watershed into a number of subbasins. Each subbasin delineated within the model is simulated as a homogeneous area in terms of climatic conditions, but with additional subdivisions within each subbasin to represent various soils and land use types. Each of these subdivisions is referred to as a hydrologic response unit (HRU) and is assumed to be spatially uniform in terms of soils, land use, topographic and climatic data (Van Liew, 2009). HRU categories used in the Bitterroot sediment SWAT model are listed in **Table H-1**.

**Table H-1. SWAT HRU Categories**

| SWAT Code | Land Cover/LandUse Description |
|---|---|
| AGRL | Alfalfa/Grass/Hay/Cultivated Crops |
| BARN | Small Rural Properties |
| FRST | Deciduous Forest, Evergreen Forest, Wetland |
| RNGB | Range Brush |
| RNGE | Range Grass |
| URML | Medium/Low Density Urban |

Once the hydrologic response unit (HRU) categories have been defined, the model then introduces the hydrologic and land management information in order to generate the sediment loads from the landscape. Sediment loadings for the baseline watershed condition were taken directly from HRU output of the preliminary SWAT model. HRU loads are reflective of only landscape-based loadings (e.g. prior to channel routing), and are the direct output of the Modified Universal Soil Loss Equation (MUSLE). Simulated values reflect the integrated effects of soil erodibility, slope length and steepness, vegetative cover, and sediment delivery ratio. They are comparable to an uncalibrated GIS Universal Soil Loss Equation (USLE) model, similar to what DEQ would employ if nutrients were not of interest in the watershed. Thus the approach is adequate for this particular application.

## H2.2 Establishing the Total Allowable Load

From the model output, the average annual sediment load delivered to the stream is determined for each subbasin, (or listed stream watershed). The average annual upland sediment load is the sum of the average annual loads from each land cover/ landuse type (HRU category). This sediment load represents the best estimation of current conditions resulting in sediment from upland sources. **Table H-2** below presents the existing sediment load from the preliminary SWAT model, with additional information to provide comparisons in severity of sediment loading among subbasins.

**Table H-2. Sediment Load from Upland Sources and Comparison Among Watersheds**

| Subbasin | Delivered Sediment Load (T/year) | Subbasin Area (sq. miles) | Normalized to tons per square mile |
|---|---|---|---|
| Ambrose | 590 | 21.1 | 28.0 |
| Bass | 369 | 15.3 | 24.1 |
| Lick | 3 | 8.5 | 0.4 |
| Lolo 11 (Lower) | 199 | 3.6 | 55.6 |
| Lolo 12 (Middle) | 2690 | 132.6 | 20.3 |
| Lolo 13 (Upper) | 2256 | 135.6 | 16.6 |
| McClain | 78 | 4.1 | 19.2 |
| Miller | 131 | 47.3 | 2.8 |
| Muddy Spring Creek | 17 | 1.7 | 10.3 |
| North Burnt Fork | 2279 | 85.9 | 26.5 |
| Rye | 10 | 41.7 | 0.2 |
| Sleeping Child | 243 | 89.5 | 2.7 |

**Table H-2. Sediment Load from Upland Sources and Comparison Among Watersheds**

| Subbasin | Delivered Sediment Load (T/year) | Subbasin Area (sq. miles) | Normalized to tons per square mile |
|---|---|---|---|
| Sweathouse | 127 | 28.3 | 4.5 |
| Threemile | 1384 | 49.6 | 27.9 |
| Willow | 621 | 48.3 | 12.8 |

## H2.3 Scenario Analysis

Following simulation of the existing condition baseline, scenarios were developed to estimate load reductions for particular best management practices in the watershed. Specific management practices that DEQ wishes to evaluate as part of the TMDL include the following: (1) agricultural best management practices (BMPs) and (2) riparian buffer strip or corridor enhancements. BMP efficiencies were taken directly from the literature when applicable, or were established using reasonable scientific judgment. To determine load reductions, the BMP efficiency was multiplied by the initial landcover load calculated from SWAT (Eq. 1), and the difference between the baseline and subsequent calculation became the load reduction for the proposed scenario (Eq. 2). Numerically, these calculations are shown below.

$$ScenarioX_{load} = \sum_{lulc=i}^{n} SWAT_{load\ i} \times BMP_{eff\ i} + SWAT_{load\ i+1} \times BMP_{eff\ i+1} \ldots SWAT_{load\ n} \times BMP_{eff\ n} \quad \text{(Eq. 1)}$$

$$Load_{reduction} = Baseline_{load} - ScenarioX_{load} \quad \text{(Eq. 2)}$$

Where:

$Baseline_{load}$ = Load for baseline scenario
$ScenarioX_{load}$ = Load for scenario
$SWAT_{load\ i}$ = Load from SWAT for a specific landcover type
$BMP_{eff\ I}$ = BMP efficiency applied to specific landcover type

Given that the baseline loadings will likely change as a result of refinement during the nutrient TMDL, all sediment loading reductions are formulated around the BMP efficiency factor, which can be directly transferred to the final loads at a later date (if desired). The scenario analyses and methods for which this factor were derived are described in subsequent sections.

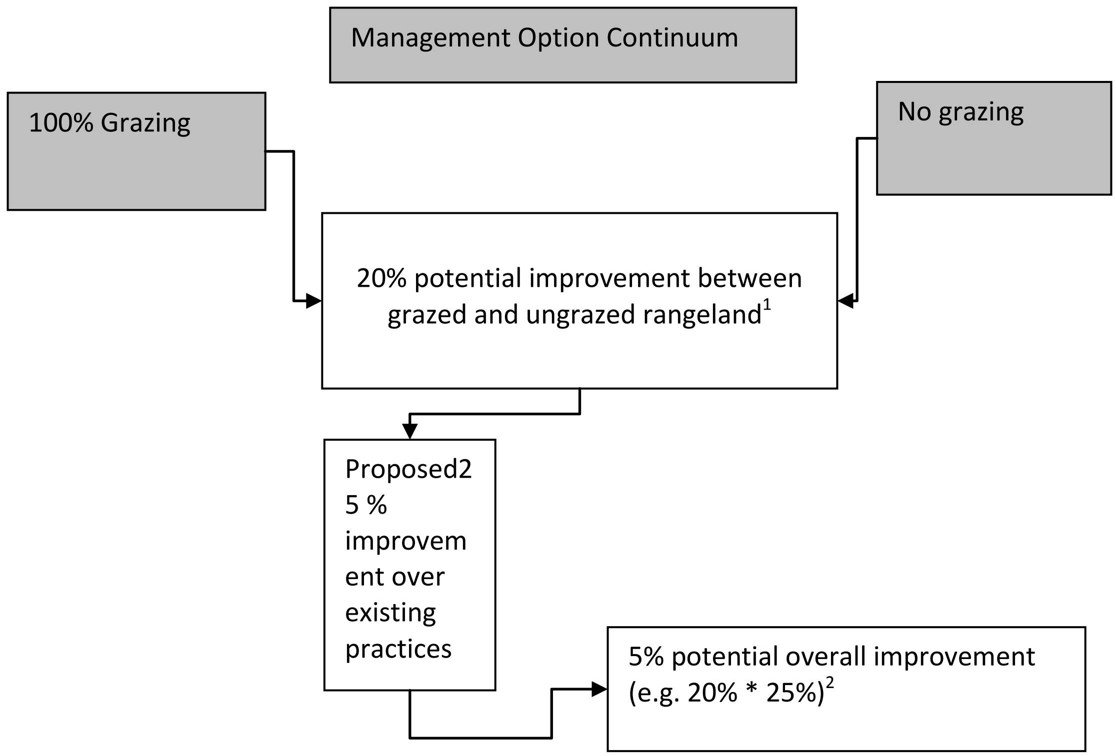
### H2.3.1 Agricultural Best Management Practice Scenario

Agricultural best management practices (BMPs) are proposed to reduce agricultural non-point source loads and improve overall stream water quality in the Bitterroot watershed. Agouridis et al. (2005) provide a comprehensive review of common agricultural BMP implementation practices in the United States. In general, at least one aspect of stream water quality has improved after receiving one or more of the following BMP treatments: off-stream water, alternate shade, rotational grazing, supplemental feeding, buffer strips, or livestock exclusion. As such, DEQ believes that implementation of at least one or more of these practices could cost-effectively reduce sediment loads, and improve water quality in the Bitterroot watershed. While application and effectiveness of such practices are site-specific, the agricultural BMP scenario was formulated to evaluate the hypothetical load reductions from the following BMPs: (1) improved upland range management, (2) better barnyard management, and (3) reduced tillage.

#### *H2.3.1.1 Upland Range Improvement Scenario*

The upland range improvement scenario was developed to reflect improved grazing management practices in the agricultural portions of watershed. It is well known that grazing reduces groundcover, and excellent review of regional studies has been presented by Thrift (2006). In her thesis, she concludes that domestic animals (e.g. cattle and sheep) reduce ground cover through both grazing and trample. Generally, this could be linked to increased rill and interill erosion. Plot studies on the Beaverhead National Forest near Dillon, MT suggest similar conclusions, finding sites that received heavy, moderate, and light grazing had 14.9, 18.6, and 6.8 percent more bare ground than plots with no cattle (Evanko and Peterson, 1955). Similarly, in an exclusion study on foothill sheep ranges in Meagher County near White Sulpher Springs, MT, total cover (e.g. foliage and litter) was 16.9 percent higher on protected plots than on those that received grazing (Vogel and Van Dyne, 1966).

Given that the relationship between ground cover and erosion is apparent, and that regional studies tend to suggest that ground cover is approximately 15-20 percent higher on ungrazed rangeland than sites receiving grazing (note: this is a relative change in percent cover not an absolute percentage), a scenario was developed to evaluate improvements in rangeland condition. However, because the BMP implementation described previously reflects only the difference between grazed and excluded plots, a fractional adjustment is necessary to reflect reasonable grazing practices (e.g. it is unrealistic to evaluate an ungrazed condition). A 25% improvement over the existing condition is proposed which calculates out to a 5% relative potential improvement in groundcover as illustrated in **Figure H-1**. Note this is not an absolute change in cover, rather it needs to be multiplied by the existing groundcover to come up with the actual percent change in cover. A similar procedure was completed for range-brush (e.g. sagebrush land); although it was assumed that only 50% of the land had grass forage therefore the percent improvement in cover would only be 2.5%.




[1] A 20% relative potential change over the existing cover condition, not a 20% absolute change in cover.
[2] A 5% relative potential change over the existing cover condition based on the previous assumption (e.g.20% x proposed 25% improvement is 5% potential improvement).

**Figure H-1. Rangeland cover improvement scenario management option propagated on the SWAT model output.**

BMP efficiency factors for this scenario were formulated using the multiplicative nature of MUSLE and the straightforward relationship between percent cover and c-factor. Assumptions used in this estimation procedure for the rangeland management scenario are shown in Table H-3. A similar approach was taken for the tillage and confined animal management scenario, as described in subsequent sections (also shown in the table).

**Table H-3. Assumptions used in development of agricultural best management scenario.**

| Cover Type | Assumptions | Existing Condition Cover (%) | Annual USLE C-factor, (minimum c-factor in parenthesis) | Improved Condition Cover (%) | Annual USLE C-factor | BMP efficiency (%) |
|---|---|---|---|---|---|---|
| Barnyard[1] | Heavily compacted soil; no cover | 0 | 1.000 (1.0) | 20 | 0.5 | 50% |
| Cultivated Crops[1] | Intensive tillage practices | <15% residue | 0.230 (0.13) | 15-30% residue (reduced tillage) | 0.15 | 35% |
| Range Grass[2] | Grass cover type; no canopy cover | 57 | 0.050 (0.014) | 60 | 0.042 | 16% |
| Range Brush[2] | 50% grass cover, 50% brush canopy; 0.5 m fall height | 56 | 0.042 (0.0107) | 57 | 0.037 | 12% |

[1] From McCuen (1998)
[2] From Brooks et al. (1997)

#### *H2.3.1.2 Reduced tillage scenario*
According to the 2002 Census of Agriculture for Montana, Ravalli County produced approximately 1,789 acres of wheat (both winter and spring grains). While exact tillage practices are not apparent, it is believed that intensive ones are most likely used in the watershed. This constitutes less than 15% surface residue left, or <500 lbs/acre stubble mulch. Therefore, as part of the agricultural best management practice scenario, a reduced tillage system was evaluated which resulted in a BMP reduction efficiency of 35% per the cover management practice factors in McCuen (1998). This represents between 500-1000 lb/acre stubble mulch, or15-30% surface residue.

#### *H2.3.1.3 Confined Animal Management Scenario*
Rural development in the Bitterroot watershed has been on the rise, much of which has taken the form of small-scale residential acreages. Based on windshield surveys conducted by Montana DEQ, one in four of these areas typically has a confined animal area, e.g. a corralled and/or fenced area where livestock are present. Because bare soil in these areas is an erosion risk, a scenario was developed to address the potential sediment reduction from these practices. An increase from 0 to 20 percent ground cover was proposed which translates to a direct BMP efficiency of approximately 50%.

### H2.3.2 Incorporating Improved Riparian Condition
Aerial assessment techniques using GIS and aerial photos were completed for each stream of interest to provide a coarse summary of riparian conditions in the subbasins. Delineated reaches were given a riparian condition category of good, fair, or poor based on land use adjacent to the stream, riparian vegetation type and density, and the presence or absence of human related activities near the stream corridor. Based on this, each stream investigated was given corresponding percentages of condition based on the total length of stream assessed.

Literature review (Wegner 1999, Knutson and Naef 1997) 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. Conversely, this analysis conservatively assumes that a riparian zone without vegetation cover (corresponding to a riparian health assessment of ‘none’) would only filter 10% of incoming sediment from reaching its stream.

Based on the above information, sediment reduction factors were chosen to account for the potential in sediment reduction efficiency from improved riparian conditions. The range between filtering capacity between ‘good’ and ‘none’ is roughly 65-80%. A conservative assumption was then made that sediment reduction potential representing ‘poor’ conditions may be close to 25%, ‘moderate’ riparian condition filters 50% of the sediment load, and ‘good’ riparian condition has the effect of reducing upland sediment load by 75%.

To then incorporate riparian filtering capacity, in addition to the load from the improved condition, the riparian condition and associated reduction potential for each stream is applied to simulate the total sediment reduction potential if all land management improvements across the landscape and within the riparian corridor are implemented. For instance, if stream A is determined by the SWAT model desired condition to have a sediment load of 100 tons/year, and 50% (50 tons/year) of the stream is considered to be in Good riparian condition, and 50% (50 tons/year) is considered to be Poor, than a total of 50% (25 tons/year) of the load from the Poor riparian could be buffered if the riparian condition was improved to Good, resulting in a total load for stream A of 75 tons/year when all best management practices are implemented (**Table H-4**). The filtering capacity of the buffers is only applied in the improvement scenarios. Since the model serves only as a representation of existing conditions, it is implied that additional reduction through riparian filters is only applicable once modifications in land management improve riparian condition.

**Table H-4. Example Riparian Buffer Load Reduction Estimate**

| Riparian Condition | | | Buffering Capacity | |
|---|---|---|---|---|
| **Category** | **Percent Stream Length** | **Upland Load Distribution** | **Estimated Load Reduction with Buffer Improvement** | **Upland Load Reduction** |
| Good | 50% | 50 | 0% | 50 |
| Fair | - | - | 25% | - |
| Poor | 50% | 50 | 50% | 25 |
| Upland Load From Model | | 100 | Desired Load | 75 |

No specified BMP practices were recommended by DEQ to reach these improvements. Rather it should be up to the stakeholders and watershed managers in the area to define what practices, and associated locations, will be most effective and cost-efficient for watershed restoration. Subsequently, more detailed set of practices should be tailored to each agricultural producer during actual watershed restoration planning.

## H2.4 Results - Load Reduction Summaries

The following tables (**H-5 to H-19**) display the current estimated load based on SWAT, the load resulting when BMPs are applied to each specific land use, and the total load with land use BMPs and improved riparian areas in place to get the total possible percent upland reduction.

**Table H-5. Ambrose Creek Upland Load Reductions**

| AMBROSE CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| **Sources** | | **Current estimated load based on SWAT (T/Year)** | **Land use BMP efficiency** | **Sediment load with land use BMP efficiency applied to current load (T/Year)** | **Resultant sediment load with 31% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)** | **Total possible upland % reductio n** |
| Upland Erosion | Barnyard[1] | 18 | 50% | 9 | | |
| | Agriculture | 101 | 35% | 66 | | |
| | Range Grass[2] | 211 | 16% | 177 | | |
| | Range Brush[2] | 182 | 12% | 161 | | |
| | Forest | 76 | N/A | 76 | | |
| | Low/Med Urban | 2 | N/A | 2 | | |
| | Total | 590 | | 490 | 338 | 43% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-6. Bass Creek Upland Load Reductions**

| BASS CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 6% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 0 | 50% | 0 | | |
| | Agriculture | 20 | 35% | 13 | | |
| | Range Grass[2] | 212 | 16% | 178 | | |
| | Range Brush[2] | 131 | 12% | 115 | | |
| | Forest | 6 | N/A | 6 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 369 | | 313 | 294 | 20% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-7. Lick Creek Upland Load Reductions**

| LICK CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 8% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 0 | 50% | 0 | | |
| | Agriculture | 0 | 35% | 0 | | |
| | Range Grass[2] | 0 | 16% | 0 | | |
| | Range Brush[2] | 0 | 12% | 0 | | |
| | Forest | 2 | N/A | 2 | | |
| | Low/Med Urban | 1 | N/A | 1 | | |
| | Total | 3 | | 3 | 2 | 32% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-8. Lolo Creek 11 (Lower) Upland Load Reductions**

| LOLO CREEK 11 (LOWER) | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 25% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 4 | 50% | 2 | | |
| | Agriculture | 57 | 35% | 37 | | |
| | Range Grass[2] | 83 | 16% | 70 | | |
| | Range Brush[2] | 42 | 12% | 37 | | |
| | Forest | 10 | N/A | 10 | | |
| | Low/Med Urban | 3 | N/A | 3 | | |
| | Total | 199 | | 159 | 119 | 40% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-9. Lolo Creek 12 (Middle) Upland Load Reductions**

| LOLO CREEK 12 (MIDDLE) | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 26% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 11 | 50% | 6 | | |
| | Agriculture | 126 | 35% | 82 | | |
| | Range Grass[2] | 415 | 16% | 349 | | |
| | Range Brush[2] | 1074 | 12% | 945 | | |
| | Forest | 1057 | N/A | 1057 | | |
| | Low/Med Urban | 7 | N/A | 7 | | |
| | Total | 2690 | | 2445 | 1809 | 33% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-10. Lolo Creek 13 (Upper – Includes Upper Lolo TPA) Upland Load Reductions**

| LOLO CREEK 13 (UPPER – Includes Upper Lolo TPA) | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 21% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 1 | 50% | 0 | | |
| | Agriculture | 2 | 35% | 1 | | |
| | Range Grass[2] | 98 | 16% | 82 | | |
| | Range Brush[2] | 1022 | 12% | 899 | | |
| | Forest | 1125 | N/A | 1125 | | |
| | Low/Med Urban | 8 | N/A | 8 | | |
| | Total | 2256 | | 2116 | 1672 | 26% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-11. McClain Creek Upland Load Reductions**

| MCCLAIN CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 21% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 0 | 50% | 0 | | |
| | Agriculture | 3 | 35% | 2 | | |
| | Range Grass[2] | 4 | 16% | 3 | | |
| | Range Brush[2] | 39 | 12% | 34 | | |
| | Forest | 32 | N/A | 32 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 78 | | 72 | 57 | 28% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-12. Miller Creek Upland Load Reductions**

| MILLER CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 34% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 0 | 50% | 0 | | |
| | Agriculture | 0 | 35% | 0 | | |
| | Range Grass[2] | 53 | 16% | 45 | | |
| | Range Brush[2] | 42 | 12% | 37 | | |
| | Forest | 35 | N/A | 35 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 131 | | 117 | 77 | 41% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-13. Muddy Spring Creek Upland Load Reductions**

| MUDDY SPRING CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 1% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 0 | 50% | 0 | | |
| | Agriculture | 0 | 35% | 0 | | |
| | Range Grass[2] | 7 | 16% | 6 | | |
| | Range Brush[2] | 8 | 12% | 7 | | |
| | Forest | 2 | N/A | 2 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 17 | | 15 | 15 | 14% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-14. North Burnt Fork Creek Upland Load Reductions**

| NORTH BURNT FORK CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 37% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 23 | 50% | 12 | | |
| | Agriculture | 165 | 35% | 107 | | |
| | Range Grass[2] | 1592 | 16% | 1337 | | |
| | Range Brush[2] | 487 | 12% | 429 | | |
| | Forest | 11 | N/A | 11 | | |
| | Low/Med Urban | 1 | N/A | 1 | | |
| | Total | 2279 | | 1897 | 1195 | 48% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-15. Rye Creek Upland Load Reductions**

| RYE CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 19% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 0 | 50% | 0 | | |
| | Agriculture | 1 | 35% | 1 | | |
| | Range Grass[2] | 5 | 16% | 4 | | |
| | Range Brush[2] | 4 | 12% | 4 | | |
| | Forest | 0 | N/A | 0 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 10 | | 9 | 7 | 33% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-16. Sleeping Child Creek Upland Load Reductions**

| SLEEPING CHILD CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 10% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 3 | 50% | 2 | | |
| | Agriculture | 1 | 35% | 1 | | |
| | Range Grass[2] | 61 | 16% | 51 | | |
| | Range Brush[2] | 101 | 12% | 89 | | |
| | Forest | 77 | N/A | 77 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 243 | | 219 | 197 | 19% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-17. Sweathouse Creek Upland Load Reductions**

| SWEATHOUSE CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 14% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 7 | 50% | 4 | | |
| | Agriculture | 7 | 35% | 5 | | |
| | Range Grass[2] | 2 | 16% | 2 | | |
| | Range Brush[2] | 84 | 12% | 74 | | |
| | Forest | 27 | N/A | 27 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 127 | | 111 | 95 | 25% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-18. Threemile Creek Upland Load Reductions**

| THREEMILE CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 28% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 40 | 50% | 20 | | |
| | Agriculture | 186 | 35% | 121 | | |
| | Range Grass[2] | 608 | 16% | 511 | | |
| | Range Brush[2] | 341 | 12% | 300 | | |
| | Forest | 204 | N/A | 204 | | |
| | Low/Med Urban | 5 | N/A | 5 | | |
| | Total | 1384 | | 1161 | 836 | 40% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

**Table H-19. Willow Creek Upland Load Reductions**

| WILLOW CREEK | | | Land Use BMP Efficiency Only | | Combined Land Use and Riparian BMP Efficiency | |
|---|---|---|---|---|---|---|
| Sources | | Current estimated load based on SWAT (T/Year) | Land use BMP efficiency | Sediment load with land use BMP efficiency applied to current estimated load (T/Year) | Resultant sediment load with 27% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year) | Total possible upland % reduction |
| Upland Erosion | Barnyard[1] | 15 | 50% | 8 | | |
| | Agriculture | 18 | 35% | 12 | | |
| | Range Grass[2] | 201 | 16% | 169 | | |
| | Range Brush[2] | 297 | 12% | 261 | | |
| | Forest | 90 | N/A | 90 | | |
| | Low/Med Urban | 0 | N/A | 0 | | |
| | Total | 621 | | 539 | 394 | 37% |

[1] From McCuen (1998), [2] From Brooks et al. (1997)

# 3.0 REFERENCES


Agouridis, C.T., Workman, S.R., Warner, R.C., and G.D. Jennings. 2005. Livestock grazing management impacts on stream water quality: a review. Journal of American Water Resources Association. 2005 41(3). p.591-606

Brooks, K.N., Ffolliot, P.F., Gregerson, H.M., and DeBano, L.F. 1997. Hydrology and the management of watersheds. Iowa State University Press. Ames, Iowa.

Evanko, Anthony B.; Peterson, Roald A. 1955. Comparisons of protected and grazed mountain rangelands in southwestern Montana. Ecology. 36(1): 71-82.

Lacey, J.R., Marlow, C.B., and J.R. Lane. 1989. Influence of spotted knapweed (Centaurea maculosa) on surface runoff and sediment yield. Weed Technology. Volume 3: 627-631.

McCuen. R.H. 1998. Hydrologic Analysis and Design 2$^{nd}$ edition. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

Thrift, T.M. 2006. Effects of long-term winter-spring grazing on foothill rangeland. Master's Thesis. Montana State University. Bozeman, Montana. April 2006.

Vogel, W. G.; Van Dyne, G. M. 1966. Vegetation responses to grazing management on a foothill sheep range. Journal of Range Management. 19: 80-85. [12263]

# Appendix I - Total Maximum Daily Loads

# I1.0 Sediment

## I1.1 Overview

A percent reduction based on average yearly loading was used as the primary approach for expressing the sediment TMDLs within this document because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads alone creates a rigid perception that the loads are absolutely conclusive. However, in this appendix the TMDL is expressed using daily loads to satisfy an additional EPA required TMDL element. Daily loads should not be considered absolutely conclusive 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, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired. It is not expected that daily loads will drive implementation activities.

## I1.2 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 entire Bitterroot River watershed, there are several USGS gage stations with extensive discharge datasets but no gage stations with daily suspended sediment measurements. The USGS station on Skalkaho Creek near Hamilton, MT (12346500) was selected to represent the daily variability in mean daily discharge because it has the longest period of record for the Bitterroot tributaries. The mean daily discharge values from 55 years of record (1948 - 2003) at the gage Skalkaho Creek near Hamilton, MT were used to calculate daily sediment values for TMDLs in the tributaries of the Bitterroot River watershed.

Using the mean of daily mean discharge values from the gage, a daily percentage relative to the mean annual discharge was calculated for each day (**Table I-1**). For each TMDL, the daily percentages in **Table I-1** were multiplied by the total average annual load associated with the TMDL percent reductions in **Section 5.7** to calculate the daily load. The TMDLs expressed as an average annual load, which are discussed in **Section 5.7** are provided in **Table I-2**. For instance, the total allowable annual sediment load for the Lick Creek is 166 tons. To determine the TMDL for January 1, 166 tons is multiplied by 0.29% which provides a daily load for Lick Creek on January 1st of 0.48 tons. The daily loads are a composite of the allocations, but as allocations are not feasible on a daily basis, they are not contained within this appendix. If desired, daily allocations may be obtained by applying allocations provided in **Section 5.6** to the daily load.

**Table I-1. USGS Stream Gage 12346500 (Skalkaho Creek near Hamilton, MT ) – Percent of Mean Annual Discharge Based on Mean of Daily Mean Discharge Values for each Day of Record (Calculation Period 1948-12-01 -> 2003-09-30)**

| Day of month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.29% | 0.28% | 0.27% | 0.34% | 1.03% | 4.20% | 2.73% | 0.92% | 0.59% | 0.46% | 0.41% | 0.35% |
| **2** | 0.29% | 0.28% | 0.26% | 0.35% | 1.05% | 4.29% | 2.64% | 0.90% | 0.58% | 0.46% | 0.40% | 0.36% |
| **3** | 0.29% | 0.28% | 0.26% | 0.34% | 1.10% | 4.46% | 2.53% | 0.88% | 0.55% | 0.46% | 0.40% | 0.36% |
| **4** | 0.29% | 0.28% | 0.26% | 0.35% | 1.17% | 4.51% | 2.47% | 0.88% | 0.54% | 0.45% | 0.40% | 0.35% |
| **5** | 0.29% | 0.28% | 0.26% | 0.37% | 1.24% | 4.52% | 2.40% | 0.86% | 0.54% | 0.45% | 0.40% | 0.35% |
| **6** | 0.29% | 0.27% | 0.27% | 0.39% | 1.30% | 4.66% | 2.28% | 0.84% | 0.54% | 0.45% | 0.40% | 0.34% |
| **7** | 0.29% | 0.27% | 0.27% | 0.41% | 1.42% | 4.70% | 2.18% | 0.82% | 0.53% | 0.46% | 0.40% | 0.33% |
| **8** | 0.29% | 0.27% | 0.27% | 0.41% | 1.54% | 4.66% | 2.08% | 0.79% | 0.54% | 0.45% | 0.39% | 0.32% |
| **9** | 0.29% | 0.28% | 0.27% | 0.42% | 1.64% | 4.63% | 1.97% | 0.78% | 0.51% | 0.43% | 0.39% | 0.32% |
| **10** | 0.29% | 0.28% | 0.27% | 0.45% | 1.78% | 4.52% | 1.89% | 0.77% | 0.51% | 0.45% | 0.39% | 0.32% |
| **11** | 0.28% | 0.28% | 0.27% | 0.46% | 1.96% | 4.40% | 1.79% | 0.75% | 0.51% | 0.46% | 0.39% | 0.33% |
| **12** | 0.29% | 0.28% | 0.27% | 0.47% | 2.10% | 4.38% | 1.71% | 0.74% | 0.53% | 0.48% | 0.39% | 0.33% |
| **13** | 0.29% | 0.28% | 0.27% | 0.50% | 2.20% | 4.41% | 1.63% | 0.73% | 0.51% | 0.47% | 0.38% | 0.33% |
| **14** | 0.29% | 0.28% | 0.27% | 0.52% | 2.34% | 4.37% | 1.55% | 0.73% | 0.51% | 0.46% | 0.37% | 0.33% |
| **15** | 0.29% | 0.27% | 0.27% | 0.53% | 2.46% | 4.35% | 1.49% | 0.71% | 0.53% | 0.46% | 0.38% | 0.33% |
| **16** | 0.32% | 0.27% | 0.28% | 0.54% | 2.57% | 4.33% | 1.43% | 0.70% | 0.51% | 0.45% | 0.37% | 0.32% |
| **17** | 0.30% | 0.27% | 0.28% | 0.54% | 2.65% | 4.35% | 1.37% | 0.68% | 0.50% | 0.43% | 0.36% | 0.32% |
| **18** | 0.29% | 0.27% | 0.28% | 0.57% | 2.71% | 4.27% | 1.33% | 0.67% | 0.50% | 0.43% | 0.36% | 0.32% |
| **19** | 0.29% | 0.27% | 0.28% | 0.58% | 2.76% | 4.20% | 1.29% | 0.68% | 0.49% | 0.42% | 0.36% | 0.32% |
| **20** | 0.28% | 0.27% | 0.28% | 0.63% | 2.95% | 4.03% | 1.24% | 0.68% | 0.50% | 0.43% | 0.36% | 0.30% |
| **21** | 0.28% | 0.27% | 0.28% | 0.62% | 3.01% | 3.93% | 1.20% | 0.65% | 0.50% | 0.43% | 0.36% | 0.32% |
| **22** | 0.27% | 0.27% | 0.28% | 0.63% | 3.09% | 3.76% | 1.15% | 0.65% | 0.50% | 0.43% | 0.36% | 0.32% |
| **23** | 0.27% | 0.26% | 0.29% | 0.68% | 3.21% | 3.64% | 1.12% | 0.67% | 0.49% | 0.43% | 0.36% | 0.30% |
| **24** | 0.27% | 0.27% | 0.29% | 0.75% | 3.37% | 3.58% | 1.09% | 0.65% | 0.48% | 0.42% | 0.37% | 0.30% |
| **25** | 0.28% | 0.26% | 0.29% | 0.79% | 3.53% | 3.49% | 1.07% | 0.63% | 0.47% | 0.42% | 0.37% | 0.30% |
| **26** | 0.28% | 0.26% | 0.29% | 0.82% | 3.64% | 3.27% | 1.03% | 0.63% | 0.47% | 0.42% | 0.37% | 0.29% |
| **27** | 0.28% | 0.26% | 0.29% | 0.86% | 3.85% | 3.10% | 1.01% | 0.62% | 0.46% | 0.41% | 0.36% | 0.30% |
| **28** | 0.27% | 0.27% | 0.30% | 0.89% | 4.00% | 2.98% | 0.99% | 0.61% | 0.46% | 0.42% | 0.35% | 0.30% |
| **29** | 0.27% | 0.30% | 0.30% | 0.91% | 4.12% | 2.91% | 0.97% | 0.60% | 0.45% | 0.42% | 0.35% | 0.29% |
| **30** | 0.27% | 0.00% | 0.32% | 0.96% | 4.18% | 2.83% | 0.97% | 0.60% | 0.45% | 0.41% | 0.35% | 0.30% |
| **31** | 0.28% | 0.00% | 0.33% | 0.00% | 4.17% | 0.00% | 0.96% | 0.60% | 0.00% | 0.41% | 0.00% | 0.29% |

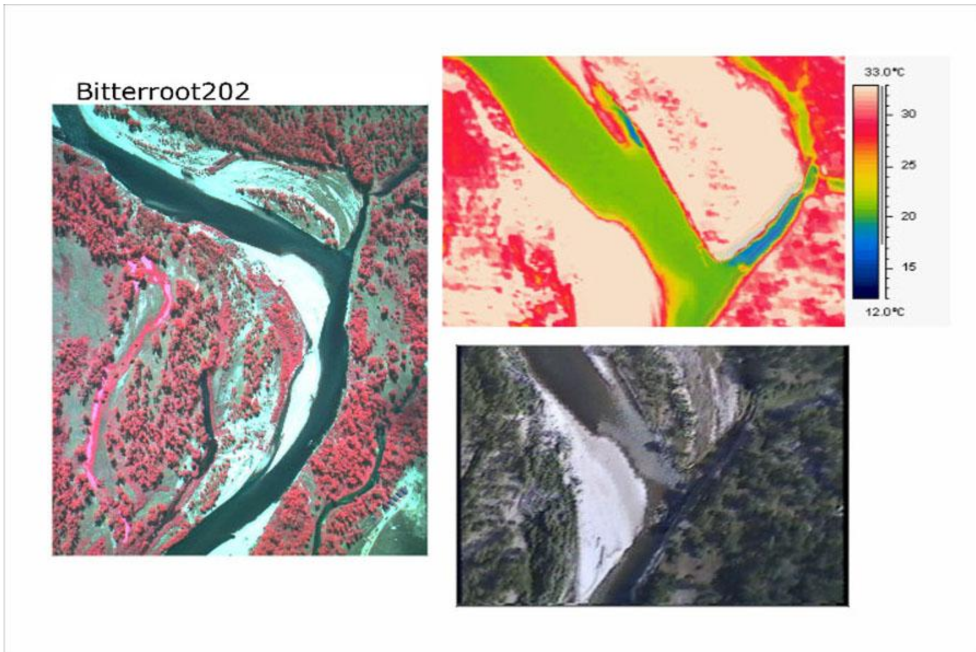
**Table I-2. TMDLs expressed as an average annual load and can be used in conjunction with the values in Table I-1 to compute daily loads.**

| Stream Segment | Waterbody ID | TMDL Expressed as Average Annual Load (tons/year) |
|---|---|---|
| Ambrose Creek | MT76H004_120 | 887 |
| Bass Creek | MT76H004_010 | 527 |
| Lick Creek | MT76H004_170 | 166 |
| Lolo Creek (headwaters to Sheldon Creek) | MT76H005_013 | 2094 |
| Lolo Creek (Mormon Creek to Mouth) | MT76H005_011 | 4690 |
| Lolo Creek (Sheldon Creek to Mormon Creek) | MT76H005_012 | 176 |
| McClain Creek | MT76H004_150 | 171 |
| Miller Creek | MT76H004_130 | 1538 |
| Muddy Spring Creek | MT76H004_180 | 15 |
| North Burnt Fork Creek | MT76H004_200 | 2830 |
| Rye Creek | MT76H004_190 | 1724 |
| Sleeping Child Creek | MT76H004_090 | 2306 |
| Sweathouse Creek | MT76H004_210 | 705 |
| Threemile Creek | MT76H004_140 | 3034 |
| Willow Creek | MT76H004_110 | 1654 |

# ATTACHMENT A - BITTERROOT RIVER FLIR TEMPERATURE ANALYSIS INTERPRETIVE REPORT

# Bitterroot River FLIR Temperature Analysis

## Interpretive Report

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PO Box 200901
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**February 2005**

**INTERPRETIVE REPORT**
**BITTERROOT RIVER FLIR TEMPERATURE ANALYSIS**

# Introduction

Temperature and heat source mapping was conducted in 2004 using Forward-Looking Infra-Red (FLIR) technology to facilitate source assessment for the temperature-listed streams in the Bitterroot River TPA. The FLIR analysis was conducted to support Total Maximum Daily Load (TMDL) development for temperature-listed streams in the Bitterroot River TPA. This document is a summary of the FLIR temperature monitoring methods and results. The FLIR method is an effective way to measure temperature trends over a spatial gradient. Color-infrared (CIR) imagery and color-normal video were also collected to provide context for the FLIR images by showing the adjacent terrain and associated land use practices. The aerial imagery was used with field data collected during the same timeframe and temperature loggers installed in the temperature-listed streams. The combined data were utilized to identify heat sources, to assess the effects of thermal refugia, tributary inputs, irrigation return flows and groundwater inputs on temperature, and for overall assessment of streamside conditions. This document describes methods used in the FLIR analysis and interpretation followed by the analysis results for temperature trends and sources.

# Methods

*Data Collection*
During the summer of 2004, Infrared Image Solutions, Inc. of Hermiston, OR was contracted to collect multi-spectral imagery on the Bitterroot River and selected tributaries near Missoula, Montana (Figure 1).

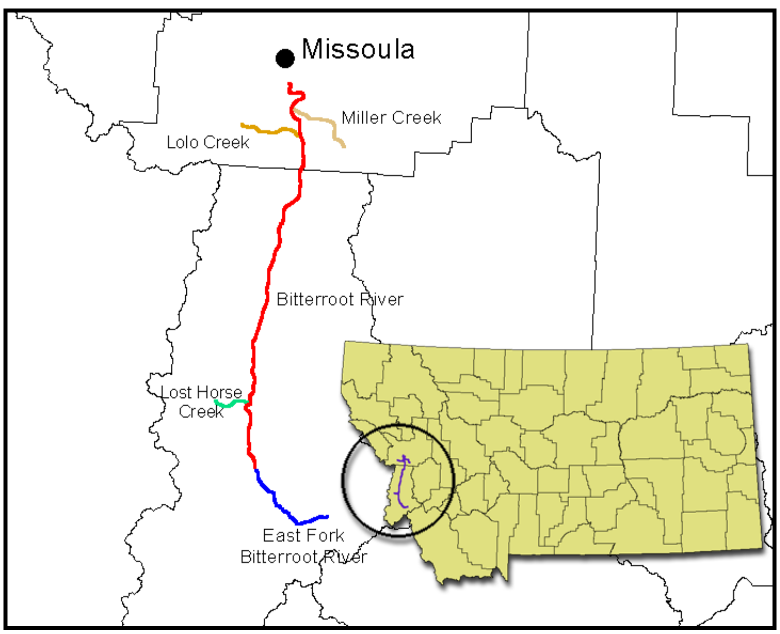


**Figure 1. Project area overview.**

The purpose of the project was to collect continuous temperature measurements along the entire project area and to identify areas of cool water inputs to the stream. A morning flight and an evening flight were conducted on each stream to document diurnal fluctuations. Project data consists of digital imagery in thermal infrared (FLIR), color-infrared (CIR) and normal color videography.

*Equipment*

### FLIR ThermaCam S60

FLIR imagery was collected with a FLIR ThermaCam S60. The S60 images were fed via firewire connection to a laptop computer at a rate of 7.5 frames per second. The ThermaCam S60 camera has a built in normal color video camera. The normal color video was recorded to standard VHS video simultaneously with the FLIR imagery.
Pertinent specifications are listed below in **Error! Reference source not found.**.

**Table 1. Summary of S60 specifications.**

| ThermaCam S60 Specifications | |
|---|---|
| Spectral Range | 7.5 to 13 µm |
| Thermal Sensitivity | 0.06 C. at 30 C. |
| Detector Type | Focal plane array (FPA) uncooled microbolometer 320 x 240 pixels |
| Accuracy (% of reading) | ±2 °C or ±2% |

### Redlake MS4100

CIR imagery was collected with a RedLake MS4100. The MS4100 is a multi-spectral camera that can capture images in normal color (RGB) or color infrared (green, red and near-infrared). For this project the camera was configured for CIR imagery. Pertinent specifications are listed below in Table 2.

**Table 2. Summary of MS100 specifications.**

| RedLake MS4100 Specifications | |
|---|---|
| Pixel array | 1920 x 1080 |
| Bit depth | 24 bit |
| Sensor type | 3 CCD, interline |
| Max frame rate | 10 frames per second |

*Data Collection*

<u>FLIR Data Collection</u>

FLIR imagery was collected on a morning flight and an afternoon flight. Because of equipment problems and weather delays we were not able to collect the data for each flight on the same day. An evening flight was conducted on August 2, 2004 between 16:09 and 19:16 MDT. A morning flight occurred on August 4, 2004 between 7:00 and 9:58 MDT. Flights were conducted from a helicopter flying between 1000 and 2500 feet above the ground. Visual videography was recorded simultaneously with the FLIR imagery. Weather conditions for the flights are detailed in Table 3 below.

**Table 3. Atmospheric conditions.**

| | PM Flight | AM Flight |
|---|---|---|
| Flight Date | August 2, 2004 | August 4, 2004 |
| Flight Time | 4:00 - 7:15 MDT | 7:00 – 10:00 MDT |
| Air temperature (Missoula airport) | 29 C. | 12 C. |

This date was chosen because it is during what is historically the hottest 2-week period of the year in the Bitterroot valley. Figure 2 shows the historic temperatures in the Bitterroot watershed and the temperature trends for 2004.

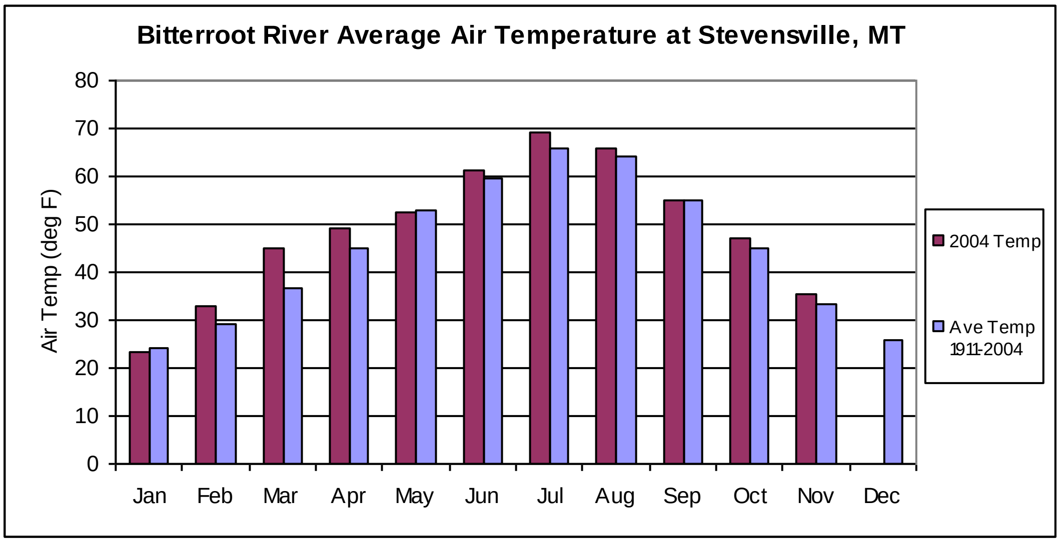


**Figure 2. Average annual air temperature at Stevensville, Montana. Source: Western Regional Climate Center.**

As illustrated in Figure 2, temperatures in 2004 were consistent with historic averages.

<u>Video Data Collection</u>

Visual videography was recorded simultaneously with the FLIR imagery. Video recording was done with an 8 mm VHS video recorder. The video is a normal color presentation of the FLIR imagery. Video lends understanding of the FLIR imagery, as the human eye is not accustomed to distinguishing features in thermal infrared. Video is synchronized with the FLIR imagery and delivered in MPG format (Figure 3).

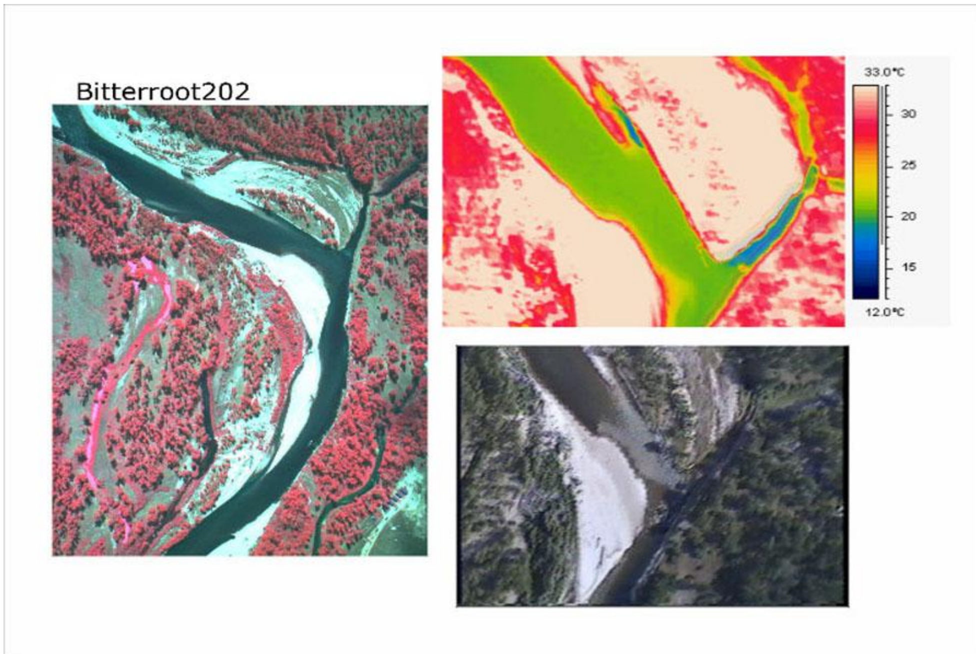


**Figure 3. Simulated frame capture of synchronized video, CIR and FLIR images on the Bitterroot River.**

* Note: In all of the FLIR images, downstream is toward the bottom of the page.

<u>CIR Data Collection</u>

Color-infrared images were collected from a fixed-wing airplane on August $2^{nd}$ and $4^{th}$, 2004. The CIR camera has a much higher resolution than the FLIR camera and therefore can be flown from a higher altitude. The higher altitude affords a wider field of view while still maintaining pixel resolutions of less than a meter. The CIR images put the watershed into context by showing the adjacent terrain and associated land use practices (Figure 3 and 4).

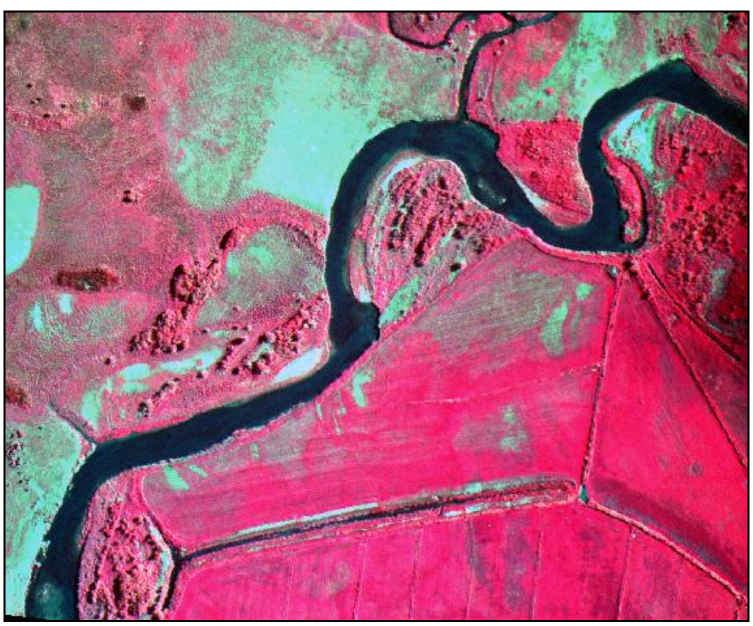

**Figure 4. CIR Image on the Bitterroot.**

CIR images were captured at a rate of 1 image every 5 seconds. This rate yielded an endlap of approximately 60%. A shapefile of the CIR image locations was created to facilitate comparison of FLIR and CIR images. Additionally, the CIRs were geo-referenced and put in mosaic at a 2 meter resolution to facilitate comparison of temperature trends and land use practices over a greater area.

<u>Instream Temperature Data Collection</u>

In-stream temperature loggers were deployed at 44 locations within the Bitterroot River Watershed prior to the aerial surveys (Figure 5). Temperature readings from the streams were recorded at half hour intervals (15 minute intervals on Lolo Creek) from July through September 2004. Figure 5 also illustrates the flight path and extent of the surveys, which began south of Missoula, Montana and progressed south past Sula, Montana to the headwaters of the East Fork of the Bitterroot River.

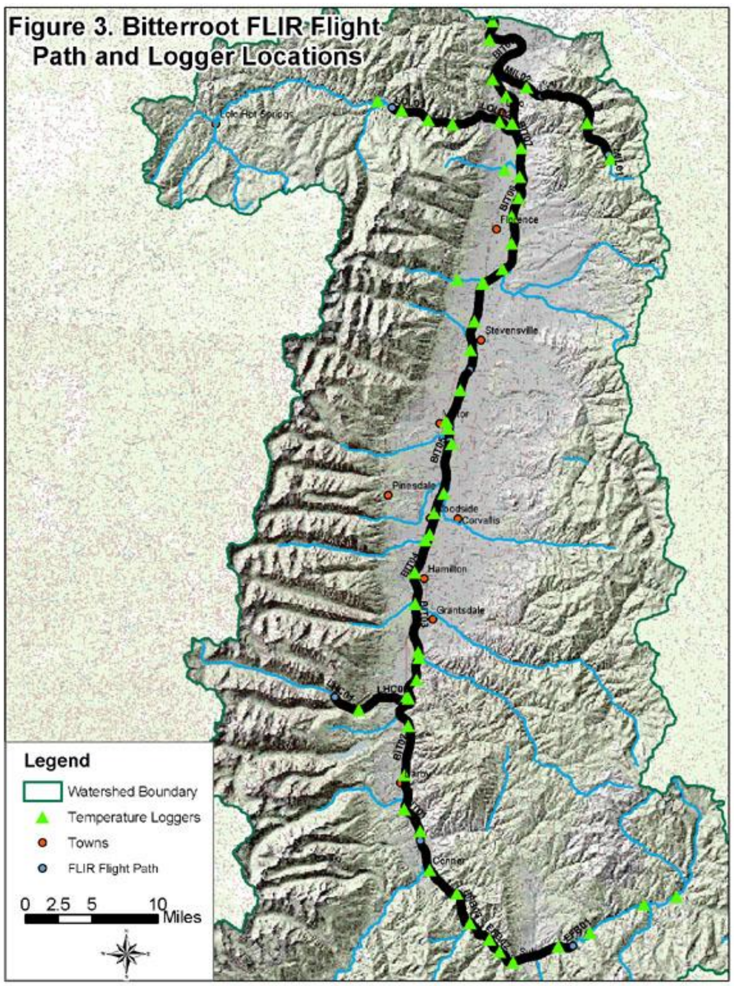


**Figure 5. Bitterroot River FLIR path and temperature logger locations**

The in-stream sensors were used to ground truth the radiant temperatures measured by the FLIR sensors. Temperature logger locations are given in Table 3.

**Table 3. Temperature logger locations**

| **Stream** | **DEQ Site ID** | **Serial #** | **Reach/Site Description** |
|---|---|---|---|
| | BCK1 | 530231 | BIT04 – RM 53.4 |
| | BLOD2 | 530243 | BIT04 – RM 50.9 |
| | BLOD3 | 530244 | BIT04 – RM 48.9 |
| | CLG2 | 530258 | BIT06 – RM 17.7 |
| | CLG3 | 530257 | BIT07 – RM 14.9 |
| | CLG4 | 530210 | BIT07 – RM 12.8 |
| | CLG5 | 530211 | BIT07 – RM 10.3 |
| | CLG6 | 530259 | BIT07 – RM 8.6 |
| | COMO 1 | 530215 | BIT03 – RM 67.6 |
| | COMO 2 | 530209 | BIT03 – RM 65.8 |
| | COMO 3 | 530212 | BIT03 – RM 63.3 |
| | COMO 4 | 530208 | BIT03 – RM 59.1 |
| | HAN1 | 530218 | BIT01 – RM 80.6 |
| | HAN3 | 530207 | BIT02 – RM 75.4 |
| | HAN4 | 530219 | BIT02 – RM 71.1 |
| | KEL1 | 530240 | BIT08 – RM 0.1 |
| | STEVI2 | 530247 | BIT06 – RM 29.1 |
| | STEVI3 | 530248 | BIT06 – RM 27.2 |
| | STEVI5 | 530250 | BIT06 – RM 21.7 |
| | VXING1 | 530251 | BIT05 – RM 42.0 |
| | VXING2 | 530253 | BIT05 – RM 39.0 |
| Bitterroot | WTP1 | 530230 | BIT04 – RM 56.2 |
| Blodgett | BLOD1B | 530242 | BIT04 (Blodgett Creek mouth) RM 52.8 |
| | EFK10 | 530228 | EFB03 – RM 1.3 |
| | EFK4 | 530225 | EFB01 – RM 17.0 |
| | EFK5 | 530222 | EFB02 – RM 12.9 |
| | EFK6 | 530220 | EFB02 – RM 11.3 |
| | EFK7 | 530223 | EFB02 – RM 9.9 |
| | EFK8 | 530221 | EFB03 – RM 7.4 |
| East Fork | EFK9 | 530227 | EFB03 – RM 4.3 |
| Lost Horse | LOST HORSE 1 | 530213 | LHC02 – RM 0.1 |
| Creek | LST1 | 530234 | LHC02 – RM 4.8 |
| Miller | Mil1 | 530236 | MIL02 – RM 3.6 |
| Creek | Mil3 | 530238 | MIL01 – RM 10.2 |
| | NA | 578042 | At Mormon Creek bridge – RM 5.6 |
| | NA | 578043 | At Hwy 93 bridge – RM 1.4 |
| | NA | 578044 | Below South Fork – RM 10.1 |
| Lolo Creek | NA | 578045 | At TD Antiques – RM 7.8 |

*Data Processing*

FLIR Processing

FLIR images were analyzed to extract temperature data from the center portion of the images. The final result is an ArcView point shapefile with field categories including river mile, time and temperature.

Approximately 1 out of every 15 frames (1 frame every two seconds) was sampled by averaging the temperatures in the center of the river (5). At times the area sampled was along a line, while at other times points sampled were within a circle. When the stream was very small a point was used.

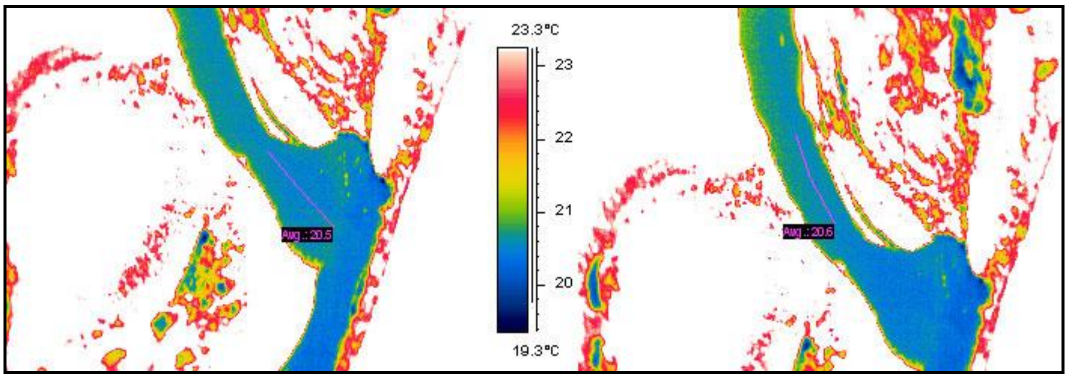


**Figure 5. Temperature sampling method. The image on the right was captured two seconds after the image on the left as the helicopter was moving upstream. Temperature data for each image is averaged along the magenta line in the center of each image.**

Tabular data from the FLIR image analysis was utilized to create an ArcView GIS shapefile.

Throughout this report, FLIR images are included to illustrate certain features. The temperature scales accompanying these images vary from image to image. This is to emphasize, with best contrast possible, the feature that is being discussed.

CIR Processing

CIR processing consisted of sorting all images into subfolders by river name and applying a universal histogram stretch to give the images a consistent contrast, brightness, and color balance.

Using ERDAS imagine software, the CIR images were first geo-referenced and then stitched together to form a mosaic. The images for the mosaic were sub sampled to 2-meter pixel resolution to reduce file size. The image mosaics comprise approximately 5 river miles each. A GIS shapefile was included to show the location of the georeferenced higher resolution individual CIRs as well.

Temperature Data Processing

Temperature loggers were downloaded by MDEQ. Temperature logger data was analyzed using an Excel macro (Tempture), which summarizes temperature metrics pertinent to coldwater fisheries. Raw temperature data and summary temperature metrics were provided by DEQ to Watershed Consulting for FLIR calibration and data analysis.

*Thermal Accuracy*

Temperatures from the in-stream temperature loggers were compared to radiant temperatures from the FLIR imagery for each survey (Table 4). The data were assessed at the time the flight was taken and the imagery acquired.

**Table 4. Comparison of logger temperatures with radiant temperatures.**

| Site ID | River Mile | Logger Temp PM | FLIR Temp PM | Difference PM | Logger Temp PM | FLIR Temp PM | Difference AM |
|---|---|---|---|---|---|---|---|
| | 0.1 | 20.7 | 21.0 | -0.3 | 17.9 | 17.9 | 0.0 |
| | 8.6 | 20.9 | 21.1 | -0.2 | 18.1 | 17.7 | 0.4 |
| | 10.3 | 20.7 | 21.1 | -0.4 | 18.1 | 17.8 | 0.3 |
| | 12.8 | 21.2 | 21.0 | 0.2 | 17.7 | 17.7 | 0.0 |
| | 14.9 | 20.4 | 21.0 | -0.6 | 18.1 | 17.8 | 0.3 |
| | 17.7 | 20.8 | 20.9 | -0.1 | 18.0 | 17.9 | 0.1 |
| | 21.7 | 20.9 | 20.7 | 0.2 | 17.6 | 18.1 | -0.5 |
| | 27.2 | 20.2 | 20.1 | 0.1 | 17.5 | 17.6 | -0.1 |
| | 29.1 | 20.1 | 20.4 | -0.3 | 17.1 | 17.5 | -0.4 |
| | 39 | 20.2 | 20.1 | 0.1 | 15.1 | 17.6 | -2.5 |
| | 42 | 20.2 | 20.7 | -0.5 | 16.8 | 17.0 | -0.2 |
| | 48.9 | 20.7 | 21.1 | -0.4 | 16.7 | 16.7 | 0.0 |
| | 50.9 | 19.9 | 21.2 | -1.3 | 16.6 | 16.6 | 0.0 |
| | 52.8 | 19.8 | 20.1 | -0.3 | 16.3 | 16.1 | 0.2 |
| | 53.4 | 19.6 | 20.0 | -0.4 | 15.8 | 16.0 | -0.2 |
| | 56.2 | 19.3 | 19.7 | -0.4 | 15.4 | NA | NA |
| | 59.1 | 19.4 | 19.2 | 0.2 | 15.6 | NA | NA |
| | 63.3 | 18.7 | 18.6 | 0.1 | 15.6 | NA | NA |
| | 65.8 | 19.2 | 19.2 | 0.0 | 14.6 | NA | NA |
| | 67.6 | 18.2 | 18.1 | 0.1 | 15.4 | NA | NA |
| | 71.1 | 17.8 | 17.9 | -0.1 | 15.2 | NA | NA |
| | 75.4 | 17.2 | 17.0 | 0.2 | 14.8 | 14.4 | 0.4 |
| Bitterroot | 80.6 | 16.2 | 16.4 | -0.2 | 14.1 | 13.4 | 0.7 |
| | 1.3 | 17.8 | 18.4 | -0.6 | 15.2 | 14.9 | 0.3 |
| | 4.3 | 17.5 | 18.3 | -0.8 | 14.7 | 14.5 | 0.2 |
| | 7.4 | 17.5 | 18.0 | -0.5 | 14.3 | 13.4 | 0.9 |
| | 9.9 | 16.9 | 17.4 | -0.5 | 13.7 | 12.9 | 0.8 |
| | 11.3 | 16.7 | 18.4 | -1.7 | 13.7 | 12.4 | 1.3 |
| | 12.9 | 16.5 | 17.1 | -0.6 | 14.1 | 12.4 | 1.7 |
| East Fork | 17 | 16.3 | 16.7 | -0.4 | 13.6 | 12.1 | 1.5 |
| Lost | 0.1 | 19.3 | 19.6 | -0.3 | 16.5 | 16.4 | 0.1 |
| Horse | 4.8 | 17.5 | 17.4 | 0.1 | 13.2 | 14.7 | -1.5 |
| | 3.6 | 21.8 | 22.2 | -0.4 | 13.5 | 13.9 | -0.4 |
| Miller | 10.2 | 19.0 | 18.9 | 0.1 | 9.9 | 9.5 | 0.4 |
| | 1.4 | 19.7 | 20.8 | -1.1 | 15.5 | 15.4 | 0.1 |
| | 5.6 | 19.8 | 21.2 | -1.4 | 14.5 | 14.4 | 0.1 |
| | 7.8 | 19.8 | 21.1 | -1.3 | 14.3 | 14.1 | 0.2 |
| Lolo | 10.1 | 19.5 | 20.6 | -1.1 | 14.1 | 13.7 | 0.4 |

The differences ranged from 2.5°C to 0.0°C. The average difference of 0.5°C for all the points is consistent with thermal infrared surveys conducted on other streams since 1994 (Torgersen et.al 2001).

GIS Processing

ArcView GIS is used to present the data in a meaningful and organized format for viewing, analyzing and sharing. Shapefiles were created to show the location of the CIR and FLIR images and the instream temperature loggers.

ArcGIS 8.3 was used to create shapefiles to identify and locate side-channels, oxbows, cold-water refugia, impoundments, tributary inflows, irrigation returns, and diversions. Digitizing occurred with the aid of the FLIR images, CIR images and DOQs to accurately locate features. The Bitterroot River is characterized through much of its length by a braided channel with a number of meander bends. Because of the large number of side channels on the Bitterroot and its tributaries, only those features that show a clear temperature difference from the main stem (in either the AM or the PM) in the FLIR images were digitized. Features were identified as a side channel if they appeared to originate from and connect to the river. Side channels do not necessarily have surface flow for their entire length, but are connected to the river on at least one end as surface water. There is a column included in the attribute table of the side channel shapefile that indicates whether or not there was surface water connectivity at the time of the flight.

Because of the braided nature of the Bitterroot River, the FLIR imagery was occasionally unable to capture all of the channels within the view of the camera lens. In these instances, only those channels which are included in the FLIR imagery are included in the analysis and digitizing.

Flights were conducted in the morning and the evening to compare temperatures throughout the day. (The image quality for Miller Creek in the morning was poor and no temperature differences were seen). In general the digitized features show greater temperature fluctuation throughout the day than the main stem. Coldwater refugia, as used in this analysis, indicates a noticeable change in temperature in the stream. It is not necessarily a 2°C difference.

## Results

*Longitudinal Temperature Profile*

The FLIR temperatures for the Bitterroot River were plotted versus the corresponding river mile (Figure 6). This figure shows the temperatures during the evening flight. The plot also contains temperatures of 16 tributaries. The tributary temperatures are from FLIR temperatures at the downstream end of each named tributary (just above confluence with the Ruby). There were a few tributaries for which FLIR temperatures could not be clearly determined, which are not included in Figure 4. The downstream end of the study segment (river mile 0) is on the left side of the graph, therefore trends downstream of a tributary are to the left of the data point for that tributary.

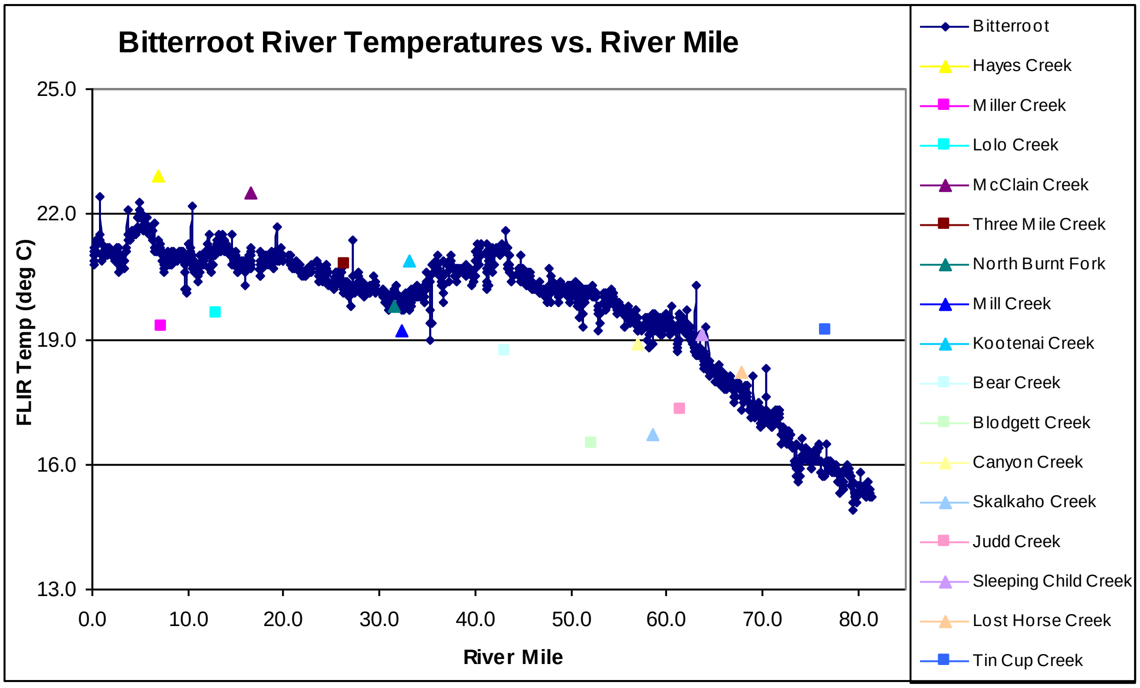


**Figure 6. Channel temperatures plotted by river mile for Bitterroot River**

A map illustrating temperature trends along the lower Bitterroot River and major tributaries is included in Appendix A (Maps 1-3). This map is based on GIS data derived from FLIR temperature data, as described above under FLIR Processing.

*Results by Stream Reach*

The following sections are organized by stream divided into reaches. The reaches were delineated based on major tributaries or diversions. The first figure for each stream is a longitudinal profile. Next is a table for each stream reach illustrating the features identified in the FLIR coverage on the Bitterroot. Also included is the average temperature of each of the features. This is not a comprehensive list of features due to the fact that some of the features were located outside the area covered by the FLIR flight, i.e. some areas of the river and adjacent riparian area were not captured in the flight.

Number and location of irrigation diversions are included for each reach, but there is no way to quantify the irrigation withdrawals for each diversion at the time of the FLIR flight. Some diversions were dry at the time of the flight, but may be used at other times.
Thermal inputs to a stream are cumulative and often show trends over a watershed scale. The results by reach discuss sources of higher and lower temperature water that are specific to that reach, but are not indicative of temperature trends at the watershed scale.

**<u>Bitterroot</u>**
Temperatures on the main Bitterroot ranged from a maximum of 22.4°C and a minimum of 14.9°C on the afternoon of August 2, 2004. Average afternoon temperature was 19.7°C. During the morning flight, the maximum temperature was 19.0°C and the minimum temperature was 12.0°C. The average morning temperature was 16.6°C. In general the temperature trends

were similar at both flight times, with the morning temperatures around 3°C cooler overall (Figure 7, also Map1-3 Appendix A).

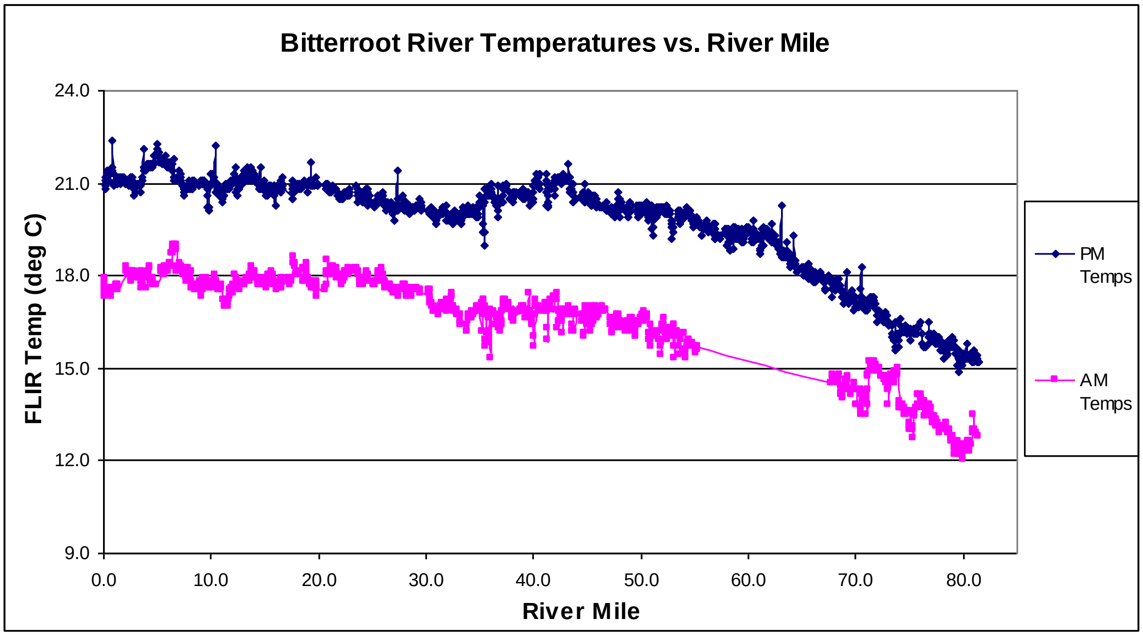


**Figure 7. Afternoon and morning channel temperatures plotted by river mile for Bitterroot River**

Because of the similarities in temperature trends in the Bitterroot, only the afternoon flight will be discussed in detail for the remainder of this section. The exception to this is where temperatures dramatically differed from the trend of being approximately 3°C cooler in the morning.

Overall the Bitterroot River showed a warming trend from the upstream end to the mouth in both the morning and afternoon flights. The Bitterroot River was broken into 8 reaches determined by tributary locations and irrigation returns or diversions (length was also taken into account).

Bitterroot 01 (River Mile 76.6-81.5)

Total length for Bitterroot 01 was approximately 4.9 miles. Bitterroot 01 had an afternoon temperature of 15.2°C at the upstream end (river mile 81.5) and 15.8°C at the downstream end (river mile 76.6) (Appendix A, Map 1). While an overall warming trend was observed (the stream warmed 0.6°C over 4.9 miles), the longitudinal profile shows locally cooler areas within this reach. The stream temperature fluctuated between 15.2°C and 15.6°C for the first mile and a half. The coolest water temperature (14.9°C) recorded during the Bitterroot River survey was observed on this reach at river mile 79.5. The imagery did not reveal any significant surface water inputs at this point. There were two side channels seen in the 79.5-79.6 area, however, neither side channel showed cold temperatures relative to the stream. Stream temperatures fluctuated and slowly rose from mile 79.5 to the end of the reach. The high temperature for the reach of 16.5°C was seen at river mile 76.7. Side channels were the only features identified on Bitterroot 01 (Table 5 and Appendix A, Map 4).

**Table 5. Bitterroot 01 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Side Channel | 81.2 | 14.4 | 15.3 | -0.9 | NA | 13.0 | NA |
| Side Channel | 80.9 | 18.3 | 15.3 | 3.0 | 10.6 | 13.0 | -2.4 |
| Side Channel | 79.6 | 17.4 | 15.3 | 2.1 | 12.5 | 12.3 | 0.2 |
| Side Channel | 79.5 | 17.2 | 15.3 | 1.9 | 11.8 | 12.6 | -0.8 |
| Side Channel | 79.1 | 17.0 | 14.9 | 3.7 | 12.8 | 12.7 | 0.1 |
| Side Channel | 78.9 | 16.1 | 15.8 | 0.3 | 12.0 | 12.8 | -0.8 |
| Side Channel | 78.0 | 16.2 | 15.9 | 0.3 | NA | 13.0 | NA |

In general the temperatures on the side channels on this reach of the Bitterroot were warmer than the main stem in the afternoon. The average side channel temperature was 16.7°C during the afternoon flight, while the average stream temperature on this reach was 15.6°C during the same time period. The only exception to this trend was the side channel at river mile 81.2 which was almost one degree Celsius cooler than the Bitterroot River at the same point.

<u>Bitterroot 02 (River Mile 67.8-76.5)</u>

Total length of reach Bitterroot 02 was approximately 8.7 miles. The upstream end of this reach is near the town of Darby, Montana. The temperature at the upstream end of this reach on the afternoon of August 2, 2004 was 15.7°C, while the temperature at the downstream end was 17.8°C (Appendix A, Map 1). This was an overall increase in stream temperature of 2.1°C from the upstream end to the downstream end of the reach. The high temperature in this reach was 18.3°C at river mile 70.5. Neither the CIR nor FLIR imagery revealed any significant surface water inputs directly at this point. However, an impoundment just upstream of this point had a temperature of 20.1°C. This feature may contribute warm water to the stream. The low temperature was 15.6°C at river mile 73.7. The imagery did not reveal any significant surface water inputs at this point. There were tributaries, impoundments and a side channel identified on this reach (Table 6 and Appendix A, Map 4).

**Table 6. Bitterroot 02 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Tin Cup Creek | 76.6 | 19.2 | 15.9 | 3.3 | NA | 13.6 | NA |
| Impoundment | 75.5 | 21.6 | 16.2 | 5.4 | NA | 13.5 | NA |
| Side Channel | 74.1 | 19.7 | 16.3 | 3.4 | NA | 13.8 | NA |
| Impoundment | 70.8 | 20.1 | 17.2 | 2.9 | NA | 13.9 | NA |
| Lick Creek | 69.6 | NA | 17.3 | NA | NA | 14.1 | NA |

There were no morning FLIR images, and thus no feature temperature information available on this and the subsequent reaches due to technical difficulties during the flight. All of the features identified on this reach of the Bitterroot on the afternoon of August 2, 2004 were warmer than the main stem. The two impoundments had an average temperature that was 4.2°C warmer than the stream temperature adjacent to them. Both the side channel and Tin Cup Creek were over 3°C warmer than the Bitterroot. These warm features likely contribute to the temperature increase seen on this reach.

Bitterroot 03 (River Mile 58.7-67.7)

Total length of Bitterroot 03 was approximately 9.0 miles. The temperature was 17.9°C at the upstream end and 19.5°C at the downstream end (Appendix A, Map 2). The stream temperature increased by 1.6°C in nine miles on this reach. The high temperature of 20.3°C was seen at mile 63.1. Table 7 shows the features identified on Bitterroot 03 (Appendix A, Map 5).

**Table 7. Bitterroot 03 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Lost Horse Creek | 67.8 | 18.2 | 17.5 | 0.7 | NA | NA | NA |
| Side Channel | 67.5 | 19.2 | 17.8 | 1.4 | NA | NA | NA |
| Side Channel | 64.5 | 20.0 | 18.3 | 1.7 | NA | NA | NA |
| Sleeping Child Creek | 63.7 | 19.1 | 18.7 | 0.4 | NA | NA | NA |
| Side Channel | 61.7 | 16.4 | 19.4 | -3.0 | NA | NA | NA |
| Judd Creek | 61.6 | 17.3 | 19.3 | -2.0 | NA | NA | NA |
| Side Channel | 60.2 | 18.1 | 19.4 | -1.3 | NA | NA | NA |
| Impoundment | 60.0 | 19.3 | 19.5 | -0.2 | NA | NA | NA |
| Roaring Lion Creek | 58.8 | NA | 19.4 | NA | NA | NA | NA |

The features identified on the upstream end of this reach were warmer than the main stem, while the downstream features were cooler than the Bitterroot on this reach. It is interesting to note that at the same area the features alternate from being warmer to being cooler, the temperature trend on the Bitterroot also changes. As the Bitterroot thermograph shows, the steady increase in temperature seen from the upstream end of the Bitterroot down to this point levels off near river mile 62 (Figure 7). Just downstream of this point a cold side channel and tributary enter the Bitterroot (Figure 8).

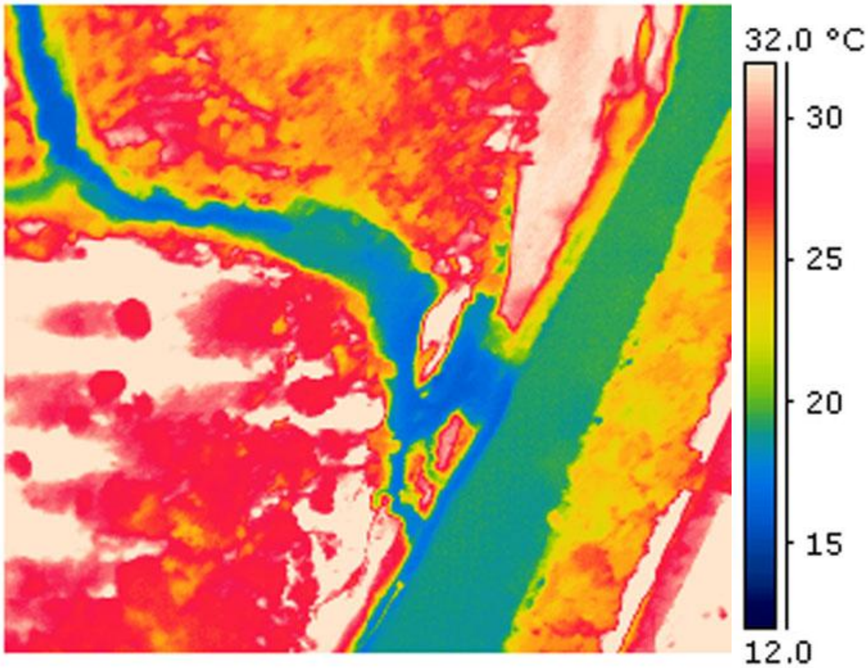


**Figure 8. Cold side channel entering the Bitterroot at mile61.7.**

The stream temperature is 19.7°C just upstream of this feature. This cool side channel and Judd Creek then enter and the Bitterroot stream temperature drops to 18.7°C. It is likely that the water from Judd Creek and a side channel at river mile 61.7 are the source of thermal cooling seen on the longitudinal profile at this point on the Bitterroot.

Bitterroot 04 (River Mile 48.9-58.6)

Total length of Bitterroot 04 was approximately 9.7 miles. The temperature at the upstream end was 19.4°C and 20.2°C at the downstream end (Appendix A, Map 2). This is a relatively small temperature increase of 0.8°C over ten miles. The change was stable with few local fluctuations in temperature. The many features identified in this reach were both warmer and cooler than the Bitterroot (Table 8 and Appendix A, Map 5).

**Table 8. Bitterroot 04 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Skalkaho Creek | 58.6 | 16.7 | 19.5 | -2.8 | NA | NA | NA |
| Side Channel | 58.1 | 17.1 | 19.2 | -2.1 | NA | NA | NA |
| Canyon Creek | 56.8 | 18.9 | 19.6 | -0.7 | NA | NA | NA |
| Impoundment | 55.0 | NA | 19.8 | NA | 17.5 | 15.7 | 1.7 |
| Side Channel | 54.8 | 21.7 | 19.9 | 1.8 | 12.0 | 15.7 | -3.7 |
| Side Channel | 54.6 | 23.0 | 19.9 | 3.1 | 16.6 | 15.7 | 0.9 |
| Side Channel | 54.3 | 22.9 | 20.1 | 2.8 | 14.4 | 15.6 | -2.8 |
| Side Channel | 54.1 | 15.7 | 19.9 | -4.2 | NA | 15.8 | NA |
| Blodgett Creek | 52.2 | 16.5 | 20.1 | -3.6 | 10.5 | 16.5 | -6.0 |
| Side Channel | 52.0 | 19.1 | 20.1 | -1.0 | 15.6 | 16.0 | -0.4 |
| Side Channel | 51.9 | 21.5 | 20.1 | 0.4 | 13.9 | 15.5 | -1.6 |
| Impoundment | 50.8 | 22.8 | 20.2 | 2.6 | NA | 15.9 | NA |
| Side Channel | 50.5 | 20.5 | 20.1 | 0.4 | 14.0 | 16.6 | -2.6 |

Blodgett Creek was the most significant contributor of cold water on this reach with temperatures 3.6°C cooler than the Bitterroot in the evening and 6°C cooler in the morning. Skalkaho and Canyon Creek also contributed cooler water into the Bitterroot. At river mile 56.2 the river flows past the sewage treatment ponds of the town of Hamilton. The stream temperature shows a slight increase in temperature (0.3°C) just after the ponds. Side channels on Bitterroot 04 were both warmer and cooler than the main channel (Figures 9 and 10).

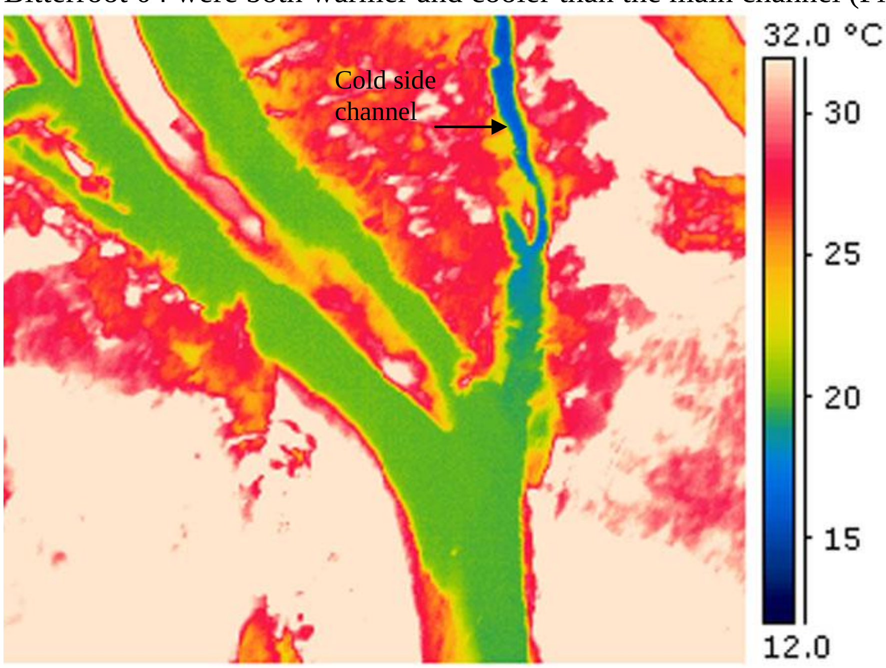


**Figure 9. Cold water side channel at river mile 54.1.**

This side channel was 4.2°C cooler than the Bitterroot; however, it did not alter the overall stream temperature.

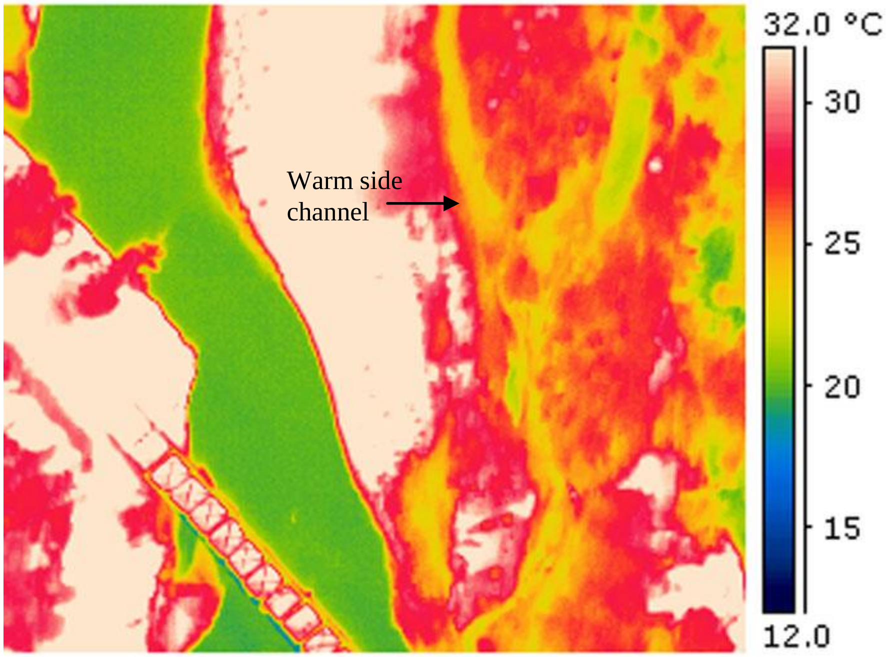


**Figure 10. Warm water side channel at river mile 54.6.**

This feature did not increase the overall temperature on the Bitterroot, thought the temperature of the side channel was 3.1°C warmer than the main channel. The blend of warm and cool water influences on this reach are probable contributors to overall temperatures that were relatively steady.

Bitterroot 05 (River Mile 33.1-48.8)

Total stream length of Bitterroot 05 was approximately 15.7 miles. The temperature at the upstream end of this reach was 19.9°C (Appendix A, Map 2). The downstream temperature was 20.0°C. Overall this is an insignificant increase over 15.6 miles, however, there was a large amount local thermal spatial variability within this reach. From the upstream end of this reach, the temperature increases to a high of 21.6°C at river mile 43.2. The Bitterroot then passes through the town of Victor, Montana and shows a cooling trend between river miles 43-33. The low temperature on the reach was 19.0°C at river mile 35.4. Around river mile 34 the Bitterroot passes the sewage disposal ponds for the town of Stevensville with no impact on stream temperatures. The features identified on Bitterroot 05 are primarily cooler then the main stem (Table 9 and Appendix A, Map 6).

**Table 9. Bitterroot 05 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Side Channel | 46.7 | 16.5 | 20.2 | -3.7 | 10.5 | 16.9 | -6.4 |
| Side Channel | 46.5 | 21.6 | 20.2 | 1.4 | 15.6 | 16.8 | -1.2 |
| Side Channel | 45.3 | 18.5 | 20.5 | -2.0 | 10.5 | 16.8 | -6.3 |
| Side Channel | 44.8 | 18.1 | 20.6 | -2.5 | NA | 16.5 | NA |
| Bear Creek | 43.2 | 18.7 | 21.3 | -2.6 | 12.0 | 16.8 | -4.8 |
| Tributary | 42.7 | 20.1 | 21.1 | -1.0 | 10.9 | 16.3 | -5.4 |
| Tributary | 42.3 | 17.9 | 21.1 | -3.2 | NA | 16.3 | NA |
| Side Channel | 41.7 | 23.1 | 20.9 | 2.2 | 15.9 | 17.0 | -1.1 |
| Side Channel | 40.5 | 19.9 | 21.0 | -1.1 | 15.2 | 16.8 | -1.6 |
| Side Channel | 39.7 | 17.6 | 20.4 | -2.8 | 13.9 | 17.0 | -3.1 |
| Side Channel | 38.0 | 17.6 | 20.6 | -3.0 | 14.0 | 16.8 | -2.8 |
| Side Channel | 36.5 | 19.6 | 20.3 | -0.7 | 11.5 | 16.7 | -5.2 |
| Willoughby Creek | 35.8 | NA | 20.7 | NA | 11.5 | 15.8 | -4.3 |
| Cold Water Refuge | 35.5 | 18.2 | 20.4 | -2.2 | 10.0 | 17.2 | -7.2 |
| Side Channel | 35.4 | 19.8 | 20.0 | -0.2 | 12.9 | 16.9 | -4.0 |
| Side Channel | 34.8 | 18.7 | 20.1 | -1.4 | 11.1 | 16.9 | -5.8 |
| Return | 34.4 | 16.7 | 20.0 | -3.3 | 9.8 | 16.8 | 7.0 |
| Side Channel | 33.8 | 17.4 | 20.0 | -2.6 | NA | 16.2 | NA |
| Side Channel | 33.2 | 17.7 | 20.0 | -2.3 | 10.8 | 16.7 | -5.9 |

All of the tributaries on this reach were cooler than the Bitterroot. This coldest spot identified, according to FLIR imagery, was located just downstream of the inflow of Willoughby Creek and a cold water refugia at river mile 35.5. Although Willoughby Creek was outside the scope of the FLIR imagery it is likely the source of the cool water seen in Figure 11.

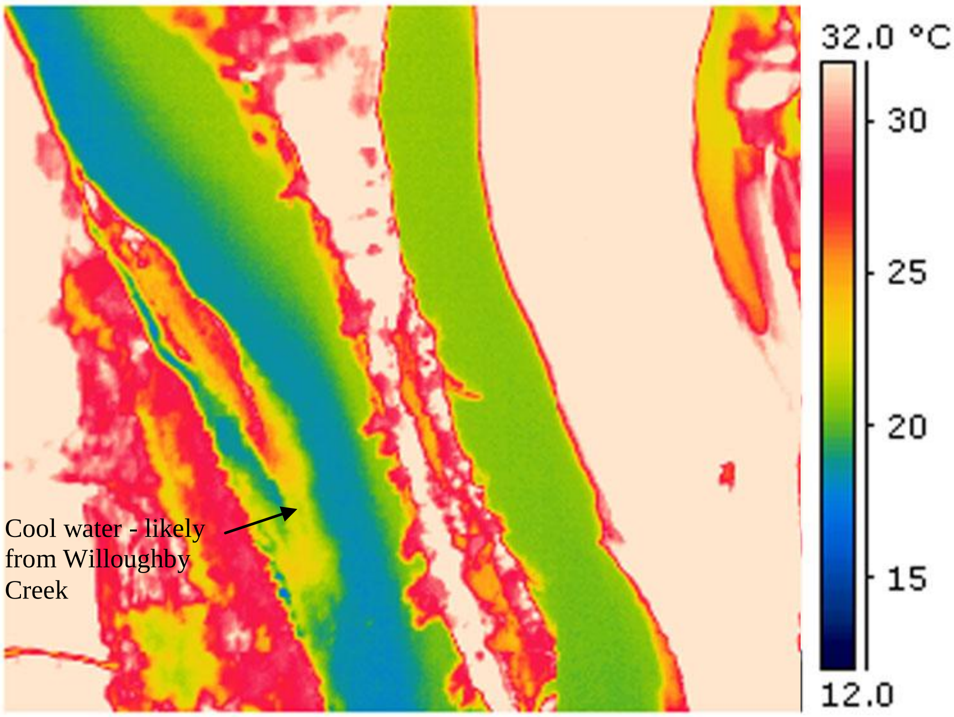


**Figure 11. Cool water at river mile 35.5.**

Overall the many cool inflows likely contribute to the cooling trend seen on almost ten miles of this reach. This cooling trend was unique on the Bitterroot the day the images were collected.

Bitterroot 06 (River Mile 16.5-33.0)

Total length of Bitterroot 06 was approximately 16.5 miles. The temperature at the upstream end of this reach was 19.8°C, while the downstream temperature was 20.7°C (Appendix A, Map 3). The overall increase of just under one degree Celsius accurately reflects the gradual temperature increase seen on this section of the Bitterroot longitudinal profile (Figure 7). The features identified on this reach showed varied temperatures relative to the Bitterroot (Table 10 and Appendix A, Map 6).

**Table 10. Bitterroot 06 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Kootenai Creek | 33.1 | 20.9 | 20.0 | 0.9 | 13.0 | 16.7 | -3.7 |
| Mill Creek | 32.4 | 19.2 | 19.8 | -0.6 | 15.0 | 17.3 | -2.3 |
| North Burnt Fork | 31.5 | 19.8 | 20.0 | -0.2 | 13.6 | 17.0 | -3.4 |
| Return | 30.5 | 23.2 | 20.0 | 3.2 | 15.6 | 17.1 | -1.5 |
| Side Channel | 28.9 | 26.3 | 20.2 | 6.1 | 14.6 | 17.6 | 3.0 |
| Bass Creek | 28.9 | NA | 20.1 | NA | 14.9 | 17.6 | -5.6 |
| Side Channel | 28.3 | 26.1 | 20.2 | 5.9 | 14.5 | 17.4 | -2.9 |
| Impoundment | 28.2 | 26.1 | 20.2 | 5.9 | 15.5 | 17.5 | -2.0 |
| Side Channel | 28.1 | 22.1 | 20.1 | 2.0 | 16.9 | 17.7 | -0.8 |
| Side Channel | 27.4 | 19.7 | 20.2 | -0.5 | 15.2 | 17.5 | -2.3 |
| Side Channel | 27.3 | 25.2 | 20.2 | 5.0 | 17.3 | 17.5 | -0.2 |
| Three Mile Creek | 26.4 | 20.8 | 20.2 | 0.6 | 15.2 | 17.6 | -2.4 |
| Side Channel | 26.3 | 23.9 | 20.2 | 3.7 | 16.6 | 17.7 | -1.1 |
| Side Channel | 25.4 | 17.1 | 20.4 | -3.3 | 11.5 | 17.8 | -6.3 |
| Side Channel | 25.4 | 22.8 | 20.5 | 2.3 | 16.3 | 17.8 | -1.5 |
| Side Channel | 24.5 | 19.7 | 20.6 | -0.9 | NA | 18.0 | NA |
| Cold Water Refuge | 24.3 | 18.5 | 20.6 | -2.1 | 14.1 | 17.8 | -3.7 |
| Cold Water Refuge | 22.8 | 16.8 | 20.6 | -3.8 | 14.9 | 18.1 | -3.2 |
| Side Channel | 21.4 | 22.5 | 20.8 | 1.7 | 15.7 | 18.3 | -2.6 |
| Side Channel | 19.0 | 16.1 | 21.0 | -4.9 | 10.0 | 18.1 | -8.1 |
| Side Channel | 16.7 | 18.2 | 20.1 | -1.9 | 13.4 | 17.7 | -4.3 |

On other reaches of the Bitterroot, tributaries have been a source of thermal cooling. However, on this reach the tributaries visible in the afternoon FLIR imagery were on average 0.2°C warmer than the main stem. Bass Creek was not visible in the afternoon FLIR imagery, however there was no noticeable temperature change downstream of the inflow and logger data does not suggest significantly cooler water on Bass Creek. There were 12 side channels identified on Bitterroot 06. They were on average 1.3°C warmer than the Bitterroot. Figure 12 illustrates one of the warm side channels.

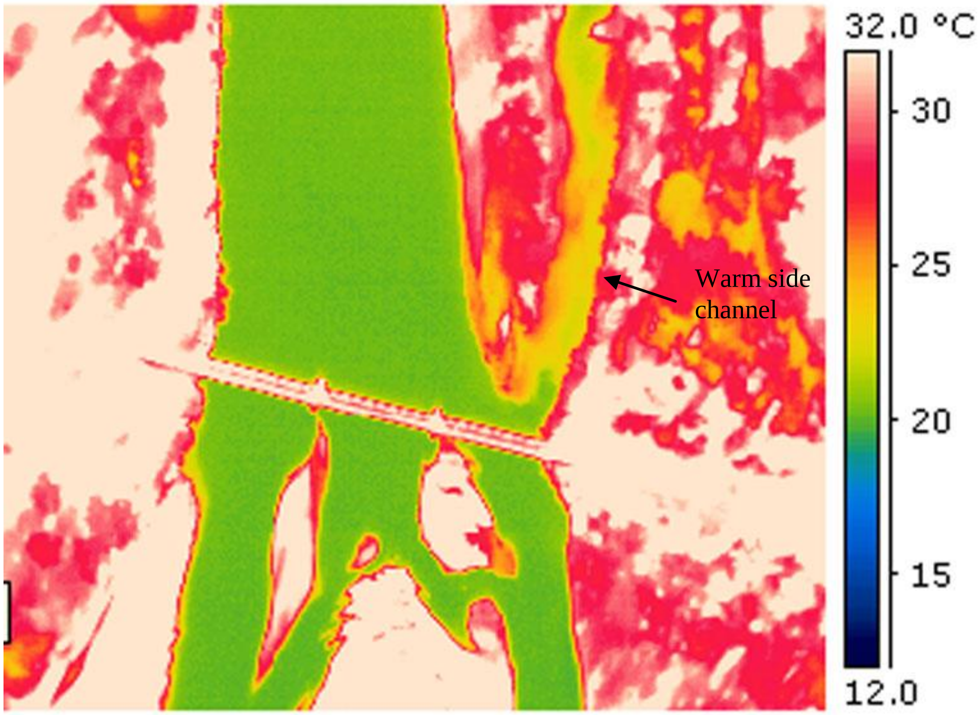


**Figure 12. Warm side channel at river mile 28.3.**

This side channel, although almost 6°C warmer than the main stem, did not have a visible impact on the Bitterroot temperature. Looking at the thermograph, a one degree temperature spike is visible at mile 27.3. There is a side channel at the same location that was 5.0°C warmer than the Bitterroot. The side channel does not appear to have connectivity at the upstream end. Consequently, the source of the dramatic, yet brief, warming of the Bitterroot it is not exactly clear from the imagery. Overall the combination of both warm and cool features result in the relatively stable stream temperatures on Bitterroot 06.

Bitterroot 07 (River Mile 7.4-16.4)

Total length of Bitterroot 07 was approximately 9.0 miles. The upstream temperature was 20.7°C, while the downstream temperature was 20.9°C (Appendix A, Map 3). This was an overall temperature increase of only 0.2°C over nine miles; however, there was some local temperature fluctuations within Bitterroot 07. The greatest temperature fluctuation was seen from river mile 10.4 to 9.8 where temperatures ranged from a high of 22.2°C to a low of 20.1°C. The features identified in this area partially explain the temperature fluctuations (Table 11 and Appendix A, Map 7)

**Table 11. Bitterroot 07 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| McClain Creek | 16.5 | 22.5 | 20.8 | 1.7 | 15.7 | 17.7 | -2.0 |
| Side Channel | 15.9 | 18.1 | 20.7 | -2.6 | 9.3 | 17.8 | -8.5 |
| Side Channel | 14.2 | 19.1 | 21.1 | -2.0 | 11.1 | 18.0 | -6.9 |
| Side Channel | 13.4 | 20.2 | 21.3 | -1.1 | 13.1 | 17.8 | -4.7 |
| Lolo Creek | 13.2 | 19.6 | 21.4 | -1.8 | 12.7 | 17.7 | -5.0 |
| Side Channel | 12.5 | 19.3 | 21.0 | -1.7 | 10.9 | 17.8 | -6.9 |
| Side Channel | 12.3 | 22.4 | 21.1 | 1.3 | 15.1 | 18.0 | -2.9 |
| Side Channel | 12.2 | 15.6 | 21.2 | -5.6 | 13.5 | 17.6 | -4.1 |
| Side Channel | 11.6 | 15.5 | 20.8 | -5.3 | 9.3 | 17.1 | -7.8 |
| Cold Water Refuge | 10.9 | 18.9 | 20.6 | -1.7 | 14.1 | 17.5 | -3.4 |
| Side Channel | 10.8 | 22.4 | 20.6 | 1.8 | 16.3 | 17.5 | -1.2 |
| Impoundment | 10.7 | 24.1 | 20.7 | 3.4 | 18.7 | 17.6 | 1.1 |
| Side Channel | 9.8 | 25.9 | 20.9 | 5.0 | 14.8 | 17.8 | -3.0 |
| Side Channel | 9.1 | 24.1 | 21.0 | 3.1 | 16.8 | 17.4 | -0.6 |
| Side Channel | 7.7 | 18.2 | 20.9 | -2.7 | 13.5 | 17.9 | -4.4 |

A warming trend is visible in the longitudinal profile after McClain Creek (with approximately 1.7°C warmer water) enters the Bitterroot (Figure 5). Similarly, Lolo Creek is a source of thermal cooling when it enters the Bitterroot at river mile 13.2. The high temperature at mile 10.4 could be influenced by the warm impoundment and side channels seen just upstream. The temperature drop to 20.1°C at river mile 9.8 is not explained by the imagery, as no surface water inflows were detected that would contribute to the temperature decrease. Although out of range of the FLIR imagery, there are two sloughs (Doyle's and Plummer's) in this area that may also impact Bitterroot temperatures. Overall the features identified on Bitterroot 07 had variable temperatures with warm and cool water influences.

Bitterroot 08 (River Mile 0.0-7.3)

Total length of Bitterroot 08 was approximately 7.3 miles. The upstream temperature was 20.9°C and the temperature at the mouth was 21.0°C (Appendix A, Map 3). This miniscule temperature increase overall does not reflect the local temperature variation seen on this reach. The features located on this reach are identified in Table 12 (Appendix A, Map 7).

**Table 12. Bitterroot 08 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Bitterroot PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Bitterroot AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Miller Creek | 7.3 | 19.3 | 21.0 | -1.7 | 11.5 | 18.3 | -6.8 |
| Side Channel | 7.1 | 24.1 | 21.0 | 3.1 | 17.5 | 18.2 | -0.7 |
| Hayes Creek | 7.0 | 22.9 | 21.2 | 1.7 | 17.3 | 18.3 | -1.0 |
| Diversion | 6.1 | 20.9 | 21.5 | -0.6 | 16.5 | 18.1 | -1.6 |
| Impoundment | 5.6 | 25.7 | 21.8 | 3.9 | 19.2 | 18.1 | 1.1 |
| Side Channel | 5.4 | 23.9 | 21.7 | 2.2 | 18.0 | 18.2 | -0.2 |
| Side Channel | 5.1 | 22.6 | 21.9 | 0.7 | 15.2 | 17.8 | -2.6 |
| Side Channel | 4.1 | 17.4 | 21.5 | -4.1 | 9.4 | 17.9 | -8.5 |
| Cold Water Refuge | 4.0 | 19.1 | 21.5 | -2.4 | 9.4 | 17.6 | -8.2 |
| Impoundment | 3.6 | 22.1 | 21.5 | 0.6 | 18.0 | 18.0 | 0 |
| Side Channel | 3.5 | 19.5 | 21.1 | -1.6 | 9.8 | 17.8 | -8.0 |
| Side Channel | 3.2 | 17.6 | 20.9 | -3.3 | NA | 18.0 | NA |
| Impoundment | 2.7 | 24.5 | 20.8 | 3.7 | 18.6 | 17.8 | 0.8 |
| Return | 2.7 | 24.5 | 21.1 | 3.4 | 18.6 | 17.8 | 0.8 |
| Side Channel | 2.1 | 24.1 | 21.0 | 3.1 | 15.0 | 18.1 | -3.1 |
| Side Channel | 0.8 | 23.6 | 21.4 | 2.2 | 14.9 | 17.5 | -2.6 |

The longitudinal profile shows a warming trend from 7.4 -4.9 where there is a 1.4°C increase in stream temperature.  The temperature then decreases to the reach minimum of 20.7°C at mile 3.0.  There are three side cannels with cooler water in this area.  In addition, the cold water refuge seen in Figures 13 and 14 is located at river mile 4.0.

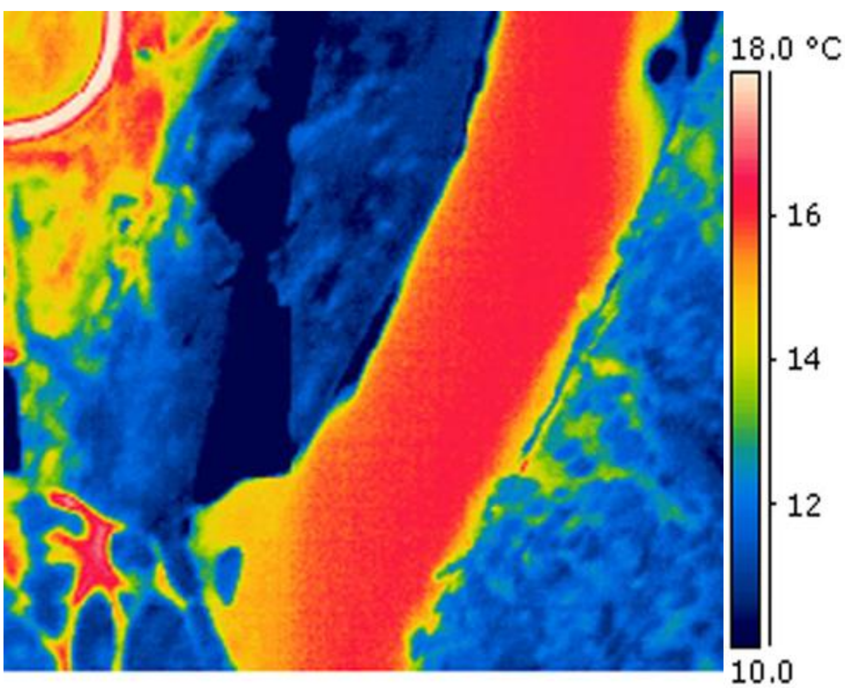

**Figure 13. Morning FLIR image of cold water refugia at river mile 4.0.**

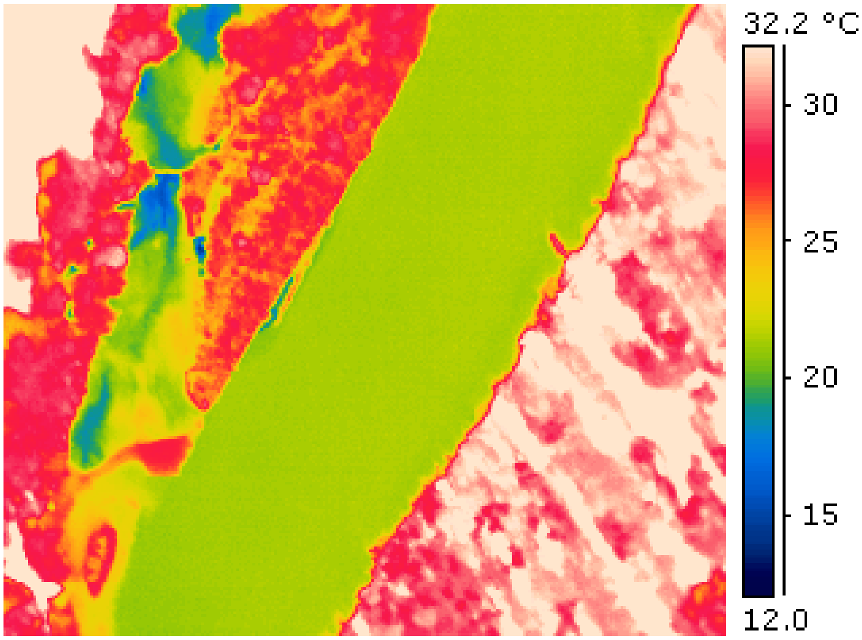


**Figure 14. Afternoon FLIR image of cold water refuge at river mile 4.0.**

The figures above show the same feature in the morning and afternoon to illustrate the differences in temperature variation throughout the day. The warmest temperature (22.4°C) recorded during the Bitterroot River survey was observed in this reach at river mile 0.8.

## Miller Creek

The median water temperatures for each sampled image of Miller Creek were plotted versus river mile (Figure 15). The morning and afternoon temperatures showed the same basic trend, and the morning temperatures were approximately 6°C cooler than the afternoon temperatures. However, there was less variability on the steady warming trend in the morning flight. Furthermore, the drop in temperature seen at the mouth of Miller Creek occurred father upstream in the morning. The afternoon temperatures on Miller Creek will be the primary focus of the following discussion.

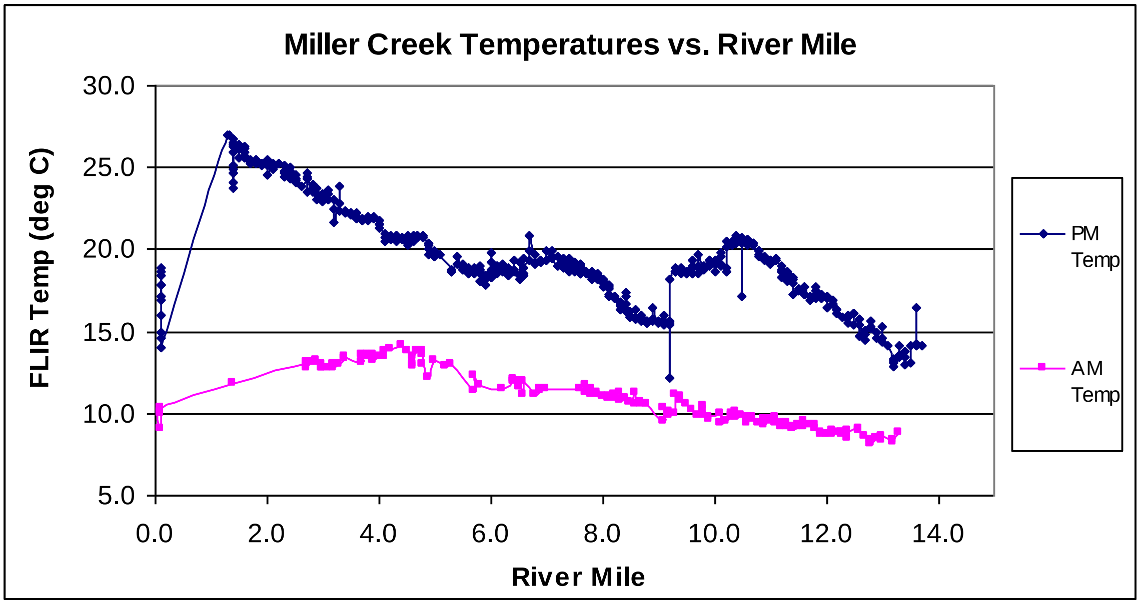


**Figure 15. Afternoon and morning channel temperatures plotted vs river mile for Miller Creek.**

Afternoon temperatures on Miller Creek ranged from 27.0 to 12.2°C (Appendix A, Map 3). This was a large temperature fluctuation (14.8°C) relative to the fluctuations seen on other streams included in this survey. The mean temperature was 19.5°C. Miller Creek showed a basic warming trend from the upstream to the downstream end, however, there was a greater temperature range seen on Miller Creek than on any other stream included in this survey. Miller Creek was broken into two reaches.

Miller Creek 01 (River Mile 8.5-13.7)

The section of Miller Creek 01 covered in this FLIR assessment is approximately 5.2 miles long. The stream temperature at the upstream end was 14.2°C and 16.2°C at the downstream end of this reach. A steady warming trend was observed between river miles 13.7 and 10.5 with temperatures increasing 7.5°C in approximately 3 miles. The irrigation return and two tributaries identified in this section of stream contributed water that was warmer than Miller Creek on this section, and were likely sources of warming (Table 13 and Appendix A, Map 9).

**Table 13. Miller Creek 01 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Miller Creek PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Miller Creek AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Return | 13.3 | 22.8 | 13.1 | 9.7 | NA | 8.8 | NA |
| Diversion | 13.2 | 25.8 | 12.9 | 12.9 | NA | 8.3 | NA |
| Tributary | 12.6 | 22.8 | 14.7 | 8.1 | 6.2 | 9.0 | -2.8 |
| Park Creek | 11.7 | 21.5 | 17.0 | 4.5 | NA | 9.3 | NA |
| Little Park Creek | 9.3 | 12.7 | 18.6 | -5.9 | 5.5 | 11.1 | -5.6 |

The longitudinal profile for Miller Creek reveals some spikes in temperature on this reach (Figure 17). The source of the spikes at river miles 13.6 and 10.5 are not apparent from the imagery. It is interesting that the -3°C spike at mile 10.5 is associated with the change from warming to a cooling trend on Miller Creek. A cooling trend was observed from miles 10.5 to

9.2. Little Park Creek (mile 9.3) contributed water that was almost 6°C cooler than Miller Creek. This inflow resulted in another spike in the temperature profile (from 18.2 to 12.2°C). The temperature increases to 15.4°C at river mile 9.1and is stable to the end of the reach.

Miller Creek 02 (River Mile 0.0-8.4)

This reach of Miller Creek is approximately 8.4 miles long. The temperature at the upstream end (river mile 8.4) of Miller 02 was 16.2°C. Temperature at downstream end (river mile 0.1) was 17.8°C. This was an overall temperature increase on 1.6°C. Overall Miller Creek showed a steady increasing trend on this reach (Figure 10). Miller Creek increased to 27.0°C at mile 1.3. A significant gap in the data occurs in the following segment where the pilot was unable to locate the channel. At this point Miller Creek has a non distinct channel and it was impossible to tell where to take a temperature. Based on CIR and DOQ images, Miller Creek appears to spread out into a marshy area. The final FLIR readings in this reach are significantly cooler. Both the AM and PM flights showed this drop in temperature at the downstream end of Miller Creek. It is likely that there is groundwater influences here contributing cooler water. The features identifies on Miller 01 were both warmer and cooler than the main channel (Figure 14 and Appendix A, Map 9).

**Table 14. Miller Creek 02 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Miller Creek PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Miller Creek AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Bear Run Creek | 8.4 | 16.7 | 16.2 | 0.5 | 7.7 | 10.9 | -3.2 |
| Tributary | 8.0 | 25.7 | 17.8 | 7.9 | NA | 11.0 | NA |
| Side Channel | 3.9 | 23.8 | 22.0 | 3.8 | 11.2 | 13.4 | -2.2 |
| Diversion | 2.7 | 26.9 | 24.2 | 2.7 | NA | 12.9 | NA |
| Impoundment | 0.1 | 17.3 | 18.3 | -1.0 | NA | NA | NA |

The quality of the morning flight FLIR images was poor on Miller Creek. It was almost impossible to differentiate between the channel and surrounding areas, therefore, most of the AM feature temperatures were recorded as “NA”. The tributary seen at river mile 8.0 was 7.9°C warmer that Miller Creek on the afternoon of 8/2/04 (Figure 16). The CIR images suggest that there is some water in this tributary at the time of the flight; however, it is not possible to quantify the amount.

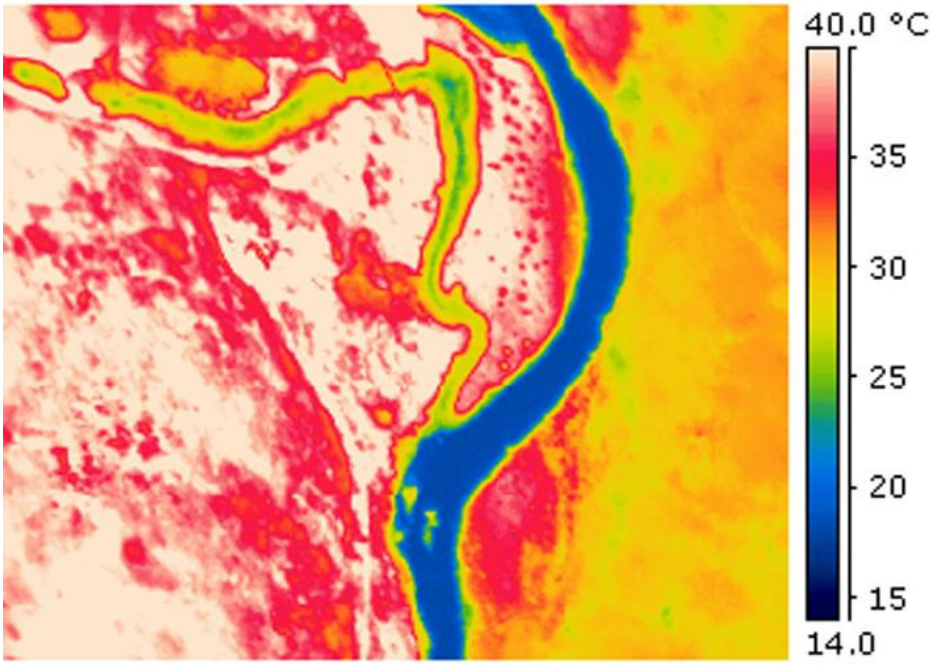


**Figure 16. Warm water tributary on Miler Creek, river mile 8.0.**

This warm feature does not appear to significantly increase the rate of temperature seen on this reach of Miller Creek.

**Lolo Creek**

The median water temperatures for each sampled image of Lolo Creek were plotted versus river mile (Figure 17). The morning and afternoon surveys show similar temperature trends with the morning stream temperatures 6-7°C cooler than the afternoon temperatures. The following discussion will focus primarily on the afternoon FLIR temperatures.

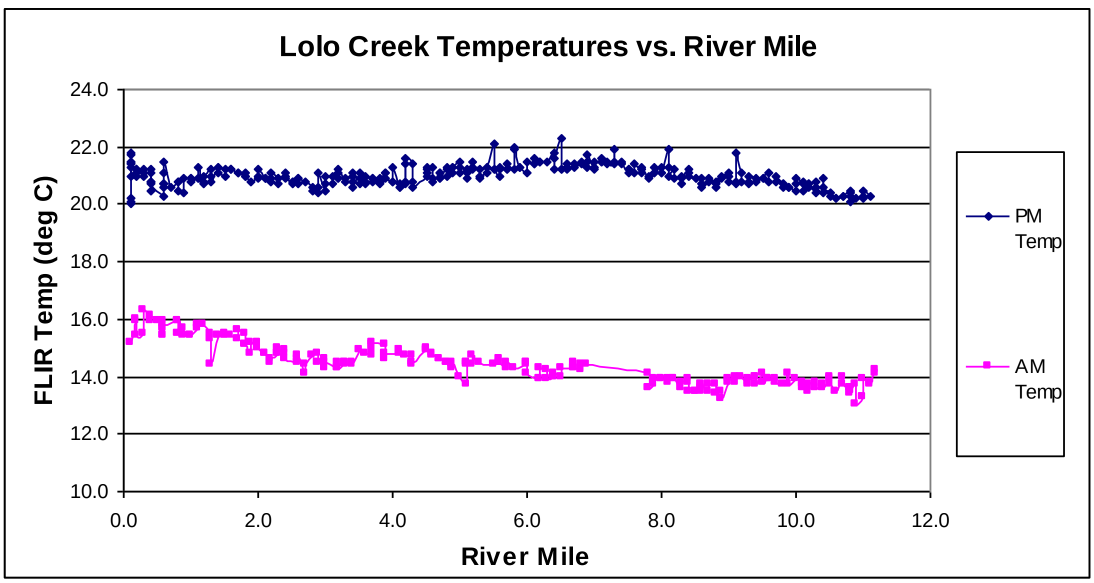


**Figure 17. Afternoon and morning channel temperatures plotted vs. river mile for Lolo Creek.**

As seen in Figure 17, the temperatures on Lolo Creek were relatively stable. The high afternoon stream temperature was 22.3°C while the low temperature was 20.0°C (Appendix A, Map 3). Lolo Creek was broken out into two reaches.

<u>Lolo Creek 01 (River Mile 5.0–11.0)</u>
Length of Lolo 01 is 6.0 miles. The temperature at the upstream end of this reach was 20.3°C, while the downstream temperature was 21.5°C. A slight warming trend was seen on this reach with areas of local temperature fluctuations. The majority of the features identified on this reach were warmer than Lolo Creek (Table 15 and Appendix A, Map 8).

**Table 15. Lolo Creek 01 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Lolo Creek PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Lolo Creek AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Impoundment | 10.6 | 25.2 | 20.2 | 5.0 | 13.5 | 13.9 | -0.4 |
| Return | 10.6 | 18.2 | 20.2 | -2.0 | 13.5 | 13.9 | -0.4 |
| Side Channel | 10.4 | 21.2 | 20.6 | 0.6 | 13.5 | 13.6 | -0.1 |
| Side Channel | 10.0 | 23.5 | 20.6 | 2.9 | 14.3 | 13.9 | 0.4 |
| Side Channel | 9.6 | 20.9 | 20.9 | 0.0 | 13.6 | 13.9 | -0.3 |
| Tributary | 9.4 | 18.5 | 20.9 | -2.4 | 9.5 | 14.0 | -4.5 |
| Return | 9.2 | 21.4 | 20.8 | 0.6 | 10.9 | 14.0 | -3.1 |
| Impoundment | 8.8 | 28.5 | 20.7 | 7.8 | 15.0 | 13.7 | 1.3 |
| Side Channel | 8.3 | 23.1 | 20.9 | 2.2 | 15.2 | 13.9 | 1.3 |
| Side Channel | 7.4 | 21.2 | 21.4 | -0.2 | NA | NA | NA |
| Impoundment | 7.0 | 23.5 | 21.4 | 2.1 | NA | 14.4 | NA |
| Side Channel | 6.2 | 18.2 | 21.5 | -3.3 | 11.1 | 14.3 | -3.2 |
| Side Channel | 6.1 | 22.3 | 21.5 | 0.8 | 14.5 | 13.9 | 0.6 |
| Impoundment | 5.1 | NA | 21.1 | NA | 15.0 | 14.3 | 0.7 |

At river mile 10.6 an impoundment, which was notably (5°C) warmer than Lolo Creek, was identified (Figure 18). This image was interesting because it illustrates a potential weakness in FLIR analysis. The images only record surface temperatures. It is clear that although the surface water was warmer than Lolo Creek, the water entering Lolo Creek (labeled an irrigation return) was cooler. The return water was clearly being released from the bottom of the reservoir and thus has cooler temperatures.

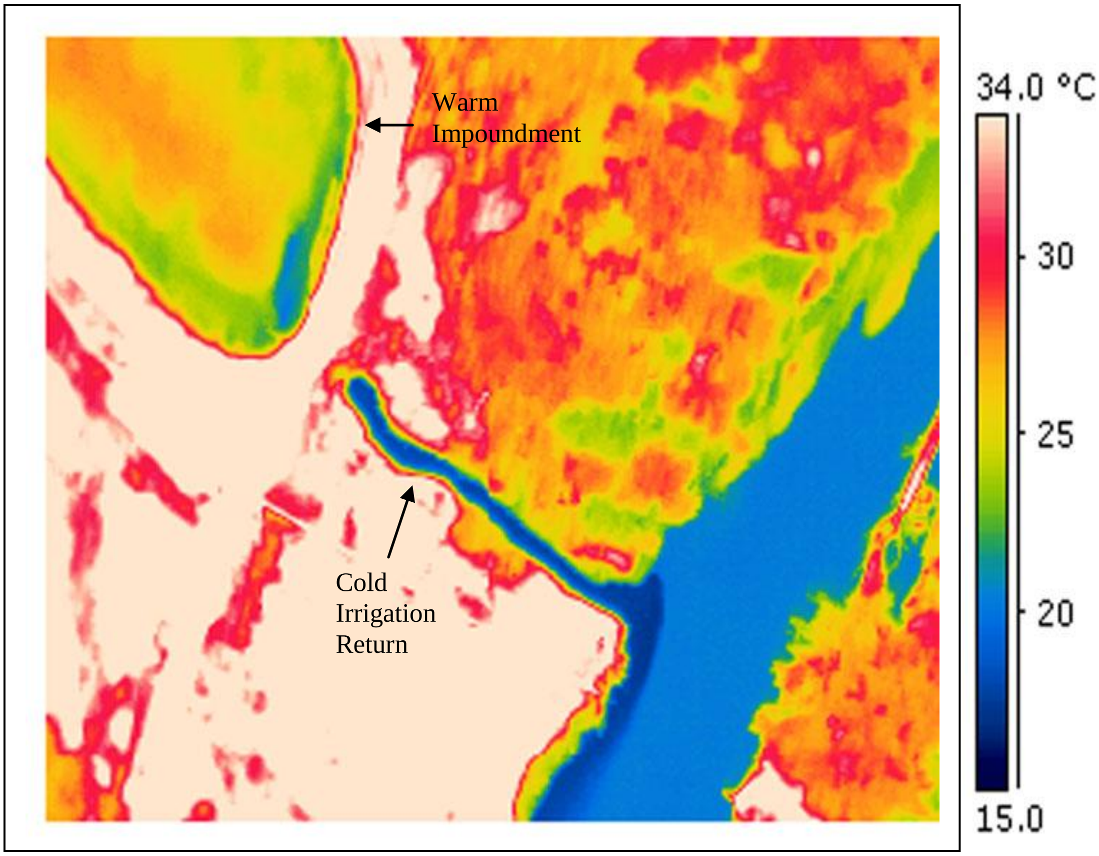


**Figure 18. Cold irrigation return and warm impoundment at river mile 10.6.**

This cooler water did not impact the overall temperatures of Lolo Creek. There were several small spikes in temperature seen in the longitudinal profile for this reach (Figure 15). The first stream temperature spike occurred at river mile 9.1 where the temperature increased by one degree Celsius and then dropped one degree Celsius. It is possible that the return at river mile 9.2 caused this temporary temperature increase. Additional temperature spikes can be seen on this reach (river mile 8.1, 6.5, 5.8, and 5.5). A review of the imagery did not reveal any point source inputs at any of these locations.

<u>Lolo Creek 02 (River Mile 0.0-4.9)</u>

Length of Lolo 02 is approximately 4.9 miles long. The temperature at the upstream end of this reach was 20.8°C, while the downstream temperature was 20.2°C. Overall the temperatures on this reach were relatively stable (Figure 15 and Appendix A, Map 3). There were three cold water refuges identified on this reach (Table 16 and Appendix A, Map 8).

**Table 16. Lolo Creek 02 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | LoloCreek PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | LoloCreek AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Diversion | 4.9 | 21.1 | 21.4 | -0.3 | 11.9 | 14.4 | -2.5 |
| Cold Water Refuge | 3.4 | 16.6 | 20.8 | -4.2 | 10.0 | 14.4 | -4.4 |
| Cold Water Refuge | 2.4 | 17.9 | 20.9 | -3.0 | 12.5 | 14.7 | -2.2 |
| Cold Water Refuge | 1.8 | 15.9 | 21.0 | -5.1 | 12.8 | 15.2 | -2.4 |
| Side Channel | 1.1 | 24.2 | 21.3 | 2.9 | 16.1 | 15.7 | 0.4 |
| Side Channel | 0.7 | 21.3 | 20.7 | 0.6 | 13.4 | 15.8 | -2.4 |
| Side Channel | 0.2 | 23.1 | 21.2 | 1.9 | 12.1 | 15.8 | -3.7 |

The cold water refuges were on average 4.1°C cooler than Lolo Creek. None of these features appear to affect the overall temperature on Lolo Creek. The largest temperature fluctuations on Lolo 02 occurred near the mouth. The side channels identified on the downstream end of this reach were all warmer than Lolo Creek. They may have contributed to the warmer temperature spikes seem on lower Lolo Creek, however there were also temperature drops towards the mouth. Because it is impossible to quantify the amount of water in the many side channels at the mouth of Lolo Creek, it is difficult to isolate the source of the temperature fluctuations seen here.

## Lost Horse Creek

Lost Horse Creek shows a general warming trend as you move downstream. The upstream temperature (river mile 7.4) was 16.1°C. The downstream temperature (river mile 0.1) was 21.6°C for a total temperature gain of 5.5°C. The longitudinal profile (Figure 19 and Appendix A, Map 1) showed that Lost Horse Creek had many significant temperature fluctuations in short distances, particularly at the downstream end. The morning and afternoon temperatures were similar, however the temperature spikes were not consistent in the two times. Despite these inconsistencies, the following section will focus on the afternoon temperatures.

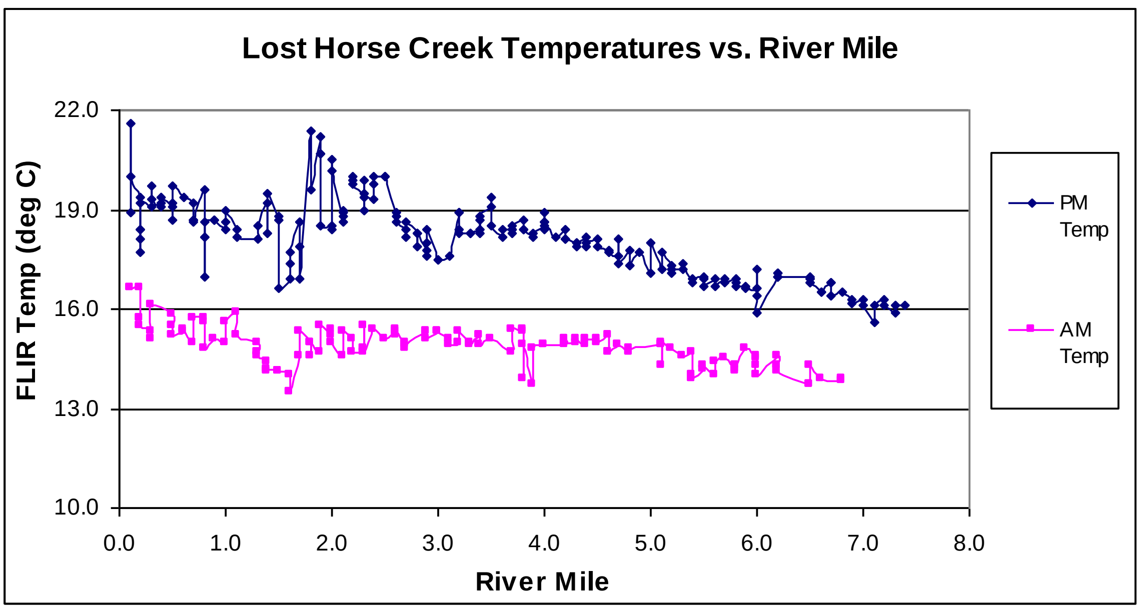

**Figure 19. Afternoon and morning channel temperatures plotted vs. river mile for Lost Horse Creek.**

Lost Horse Creek was broken in to two reaches.

Lost Horse Creek 01 (River Mile 5.4-7.4)

The total length of Lost Horse Creek 01 included in this assessment is approximately 2.0 miles. Overall the temperature in this reach increased slightly from 16.1°C at the upstream end to 16.8°C at the downstream end. The high temperature for this reach in the afternoon was 17.2°C at river mile 6.0. The low temperature was located at river mile 7.1 with 15.6°C. This is at the far upstream end of the area covered during the FLIR flight. The low temperature was only slightly cooler (0.5-0.3°C) than the temperatures in the surrounding stream. Looking at the CIR images, it appears that shade may play a role in the cooler temperatures at this location on Lost Horse Creek. In addition, there was a cold water refugia identified at river mile 7.2 that was 3.0°C cooler than the surrounding stream which may have contributed to the cool temperatures (Table17 and Appendix A, Map 4). This feature appears to be a pool and is perhaps shade influenced.

**Table 17. Lost Horse Creek 01 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Lost Horse Creek PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Lost Horse Creek AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Cold Water Refuge | 7.2 | 13.1 | 16.1 | -3.0 | NA | NA | NA |
| Side Channel | 6.0 | 13.7 | 16.8 | -3.1 | 7.9 | 14.4 | -11.9 |
| Side Channel | 5.6 | 16.9 | 16.8 | 0.1 | 11.1 | 14.4 | -5.4 |
| Impoundment | 5.4 | 16.9 | 16.9 | 0 | 12.0 | 14.1 | -2.1 |

A side channel located at river mile 6.0 was also 3°C cooler than the main stem of Lost Horse Creek at the same location (Figure 20).

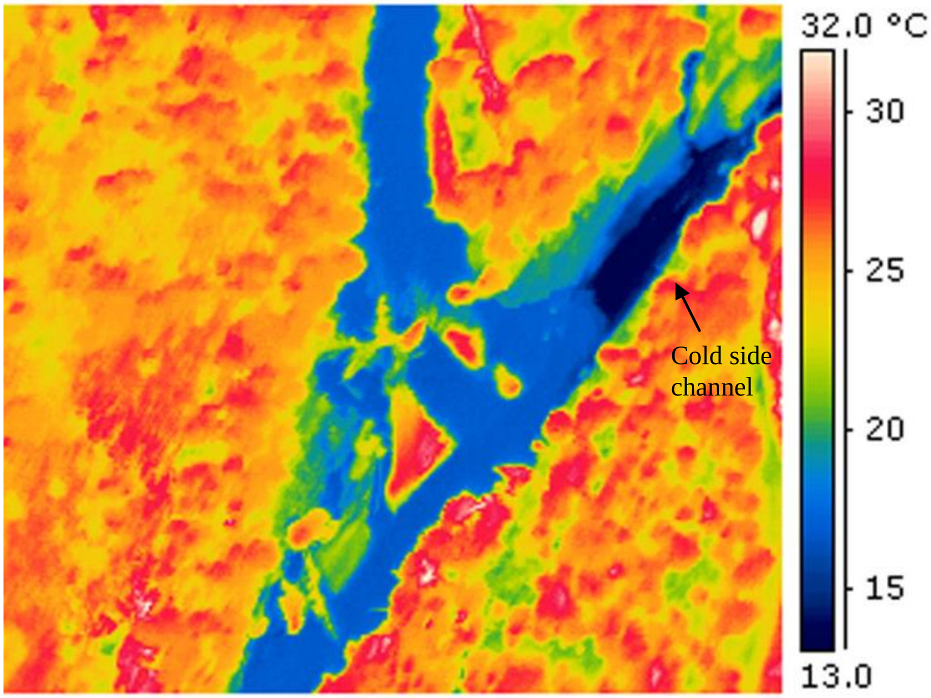


**Figure 20. Cold side channel at river mile 6.0.**

It is not clear from the imagery if the side channel is connected at the upstream end. No surface water coming into the stream is visible at this location. The cooler side channel could be shade or perhaps groundwater influenced. The cold side channel did not impact downstream temperatures.

<u>Lost Horse Creek 02 (River Mile 0.0-5.3)</u>

Lost Horse 02 includes approximately 5.3 miles of stream. The upstream temperature on this reach was 17.4°C. The downstream temperature was 21.6°C. This was a 4.2°C temperature increase over 5.2 miles. The temperature on this section of stream was far from constant. The stream showed a basic warming trend from river mile 5.3 to river mile 3.2 where the temperature was 18.9°C. At this point the stream temperature dropped 1.3°C. A cool side channel may have influenced this drop in temperature (Table 18 and Appendix A, Map 4).

**Table 18. Lost Horse Creek 02 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | Lost Horse Creek PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | Lost Horse Creek AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Diversion | 5.3 | 17.1 | 16.9 | 0.2 | 12.4 | 14.3 | -1.9 |
| Side Channel | 3.3 | 18.0 | 18.4 | -0.4 | 12.3 | 15.0 | -2.7 |
| Side Channel | 3.1 | 19.5 | 17.7 | 1.8 | 11.9 | 15.0 | -3.1 |
| Side Channel | 3.0 | 13.9 | 17.9 | -4.0 | 9.3 | 15.3 | -6.0 |
| Side Channel | 1.5 | 13.5 | 18.8 | -5.3 | 9.1 | 14.1 | -5.0 |
| Side Channel | 0.5 | 17.9 | 19.0 | -1.1 | 12.6 | 15.3 | -2.7 |

For the next mile the stream temperatures increased until around river mile 2.1. From this point to the mouth Lost Horse Creek temperatures fluctuated from 21.4 to 16.6°C. The two features identified on this section were warm side channels, which do not explain the great temperature variability. Perhaps there are sub surface influences that are not visible from the imagery.

**East Fork Bitterroot**

The median water temperatures for each sampled image of East Fork of Bitterroot were plotted versus river mile (Figure 21). Temperature trends were similar during the morning and afternoon flights. The afternoon temperatures were 4-5 °C warmer than the morning temperatures. Afternoon temperatures will be the focus of the following section.

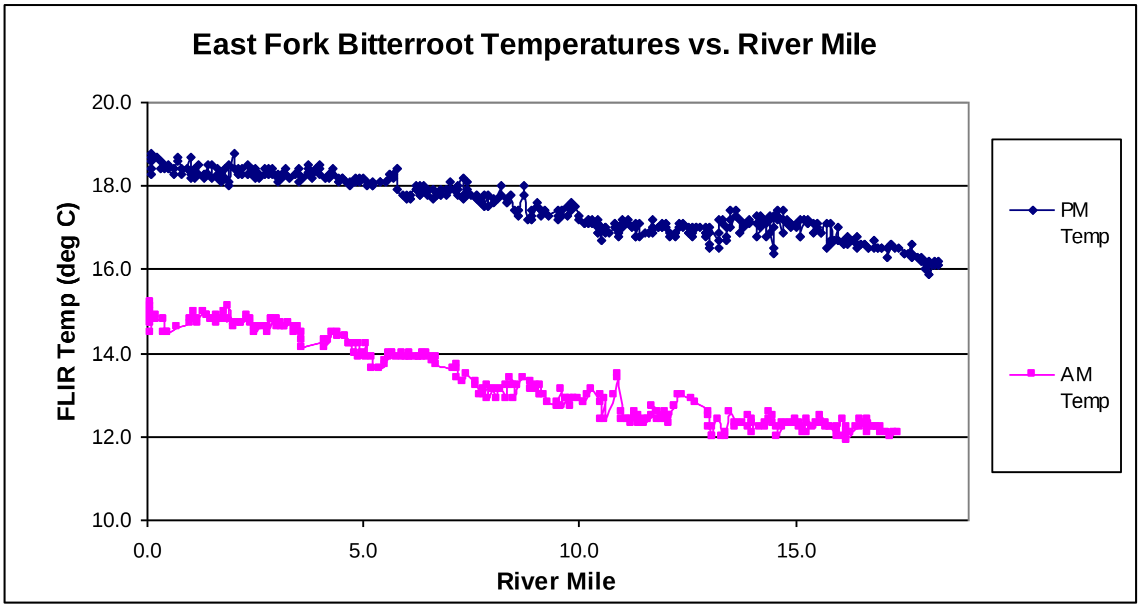


**Figure 21. Afternoon and morning channel temperatures plotted by river mile for East Fork Bitterroot River.**

The temperature at the upstream end of East Fork of Bitterroot was 16.2°C and the temperature at the mouth was 18.6°C (Appendix A, Map 1). This is an overall increase in stream temperature of 2.9°C over 18 miles. The maximum temperature on East Fork of Bitterroot was 18.8°C and the minimum stream temperature was 15.9°C. The East Fork was divided into three reaches.

East Fork Bitterroot 01 (River Mile 14.3-18.3)

The section of East Fork Bitterroot 01 covered in this FLIR assessment is approximately 4.0 miles long. The low temperature seen on the East Fork during this survey was on this reach at river mile 18.1. East Fork 01 showed a slight but steady warming trend through most of the reach. There were two side channels and one tributary (Tolan Creek) identified on this reach. All of these features were colder than the main channel (Table 19 and Appendix A, Map 10).

**Table 19. East Fork Bitterroot 01 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | East Fork PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | East Fork AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Tolan Creek | 17.2 | 15.2 | 16.5 | -1.3 | 11.6 | 12.0 | -0.4 |
| Cold Water Refuge | 16.6 | 13.2 | 16.6 | -3.4 | 12.4 | 12.3 | 0.1 |
| Side Channel | 15.8 | 16.1 | 16.7 | -0.6 | 12.9 | 12.2 | 0.7 |
| Side Channel | 14.5 | 15.6 | 17.1 | -1.5 | 13.8 | 12.4 | 1.4 |
| Reimel Creek | 14.3 | 17.3 | 17.2 | 0.1 | 14.3 | 12.3 | 2.0 |

Additionally, there was one cold water refuge identified on this reach with a temperature 3.4°C cooler that the East Fork. This feature did not impact the stream temperature. The warming trend on this reach continued to river mile 14.7. At this point the stream temperature dropped one degree to 16.4 at river mile 14.5. This is also the location of a side channel with a temperature 1.5°C cooler than the East Fork. Cooler water from the side channel likely influences the drop in stream temperature seen at this point.

East Fork Bitterroot 02 (River Mile 7.5-14.2)

This reach of the East Fork was approximately 6.7 miles long. The temperature at the upstream end of this reach was 17.3°C, while the temperature at the downstream end was 17.8°C. Stream temperatures fluctuated between 15.6 and 17.5 °C for the first mile of this reach. The source of this fluctuation was likely the tributaries and side channels seen within the first mile (Table 20 and Appendix A, Map 10).

**Table 20. East Fork Bitterroot 02 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | East Fork PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | East Fork AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Tributary | 13.5 | 15.9 | 17.2 | -1.3 | 14.0 | 12.4 | 1.6 |
| Side Channel | 13.5 | 16.5 | 17.2 | -0.7 | 12.5 | 12.4 | 0.1 |
| Camp Creek | 13.3 | 14.2 | 17.1 | -2.9 | 12.0 | 12.0 | 0 |
| Cameron Creek | 13.1 | NA | 16.8 | NA | 12.0 | 12.0 | 0 |
| Side Channel | 12.0 | 16.9 | 17.0 | -0.1 | 13.2 | 12.5 | 0.7 |
| Cold Water Refuge | 10.4 | 13.5 | 17.1 | -3.6 | NA | 13.0 | NA |

From river mile 13-10 the temperature stabilized around 17°C. The cold water refugia at river mile 10.4 had no impact on the over stream temperature. From river mile 10 to the end of the reach there was a steady warming trend on the East Fork.

East Fork Bitterroot 03 (River Mile 0.1-7.4)

This reach of the East Fork is approximately 7.4 miles long. The temperature at the upstream end of this reach was 17.9°C, while the temperature at the downstream end was 18.6°C. The East Fork continued with the steady warming trend seen in East Fork 02 until mile 4.5. Temperatures then stabilized and remained at 18.2-18.5°C to the mouth. The features identified did not have any dramatic impact on temperatures on East Fork 03 (Table 21 and Appendix A, Map 10).

**Table 21. East Fork Bitterroot 03 features and temperatures.**

| Feature Type | River Mile | PM Feature Temp °C | East Fork PM Temp °C | PM Temp Difference °C | AM Feature Temp °C | East Fork AM Temp °C | AM Temp Difference °C |
|---|---|---|---|---|---|---|---|
| Laird Creek | 7.4 | 18.1 | 17.9 | 0.2 | 13.4 | 13.5 | -0.1 |
| Impoundment | 5.6 | 21.5 | 18.2 | 3.3 | 16.0 | 13.9 | 2.1 |
| Impoundment | 4.9 | 22.4 | 18.2 | 4.2 | 14.5 | 14.0 | 0.5 |
| Impoundment | 4.3 | 21.5 | 18.3 | 3.2 | 15.6 | 14.5 | 1.1 |
| Impoundment | 3.4 | 17.5 | 18.3 | -0.8 | 12.9 | 14.5 | -1.6 |
| Diversion | 1.8 | 18.5 | 18.2 | 0.3 | 14.8 | 14.9 | -0.1 |
| Side Channel | 0.6 | 14.1 | 18.4 | -4.3 | NA | 14.6 | NA |
| Side Channel | 0.1 | 15.5 | 18.6 | -3.1 | 13.4 | 14.8 | -1.4 |

The only inflow was Laird Creek with only a slightly higher temperature than the East Fork. The impoundments identified on this reach were on average 2.5°C warmer, but may not be contributing water. There were two side channels located from the imagery (Figure 22).

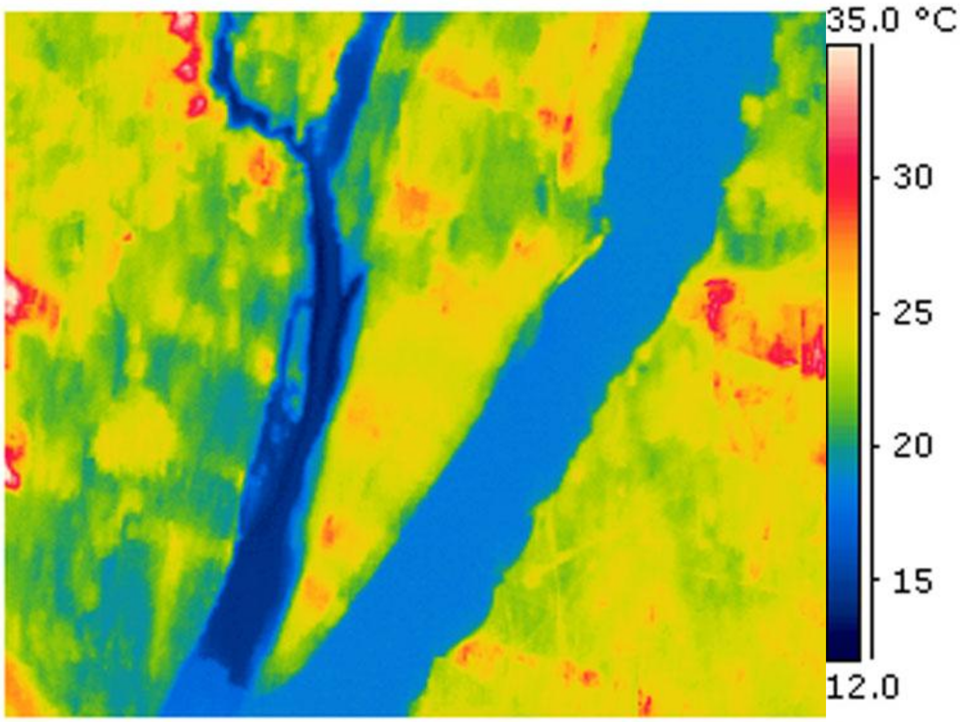


**Figure 22. Cold side channel at river mile 0.6.**

This side channel was 4.3°C cooler than the East Fork but did not impact the overall temperature downstream of its cold entry into the main channel.

## Discussion

### Summary of Potential Thermal Loading Sources

*Tributaries and Irrigation Returns*

Tributaries and returns are the features identified that are contributing water to the channel and would thus likely have a large influence on temperatures.

Tributaries were a source of thermal cooling on the Bitterroot and tributaries overall (Table 22).

**Table 22. Summary of temperature differences of tributaries compared to main channels.**

| Stream | n | Tributary – Main Channel (Afternoon Ave Temp °C ) | n | Tributary – Main Channel (Morning Ave Temp °C) |
|---|---|---|---|---|
| Bitterroot | 18 | -0.6 | 13 | -4.1 |
| Miller Creek | 5 | 3.0 | 3 | -3.8 |
| Lolo Creek | 1 | -2.4 | 1 | -4.5 |
| Lost Horse Creek | 0 | NA | 0 | NA |
| East Fork | 5 | -1.0 | 6 | 0.5 |

The average temperature of tributaries on the Bitterroot was 0.6°C cooler in the afternoon and 4.1°C cooler in the morning. The other streams follow this trend. The exception is Miller Creek with an average tributary temperature of 3°C warmer than the main channel. Looking at the data one tributary at mile 8 is almost 8°C warmer than Miller Creek. The CIR imagery does not make it clear that there is actually water in this tributary, therefore this high number could be the temperature of the dry channel. No flow data are available to determine what proportion of flow there tributaries contribute. In general tributaries were cooler and likely contributed to cooling trends.

Irrigation returns, when present, were usually a source of thermal warming on the Bitterroot and tributaries (Table 23).

**Table 23. Irrigation return summaries**

| Stream | n | Afternoon Ave Temp °C | n | Morning Ave Temp °C |
|---|---|---|---|---|
| Bitterroot | 3 | 1.1 | 3 | 2.1 |
| Miller Creek | 1 | 9.7 | 0 | NA |
| Lolo Creek | 2 | -0.7 | 2 | -1.8 |
| Lost Horse Creek | 0 | NA | 0 | NA |
| East Fork | 0 | NA | 0 | NA |

The Bitterroot and Miller Creek both had irrigation returns with temperatures higher than the main channels. Lolo Creek had cooler water entering from irrigation returns. All of these streams had a small number of irrigation returns identified. The other streams had no irrigation returns identified from the imagery. It is likely that there are additional irrigation returns on all if the streams, however they were impossible to accurately identify with this analysis. On the Bitterroot, for instance, the CIR imagery was useful in identifying irrigation returns, however the scope of these images often did not extend far enough out to capture all of the side channels, well enough the irrigation returns.

*Side Channels, Impoundments, and Cold Water Refugia*

Water stored on the floodplain in side channels and impoundments had wide-ranging temperature. Connectivity of these side features varies, but some may have an influence on stream temperature. Due to the limited scope of the images, in many locations the full extent of side channels could not be viewed. It is possible that irrigation returns, tributaries and springs could contribute water to some of the features labeled as side channels. For this reason, it seems that side channels may have a significant influence on temperature changes. The variability seen in side channels is summarized in Table 24.

**Table 24. Side channel summaries**

| Stream | n | Afternoon Ave Temp °C | n | Morning Ave Temp °C |
|---|---|---|---|---|
| Bitterroot | 63 | 0.0 | 50 | -3.2 |
| Miller Creek | 1 | 3.8 | 1 | -2.2 |
| Lolo Creek | 10 | 0.8 | 9 | -0.8 |
| Lost Horse Creek | 7 | -0.7 | 7 | -5.3 |
| East Fork | 6 | -1.7 | 5 | 0.3 |

On the main Bitterroot, the average side channel temperature was not different from the main channel. This should not suggest that there was no temperature differences, but rather that the combination of warm and cool water was balanced out and that other cumulative factors affect stream temperature. Miller and Lolo Creek had side channels with average temperatures that were warmer in the morning and cooler in the afternoon, while Lost Horse showed the opposite pattern. The influence of side channels on temperature is likely significant, particularly on the Bitterroot, however it was not easy to quantify in this assessment. Ground water influences to and connectivity of side channels should be studied further to determine if these features are a consideration for water quality management.

Impoundments were generally warmer than the streams, as seen in Table 25.

**Table 25. Impoundment summaries**

| Stream | n | Afternoon Ave Temp °C | n | Morning Ave Temp °C |
|---|---|---|---|---|
| Bitterroot | 9 | 3.1 | 6 | 0.5 |
| Miller Creek | 1 | -1.0 | 0 | NA |
| Lolo Creek | 3 | 5.0 | 3 | 0.5 |
| Lost Horse Creek | 1 | 0 | 1 | -2.1 |
| East Fork | 0 | NA | 0 | NA |

Miller Creek was the exception to this rule. Connectivity of impoundments should be studied further to determine if these features are a consideration for water quality management.

Cold water refuges were found on all of the streams except Miller Creek (Table 26).

**Table 26. Cold water refuges summaries**

| Stream | n | Afternoon Ave Temp °C | n | Morning Ave Temp °C |
|---|---|---|---|---|
| Bitterroot | 5 | -2.4 | 5 | -5.1 |
| Miller Creek | 0 | NA | 0 | NA |
| Lolo Creek | 3 | -4.1 | 3 | -3.0 |
| Lost Horse Creek | 1 | -3.0 | 0 | NA |
| East Fork | 2 | -3.5 | 1 | -0.1 |

The degree of their influence on overall stream temperatures was not clear from this assessment.

***Uncertainties***

One uncertainty seen in this assessment is that the FLIR temperatures only reflect the temperature at the top of the waters surface. As illustrated in Figure 18, deeper water could greatly increase the potential for error in assessing true temperature.

The limited scope of the images is another weakness of this study. Because the FLIR methods dictate a limited image scope, any features located outside the main channel were excluded. This was particularly a problem on the main Bitterroot, which is characterized by multiple braided channels. Often the pilot would have to choose the main channel while missing other channels, which at times had dramatically different temperatures. As explained above, many of the side channels on the Bitterroot may have groundwater, spring or even irrigation returns entering them outside the visible scope of the imagery. For this reason the side channels had greater than expected impact on overall temperatures.

Analysis of the thermal accuracy of the FLIR images compared to in-stream sensors was well within the specified tolerance of plus or minus 5°C.

Groundwater upwellings are not visible from the surface radiation captured in FLIR, and are not mapped if they do not have enough influence on stream temperature to create a noticeable change in surface temperature. Therefore some coldwater refugia may not be visible in the FLIR imagery.

The influence of diversions and irrigation return flows could not be quantified at a cumulative level because the scope of this study did not include measuring flow for every diversion and return. Additionally, the influence of the diversions and returns would vary frequently as irrigation use changes throughout the season. The role of irrigation and groundwater return should be studied further to quantify as much as possible the influence of groundwater inputs and dewatering for irrigation on stream temperature. Water commissioners in the Bitterroot area may have information about flow of irrigation diversions for the time of the flight, but irrigation returns generally are not measured.

Stream temperature reflects watershed-scale as well as local scale influences. It is subject to cumulative effects that extend beyond the reach scale. While this analysis provided a general source characterization and identified some temperature sources influencing temperature at a local scale, it was not designed to define cause-effect relationships between land management factors and temperature of the Bitterroot at the watershed scale.

## Citations

Torgersen, C.E., R. Faux, B.A. McIntosh, N. Poage, and D.J. Norton. 2001. Airborne thermal remote sensing for water temperature assessment in rivers and streams. *Remote Sensing of Environment* 76(3): 386-398.

Western Regional Climate Center. Historical climate information accessed in December 2004 at http://www.wrcc.dri.edu/CLIMATEDATA.html

# ATTACHMENT B – MODELING STREAMFLOW AND WATER TEMPERATURE IN THE BITTERROOT RIVER, MONTANA

# MODELING STREAMFLOW AND WATER TEMPERATURE

# IN THE BITTERROOT RIVER, MONTANA

# MODELING STREAMFLOW AND WATER TEMPERATURE

# IN THE BITTERROOT RIVER, MONTANA

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Montana Department of Environmental Quality
Water Quality Planning Bureau
Watershed Modeling Program
1520 East Sixth Avenue, PO Box 200901
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## EXECUTIVE SUMMARY

The Bitterroot River and several of its tributaries have been identified by the Montana Department of Environmental Quality (DEQ) as being impaired due to elevated water temperatures. The cause of the impairment has been attributed to 1) moderately impacted stream banks and riparian habitat, and 2) chronic dewatering, both of which lead to summertime temperatures at/near the high end of optimal conditions for mixed salmonid populations. As such DEQ has commissioned a water temperature study to investigate the mechanistic relationship between stream flow, shade from vegetation, and in-stream water temperature.

Field studies were carried out in 2004 and 2006 to support water quality model development for the project. QUAL2K water quality models were developed for the Bitterroot River and its three listed tributaries, Miller, Sleeping Child, and Willow creeks to evaluate management practices suitable for meeting state temperature standards. For, the Bitterroot River, a previously developed QUAL2E model (converted to QUAL2K) was used for the analysis. New QUAL2K models were constructed for the tributaries. Shadev3.0 models were also developed to assess shade conditions using previously collected field data. Overall the models show reasonable agreement with forward-looking infrared (FLIR) data based on a root mean squared error (RMSE) of 1.4$^{o}$F for the minimum water temperatures and 0.9$^{o}$F for the maximum water temperatures. Once developed, various water temperature responses were evaluated for a range of potential watershed management activities. Seven scenarios were considered including.

1. A shade scenario which uses reference conditions for all reaches where the existing vegetation density, unless impacted by fire, is less than in the existing conditions model.
2. A headwater and tributary influence scenario where the tributary mean water temperature values were reduced by 1$^{o}$F based on expected feasible reductions from the Headwater Bitterroot TMDL (DEQ, 2005b).
3. A set of flow scenarios to evaluate the effect of water use diversions on temperature.
4. A set of wastewater treatment plant/facility (WWTP) scenarios where the amount of discharge from each plant was varied.
5. A natural condition scenario where the changes in the shade, headwater and tributary, flow, and WWTP scenarios were integrated.
6. A naturally occurring scenario which combines the changes included in the shade, headwater and tributary, and flow 20 percent decrease scenarios based on DEQ's interpretation of all reasonable land, soil, and water conservation measures.

Simulation results ranged from almost no change in water temperatures to reductions as much as nearly 8$^{o}$F. Changes in shade were found to be most significant for the tributaries. Conversely, changes in flow were the most significant restoration strategy for reducing temperatures in the Bitterroot River. Overall, a range of viable outcomes were evaluated and are being considered as part of the upcoming TMDL.

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# 1.0 BACKGROUND

The Montana Department of Environmental Quality (DEQ) has commissioned a water temperature study to investigate the mechanistic relationship between stream flow, shade from vegetation, and in-stream water temperature in the Bitterroot River and three tributaries. The one-dimensional dynamic stream water quality model QUAL2K v2.11 (Chapra, Pelletier, and Tao, 2007) was applied to a 82.3-mile reach of the Bitterroot River extending from the United States Geological Survey (USGS) gage near Darby to the confluence with the Clark Fork River near Missoula, and on Miller Creek, Sleeping Child Creek, and Willow Creek. The riparian vegetation model Shade v3.0 (Ecology, 2008) was applied to the same reaches. The models were used to assess scenario responses to alternative riparian and water management conditions. The results will be used to support DEQ's Total Maximum Daily Load (TMDL) program.

## 1.1 Montana Temperature Standard (ARM 17.30.623)

Montana's in-stream temperature standard is narrative. It is more difficult to interpret for non-point sources compared to point sources. This is especially true when attempting to characterize the departure from "naturally-occurring conditions," which reflect the implementation of "all reasonable land, soil and water conservation practices" (ARM 17.30.602). B-1 (ARM 17.30.607) is the predominant water use classification adopted for the Clark Fork River watershed of the Columbia River drainage, which includes the Bitterroot River watershed. As currently written, a maximum allowable increase of 1$^{o}$F over "naturally occurring conditions" is acceptable for B-1 waters when natural temperatures are within the range of 32$^{o}$F to 66$^{o}$F. For temperatures 66$^{o}$F or greater, a 0.5$^{o}$F increase is allowed (ARM 17.30.623 (2) (e)). Based on monitoring data from the Bitterroot River and its tributaries, the 0.5$^{o}$F standard applies, except on the Bitterroot River above Skalkaho Creek near Grantsdale (60-mi) where the 1$^{o}$F standard applies.

## 1.2 Problem Statement

DEQ has divided the Bitterroot River into three segments for scientific and administrative purposes: 24.3-miles (East and West Forks of the Bitterroot River to Skalkaho Creek), 36.5-miles (Skalkaho Creek to Eightmile Creek) and 23.4-miles (Eightmile Creek to Clark Fork River). DEQ assessed the data from each of these segments in accordance with Montana's 303(d) assessment process. The assessment records indicate that the river is moderately impaired (CWAIC, 2009) and DEQ's beneficial use support assessments indicate that aquatic life and cold water fishery uses are partially supported in all three reaches. On Montana's 2008 303(d) list of impaired waters, only the middle segment of the Bitterroot River (Skalkaho Creek to Eightmile Creek) is indicated as likely impaired by thermal conditions (CWAIC, 2009). The causes of the impairment may include: 1) summertime temperatures at/near the high end of optimal conditions for mixed salmonid populations; 2) moderately impacted stream banks and riparian habitat; and 3) chronic dewatering. Models were developed and various potential scenarios that influence water temperature performed to support assessment of water temperature conditions.

# 2.0 STUDY AREA

The Bitterroot River study area drains approximately 2,800-square miles ($mi^2$) of high- and mid-elevation mountainous topography in western Montana. The East Fork Bitterroot River originates from the continental divide while the West Fork Bitterroot River originates from the Idaho-Montana border. The forks merge near Darby and the river flows south past the towns of Grantsdale, Hamilton, Woodside, Corvallis, Victor, Stevensville, Florence, and Lolo before reaching its endpoint at the Clark Fork River. The entire watershed is part of the USGS 4th Hydrologic Unit Code (HUC) 17010205.

The East and West Forks of the Bitterroot Rivers (headwaters) are part of the Bitterroot Headwaters TMDL planning area (TPA), while the lower Bitterroot River (Darby downstream to the Clark Fork River) is part of the Bitterroot TPA. This study focuses on the lower Bitterroot River. Access to the study area site is from US-93, which parallels much of this reach of the river (**Figure 2-1**).

## 2.1 Climate

Climate in the Bitterroot River watershed is intermontane continental, with marked seasonality (**Figure 2-2**). The cooperative observation station at Hamilton (COOP ID 243885) is located near the middle of the Bitterroot TPA and provides representative climatic information regarding the project site. The Cooperative Network has been recognized as the most definitive source of information on U.S. climate trends for temperature and precipitation and follows established data standards (NOAA, 2009). Records from Hamilton indicate that average air temperatures from 1895 to 2008 range from about 85$^{o}$F in the summer to about 15$^{o}$F in the winter (WRCC, 2009). This range in air temperatures is similar to those recorded at eight other cooperative observation stations in the watershed (Darby, Lolo Hot Springs 2NE, Missoula 2NE, Missoula 2WNW, Missoula WSO AP, Stevensville, Sula 3ENE, and the Western Agricultural Research Center). Average annual precipitation is approximately 12 inches with a fairly uniform distribution of about 1 inch per month. The driest months are usually February and March with about 0.8 inch of precipitation, and the wettest months are May and June with about 1.6 inches of precipitation. The eight other cooperative observation stations in the valley recorded similar precipitation. Cooperative observation stations at higher elevations recorded about double the amount of annual precipitation, with most of the additional precipitation falling as snow during the winter months.

## 2.2 Surface Water

In general, Bitterroot River watershed hydrology is predominantly snowmelt-driven, as demonstrated in the mean monthly hydrographs (**Figure 2-3**). Within the study area, there are six USGS stream flow stations on the Bitterroot River. The gages, with the drainage area in parentheses include: (1) USGS 12344000 Bitterroot River near Darby (1049-$mi^2$); (2) USGS 12346000 Bitterroot River near Grantsdale (1,414-$mi^2$); (3) USGS 12348200 Bitterroot River near Corvallis (1,711-$mi^2$); (4) USGS 12350250 Bitterroot River at Bell Crossing near Victor (1,963-$mi^2$); (5) USGS 12351200 Bitterroot River near Florence (2,354-$mi^2$); and (6) USGS 12352500 Bitterroot River near Missoula (2,814-$mi^2$). Typically, spring snowmelt begins in mid-to late-March, peaks in June, and then rapidly declines in July and August back to base flow. Tributary inflow to the Bitterroot River is variable, and depends on the aspect, basin elevation, drainage area and mountain range, water use and the presence of irrigation diversions. Many of the larger tributaries are similar in drainage area and flow. These tributaries include: Rock Creek, Lick Creek, Lost Horse Creek, Sleeping Child Creek, Skalkaho Creek, Blodgett Creek, Fred Burr Creek, Sweathouse Creek, North Fork Burnt Creek, and Lolo Creek.

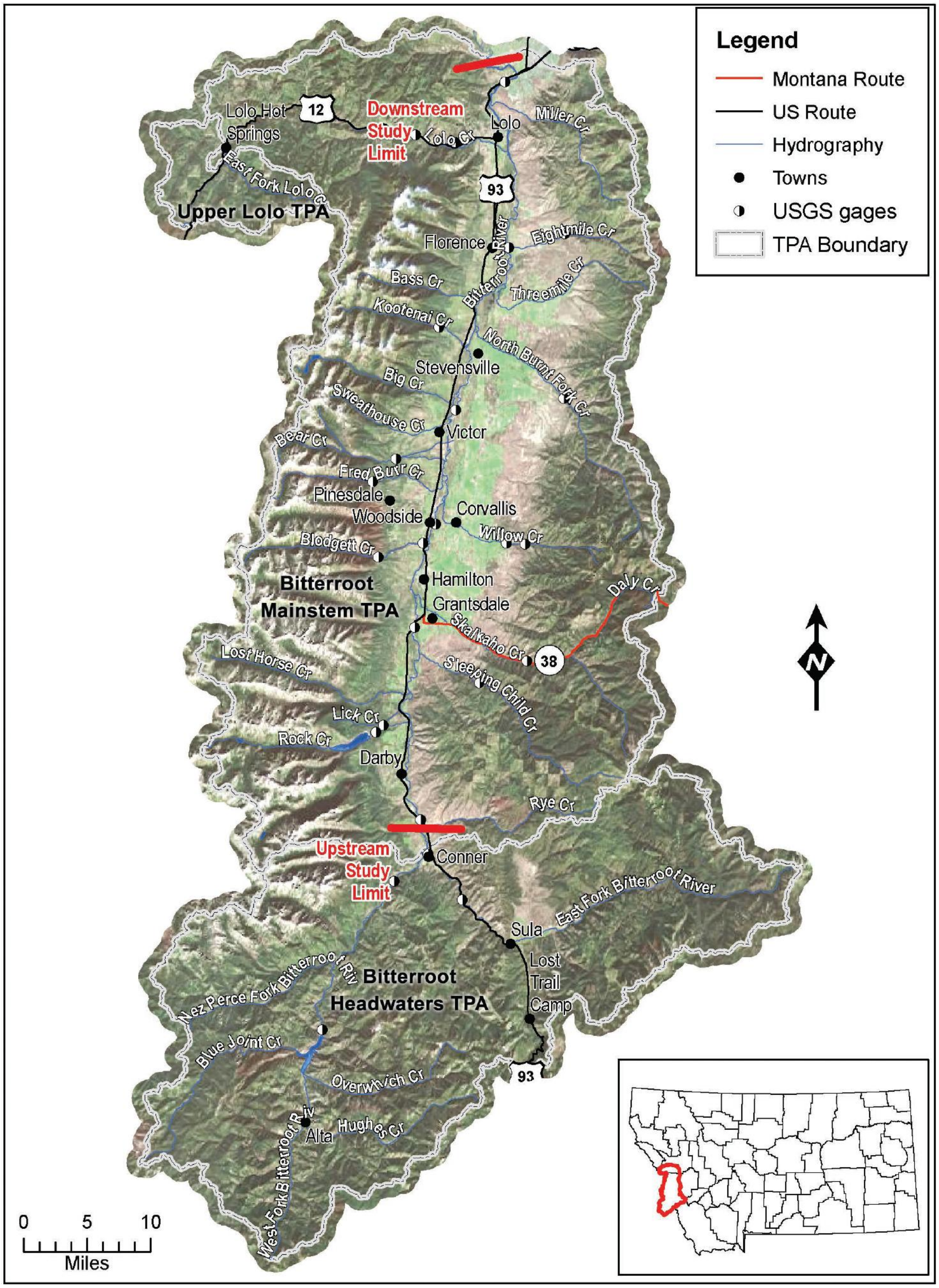


**Figure 2-1. Bitterroot River watershed, hydrography, and stream flow stations**

The modeling reach in **Figure 2-1** extends from approximately Darby to the confluence with the Clark Fork River near Missoula. The limits of the study area reach are delineated by a red line and are labeled.

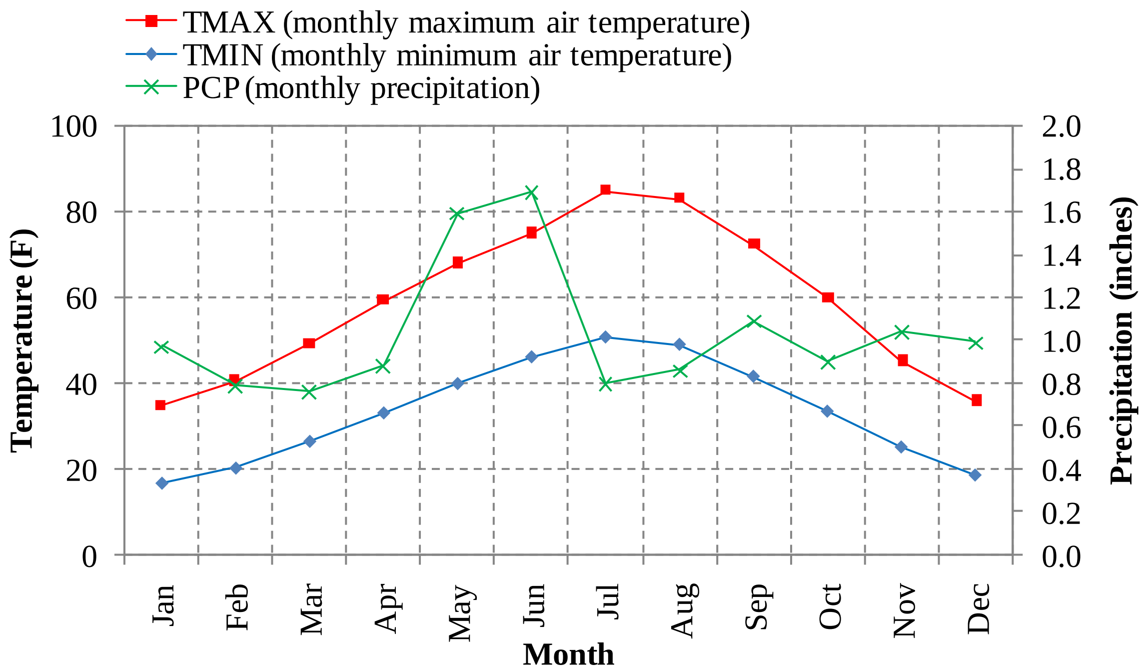


**Figure 2-2. Bitterroot River climate at Hamilton, MT**

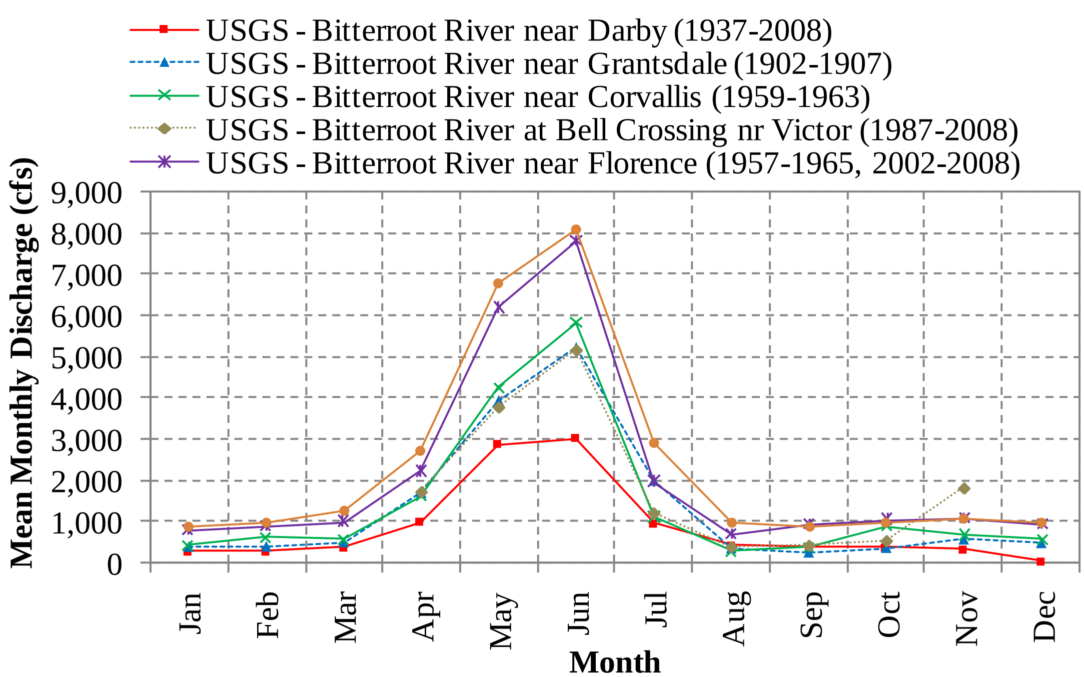


**Figure 2-3. Bitterroot River USGS hydrographs**

## 2.3 Groundwater

The Bitterroot Valley is underlain by unconsolidated to semi-consolidated tertiary sediments and groundwater flow under the valley is characterized by a complex seasonal interaction with recharge from streams and irrigation (McMurtrey, et.al., 1959). The permeable soils and extensive agricultural activities that occur in the valley generally prevent surface runoff, except during storms of high intensity or during snowmelt when the ground is frozen (Briar and Dutton, 2000). Groundwater levels tend to gradually decline through the winter and early spring, and then rise in late spring and summer due to recharge from precipitation and irrigation (McMurtrey, et.al., 1972). A result of this interaction is a systematic correlation that is suggestive of a direct relationship between snow pack, recharge, aquifer level, and stream flow. It is estimated that the shallow aquifer along the valley floor alone holds 628 billion gallons with the annual recharge averaging about 180 billion gallons per year (LaFave, 2008). (If this volume were added to the annual average volume of flow for the Bitterroot River at Missoula, it would be an increase of about 30 percent.)

# 3.0 METHODS AND MATERIALS

Data for this study came from various agencies, including: flow from the USGS, climatic data from the National Oceanic and Atmospheric Administration (NOAA), and water temperature and shade data from DEQ. The data are described as part of the Model Development sections.

# 4.0 SHADE MODEL DEVELOPMENT

## 4.1 Model Description

Shade v3.0 is a riparian vegetation and topography model that computes the hourly effective shade for a single day (Ecology, 2008). Effective shade is the reduction in solar radiation caused by both land forms (hills, mountains, etc.) and plants that block the path of solar rays. Shade is an Excel/Visual Basic for Applications program. The model uses the latitude/longitude, day of year, aspect and gradient (the direction and slope of the stream), solar path, buffer width, canopy cover, and vegetation height to compute hourly, dawn-to-dusk shade. The model input variables include channel orientation, wetted width, bankfull width, channel incision, topography, buffer width and height, and canopy cover. Bankfull width in the shade calculations is defined as the near-stream disturbance zone (NSDZ), which is the distance between the edge of the first vegetation zone on the left and right bank.

## 4.2 Available Data

The application of the Shade model to the Bitterroot River relied upon field data collected during a 2006 field study and the interpretation of these data (DEQ, 2005a and DEQ, 2007). The results of the study included: tree height, crown diameter, tree-to-channel distance, buffer width, overhang, shade density, active channel width, terrain slope, and percent of reach. Aspect was estimated and provided in the shade report; however, it was reported as Aspect Class with the bearing grouped into categories of either 60 or 120 degrees. The Aspect Class provided only a gross approximation of the bearing. No values were provided for the stream disturbance zone and the distance from the stream center to the left or right bank.

## 4.3 GIS Pre-Processing

TTools v3.0 is an ArcView extension to translate spatial data into Shade model inputs (ODEQ, 2001). TTools was used to estimate the values that were not provided in the field study report: (1) elevation; (2) aspect; (3) near stream disturbance zone (NSDZ) width, the distance from the stream center to the left bank; and (4) topographic shade. (1) Elevation was calculated using a 30-m (98-ft) digital elevation model (DEM) and the stream centerline file included with the field study report as provided by DEQ. (2) Aspect was calculated to the nearest degree using TTools with the stream centerline file. (3) The field study report only provided an estimate of the active channel or "the width of the channel at bankfull." The active channel and wetted width were assumed conservatively to be the equivalent. However, the NSDZ was always estimated as more than the wetted width, averaging 1.8 times greater. TTools calculates these values based on the stream centerline and left and right bank NSDZ. Left and right banks were delineated in GIS based on the aerial photographs from the Montana Natural Resource Information System, Natural-Color Aerial Photos of Montana, (2005) and U.S. Farm Services Agency National Agricultural Imagery Program (NAIP). Performing the delineation required some interpretation of the location of the stream centerline in the meandering and braided reaches of the Bitterroot River. This provided a method to estimate the widths required by the Shade model. Again the NSDZ was based on the available aerial photography from 2005. (4) Topographic shade was calculated using TTools with the stream centerline file and a DEM.

## 4.4 Riparian Input

The Shade model requires the description of riparian vegetation. The description includes: vegetation code, description, height, density, and overhang (OH). The results in the field study report were used to develop a riparian description table (**Table 4-1**). Vegetation descriptions used the average value for tree height and shade density when multiple field observations were recorded. The overhang reported in the field study report spreadsheet was zero for all vegetation types. While there may be some slight overhang along small portions of the Bitterroot River, the river is wide and using a value of zero provides a conservative estimate.

**Table 4-1. Riparian land cover types and associated attributes used in the Bitterroot River Shade model**

| Land Cover | Height (ft) | Density (%) |
|---|---|---|
| Brush/saplings | 41.0 | 60 |
| Coniferous/deciduous | 74.1 | 80 |
| Deciduous | 61.4 | 42 |
| Deciduous/brush | 65.9 | 70 |
| Deciduous/brush/herbaceous | 74.5 | 78 |
| Deciduous/coniferous | 73.8 | 73 |
| Deciduous/coniferous/brush | 70.2 | 79 |
| Deciduous/coniferous./brush/herbaceous | 77.8 | 66 |
| Deciduous/coniferous/herbaceous | 76.4 | 65 |
| Deciduous/coniferous/herbaceous/wetland | 107.9 | 90 |
| Deciduous/coniferous/shrubs | 72.5 | 75 |
| Deciduous/coniferous/shrubs/herbaceous | 80.4 | 66 |
| Deciduous/herbaceous | 71.5 | 59 |
| Deciduous/herbaceous/wetland | 87.6 | 83 |
| Deciduous/shrubs | 44.9 | 20 |
| Deciduous/shrubs/herbaceous | 65.9 | 58 |
| Shrubs | 7.9 | 80 |

## 4.5 Shade Input

The Shade model inputs include: (1) riparian zones, (2) reach length, (3) channel incision, and (4) elevation, aspect, wetted width, near-stream disturbance zone width, distance from the bank to the center of the stream, and topographic shade. (1) The riparian zones for the left and right bank were based on the existing vegetation composition as provided in the field study, and were assigned values based on the riparian vegetation descriptions (**Table 4-1**). (2) The Shade model requires reach lengths be an equal interval. The reaches in the field study report were not at an equal interval and were subdivided while maintaining the same reach characteristics. A uniform reach length interval of 660-ft was used. (3) Channel incision was estimated based on the bank stability provided in the field study report. Incision is the vertical drop from the bankfull edge to the water surface. Where the bank was stable, incision was set at zero (no steep eroding cutbank); otherwise the incision was estimated as 6.5 feet based on the database comment field of vertical or near vertical stream banks. (4) The remaining variables were computed as part of the GIS pre-processing.

## 4.6 Model Evaluation

The Shade model results generally indicate between 10 and 30 percent effective shade along the Bitterroot River (**Figure 4-1**). Effective shade is the reduction in solar reflection due to light reflection and shading from both vegetation and topography. The field study report included ground truth results (field measurements) (DEQ, 2007). These values are similar to the estimated shade.

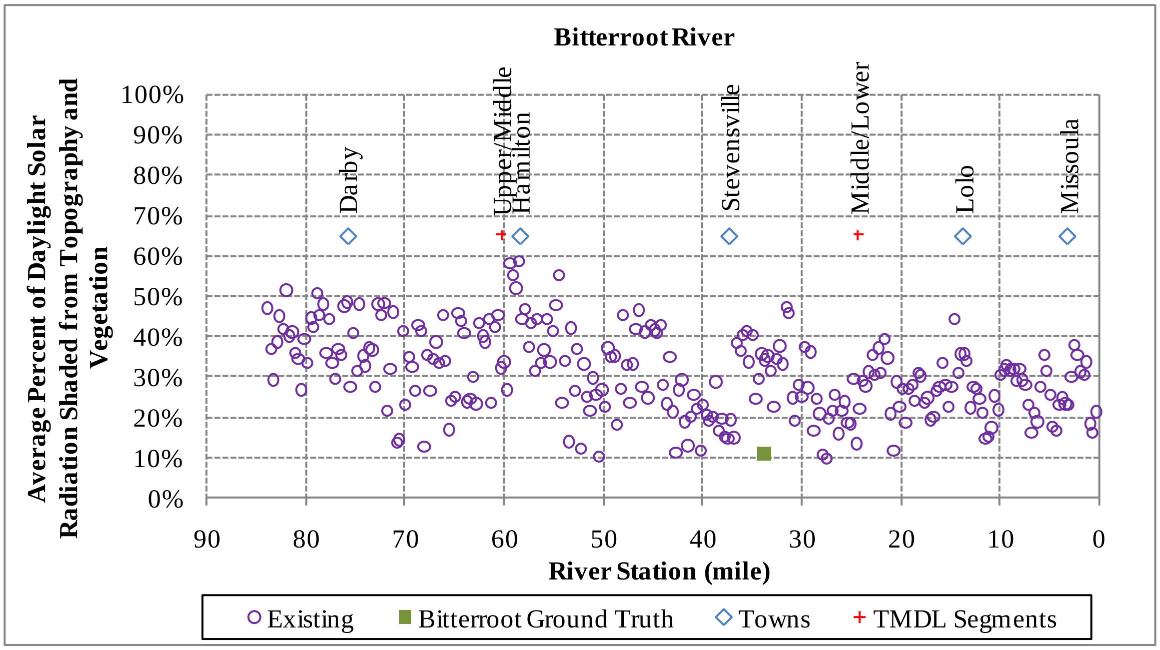


**Figure 4-1. Shade model Bitterroot River longitudinal effective shade profile**

# 5.0 QUAL2K MODEL DEVELOPMENT

## 5.1 Model Description

QUAL2K v2.11 is a river and stream water quality model that is intended to represent a modernized version of the QUAL2E model (Chapra, Pelletier, Tao, 2007). QUAL2E is a one-dimensional water quality model that was developed in the late 1980s/early 1990s and was previously supported by the U.S. Environmental Protection Agency (EPA). QUAL2K was recently developed by the EPA, Tufts University, and the Washington Department of Ecology.

The QUAL2K model is a one-dimensional, steady-state hydraulics model. In other words, flow in the stream channel is assumed to be well-mixed vertically and laterally, and that non-uniform, steady flow is simulated. The heat budget and temperature are simulated as a function of meteorology for a diel (24-hr) time scale. The model permits subdividing the river into reaches of unique length that can have multiple inflow loads and withdrawals.

## 5.2 Available Data

The application of the QUAL2K model for this study relied upon the conversion of previously developed QUAL2E model of the Bitterroot River (HDR, 2005). The model report includes data reviews and model inputs that were useful in the model conversion and upgrades.

## 5.3 Simulation Period and Model Coefficients

Models were developed for six simulation periods: June 15th, July 15th and August 15th for 1992 and 1999. These dates were selected based on data availability, representation of growing season conditions, and the capabilities of the model for single-day, steady-state conditions. For the water temperature simulations, the August 1992 date was selected as the period of critical low flows and high water temperatures.

## 5.4 Flow Input

The flow inputs in the QUAL2K model include: headwater (the most upstream reach of the model near Darby), diffuse sources (e.g., groundwater recharge and losses, shallow irrigation infiltration/return flows, bankflows, etc.) and point sources (tributaries, irrigation withdrawals, and municipal discharges). Flow accounting in the Bitterroot River watershed is challenging due to the interaction between surface water and groundwater, agricultural water use, and many small, un-gaged tributaries. Taking these factors into consideration, the following approach was used to assess the hydrology and develop flow inputs for the model.

### 5.4.1 Flow Approach

Accuracy in the water balance is important for heat transfer calculations in water temperature model simulations. The original water balance used in the QUAL2E model was reviewed by comparing historical USGS gage data and associated regressions to estimate tributary inflow to the river. Additionally, new information for the QUAL2K update was acquired regarding water use and irrigation diversions from Al Pernichele of the Bitterroot Water User's Association. USGS flow records for the mainstem Bitterroot River and tributaries were downloaded from the USGS National Water Information System Web Interface (USGS, 2009). The tributaries were organized by the east-side and the west-side of the watershed due to hydrologic differences in both annual average precipitation and water yield. The drainage area and flow records were then used as part of a flow-regression analysis.

### 5.4.2 Flow-Regression Analysis

The flow-regression analysis was completed to estimate flows for un-gaged basins as part of the water balance. The analysis included comparing mean monthly discharge with the basin drainage area. Linear, exponential, and power regressions were evaluated. Overall, the linear regression model resulted in the best coefficient of determination (e.g. r-squared value). A linear relationship also matches low-flow conditions conceptually; e.g. as the drainage area increases, the discharge from a basin typically increases proportionately under low-flow conditions. The regressions were also examined using data for the full period of record, versus using aligned datasets for common periods. Both the relationships and the r-squared values were similar for the period of record and the common period analyses.

Relationships developed for the mainstem, east-side, and west-side are shown in **Table 5-1** and **Figure 5-1**. Data from some of the west-side gages were not included in the analysis due to large differences in the drainage area (e.g. Lolo Creek), the impact of canal and reservoir operations and lack of definitive watershed area (e.g. Rock Creek), and inconsistent records and the appearance of stream depletion by water use, diversions and/or other seasonal influences (e.g. Blodgett Creek).

| **Table 5-1. Mean of monthly discharge to drainage area linear regressions** | | |
|---|---|---|
| **Bitterroot River** | **Equation** | **$R^2$** |
| June | Q=2.7369DA+693.3 | 0.8679 |
| July | Q=0.8778DA+35.991 | 0.5651 |
| August | Q=0.3414DA-133.32 | 0.6710 |
| **Stations used:** Bitterroot River near Missoula, near Florence, at Bell Crossing near Victor, near Corvallis, near Grantsdale, near Darby | | |
| **East-side tributaries** | **Equation** | **$R^2$** |
| June | Q=4.7664DA-71.37 | 0.9210 |
| July | Q=1.6855DA-27.101 | 0.8830 |
| August | Q=0.7096DA-10.757 | 0.8662 |
| **Stations used:** Eightmile Creek near Florence, Willow Creek near Corvallis, Willow Creek at Anfinson Reach near Corvallis, Sleeping Child Creek near Hamilton, Burnt Fork Bitterroot River near Stevensville, Skalkaho Creek near Hamilton, Skalkaho Creek at Brennan's Ranch near Hamilton | | |
| **West-side tributaries** | **Equation** | **$R^2$** |
| June | Q=7.1152DA+72.656 | 0.9871 |
| July | Q=7.6574DA-95.92 | 0.9901 |
| August | Q=8.4193DA-186.09 | 0.9210 |
| **Stations used:** Fred Burr Creek near Victor, Blodgett Creek near Corvallis, Bear Creek near Victor, Kootenai Creek near Stevensville, Rock Creek near Darby **Stations not used:** Lolo Creek near Lolo, Lolo Creek above Sleeman near Lolo, Rock Creek Canal near Darby, Blodgett Creek near Hamilton | | |
| Q = flow (cfs), DA = drainage area (square miles) | | |

Monthly flow produced by the regression analysis was adjusted by the ratio of the monthly mean flow to the mean of monthly discharge at the Bitterroot River at Missoula (the long-term average flow of the month to the 1992 or 1999 average flow for the month) for the final adjustment. When a long-term record was available without data for 1992 or 1999, this adjustment provided a more specific estimation of flows for that year.

In some instances, the estimated tributary flow based on the regression analysis may have over-predicted the actual flow reaching the Bitterroot River. Comments from TMDL meetings suggest much of the tributary flow does not reach the Bitterroot River in August because the flows are diverted for agricultural use. Additionally, the diversion flows may under-predict the total diverted flows for irrigation because only the main canals are explicitly identified in the water balance. The diversion flow for June, July, and August is approximately 27 percent of the total estimated irrigation surface water withdrawals in the watershed (USGS, 2004). Therefore the following two adjustments to the regression flows were made. West side tributaries from Darby to Corvallis were reduced to a minimal in-stream flow of 10-cfs in August to achieve the water balance. Flows in Willow Creek were set to zero based on the comment that the flows go into a wetland refuge.

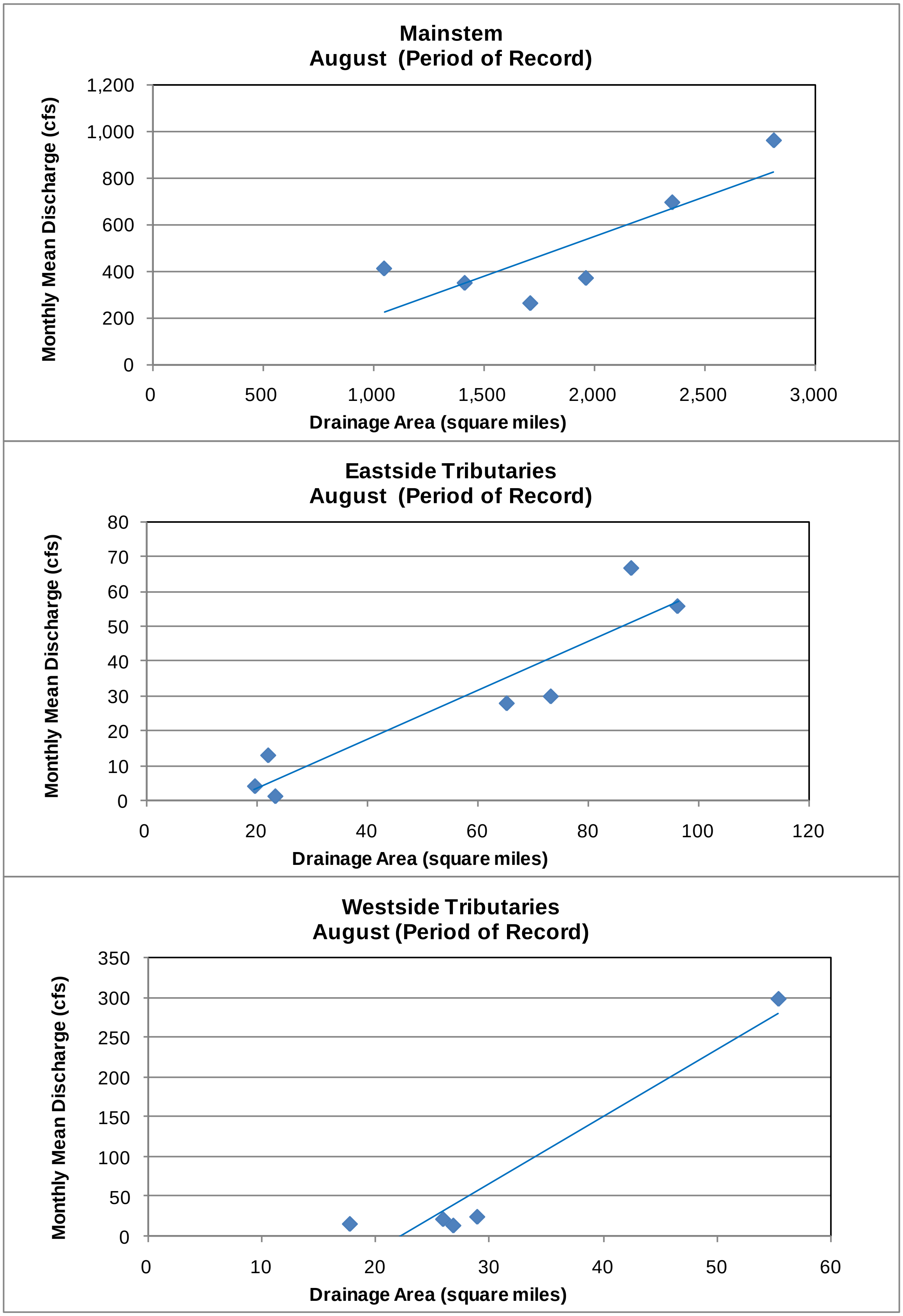


**Figure 5-1. Flow-regression relationships**

### 5.4.3 Model Flows

The flow for the upstream model boundary condition was set as the gaged monthly mean flow (June, July, or August for 1992 or 1999) from the Bitterroot River near Darby, MT. Gaged mean monthly flows were used for gages operating in the watershed during 1992 and 1999. For those gages that have operated historically in the watershed, but were not recording during 1992 and 1999, regression relationships were reviewed. The regressions for mainstem flow do not have high r-squared values during the summer because flow decreases through the middle reach of the Bitterroot River due to irrigation withdrawals. For this reason, the regressions were not used to compute the comparison of mainstem flow values. Instead, these values were estimated to be the ratio of the monthly mean flow to the mean of monthly discharge at the Bitterroot River at Missoula gage (the long-term average flow of the month to the 1992 or 1999 average flow for the month), multiplied by the mean of monthly discharge at the intermediate mainstem gage.

Diversions to main canals were set based on information regarding irrigation diversions provided by Al Pernichele from the Bitterroot Water User's Association. The municipal discharges in the model are a small percentage of the total flow (0.7 percent of the mean August 1992 flow at Missoula and 1 percent of the seven-day consecutive low flow with a 10-year return frequency (7Q10) flow at Missoula) and were based on "previous studies and the Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) database" (HDR, 2005). These were not adjusted as part of the 2009 water balance update.

An unmeasured, or accretion flow, term was developed for each reach to match the sums of the headwater, point-source, tributary, and diversion flows to the mainstem flows. The accretion flows are meant to include the combination of groundwater inflows and losses, and other unaccounted flows. Information on groundwater reach gain/losses was researched but no specific data were found. Groundwater is highly variable and interconnected with the storage of high stream flow and irrigation in the Bitterroot River valley (Sandals, 1947). This interconnectivity can result in variations of 30 feet or more in the groundwater table (McMurtrey, et.al., 1959). Comments from the technical advisory committee suggested groundwater recharge of 200-cfs for the Darby to Grantsdale reach. The results of the water balance were generally lower than 200-cfs, ranging from a loss of about 260-cfs to a gain of about 120-cfs in this reach.

No return flows are included in the water balance. It is assumed that all diverted flows are either consumptively used or lost to groundwater, and accounted for the accretion flow, given the agricultural water demand in the valley. These assumptions are based on firsthand discussions with agricultural water users about the actual water management practices that occur in the valley. Previous studies indicate that approximately half of the diverted flow has the potential to become groundwater (McMurtrey, et.al., 1959). The irrigation based groundwater flow is part of the total groundwater flow for the overall water balance and associated inflow boundary conditions for the model.

## 5.5 Water Temperature Input

Each of the flow inputs in the QUAL2K model has an associated water temperature. The following approach was used to develop water temperature inputs for the model.

### 5.5.1 Water Temperature Approach

The original estimates in the QUAL2E model were based on all available data from June, July, and August for 1971 through 2001 (HDR, 2005). The following approach was used to update these estimates. Relationships between flow and water temperature were examined using regression analysis for each tributary individually and grouped as east-side and west-side tributaries. The results of the regression analysis were used to update the water temperatures in the model for the updated flows from the water balance.

### 5.5.2 Water Temperature Regression Analysis

The goal of the water temperature regression analysis was to improve the estimates of tributary water temperatures for the modeled flow conditions. Since limited data were available a variety of regressions and groupings of data were evaluated. The exponential and power regressions did not provide a significantly different coefficient of determination (e.g. r-squared value) than the linear regression. The grouping of east-side and west-side Bitterroot River watershed tributaries did not provide stronger correlations than the individual regressions for each tributary. While all of the evaluated relationships indicated that water temperatures decrease as flows increase, the linear regression of summer data by tributary was selected as the best estimation of water temperature to flow. The linear regression relationships and r-squared values developed for each tributary using data from all three summer months, June, July, and August are in **Table 5-2**.

**Table 5-2. Flow to water temperature linear regressions for inflows**

| Inflow | Equation | $R^2$ |
|---|---|---|
| Bitterroot near Darby | T=-0.0041Q+14.872 | 0.4958 |
| Lick Creek | T=-0.5161Q+12.019 | 0.6700 |
| Lost Horse Creek | T=-0.0205Q+17.222 | 0.8013 |
| Sleeping Child Creek | T=-0.058Q+16.802 | 0.7631 |
| Skalkaho Creek | T=-0.0176Q+12.255 | 0.5995 |
| Blodgett Creek | T=-0.0094Q+8.2635 | 0.3024 |
| Willow Creek | T=-0.0293Q+5.5533 | 0.1117 |
| Big Creek | T=-0.011Q+9.6422 | 0.4416 |
| Kootenai Creek | T=-0.0045Q+8.0681 | 0.0426 |
| North Fork Burnt Creek | T=-0.0108Q+6.7344 | 0.1655 |
| Bass Creek | T=-0.0283Q+8.3962 | 0.1808 |
| Threemile Creek | T=-0.0779Q+16.049 | 0.3650 |
| Eightmile Creek | T=-0.0712Q+6.2432 | 0.4053 |
| Lolo Creek | T=-0.0067Q+16.33 | 0.8343 |
| T = water temperature ($^{o}$F), Q = flow (cfs) | | |

### 5.5.3 Model Water Temperatures

For the tributaries with data, linear regression equations were used to compute water temperatures for the model inputs. Water temperatures for the four creeks without sufficient data for regressions were estimated. Rock Creek was estimated based on two historical field measurements. Sweathouse Creek was estimated based on field aquarod measurements collected by DEQ from August of 2005 and 2006. Bear Creek was estimated to be the same as Sweathouse Creek. Miller Creek was estimated as the average of the other six east side creeks.

For the accretion flows, the average of the August aquarod measurements from Big Creek and Sweathouse Creek was used. The aquarod measurements were used to estimate the diurnal range (between 3.6 and 5.9$^{o}$F) and time of the maximum (between 6 and 10pm) for the east and west side tributaries.

The water temperatures for the tributaries were less than the mean monthly August air temperature of 64$^{o}$F, which was calculated as the average of the mean monthly air temperature from nine weather stations in the watershed. The data are from the historical summaries maintained by the Western Regional Climate Center (WRCC, 2009).

Five general types of wastewater treatment facilities exist throughout the watershed: on-site septic systems, infiltration systems (Corvallis), land application systems (Victor), lagoons (Darby and Stevensville), and mechanical treatment plants (Hamilton and Lolo). Data from lagoons in Twin Bridges and Whitehall were used to estimate the mean water temperature, range of 4.0$^{o}$F, and time of the maximum at 9pm for Darby and Stevensville. Data from the treatment plant in Missoula were used to estimate the mean water temperature, range of 5.9$^{o}$F, and time of the maximum at 8pm for Hamilton and Lolo.

For the diffuse flow, the mean of the average air temperature of the preceding months (May, June, July, and August) was used to estimate the water temperature at 60$^{o}$F. The temperature of groundwater generally varies around the mean annual air temperature above the land surface which is 45$^{o}$F for the valley (NGWA, 2009). Diffuse flows in the model include more than groundwater and thus were estimated at a higher water temperature.

## 5.6 Climate Input

The climate inputs in the QUAL2K model include air temperature, dew point temperature, wind speed, and cloud cover. Data from the Missoula 2NE station were used for the entire watershed (HDR, 2005). This station collected all the input parameters for the day modeled.

## 5.7 Shade Input

The Shade model results were incorporated into the QUAL2K August 1992 model. Since the reach lengths in QUAL2K were set the same as in the Shade model, the Shade model results (see the calculation of effective shade under the heading Shade Model Development and specifically the subheading Model Evaluation) were directly input into the QUAL2K model. The shade data are hourly percentages of the solar radiation that is blocked because of shade from topography and vegetation. Hourly values are applied as integrated values for each hour, e.g. the value at 12:00 AM is applied from 12:00 to 1:00 AM.

## 5.8 Model Evaluation and Calibration

The lowest flows tend to occur in the reach between the USGS gages near Corvallis and Victor. The USGS records for both gages have low mean monthly flows of about 120-cfs. The lowest daily average flows in the record are 114-cfs near Corvallis and 63-cfs near Victor. The flow regressions and water balance appear to be appropriately representing low flow conditions.

A quasi-calibration/validation of the 1992 model was performed using FLIR data that were collected in 2004 by using a forward-looking infrared (FLIR) device which senses infrared radiation. The QUAL2K predicted water temperatures were compared against the FLIR data. The day and night FLIR values were averaged for each tenth of a mile interval of the Bitterroot River. For locations with only a day or a night water temperature value, the missing values were interpolated. The data were averaged for each mile and resulted in 82 points, which were then compared to the QUAL2K results.

Improvements to the QUAL2K model prediction, compared to the FLIR data, were achieved with the following modifications. The water temperature at Darby, the headwater condition, along with the air temperature and dew point temperatures were modified from a single value to varying for each hour of the day to better represent the diurnal cycle minimum and maximum temperatures. Air and dew point temperatures were previously single daily averages.

The reach data include hydraulic rating curves for which velocity and depth of flow are specified as a function of discharge, and for which top width and mass transport formulations are subsequently calculated. Discharge measurement data sheets from the USGS were used to develop the coefficient and exponent values for depth and velocity to discharge relationships (HDR, 2005). However, the data poorly represent low flow conditions such as August 1992. The depth coefficient and exponent was adjusted to improve the representation at low flows (The coefficient and exponent used for each reach corresponding to the gages from upstream to downstream were: Darby 0.35 and 0.3, Grantsdale 0.33 and 0.31, Corvallis 0.31 and 0.32, Victor 0.29 and 0.33, and Florence 0.25 and 0.395).

No weather data were collected as part of the 2004 FLIR study. Daily maximum and minimum air temperatures, dew point temperature, wind speed, and sky conditions were acquired from the Missoula 2NE station, for August 1992 and 2004. Maximum and minimum air temperatures were relatively similar between the two years in August. Dew points varied the most, with 2004 near 50$^{o}$F and 1992 near 40$^{o}$F. Wind speeds were similar between about 3 and 5 mph. Cloud cover averaged about 50% during August for both 1992 and 2004. The mean monthly percent possible sunshine for Missoula is 77 percent in August (WRCC, 2009). This was translated to an average cloud cover of 23 percent.

By setting cloud cover to 23 percent and the atmospheric longwave emissivity model to Brutsaert, the model results are similar to the FLIR data (**Figure 5-2**). The root mean squared error (RMSE) (of the FLIR data to the model results) is 1.4$^{o}$F for the minimum water temperatures and 0.9$^{o}$F for the maximum water temperatures (the FLIR dataset did not include the mean daily water temperature).

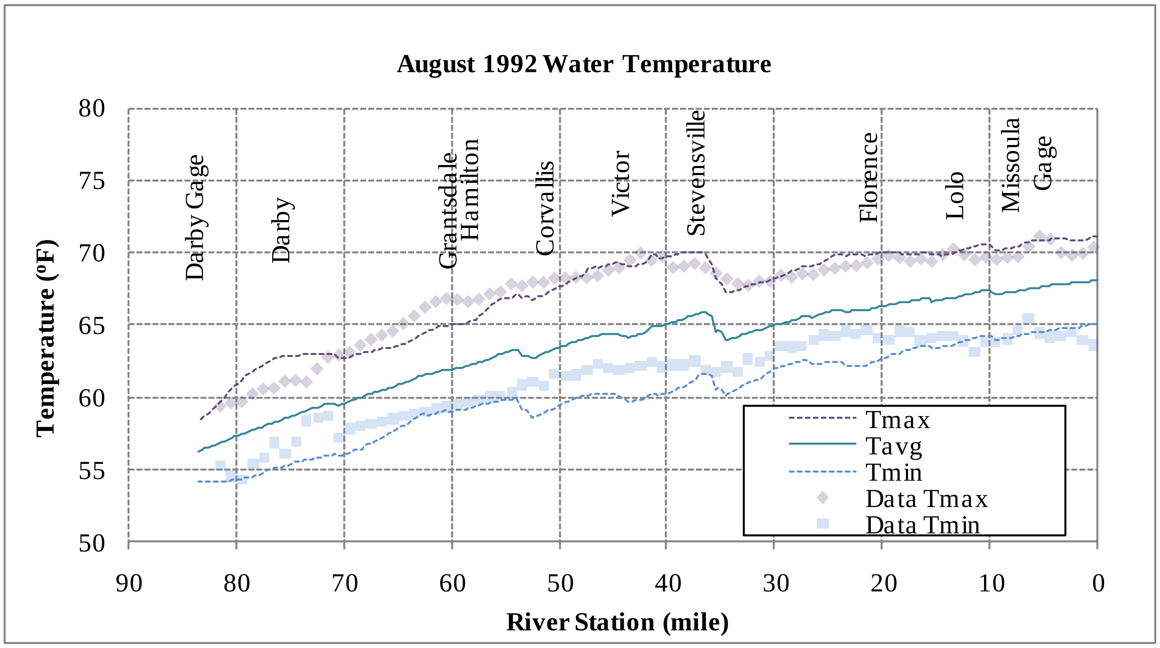


**Figure 5-2. Bitterroot River simulated water temperature (lines) for August 1992 and 2004 FLIR data (squares)**

# 6.0 RESULTS AND DISCUSSION

## 6.1 Flow

Simulated stream flows in the Bitterroot River generally increase downstream in June, with withdrawals starting to impact the increase in flows along the middle reach (**Figures 6-1** and **6-2**). The stream flows in July and August show the Bitterroot River has significantly lower flows due to withdrawals and reduced inflows in the middle reach. While limited data were used in the development of the water balance, results do match the USGS measured flows at the end of each of the reaches (the USGS reaches are defined under the heading Surface Water, DEQ's segments are defined under the heading Problem Statement).

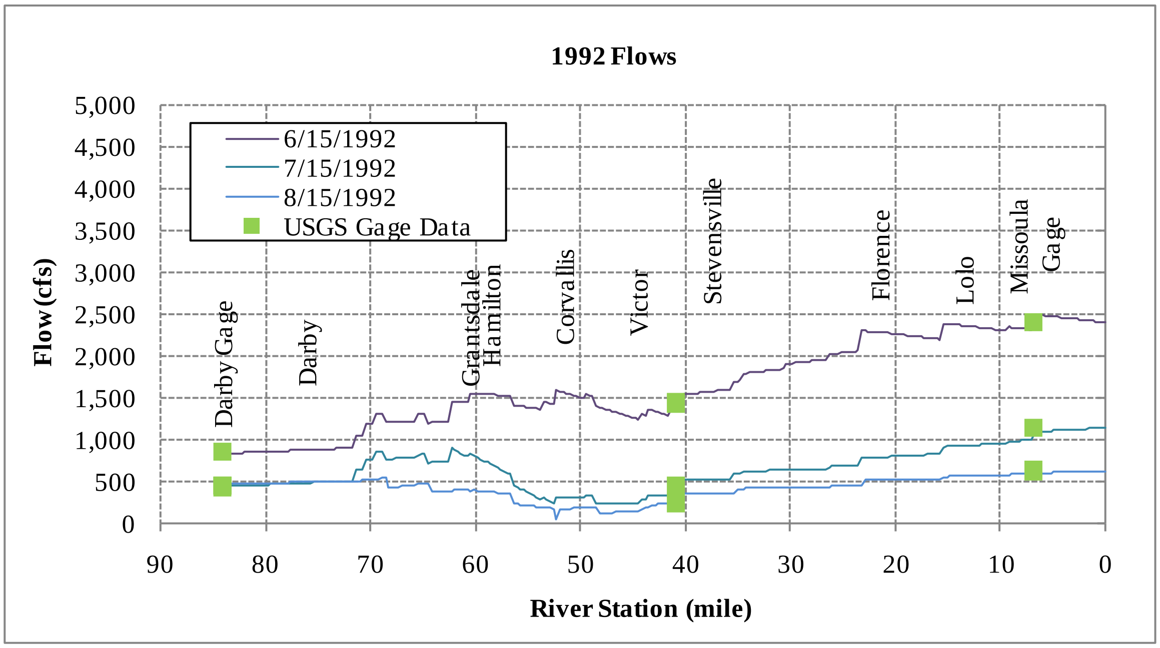


**Figure 6-1. Bitterroot River simulated flow (lines) for June, July and August for 1992. River station zero is the confluence with the Clark Fork River**

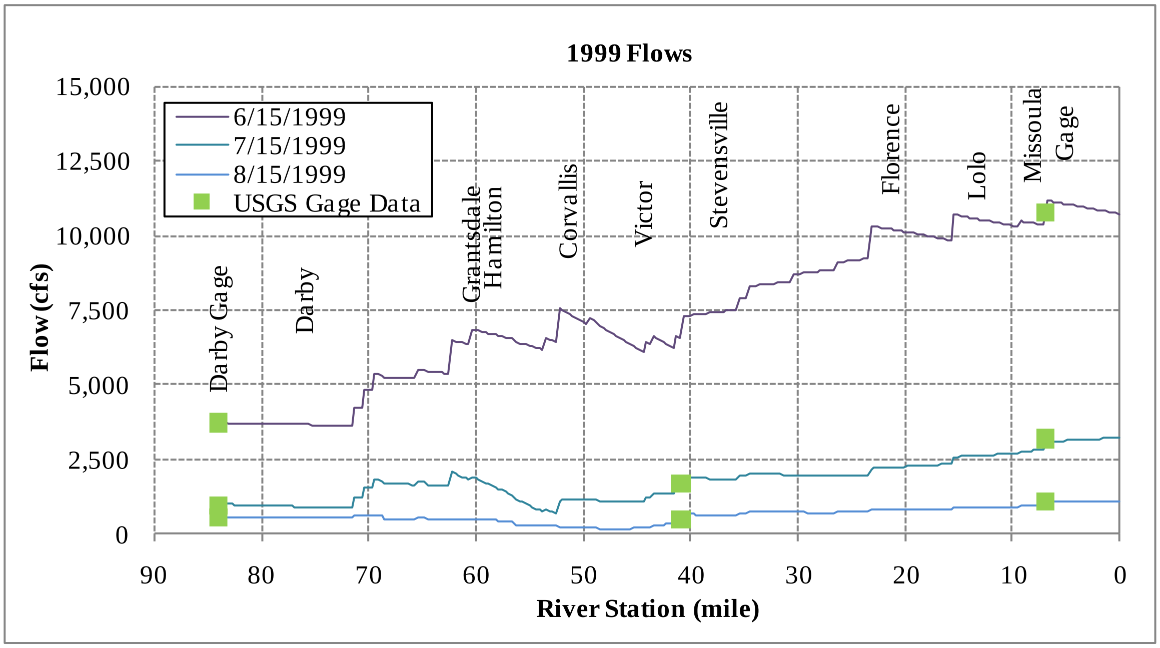


**Figure 6-2. Bitterroot River simulated flow (lines) for June, July and August for 1999. River station zero is the confluence with the Clark Fork River**

## 6.2 Water Temperature

Simulated water temperatures in the Bitterroot River generally increase downstream in August. Although limited data were available for the water temperature inputs; data from a 2004 FLIR study were available for comparison.

For comparative purposes, the headwater flow was changed to the August 2004 flow since the FLIR data are from 2004. The root mean squared error (RMSE) is 1.4°F for the minimum water temperatures and 1.0°F for the maximum water temperatures. The simulated water temperatures in the Bitterroot River are similar with some small changes in the minimum and maximum water temperatures. Maximum water temperatures continue to be slightly underestimated by the QUAL2K model near Hamilton.

# 7.0 TRIBUTARY SHADE MODEL DEVELOPMENT

The Shade model was applied to Miller Creek and Sleeping Child Creek, which are tributaries to the Bitterroot River. The Shade models of the tributaries were based on field data collected during a 2006 field study and the interpretation of these data (DEQ, 2007). The tributary shade data were collected as part of the same study as the Bitterroot River shade data. TTools was again used for the GIS pre-processing and in assisting with the development of the Shade models.

## 7.1 Riparian Input

The Shade model requires the description of riparian vegetation. The description includes: vegetation code, description, height, density, and overhang (OH). The results in the field study report, based on the aerial photograph interpretation, were used to develop the description table (**Table 7-1**). The existing vegetation composition was used to develop the codes for the model. The tree height, shade density, and overhang were averaged for each vegetation type.

## 7.2 Shade Input

The Shade model inputs include: (1) riparian zones, (2) reach length, (3) channel incision, and (4) elevation, aspect, wetted and near stream disturbance zone width, distance from the bank to the center of the stream, and topographic shade. (1) The left and right bank riparian codes for all zones were based on the existing vegetation composition as provided in the field study. (2) The reach length must be an equal interval. The reaches in the field study report were not at an equal interval and were subdivided while maintaining the same reach characteristics. A uniform reach length interval of 660-ft was used. (3) Channel incision was estimated based on the bank stability provided in the field study report. Where the bank was stable, incision was set at zero; otherwise the incision was estimated as 1.5-ft based on the database comment field of vertical or near-vertical stream banks. (4) The remaining parameters where computed using TTools and the process as described for the Bitterroot River under section 4.3 GIS Pre-processing.

**Table 7-1. Riparian land cover types and associated attributes used in the tributary Shade models**

| Land Cover | Height (ft) | Density (%) | Overhang (ft) |
|---|---|---|---|
| **Miller Creek** | | | |
| Brush | 21.3 | 10 | 2.3 |
| Coniferous | 57.4 | 73 | 12.8 |
| Coniferous/brush | 65.9 | 48 | 7.2 |
| Coniferous/brush/herbaceous | 74.1 | 60 | 16.1 |
| Coniferous/deciduous | 69.9 | 53 | 10.8 |
| Coniferous/deciduous/herbaceous | 57.1 | 10 | 2.3 |
| Coniferous/herbaceous | 38.1 | 0 | 1.6 |
| Deciduous/brush | 46.9 | 18 | 1.6 |
| Deciduous/coniferous | 67.6 | 25 | 2.3 |
| Deciduous/coniferous/brush | 45.9 | 90 | 20.7 |
| Deciduous/coniferous/herbaceous | 49.9 | 10 | 2.3 |
| **Sleeping Child Creek** | | | |
| Brush | 15.1 | 20 | 4.6 |
| Coniferous | 66.9 | 100 | 11.8 |
| Coniferous/brush | 45.9 | 86 | 4.9 |
| Coniferous/deciduous/brush | 53.1 | 100 | 23.0 |
| Coniferous/snags | 77.1 | 78 | 4.6 |
| Coniferous/wet meadow | 42.0 | 83 | 8.2 |
| Deciduous | 77.1 | 43 | 3.0 |
| Deciduous/brush | 69.9 | 70 | 16.1 |
| Deciduous/coniferous | 67.9 | 90 | 20.7 |
| Deciduous/coniferous/brush | 43.0 | 90 | 7.5 |
| Snags | 69.9 | 95 | 3.0 |

## 7.3 Model Evaluation

The Shade model results range from zero to ninety-eight percent effective shade along these two tributaries (**Figures 7-1** and **7-2**). The highest shade values are generally near the headwaters, where the stream width is small, the vegetation is tall and extensive, and the topography is steep. In general, the shade then decreases to its lowest value nearest the tributary confluence with the Bitterroot River.

Ground truth points (field measurements) were available for Miller Creek and Sleeping Child Creek. Willow Creek was does not have ground truth points because it did not meet the criteria of the ground truthing study. Both the Miller Creek and Sleeping Child Creek ground truth points plot within the model results and appear to confirm the model predictions. The results for Miller Creek appear to indicate some clustering with various areas of more or less shade. The field assessment has data coverage on the different vegetation type, height, and density for the length of the creek, but only one or two field measurements of the effective shade. The upper most reach has taller and high density vegetation and thus greater shade. The areas with less shade have shrubs and grasses and occasionally trees with a low density.

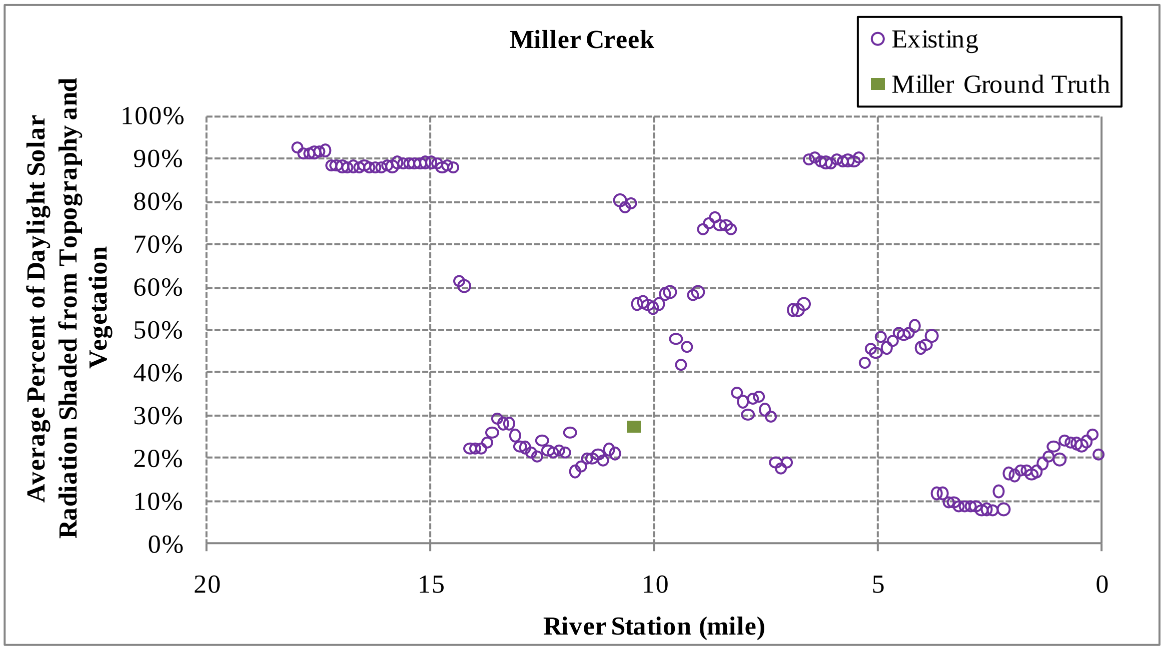


**Figure 7-1. Shade model Miller Creek longitudinal effective shade profile**

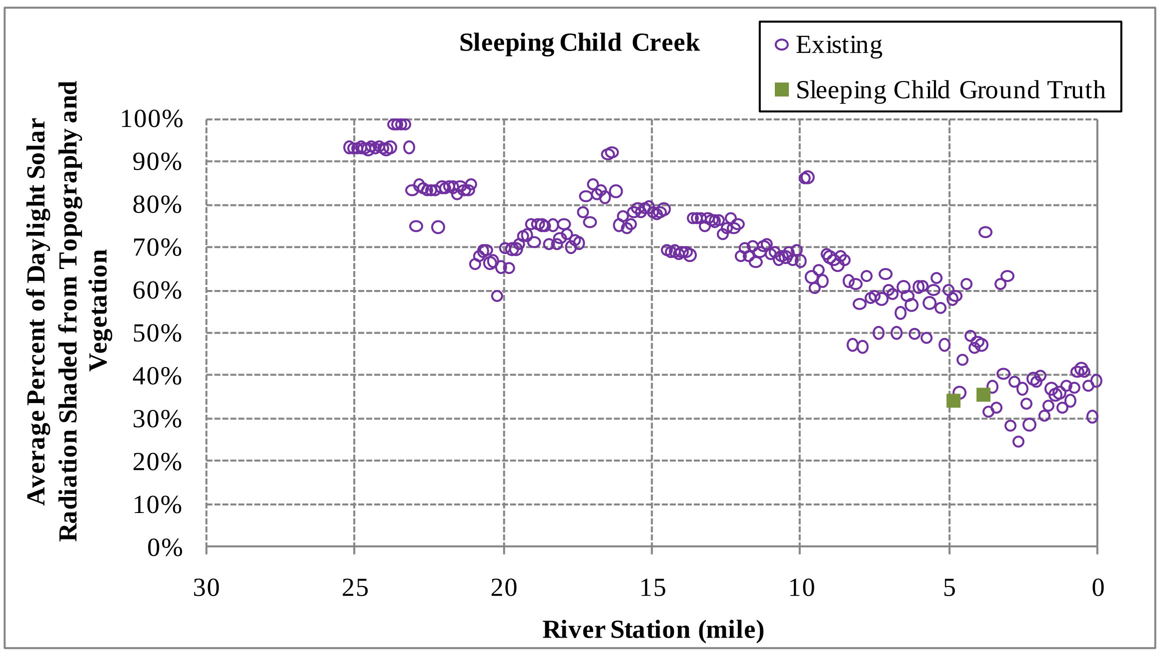


**Figure 7-2. Shade model Sleeping Child Creek longitudinal effective shade profile**

# 8.0 TRIBUTARY QUAL2K MODEL DEVELOPMENT

QUAL2K models were developed for Miller Creek, Sleeping Child Creek, and Willow Creek for August of 1992.

## 8.1 Available Data

The construction of the QUAL2K models for the tributaries relied heavily on existing data as documented and used in the Bitterroot River QUAL2E and QUAL2K models (HDR, 2005).

## 8.2 Simulation Period and Model Coefficients

Models were developed for one simulation period: August 15th for 1992. This is same date selected for the Bitterroot River water temperature simulations; the August 1992 date was considered as the period of critical low flows and high water temperatures. The water column rate coefficients (coefficients that relate physical, chemical, and biological parameters), as well as the light and heat values, were set at the same values as in the Bitterroot River model (Chapra, Pelletier, and Tao, 2007). No point sources are included.

## 8.3 Flow and Water Temperature Inputs

DEQ conducted a field study in the summer of 2007. Flow and water temperature data were collected by DEQ using a flow meter and an onset stowaway data logger at selected sites along the three tributaries. Flows were measured at the start and end of the study. The temperature loggers were installed at the start of the study, July 12, 2007, and retrieved at the end of the study, October 10, 2007. The headwater and diffuse flows were set similar to these flows. There are three points along Willow Creek that intermix with the Oilwell, Republic, and Corvallis canals. Field observations indicate that the water temperatures immediately upstream and downstream of these locations are different. QUAL2K is unable to add and remove diffuse flow in the same segment. In order to mimic this intermixing of flows, the two segments, upstream and downstream of the canal location, were used with equal addition and subtraction of flows and water temperatures from the monitoring dataset.

The headwater elevation was based on the TTools results. No hydraulic rating curves for flow relationships or other data to develop flow relationships were readily available. Instead of using hydraulic rating curves as used in the Bitterroot River model, the Manning Formula was used. The channel slope was calculated based on the reach length and elevations from TTools. The width was based on the Shade Study data, and Manning's n (0.040) and side slopes were based on the channel characteristics. The headwater water temperatures were set based on the field monitoring data.

The reaches used in the QUAL2K model are the same as the reaches developed from TTools, which were used in the Shade models. The reach length used was 660-ft, which subdivided the creeks into between 139 and 203 reaches depending upon the stream. The air temperature, dew point temperature, wind speed, and cloud cover data are the same as in the Bitterroot River model because data from the Missoula International Airport were used to represent the entire valley.

## 8.4 Shade Input

The shade inputs for Miller Creek and Sleeping Child Creek used the results of their respective Shade models. Willow Creek was not included in 2006 field study so there was insufficient information to use TTools and develop a Shade model for this creek. Averages of the shade values for Miller Creek and Sleeping Child Creek, mountain and valley reaches, were used for Willow Creek, mountain and valley reaches.

## 8.5 Model Evaluation and Calibration

Water temperatures for the three tributaries warm from the headwaters to the confluence with the Bitterroot River. The flows matched those from the 2007 field study. These flows and the model input values selected resulted in water temperatures being well represented when comparing to monitoring results.

# 9.0 TRIBUTARY RESULTS AND DISCUSSION

## 9.1 Flow

The July 2007 field data flows were used to develop the QUAL2K models. Simulated stream flows in the Miller Creek generally increase downstream with some loss near the confluence with the Bitterroot River (**Figure 9-1**). For Sleeping Child Creek, simulated stream flows also generally increase downstream (**Figure 9-2**). Simulated stream flows in Willow Creek vary along the creek, a result of the interaction with the crossing canals (**Figure 9-3**). The October 2007 field data flows are much lower than the July flows but were used as a reference point for the general magnitude of flows in the creek.

## 9.2 Water Temperature

The model results of water temperature for the tributaries were similar to the August 2007 field data (used for comparison, not calibration since the modeled date is August 15, 1992). The field data included: hourly minimum, average, and maximum values. The model averages are similar to the field data. The model range for minimum and maximum temperatures for Miller Creek is within a few degrees of the field data (**Figure 9-4**). The model range for minimum and maximum temperatures for Sleeping Child Creek is greater than the field data by a few degrees (**Figure 9-5**). The model range for minimum and maximum temperatures for Willow Creek is similar to the field data (**Figure 9-6**). The minimum, average, and maximum values from the hourly data for the monitoring season, (July through November) are shown for reference.

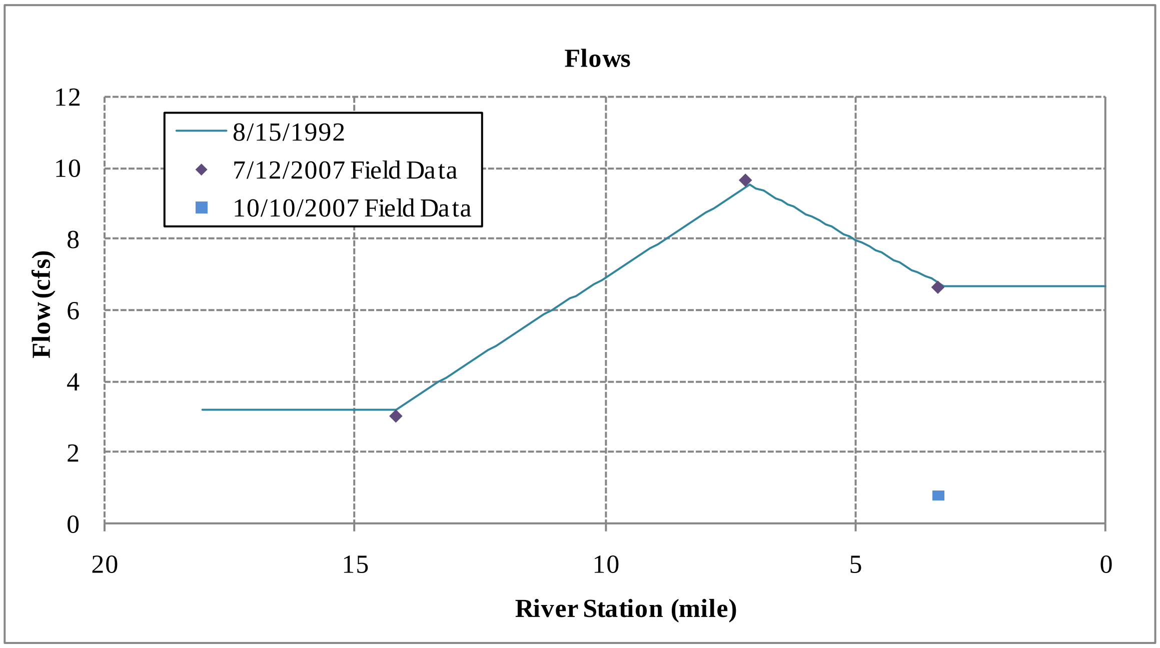


**Figure 9-1. Miller Creek simulated flow (lines) and data (diamonds and squares)**

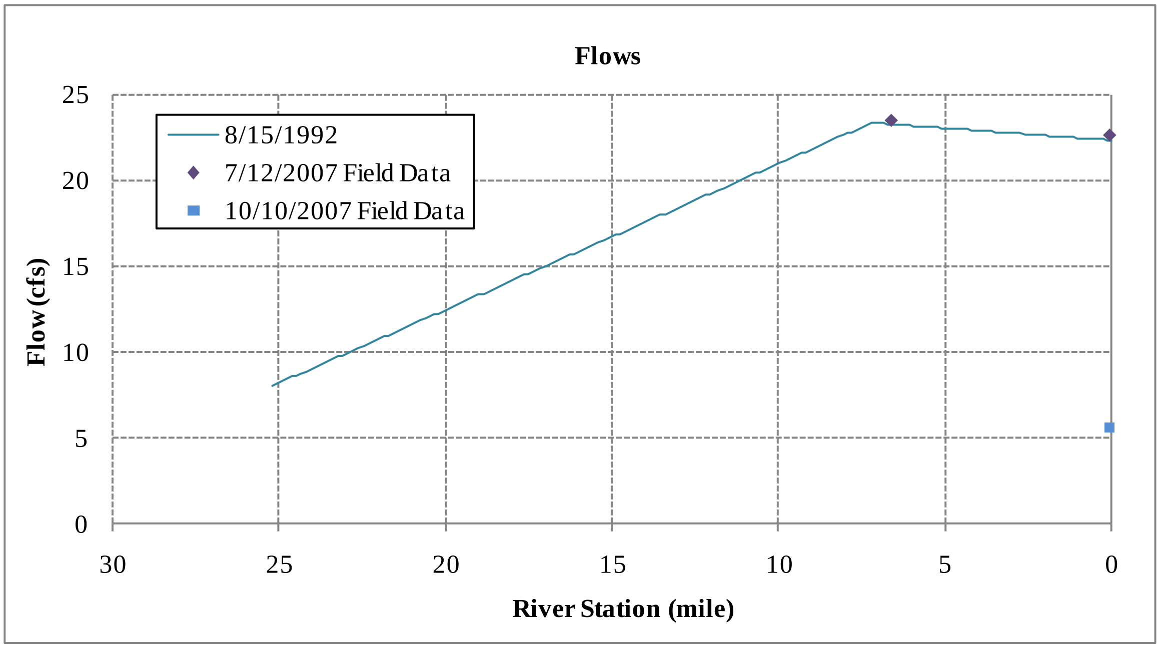


**Figure 9-2. Sleeping Child Creek simulated flow (lines) and data (diamonds and squares)**

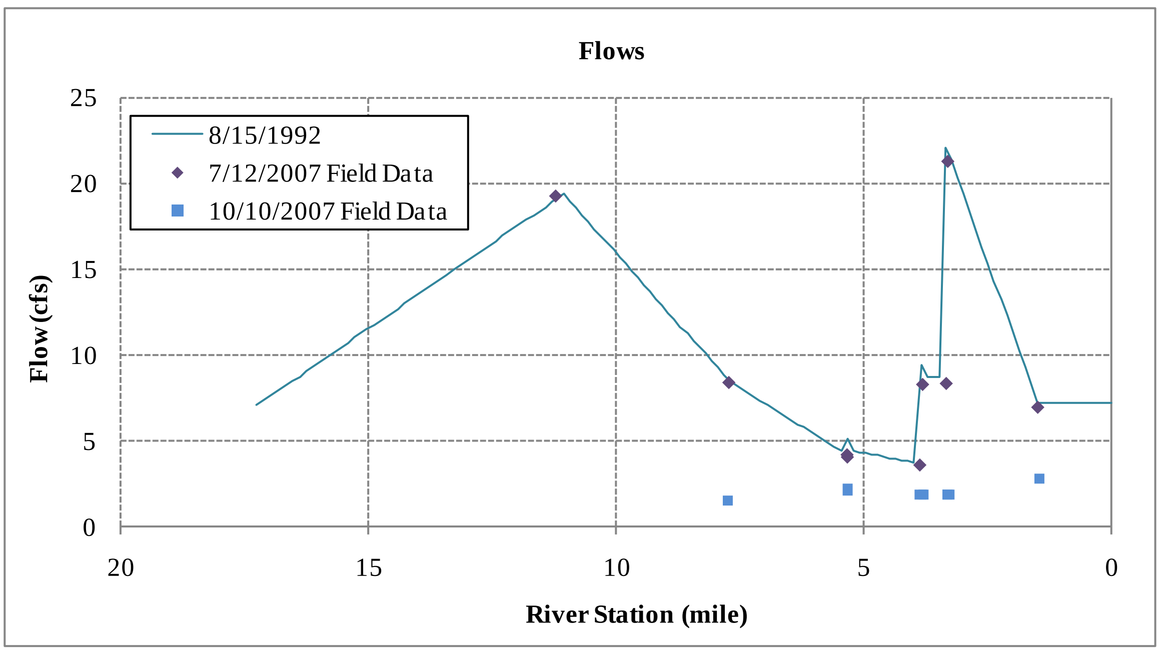


**Figure 9-3. Willow Creek simulated flow (lines) and data (diamonds and squares)**

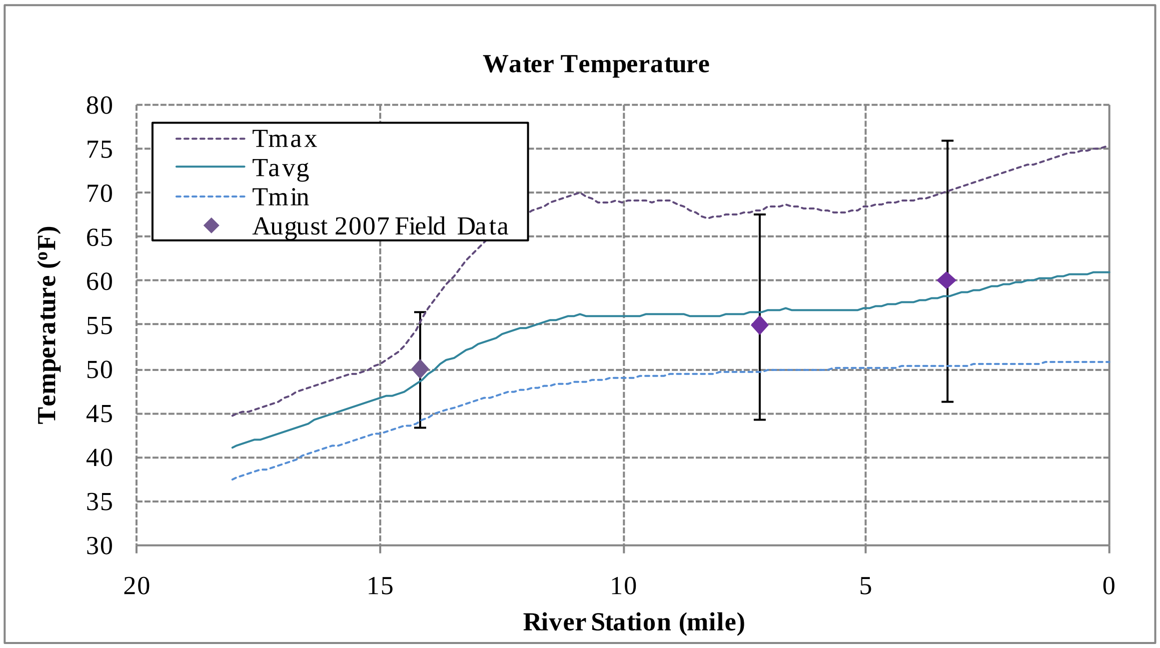


**Figure 9-4. Miller Creek simulated water temperatures (lines) and data (diamonds and squares)**

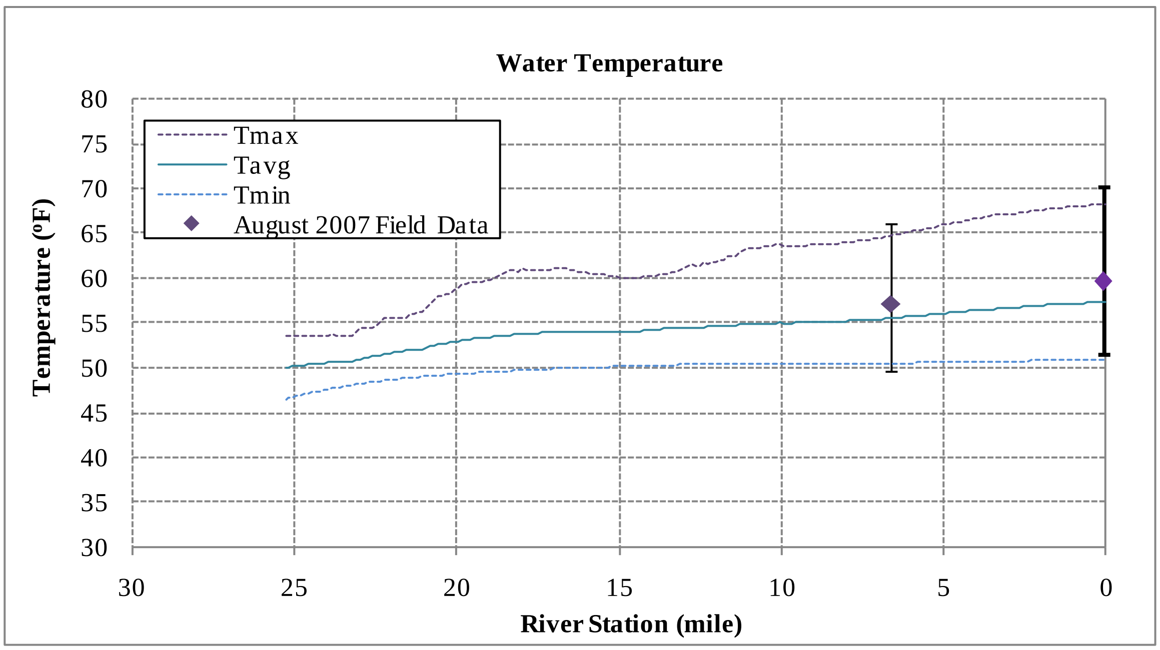


**Figure 9-5. Sleeping Child Creek simulated water temperatures (lines) and data (diamonds and squares)**

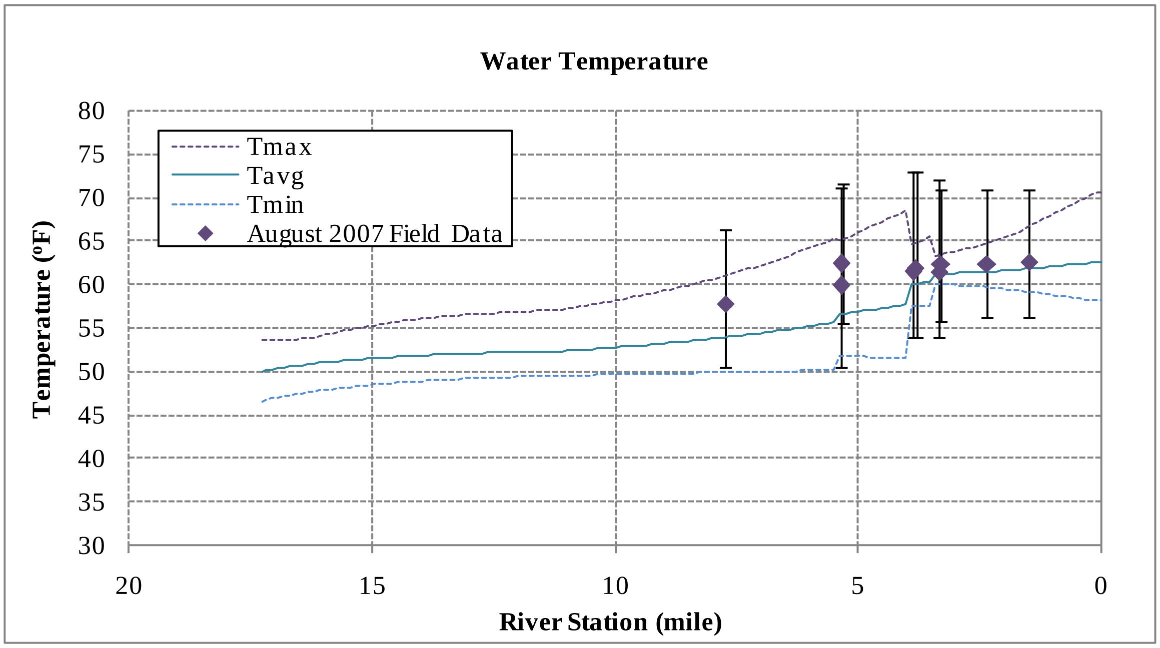


**Figure 9-6. Willow Creek simulated water temperatures (lines) and data (diamonds and squares)**

In **Figures 9-4** through **9-6**, DEQ's 2007 field monitoring data are shown for reference. The markers are the average of the hourly August 2007 data, with the minimum and maximum values for August 2007 shown as error bars. The expected water temperature should be similar since flows were low in August for both 1992 and 2007. (For comparison, the Bitterroot River at Missoula gage mean monthly flow for August 1992 was 623 cfs and for August 2007 was 498cfs. The mean annual flow for 1992 was 1,366 cfs and for 2007 was 1,934 cfs.)

# 10.0 SCENARIO ANALYSIS

Various scenarios were developed to evaluate the water temperature response of the Bitterroot River and three tributaries. These scenarios provide watershed managers information for recommendations for meeting water quality criteria in the river. The different scenarios were simulated to represent a range of potential watershed management activities. Various human influenced factors that can affect the water temperature include vegetation loss from the riparian corridor, alteration of channel morphometry, and irrigation withdrawals.

Scenarios may be simulated to assess the potential for improving water temperature conditions in the study area. Increased shading from vegetation could be accomplished with projects that improve the riparian vegetation in reaches currently with little or sparse vegetation. Changes in consumptive water use could include both increases and decreases in water demands. Increases in water demands could occur with continued development in the valley. Decreases in water demand could be accomplished through increased water use efficiency or the purchase or leasing of water rights.

Changes in channel geomorphology have the potential to influence water temperatures, but were not considered. Bitterroot River width to depth ratios are likely near their potential for such a braided river channel. The risk and cost of trying to reduce width to depth ratios for the Bitterroot River outweighs the potential for reducing temperatures. Based on the findings in Headwater Bitterroot TMDL that localized site specific streambank instability due to alterations is the main impact, channel geomorphology was not explicitly modeled for the tributaries (DEQ, 2005b and USFS, 2009).

Seven scenarios are considered to evaluate potential water temperature changes in the Bitterroot River (**Table 10-1**). Similar scenarios were developed for evaluating potential water temperatures in Miller Creek, Sleeping Child Creek, and Willow Creek.

1. The shade scenario uses reference conditions for all reaches where the existing vegetation density, unless impacted by fire, is less than in the existing conditions model. The reference condition is based on existing reaches with high quality riparian vegetation where reasonable land, soil and water conservation practices are in place.
2. The headwater and tributary influence scenario uses the existing conditions model with the headwater and all the tributary mean water temperature values reduced by 1$^{o}$F for the Bitterroot River. (The temperature range was unchanged. The headwater was not changed for the tributary models.) A reduction of 1$^{o}$F is based on expected feasible reductions and modeling results in the Headwater Bitterroot TMDL (DEQ, 2005b).
3. The flow scenarios vary the water use diversion flows by decreasing diverted flows by 15, 20, 25, and 100-percent over existing conditions. (The 100-percent decrease scenario sets all diversions to zero.) Decreased water use is based on the premise that reasonable irrigation water savings practices can achieve a certain reduction in water use. This results in four sub-scenarios for flow.
4. The wastewater treatment plant/facility (WWTP) scenarios vary the amount of flow discharged. The flow from each of the four individual dischargers (Darby, Hamilton,

Stevensville, and Lolo) is set to zero. Additionally the flow from all the dischargers is set to zero and doubled. This results in six sub-scenarios for WWTPs.

5. The stream channel dimensions scenario was not simulated given the challenges in trying to change river channel morphology, as well as the appropriateness of an overall restoration approach, as previously discussed.
6. The natural condition scenario combines the changes included in the shade, headwater and tributary, flow, and WWTP scenarios. Water use and WWTP flows were set to zero. Although this scenario is not economically viable, the natural condition scenario provides an indication of current departure from pristine conditions.
7. The naturally occurring scenario combines the changes included in the, shade, headwater and tributary, and flow 20 percent decrease scenarios. A flow decrease of 20-percent was deemed reasonable and achievable and as wells as protective of water temperatures based on the flow scenarios. The existing WWTP flows were used due to the low flow rates and localized influences based on the WWTP scenarios. DEQ's interpretation of all reasonable land, soil, and water conservation measures resulted in this selection of inputs for the naturally occurring scenario.

Since the upstream watershed conditions are relatively undisturbed and the reservoir operations are accepted by DEQ (thus DEQ has categorized the reservoirs as part of the natural condition), the upstream boundary conditions were not modified except for the water temperature in the headwater and tributary, natural condition, and naturally occurring scenarios based on the material presented in the Headwater Bitterroot TMDL (DEQ, 2005b).

The Shade and Qual2K models were modified to represent scenarios for comparison to the existing conditions. While the model provides the ability to report temperatures to the hundredth decimal, there is inherent uncertainty in the data used to construct the model, the model itself, and the ability to measure temperatures in the field to such accuracy. The model results provide the relative magnitude of potential management options.

For the Bitterroot River, the results were segmented into the three TMDL reaches. These three reaches include:

- Upper Reach - From confluence of East and West Forks near Conner, MT to Skalkaho Creek near Grantsdale, MT
- Middle Reach - From Skalkaho Creek near Grantsdale, MT to Eightmile Creek near Florence, MT
- Lower Reach - From Eightmile Creek near Florence, MT to the mouth with the Clark Fork River near Missoula, MT

For the tributaries, Miller Creek, Sleeping Child Creek, and Willow Creek, the results were not segmented and were examined for the entire reach modeled.

| Table 10-1. Model scenarios and summary of inputs | |
|---|---|
| **Location/Scenario** | **Inputs** |
| **Bitterroot River** | |
| Calibration/Existing Conditions | Field data, as previously discussed |
| Shade | Change riparian values to reference values unless existing conditions value is greater |
| Headwater and Tributary (1°F reduction) | Reduce the water temperature of the headwater and all tributaries by 1°F |
| Flow (four sub-scenarios) | Decrease water use withdrawals by 15, 20, 25, and 100 percent (i.e., set all use to zero) |
| WWTP (six sub-scenarios) | Set the four individual dischargers to zero, set all dischargers to zero, double the flow from all dischargers |
| Stream Channel Dimensions | Not simulated. |
| Natural Condition | Combine Shade, Headwater and Tributary, Flow (zero use), and WWTP (zero discharge) |
| Naturally Occurring | Combine Shade, Headwater and Tributary, and Flow (20 percent) |
| **Miller Creek** | |
| Existing Conditions | Field data, as previously discussed |
| Shade | Change riparian values to reference values unless existing conditions value is greater |
| **Sleeping Child Creek** | |
| Existing Conditions | Field data, as previously discussed |
| Shade | Change riparian values to reference values unless existing conditions value is greater or fire conditions exist |
| **Willow Creek** | |
| Existing Conditions | Use non-reference conditions |
| Shade | Change riparian values to reference values unless existing conditions value is greater |
| Natural Condition | Combine Shade, Headwater and Tributary and Flow |

## 10.1 Existing Conditions

The calibration/existing conditions models serve as the baseline model simulation for which to construct the other scenarios and compare the results against (**Table 10-1**). This model represents low flow conditions with average August cloud cover and is based on available data (**Figure 5-2**). The construction and inputs to the model have been discussed previously.

The changes to the calibration/existing conditions model for each of the scenarios is summarized in **Table 10-1** and discussed for each of the scenarios. This process isolates individual factors for evaluation of its relative impact on water temperatures.

## 10.2 Shade Scenario

The shade scenario uses the existing conditions models of the Bitterroot River, Miller Creek, Sleeping Child Creek, and Willow Creek with increase shading. For the shade scenario, the riparian shade parameters, (e.g. vegetation height, density, and overhang), were changed to reference values. In other words, for existing conditions parameters less than the reference condition, the parameters were changed to the reference condition. The reference parameters (vegetation height, density, and overhang) were developed for mountain and valley reaches. The 2006 field data were summarized by reference and non-reference reaches (**Table 10-2**). The classification was based on a visual assessment of the aerial photos including an examination of the riparian area, land use impacts, and stream meanders, along with the 2006 field data. Additionally, on-the-ground knowledge about the study streams along with best professional judgment was used for the final reference or non-reference categorization.

**Table 10-2. Riparian land cover types and associated attributes for reference and non-reference conditions**

| Location | Height (m) | Density (%) | Overhang (m) |
|---|---|---|---|
| Bitterroot River Valley Non-Reference Shade | 21.1 | 0.3 | 0.0 |
| Bitterroot River Valley Reference Shade | 22.6 | 0.4 | 0.0 |
| Miller Creek Valley Non-Reference Shade | 13.6 | 0.0 | 0.1 |
| Miller Creek Valley Reference Shade | 13.7 | 0.5 | 0.1 |
| Miller Creek Mountain Non-Reference Shade | 14.1 | 0.2 | 0.2 |
| Miller Creek Mountain Reference Shade | 20.4 | 0.6 | 0.5 |
| Sleeping Child Creek Valley Non-Reference Shade | 23.5 | 0.3 | 0.0 |
| Sleeping Child Creek Valley Reference Shade | 23.8 | 0.5 | 0.1 |
| Sleeping Child Creek Mountain Non-Reference Shade | Insufficient data, 1 non-reference reach | | |
| Sleeping Child Creek Mountain Reference Shade | 15.0 | 0.4 | 0.2 |
| Sleeping Child Creek Mountain Fire Reference Shade | 22.5 | 0.2 | 0.1 |
| Willow Creek Valley Non-Reference Shade | 13.4 | 0.0 | 0.1 |
| Willow Creek Valley Reference Shade | 23.8 | 0.5 | 0.1 |
| Willow Creek Mountain Non-Reference Shade | 15.0 | 0.4 | 0.2 |
| Willow Creek Mountain Reference Shade | 15.0 | 0.4 | 0.2 |

For the Bitterroot River, there are only valley reaches. Approximately 70 percent of the reach is at or above the reference condition. The reference shade results in an increase of about 1.5 percent to the average percent of daylight solar radiation shaded from topography and vegetation (**Figure 10-1**). For the Bitterroot River, water temperatures for the shade scenario are essentially the same as the existing conditions due to combination of the size of the river and the relatively intact shade producing vegetation (**Figure 10-2**).

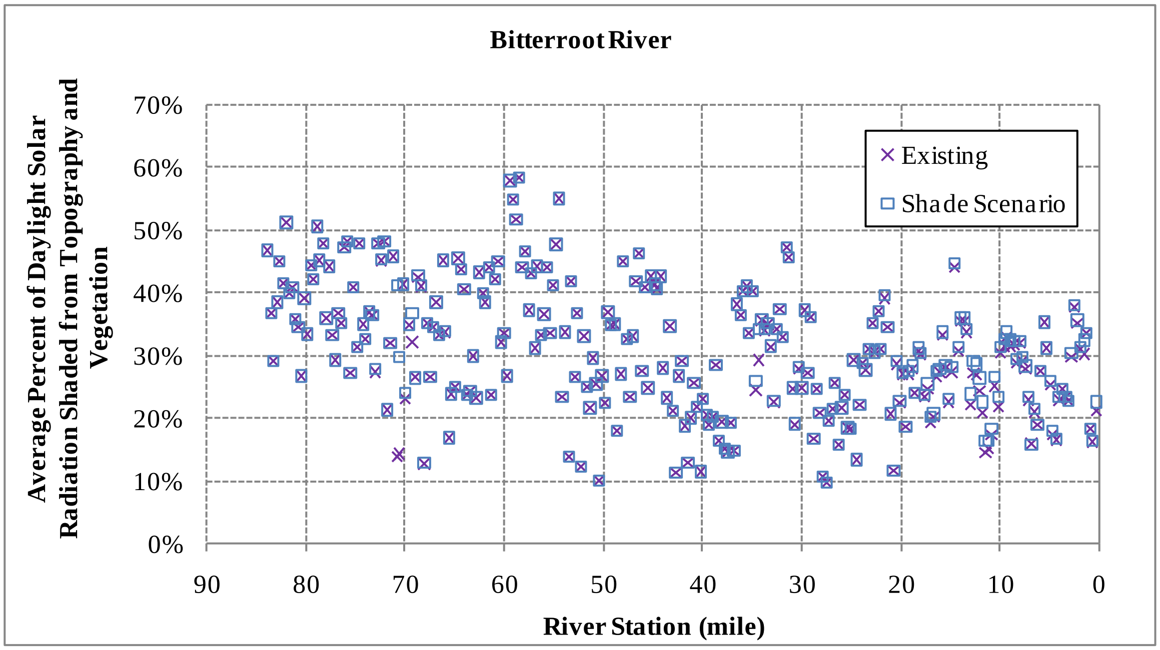


**Figure 10-1. Bitterroot River existing conditions and shade scenario effective shade**

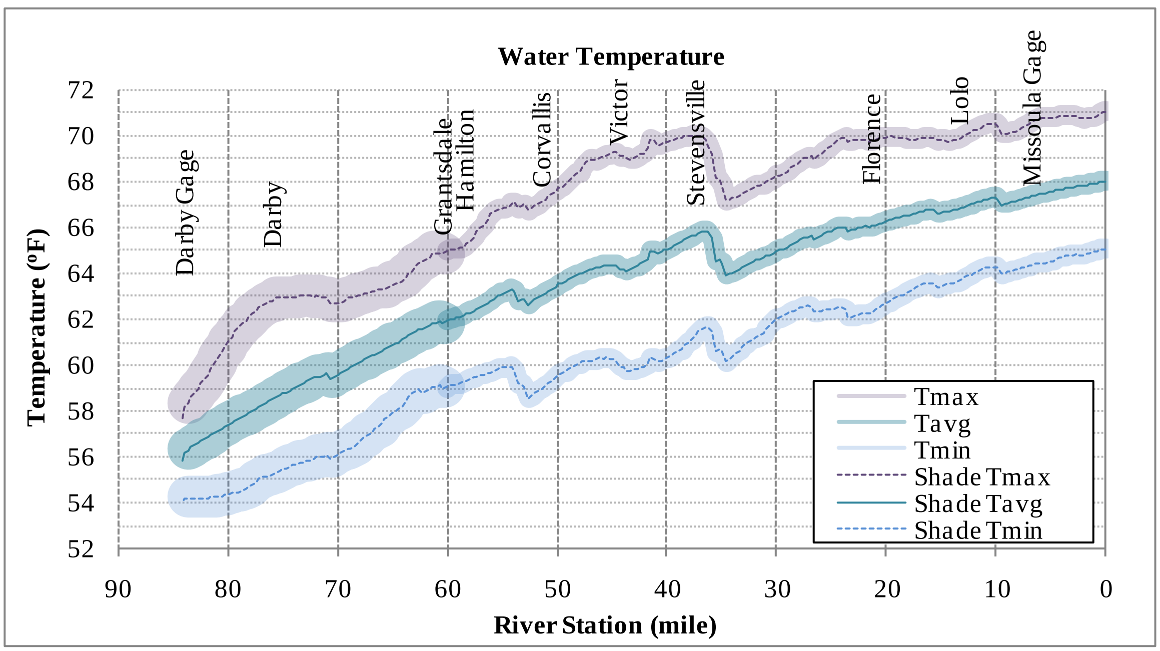


**Figure 10-2. Bitterroot River simulated water temperatures for existing conditions and shade scenario**

For Miller Creek, there are mountain and valley reaches. The valley portion of this stream runs from the confluence with the Bitterroot River to river mile 6.5 and mountain conditions are to the headwaters. There was insufficient data to develop a reference valley reach for Miller Creek, so the reference valley data from Sleeping Child Creek are used. Approximately 72 percent of the reach is below the reference conditions. The reference shade results in an increase of about 22.5 percent to the average percent of daylight solar radiation shaded from topography and vegetation

(**Figure 10-3**). For the Miller Creek, water temperatures for the shade scenario are 2°F to 6°F cooler than the existing conditions (**Figure 10-4**).

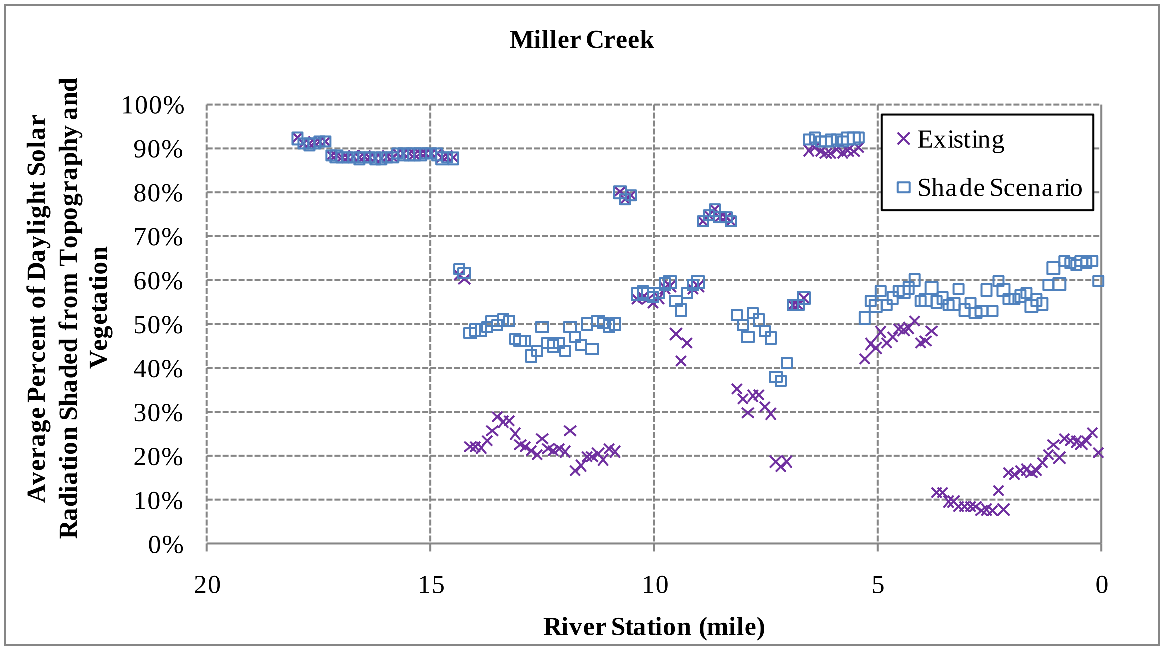


**Figure 10-3. Miller Creek existing conditions and shade scenario effective shade**

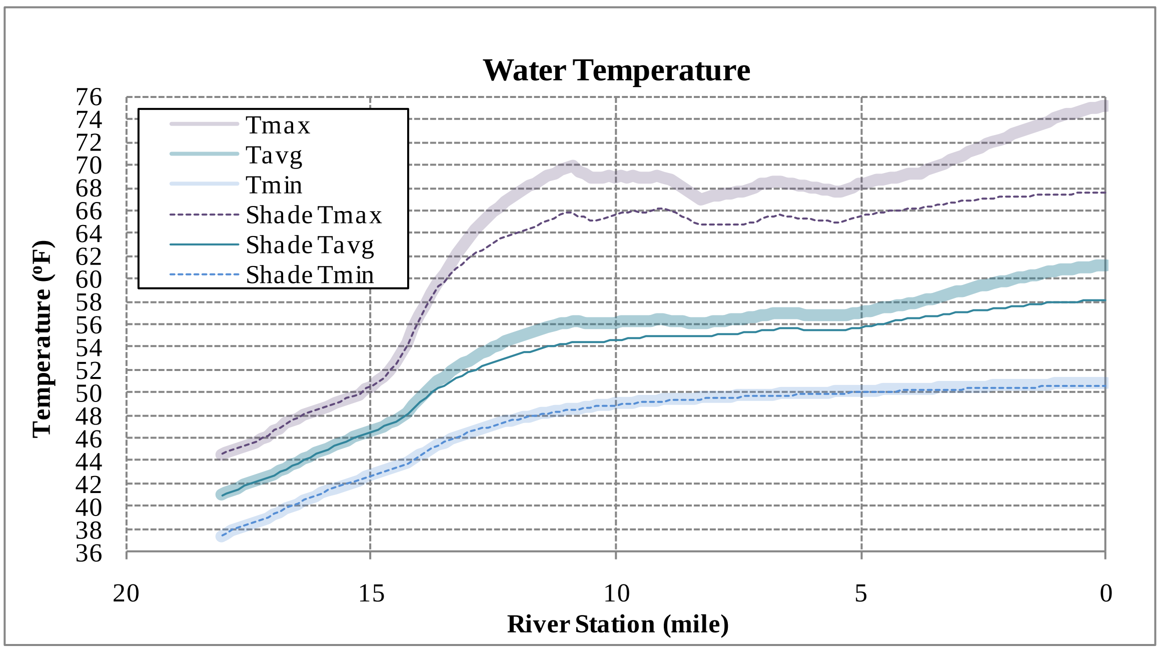


**Figure 10-4. Miller Creek simulated water temperatures for existing conditions and shade scenario**

For Sleeping Child Creek, there are mountain and valley reaches. Additionally, there is a mountain fire disturbed reach. The valley is from the confluence with the Bitterroot River to river mile 3.2, the mountain conditions extend to river mile 9.6, the fire conditions extend to river mile 19.4, and mountain conditions extend to the headwaters. Approximately 73 percent of the reach is below the reference conditions. Approximately 54 percent of the reach is below the reference condition when excluding the area with fire conditions. The fire conditions were treated as a natural occurrence and the vegetation was not changed to reference shade conditions. The reference shade results in an increase of about 2.6 percent to the average percent of daylight solar radiation shaded from topography and vegetation (**Figure 10-5**). For the Sleeping Child Creek, water temperatures for the shade scenario are about 0.5$^{o}$F cooler than the existing conditions (**Figure 10-6**).

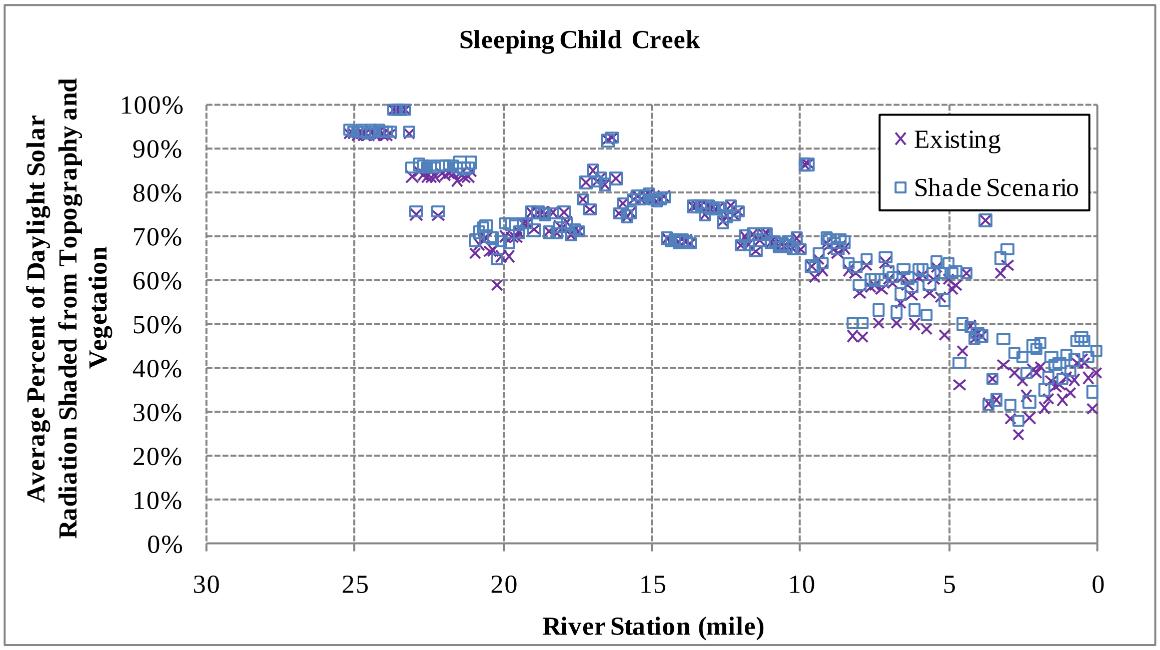

**Figure 10-5. Sleeping Child Creek existing conditions and shade scenario effective shade**

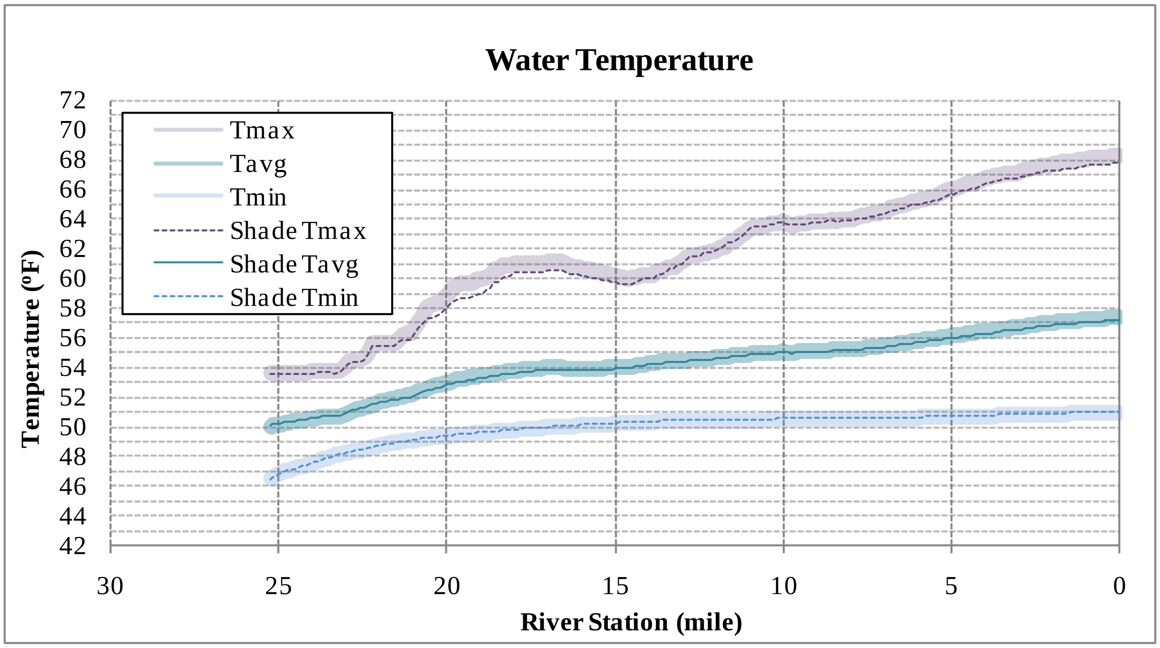


**Figure 10-6. Sleeping Child Creek simulated water temperatures for existing conditions and shade scenario**

For Willow Creek, there are mountain and valley reaches. The valley is from the confluence with the Bitterroot River to river mile 4.0 and mountain conditions extend to the headwaters. However, no field data were collected for this tributary. Without data, the average reference shade for the mountain and valley reaches from Miller Creek and Sleeping Child Creek were used for Willow Creek, mountain and valley reaches. The reference shade results in an increase of about 8.9 percent to the average percent of daylight solar radiation shaded from topography and vegetation (**Figure 10-7**). For the Willow Creek, water temperatures for the shade scenario are about 1$^{o}$F cooler than the existing conditions (**Figure 10-8**).

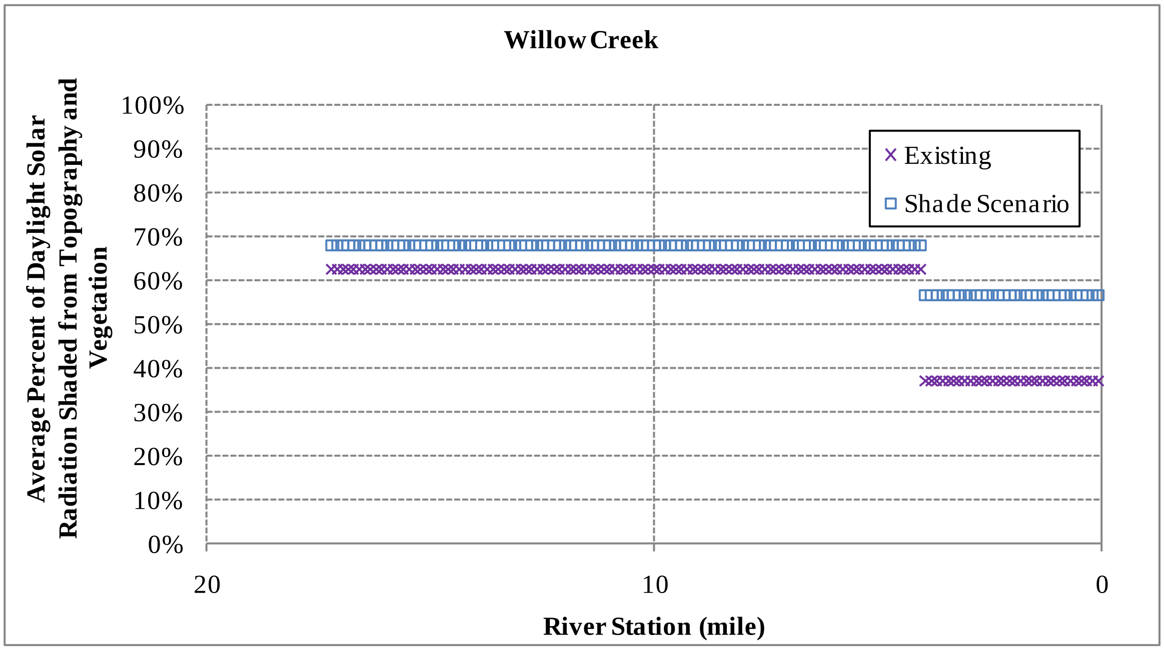


**Figure 10-7. Willow Creek existing conditions and shade scenario effective shade**

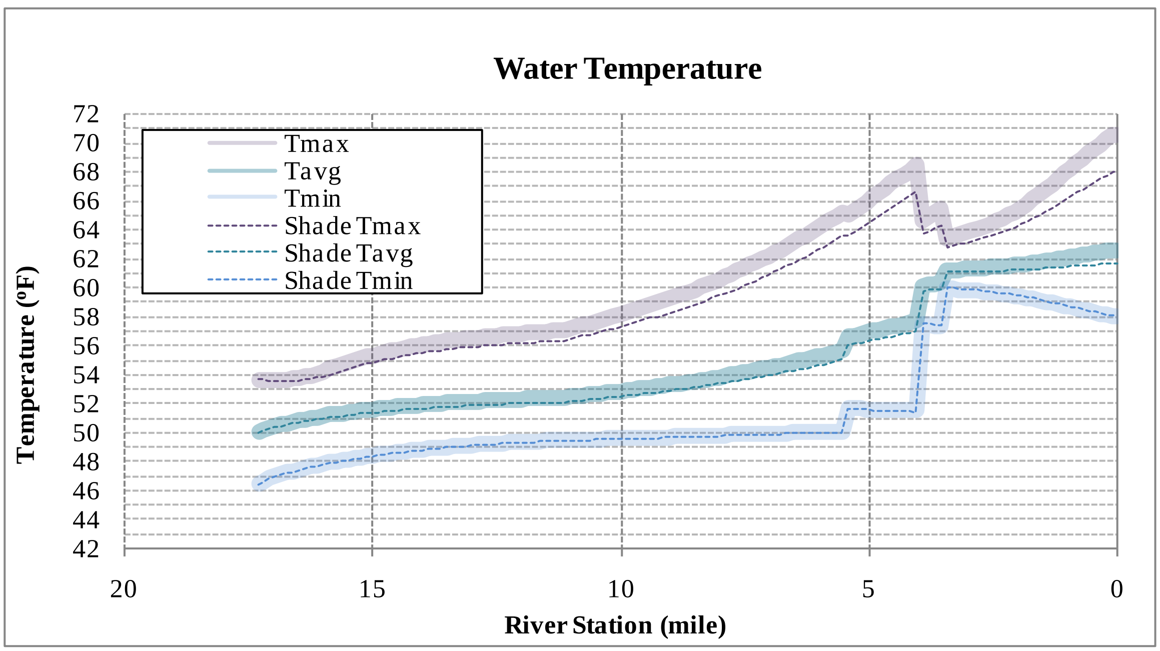


**Figure 10-8. Willow Creek simulated water temperatures for existing conditions and shade scenario**

The maximum change in the maximum daily water temperature is representative of the worst case conditions (**Table 10-3**). The locations where the difference in water temperature is greater than 0.5°F between the existing conditions and shade scenario are summarized (**Table 10-4**). The results are also shown by reach on the map of the streams (**Figure 10-9**).

**Table 10-3. Tabular results of differences in water temperatures for existing conditions and shade scenario**

| River/Creek | Maximum Change in Maximum Daily Water Temperature ($^oF$) | Location River Station (mile) |
|---|---|---|
| Bitterroot River Upper Reach | -0.11 | 63 to 67 |
| Bitterroot River Middle Reach | -0.03 | 28 to 33 |
| Bitterroot River Lower Reach | -0.07 | 7 to 12 |
| Miller Creek | -7.58 | 0 to 0.5 |
| Sleeping Child Creek | -1.03 | 18.5 to 20 |
| Willow Creek | -2.45 | 0 to 1 |

**Table 10-4. Water temperature (daily maximum and mean) comparison, existing conditions and shade scenario**

| **Maximum Daily Water Temperature** | | |
|---|---|---|
| **River/Creek** | **Difference > 0.5$^o$F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |
| Miller Creek | Yes | 0 to 13.5 |
| Sleeping Child Creek | Yes | 0 to 3 and 15.5 to 21 |
| Willow Creek | Yes | 0 to 15 |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5$^o$F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |
| Miller Creek | Yes | 0 to 13.5 |
| Sleeping Child Creek | No | n/a |
| Willow Creek | Yes | 0 to 1.5 and 4 to 7 |

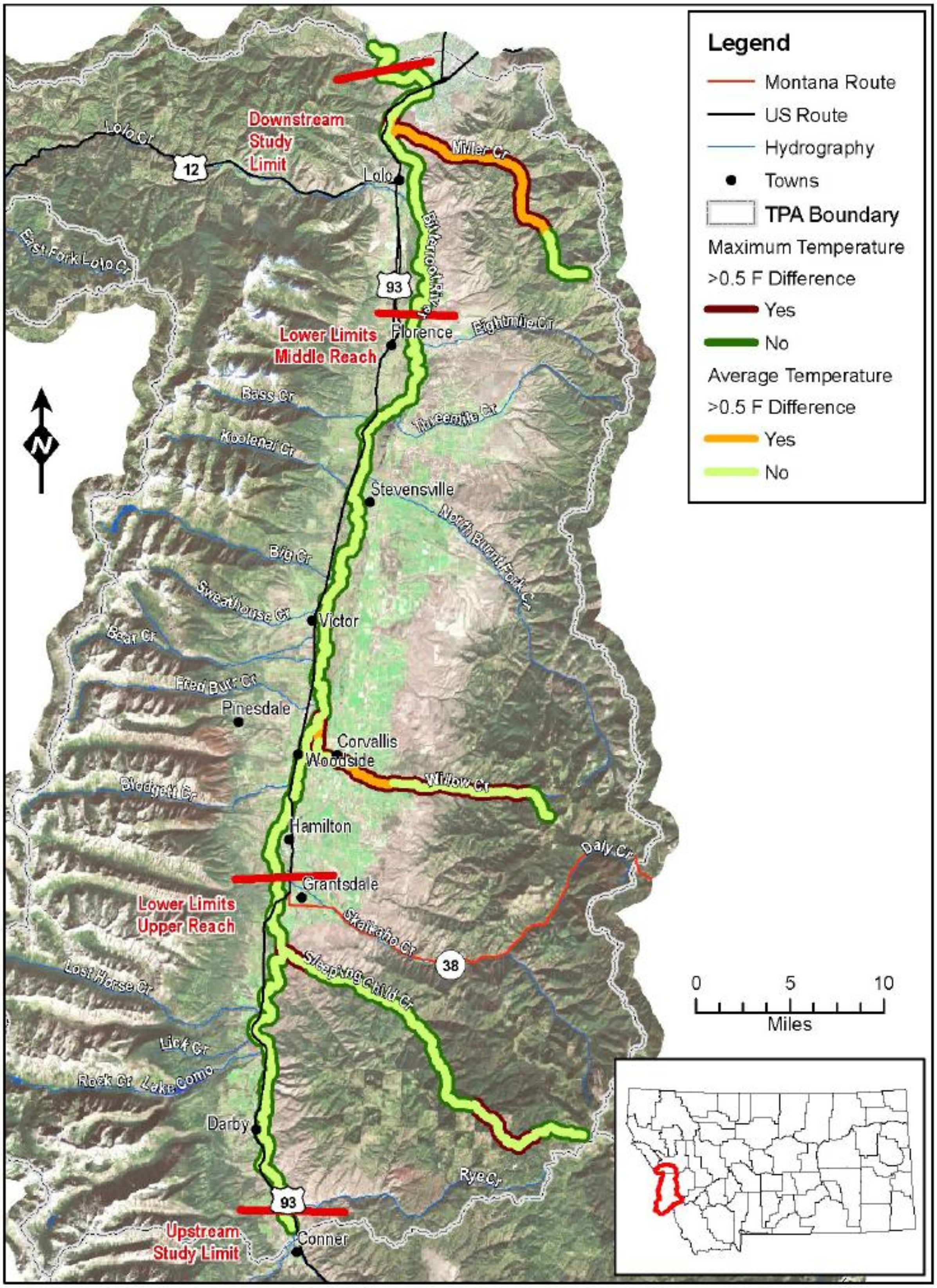


**Figure 10-9. Water temperature (maximum and mean) comparison, existing conditions and shade scenario**

## 10.3 Headwater and Tributary Water Temperature Reduction Scenario

The headwater and tributary water temperatures were reduced by 1°F in the existing conditions model of the Bitterroot River. The water temperature range was unchanged. A reduction of 1°F is based on expected feasible reductions and modeling results in the Headwater Bitterroot TMDL (DEQ, 2005b). This scenario was not performed for Miller Creek, Sleeping Child Creek, and Willow Creek since there is no basis for reducing the headwater and there are no tributaries in these models.

For the Bitterroot River, water temperatures for the headwater and tributary water temperature reduction scenario are about 0.5°F lower than the existing conditions (**Figure 10-10**). The maximum change in the maximum daily water temperature is representative of the worst case conditions (**Table 10-5**). The locations where the difference in water temperature is greater than 0.5°F between the existing conditions and headwater and tributary water temperature reduction scenario are summarized (**Table 10-6**). The results of the comparison are also shown by reach on the map of the streams (**Figure 10-14**).

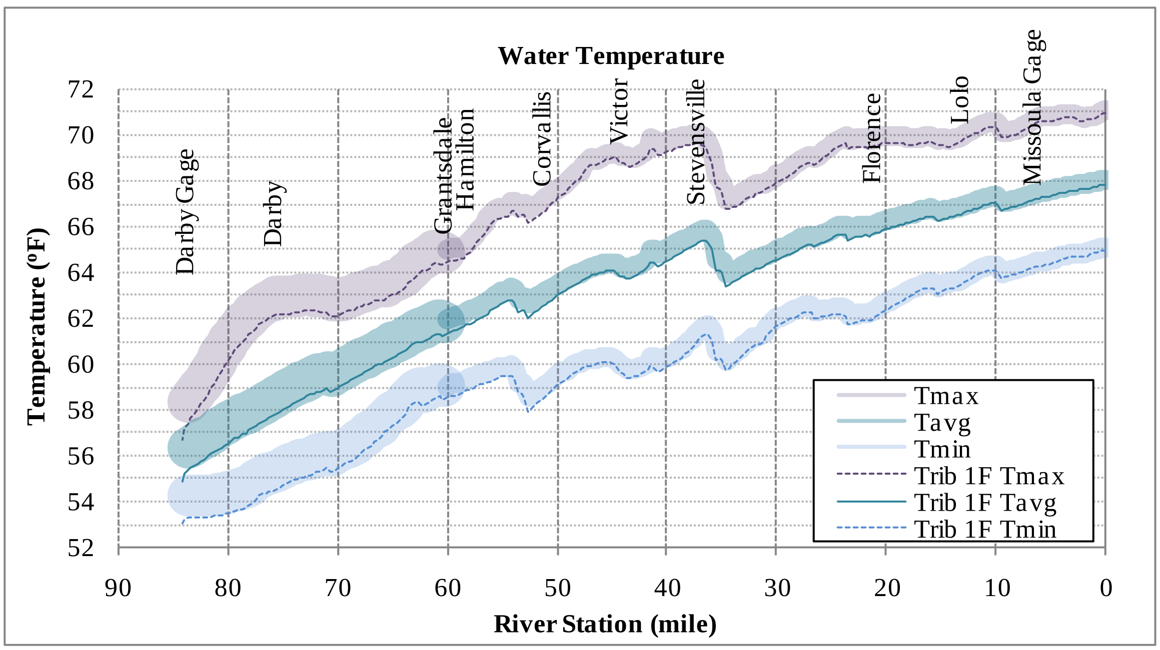


**Figure 10-10. Bitterroot River simulated water temperatures for existing conditions and headwater and tributary water temperature reduction scenario**

**Table 10-5. Tabular results of differences in water temperatures for existing conditions and headwater and tributary water temperature reduction scenario**

| River/Creek | Maximum Change in Maximum Daily Water Temperature (°F) | Location River Station (mile) |
|---|---|---|
| Bitterroot River Upper Reach | -1.00 | 82 to 84 |
| Bitterroot River Middle Reach | -0.67 | 51.5 to 53 |
| Bitterroot River Lower Reach | -0.39 | 18 to 21.5 |

| **Table 10-6. Water temperature (daily maximum and mean) comparison, existing conditions and headwater and tributary water temperature reduction scenario** | | |
|---|---|---|
| **Maximum Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5$^{o}$F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60.5 to 84 |
| Bitterroot River Middle Reach | Yes | 39.5 to 41 and 50 to 60.5 |
| Bitterroot River Lower Reach | No | n/a |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5$^{o}$F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60.5 to 84 |
| Bitterroot River Middle Reach | Yes | 39.5 to 41 and 50 to 60.5 |
| Bitterroot River Lower Reach | No | n/a |

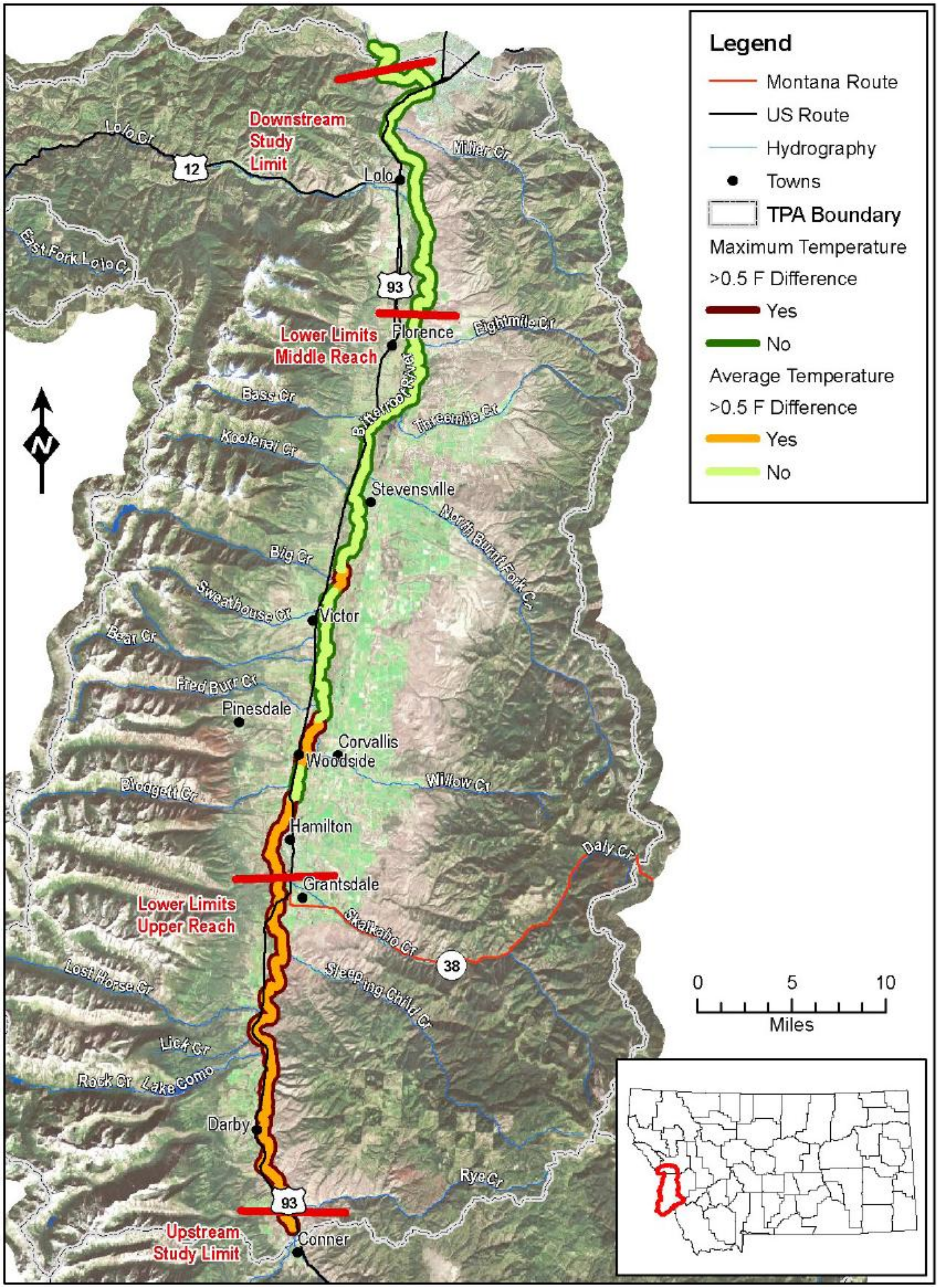


**Figure 10-11. Water temperature (maximum and mean) comparison, existing conditions and headwater and tributary water temperature reduction scenario**

## 10.4 Flow Scenarios

The flow scenarios consist of multiple simulations with decreases in water use in the existing conditions model of the Bitterroot River. The Miller Creek, Sleeping Child Creek, and Willow Creek existing conditions models do not have any water use included that reduces the streamflow and do not have separate scenario simulations. The simulations consist of decreasing water use by 15, 20, 25, and 100 percent from the Bitterroot River (**Figure 10-12**). While not feasible due to water rights and other issues, the 100 percent decrease scenario indicates the maximum possible achievable change in water temperatures from changes in water use. Decreases in water use of 15 to 25 percent may be feasible with changes in irrigation practices.

For the Bitterroot River, water temperatures for the flow scenarios result in incremental decreases in water temperature, especially in the middle reach (**Figure 10-13**, **Figure 10-14**, **Figure 10-15**, and **Figure 10-16**). The maximum change in the maximum daily water temperature is representative of the worst case conditions (**Table 10-7**). The locations where the difference in water temperature is greater than 0.5°F between the existing conditions and flow scenarios are summarized for each of the four scenarios (**Table 10-8**, **Table 10-9**, **Table 10-10**, and **Table 10-11**). The results of the comparison are also shown by reach on the map of the streams (**Figure 10-17** and **Figure 10-18**).

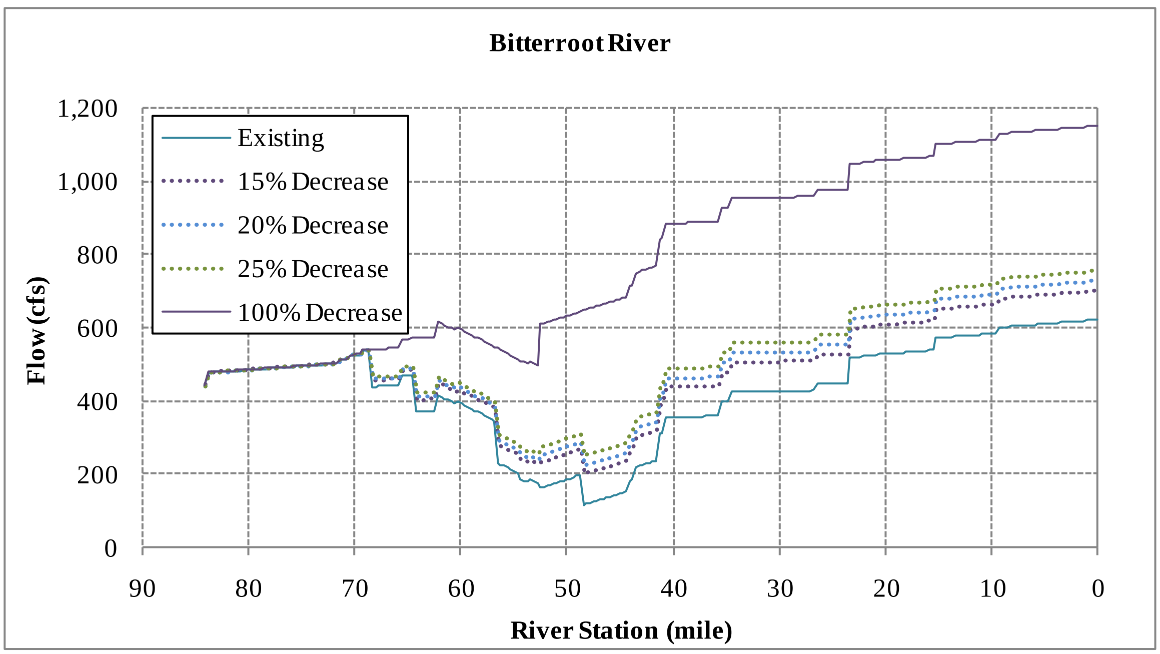


**Figure 10-12. Bitterroot River flows for flow scenarios, 15, 20, 25 and 1000 decreases in water use**

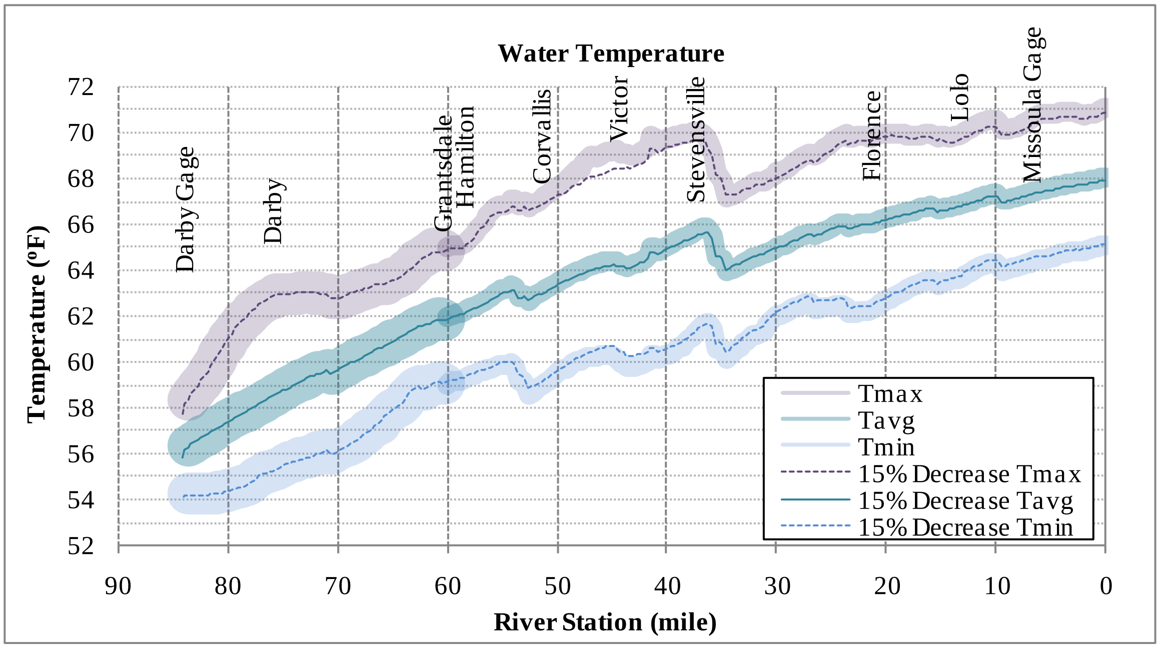


**Figure 10-13. Bitterroot River simulated water temperatures for existing conditions and flow scenarios, 15 percent decrease in water use**

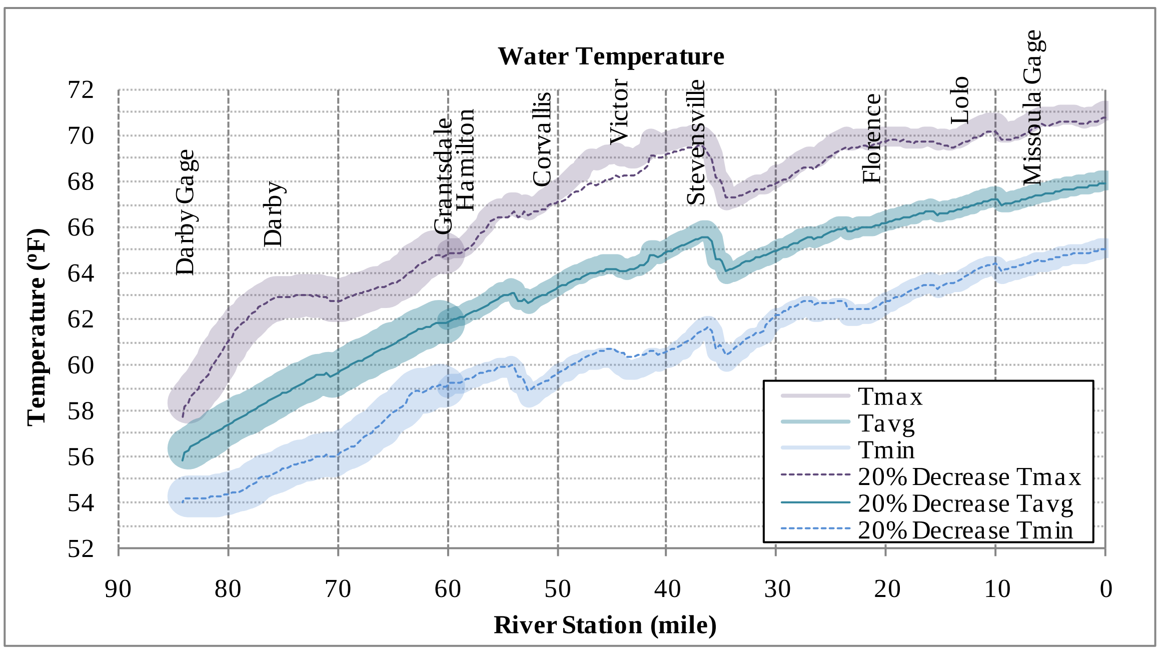


**Figure 10-14. Bitterroot River simulated water temperatures for existing conditions and flow scenarios, 20 percent decrease in water use**

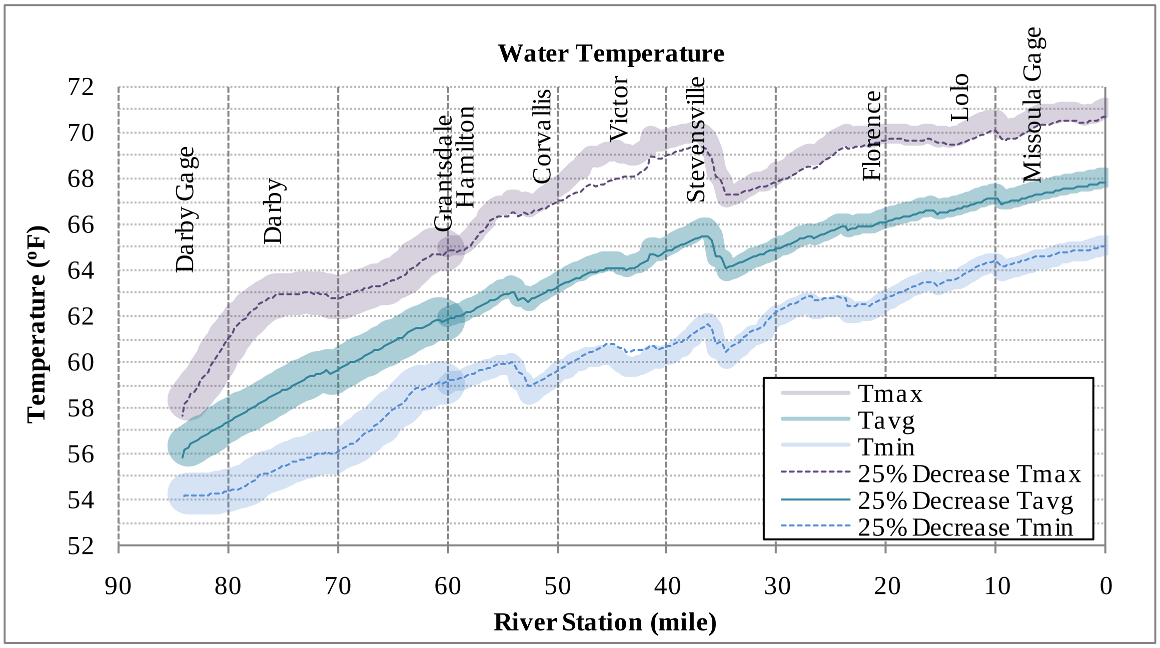


**Figure 10-15. Bitterroot River simulated water temperatures for existing conditions and flow scenarios, 25 percent decrease in water use**

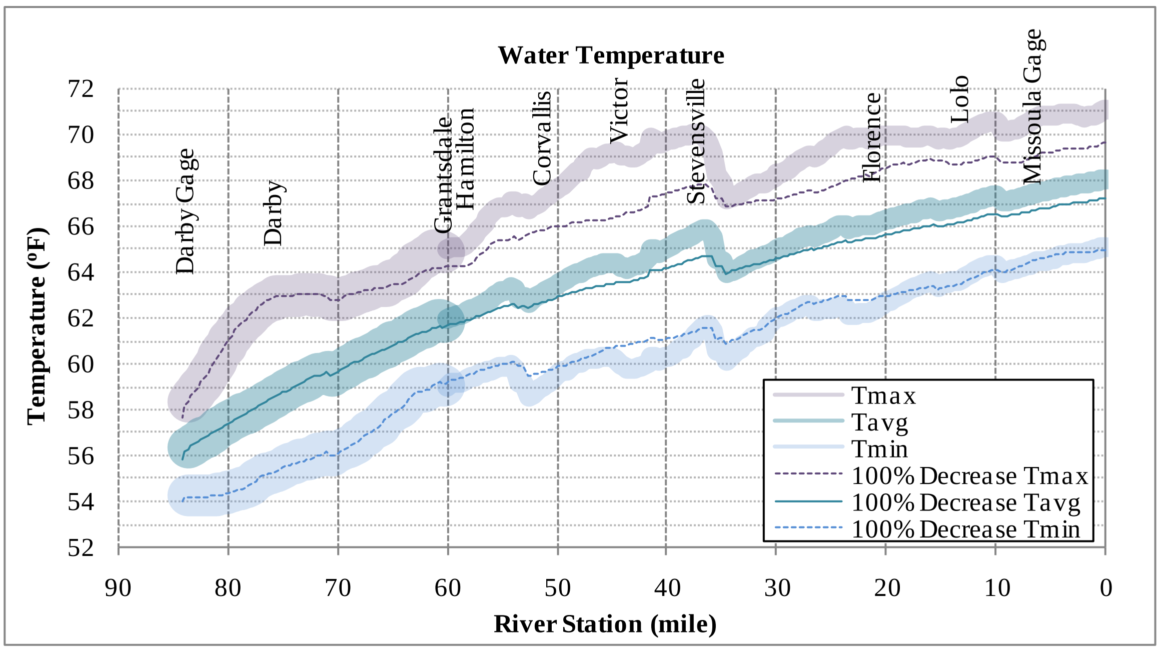


**Figure 10-16. Bitterroot River simulated water temperatures for existing conditions and flow scenarios, 100 percent decrease in water use**

| **Table 10-7. Tabular results of differences in water temperatures for existing conditions and flow scenarios** | | |
|---|---|---|
| **River/Creek** | **Maximum Change in Maximum Daily Water Temperature ($^{o}$F)** | **Location River Station (mile)** |
| Scenario: Flow 15 percent decrease in water use | | |
| Bitterroot River Upper Reach | -0.15 | 60 to 61 |
| Bitterroot River Middle Reach | -0.91 | 44.5 to 47.5 |
| Bitterroot River Lower Reach | -0.35 | 10 to 12 |
| Scenario: Flow 20 percent decrease in water use | | |
| Bitterroot River Upper Reach | -0.19 | 60 to 62 |
| Bitterroot River Middle Reach | -1.14 | 45 to 46 |
| Bitterroot River Lower Reach | -0.46 | 10 to 12 |
| Scenario: Flow 25 percent decrease in water use | | |
| Bitterroot River Upper Reach | -0.24 | 60 to 61 |
| Bitterroot River Middle Reach | -1.35 | 45 to 46 |
| Bitterroot River Lower Reach | -0.56 | 10 to 11.5 |
| Scenario: Flow 100 percent decrease in water use | | |
| Bitterroot River Upper Reach | -0.77 | 60 to 61 |
| Bitterroot River Middle Reach | -2.96 | 44.5 to 46 |
| Bitterroot River Lower Reach | -1.73 | 5 to 7 |

| **Table 10-8. Water temperature (daily maximum and mean) comparison, existing conditions and flow scenarios, 15 percent decrease in water use** | | |
|---|---|---|
| **Maximum Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5$^{o}$F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | Yes | 41 to 49.5 |
| Bitterroot River Lower Reach | No | n/a |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5$^{o}$F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |

**Table 10-9. Water temperature (daily maximum and mean) comparison, existing conditions and flow scenarios, 20 percent decrease in water use**

| **Maximum Daily Water Temperature** | | |
|---|---|---|
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | Yes | 37 to 50.5 |
| Bitterroot River Lower Reach | No | n/a |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |

**Table 10-10. Water temperature (daily maximum and mean) comparison, existing conditions and flow scenarios, 25 percent decrease in water use**

| **Maximum Daily Water Temperature** | | |
|---|---|---|
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 9.5 to 10.5 |
| Bitterroot River Middle Reach | Yes | 23.5 to 28.5 and 36.5 to 54.5 |
| Bitterroot River Lower Reach | No | n/a |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |

**Table 10-11. Water temperature (daily maximum and mean) comparison, existing conditions and flow scenarios, 100 percent decrease in water use**

| **Maximum Daily Water Temperature** | | |
|---|---|---|
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60 to 63 |
| Bitterroot River Middle Reach | Yes | 21.5 to 60 |
| Bitterroot River Lower Reach | Yes | 0 to 21.5 |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | Yes | 21.5 to 28.5 and 35.5 to 56.5 |
| Bitterroot River Lower Reach | Yes | 0 to 21.5 |

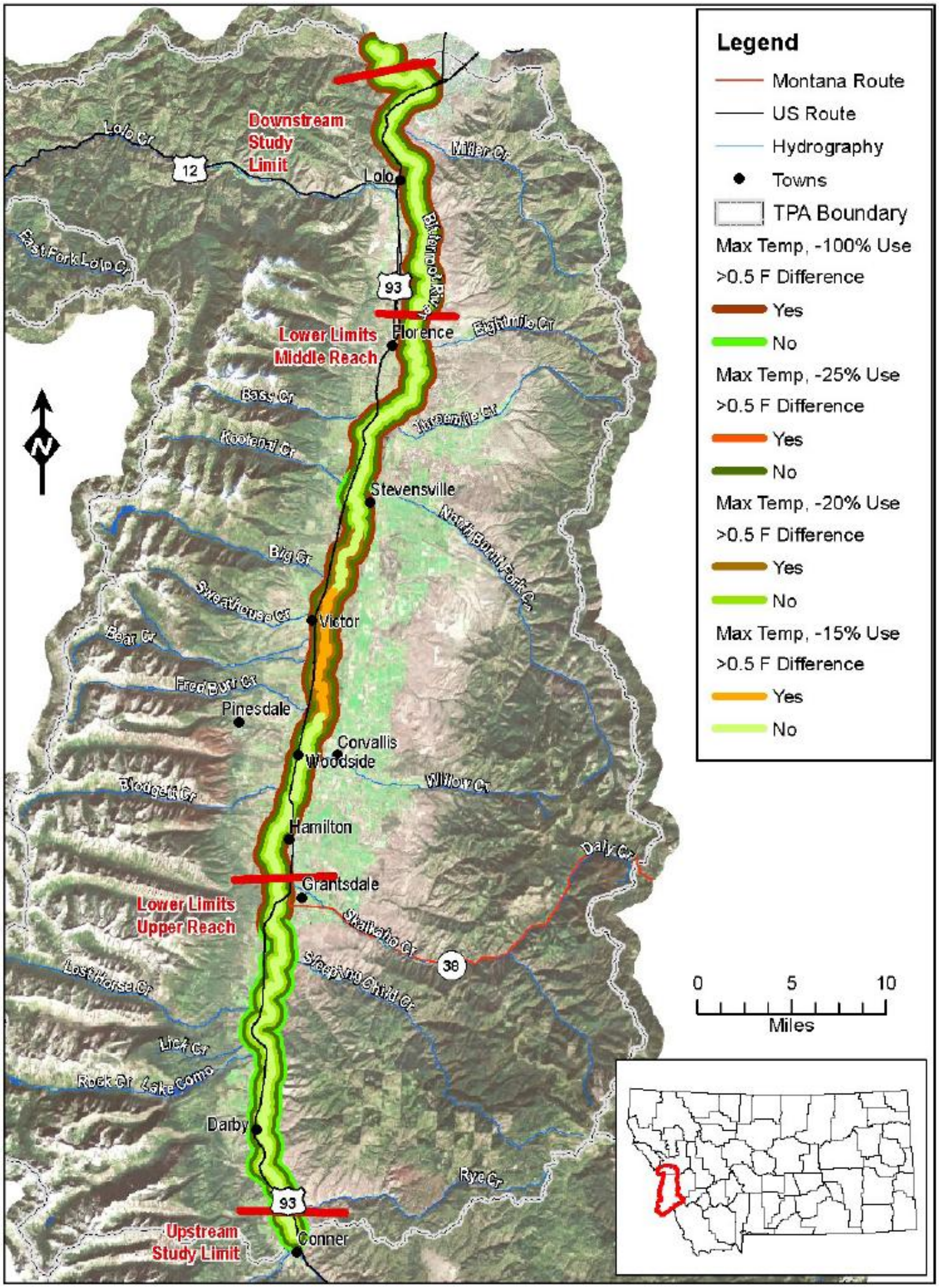


**Figure 10-17. Water temperature (maximum) comparison, existing conditions and flow scenarios**

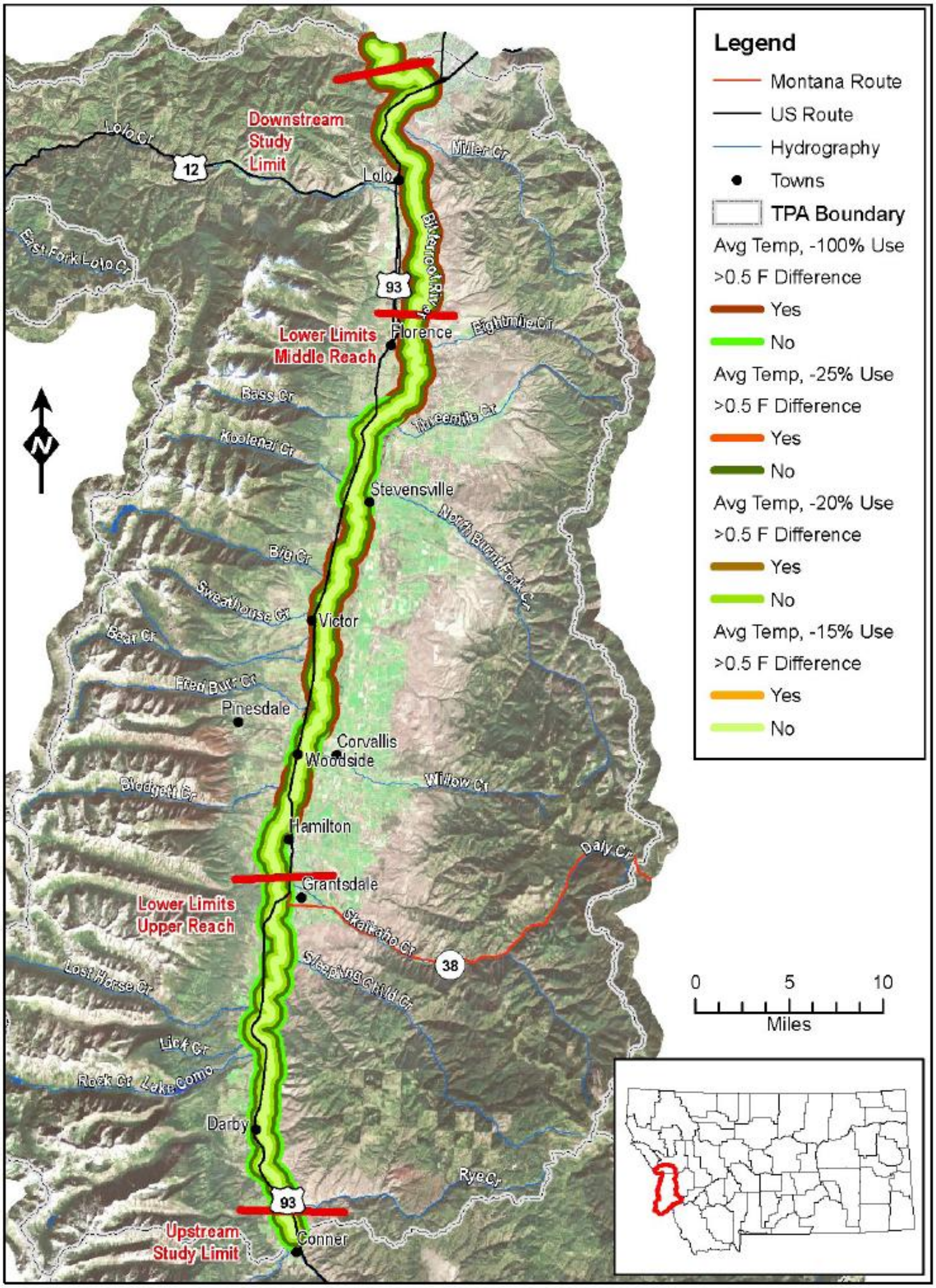


**Figure 10-18. Water temperature (mean) comparison, existing conditions and flow scenarios**

## 10.5 Wastewater Treatment Plant/Facility Scenarios

The WWTP scenarios consist of multiple simulations with changes in the discharge rates from the wastewater treatment facilities in the existing conditions model of the Bitterroot River. The Miller Creek, Sleeping Child Creek, and Willow Creek existing conditions models do not have any WWTPs and do not have separate scenario simulations. The simulations consist of setting the four individual dischargers to zero (Darby, Hamilton, Stevensville, and Lolo), setting all dischargers to zero, and doubling the flow from all the dischargers to the Bitterroot River.

For the Bitterroot River, water temperatures for the WWTP scenarios are essentially the same as the existing conditions (**Figure 10-19**, **Figure 10-20**, **Figure 10-21**, **Figure 10-22**, **Figure 10-23**, and **Figure 10-24**). The impacts are small from all facilities, with Hamilton being the greatest, since it has the greatest flow of the four. The maximum change in the maximum daily water temperature is representative of the worst case conditions (**Table 10-12**). The locations where the difference in water temperature is greater than 0.5$^{o}$F between the existing conditions and WWTP scenarios are summarized (**Table 10-13**).

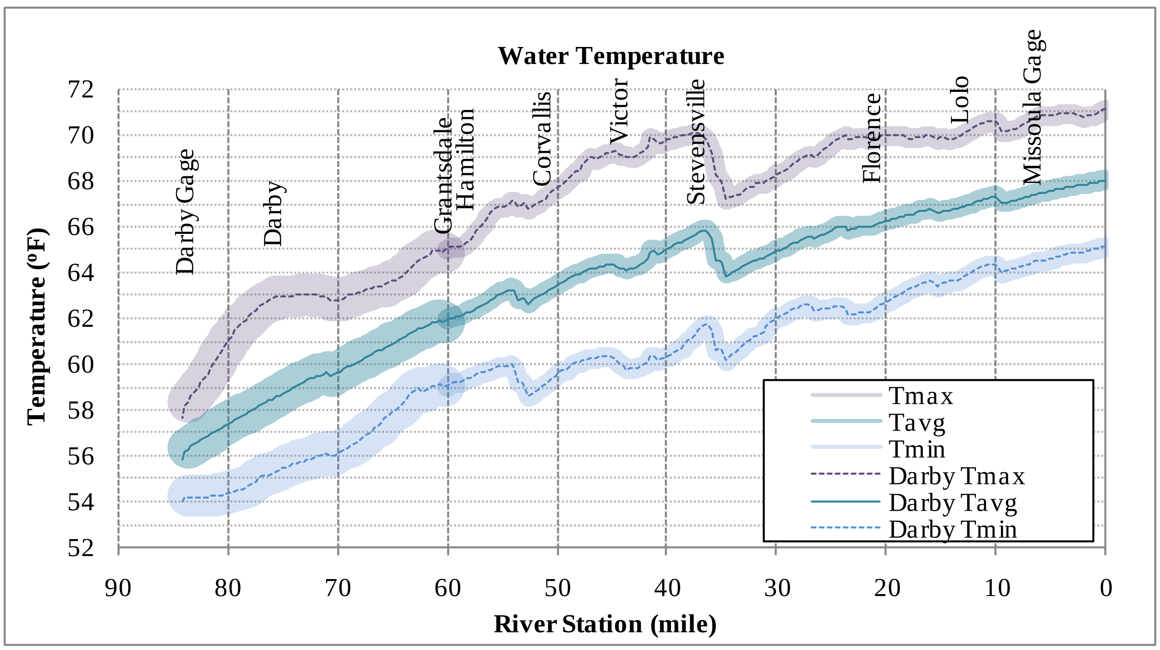


**Figure 10-19. Bitterroot River simulated water temperatures for existing conditions and WWTP scenarios, Darby flow set to zero**

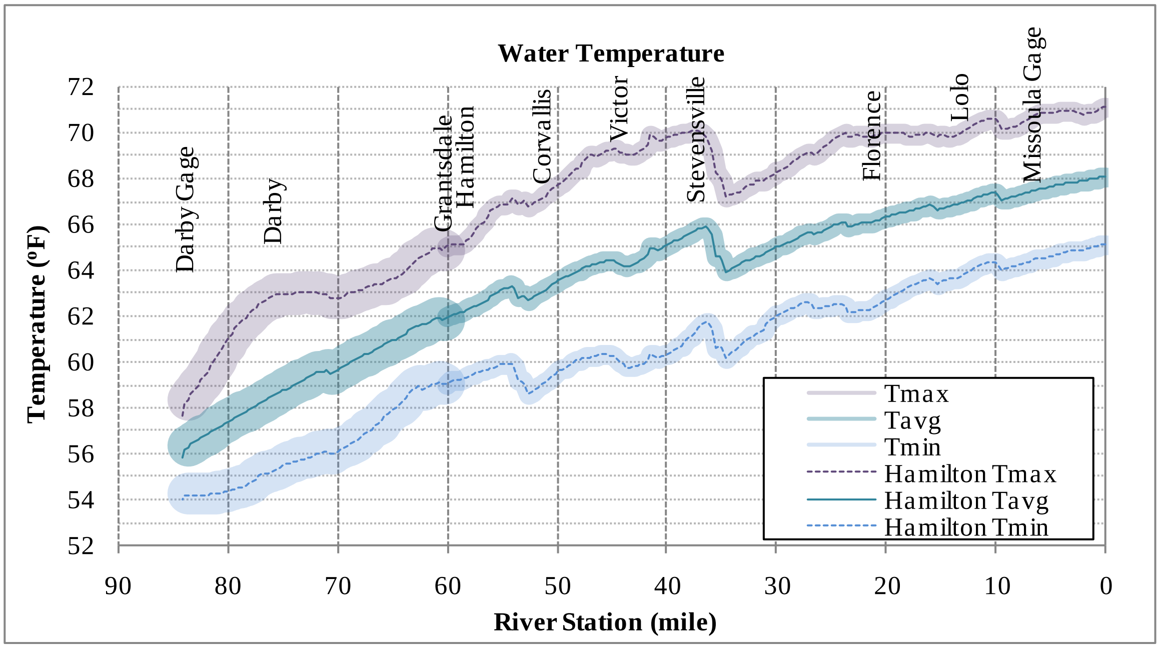


**Figure 10-20. Bitterroot River simulated water temperatures for existing conditions and WWTP scenarios, Hamilton flow set to zero**

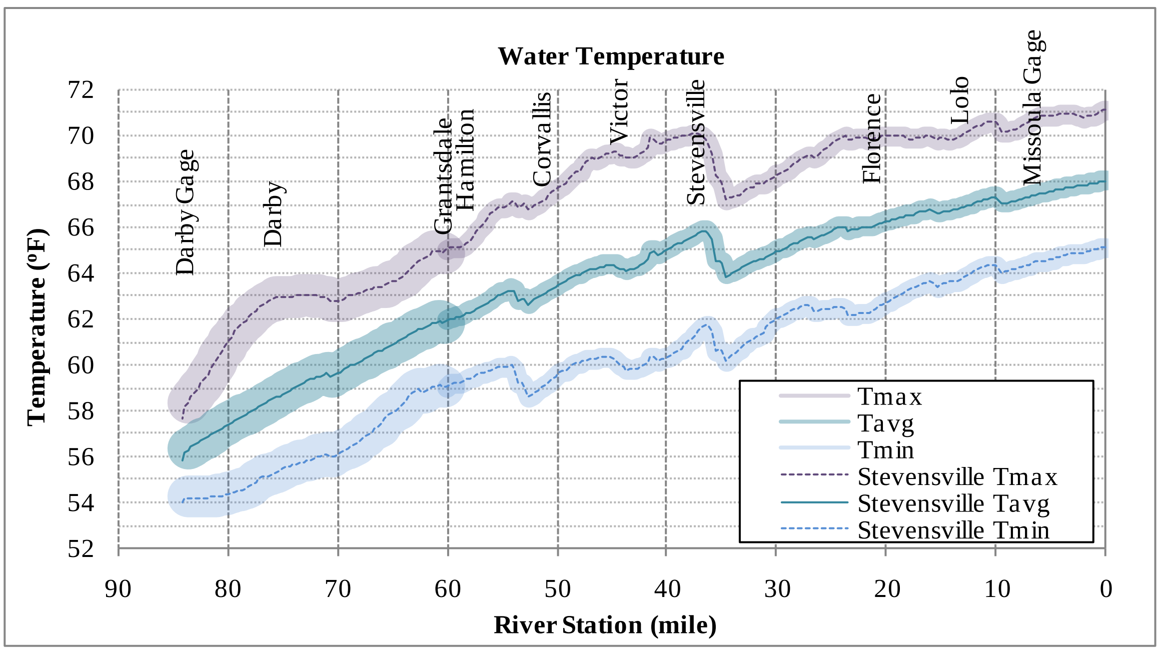


**Figure 10-21. Bitterroot River simulated water temperatures for existing conditions and WWTP scenarios, Stevensville flow set to zero**

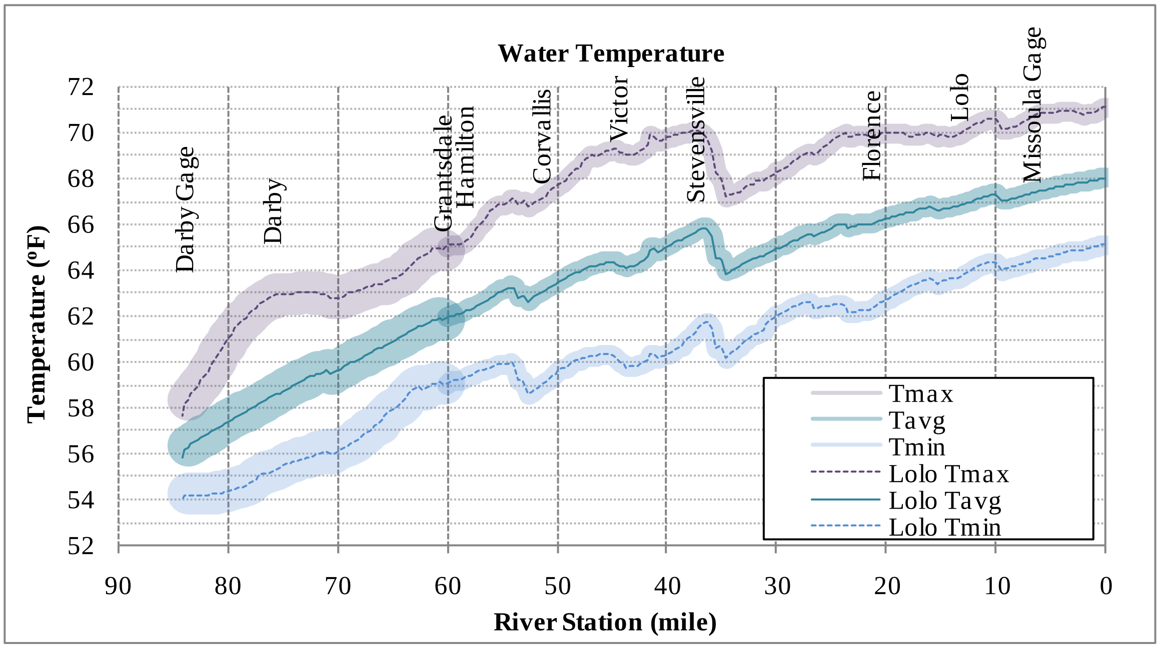


**Figure 10-22. Bitterroot River simulated water temperatures for existing conditions and WWTP scenarios, Lolo flow set to zero**

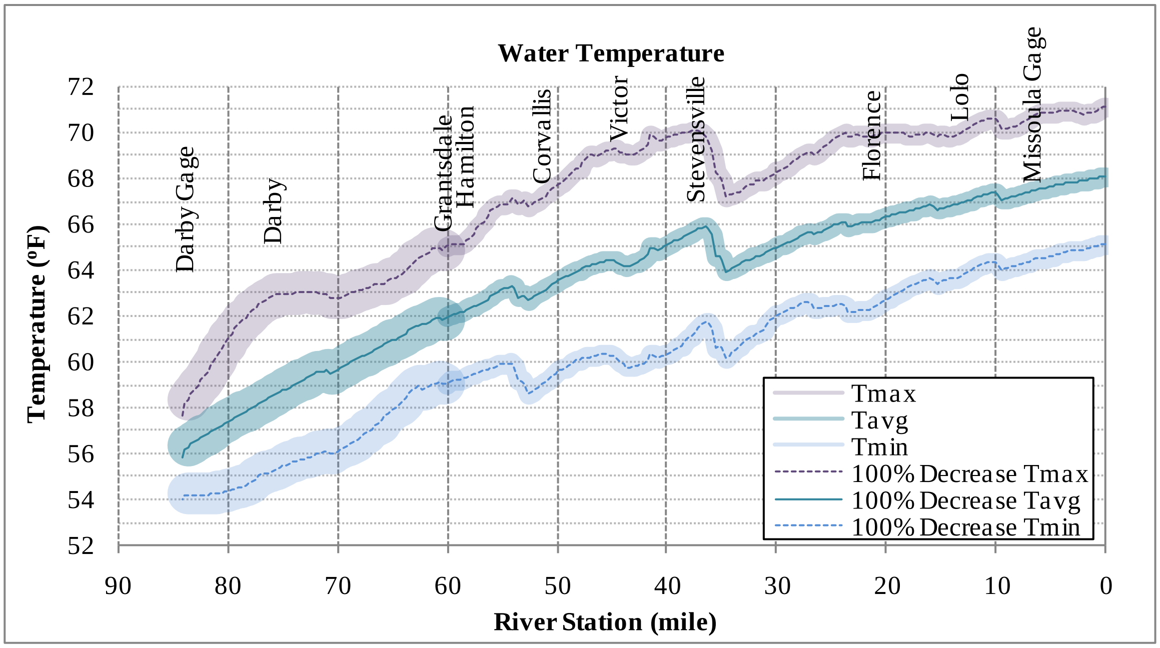


**Figure 10-23. Bitterroot River simulated water temperatures for existing conditions and WWTP scenarios, all WWTP flow set to zero**

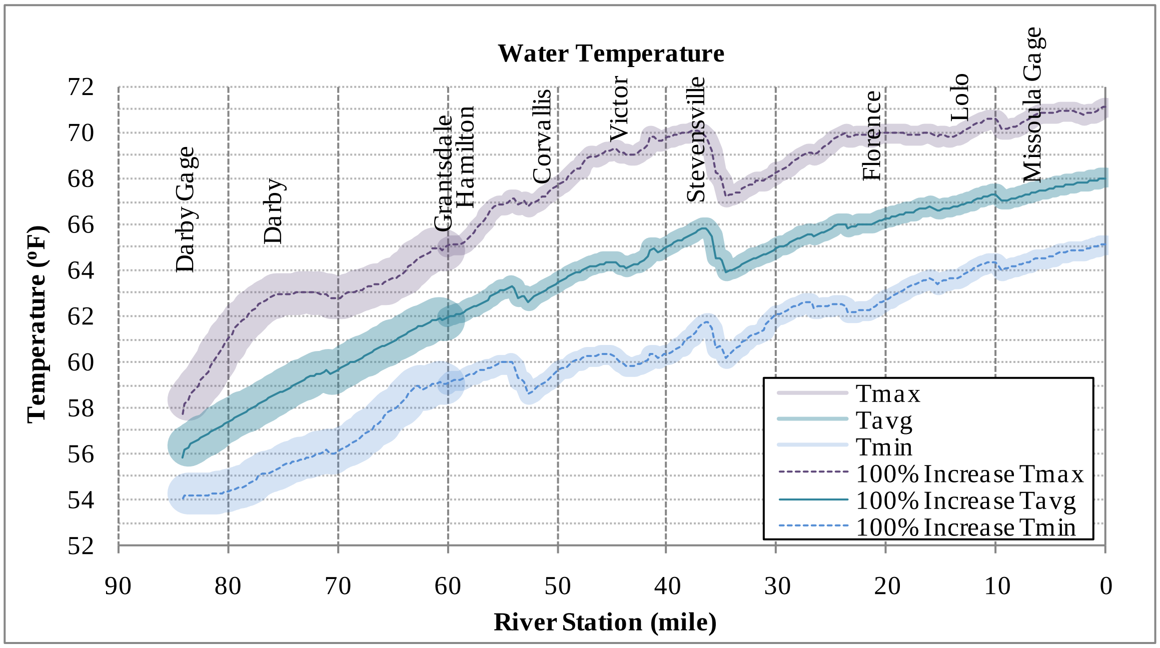


**Figure 10-24. Bitterroot River simulated water temperatures for existing conditions and WWTP scenarios, all WWTP flow doubled**

| Table 10-12. Tabular results of differences in water temperatures for existing conditions and WWTP scenarios | | |
|---|---|---|
| **River/Creek** | **Maximum Change in Maximum Daily Water Temperature (°F)** | **Location River Station (mile)** |
| Darby flow set to zero | | |
| Bitterroot River Upper Reach | 0 | n/a |
| Bitterroot River Middle Reach | 0 | n/a |
| Bitterroot River Lower Reach | 0 | n/a |
| Hamilton flow set to zero | | |
| Bitterroot River Upper Reach | 0 | n/a |
| Bitterroot River Middle Reach | -0.02 | 56.5 to 58.5 |
| Bitterroot River Lower Reach | 0 | 0 to 16 |
| Stevensville flow set to zero | | |
| Bitterroot River Upper Reach | 0 | n/a |
| Bitterroot River Middle Reach | 0 | n/a |
| Bitterroot River Lower Reach | 0 | n/a |
| Lolo flow set to zero | | |
| Bitterroot River Upper Reach | 0 | n/a |
| Bitterroot River Middle Reach | 0 | n/a |
| Bitterroot River Lower Reach | 0 | n/a |
| All WWTP flow set to zero | | |
| Bitterroot River Upper Reach | 0 | n/a |
| Bitterroot River Middle Reach | -0.02 | 56.5 to 58.5 |
| Bitterroot River Lower Reach | 0 | 0 to 16 |
| All WWTP flow doubled | | |
| Bitterroot River Upper Reach | 0 | n/a |
| Bitterroot River Middle Reach | +0.02 | 56.5 to 58.5 |
| Bitterroot River Lower Reach | 0 | 0 to 16 |

| Table 10-13. Water temperature (daily maximum and mean) comparison, existing conditions and WWTP scenarios, all six WWTP flow scenarios | | |
|---|---|---|
| **Maximum Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | No | n/a |
| Bitterroot River Middle Reach | No | n/a |
| Bitterroot River Lower Reach | No | n/a |

## 10.6 Stream Channel Dimensions Scenario

Changes in stream channel dimensions were not deemed an appropriate restoration approach on the Bitterroot River and were not simulated.

## 10.7 Natural Condition Scenario

The natural condition scenario combines many of the individual scenarios (discussed in earlier sections) and represents conditions without anthropogenic influence. Those specific to the Bitterroot River include: (1) shade improvement, (2) headwater and tributary water temperature reductions of 1°F, (3) flow reduction of 100 percent for water consumptive use, and (4) WWTPs discharge set to zero for all four wastewater facilities. The tributary natural condition scenario is the same as the shade scenario for Miller Creek and Sleeping Child Creek since there are no tributaries or WWTPs. For Willow Creek, the tributary natural condition includes the shade scenario and the removal of intermixing of Willow Creek stream water with canal water.

Results suggest that for the Bitterroot River, natural water temperatures would be about 0.1°F to 3.5°F cooler than the existing conditions, with the upper reach being the least affected and the middle reach the most (**Figure 10-25**). For Willow Creek, water temperatures average about 1°F to7.5°F cooler than the existing conditions (**Figure 10-26**).

The maximum change in the maximum daily water temperature is representative of the worst case conditions (**Table 10-14**). The locations where the difference in water temperature is greater than 0.5°F between the existing conditions and the natural condition scenario are summarized (**Table 10-15**), indicating potential impairment. The results of the comparison are also shown by reach on the map of the streams (**Figure 10-27**).

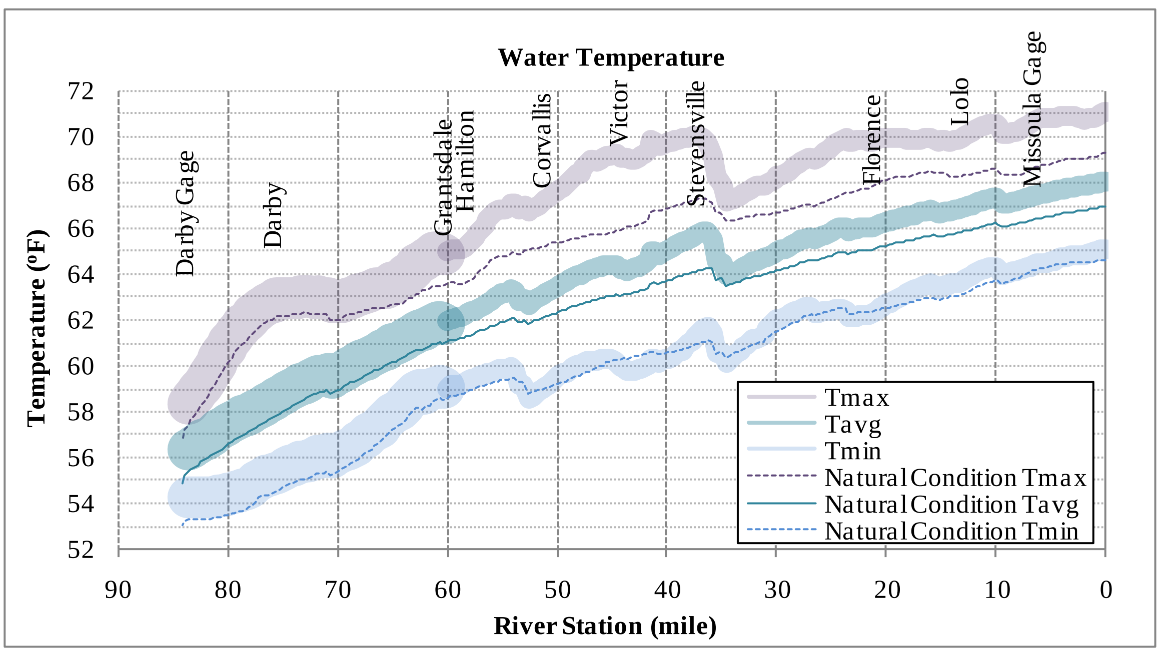


**Figure 10-25. Bitterroot River simulated water temperatures for existing conditions and natural condition scenario**

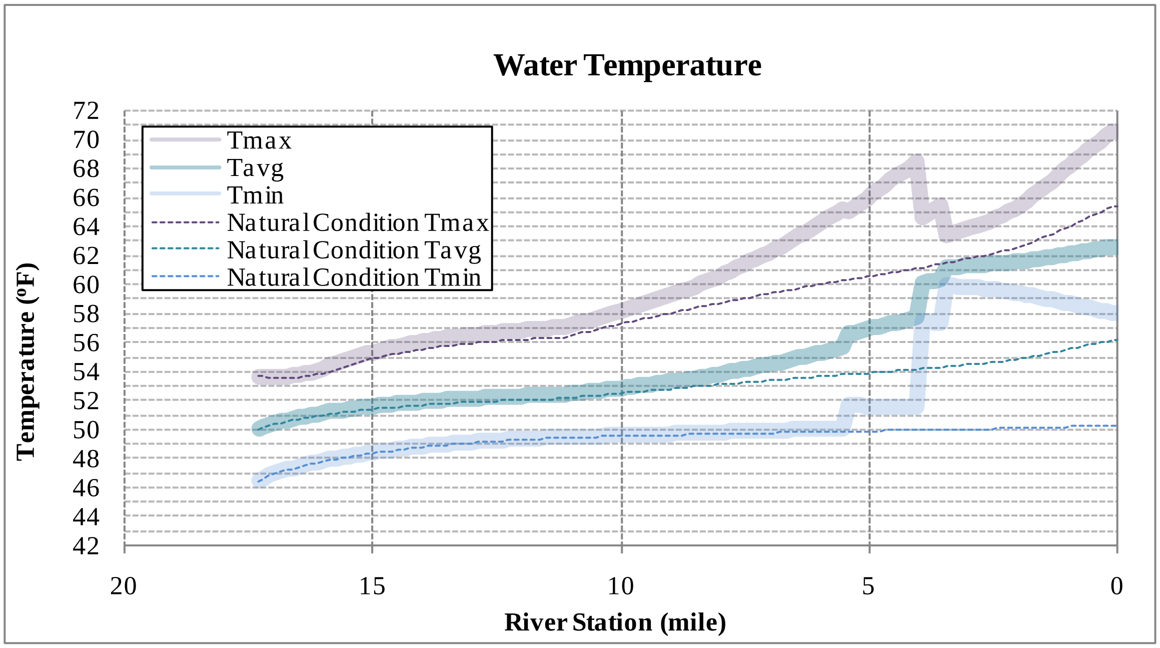


**Figure 10-26. Willow Creek simulated water temperatures for existing conditions and natural condition scenario**

| **Table 10-14. Tabular results of differences in water temperatures for existing conditions and natural condition scenario** | | |
|---|---|---|
| **River/Creek** | **Maximum Change in Maximum Daily Water Temperature (°F)** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | -1.45 | 60.5 to 63.5 |
| Bitterroot River Middle Reach | -3.45 | 44.5 to 47.5 |
| Bitterroot River Lower Reach | -2.08 | 5.5 to 7 |
| Willow Creek | -7.34 | 4 to 4.5 |

| **Table 10-15. Water temperature (daily maximum and mean) comparison, existing conditions and natural condition scenario** | | |
|---|---|---|
| **Maximum Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60.5 to 84 |
| Bitterroot River Middle Reach | Yes | 21.5 to 60.5 |
| Bitterroot River Lower Reach | Yes | 0 to 21.5 |
| Willow Creek | Yes | 0 to 15 |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60.5 to 84 |
| Bitterroot River Middle Reach | Yes | 21.5 to 60.5 |
| Bitterroot River Lower Reach | Yes | 0 to 21.5 |
| Willow Creek | Yes | 0 to 9 |

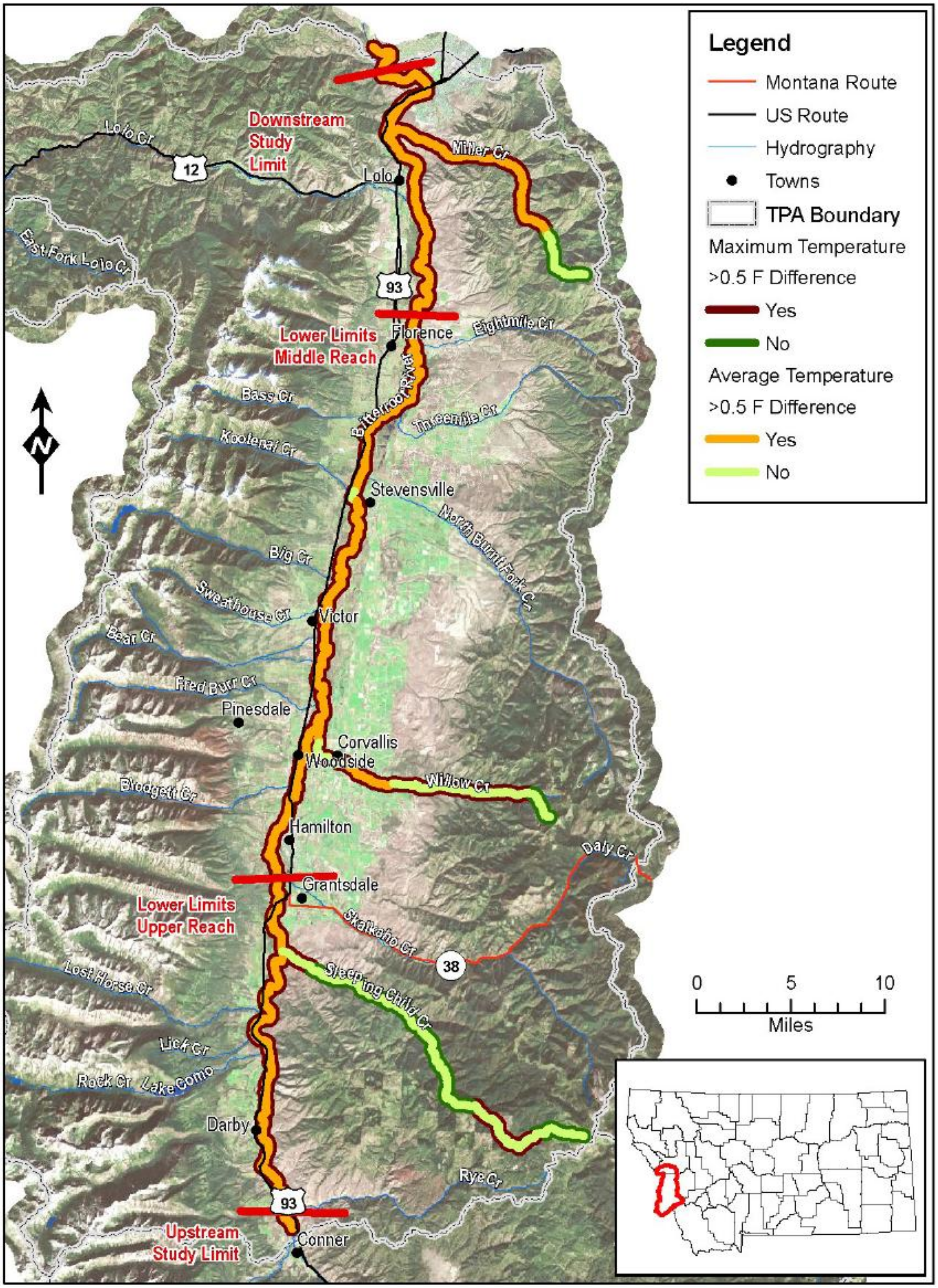


**Figure 10-27. Water temperature (maximum and mean) comparison, existing conditions and natural condition scenario**

## 10.8 Naturally Occurring Scenario

The naturally occurring scenario combines many of the individual scenario changes and represents the implementation of all reasonable land and soil water conservation practices in the watersheds. Specifically this includes: (1) shade improvement, (2) headwater and tributary water temperature reduction of 1$^{o}$F, and (3) flow reduction of 20 percent for water use. In Miller, Sleeping Child, and Willow creeks, naturally occurring scenarios are defined as the same as the natural condition scenarios, and therefore are not repeated. The differences between the naturally occurring and natural condition scenarios are flow and WWTPs and these are not present in the three tributary models.

For the Bitterroot River naturally occurring scenario, water temperatures would be about 0.1$^{o}$F to 1.5$^{o}$F cooler than the existing conditions. The upper reach exhibited the least variability from the baseline condition, with the middle reach showing the most (**Figure 10-28**). The maximum change in the maximum daily water temperature is representative of the worst case conditions and is indicative of impairment (**Table 10-16**). Locations where the difference in water temperature is greater than 0.5$^{o}$F between the existing conditions and the naturally occurring scenario are summarized in (**Table 10-17**). The results of the comparison are also shown by reach on the map of the streams (**Figure 10-29**).

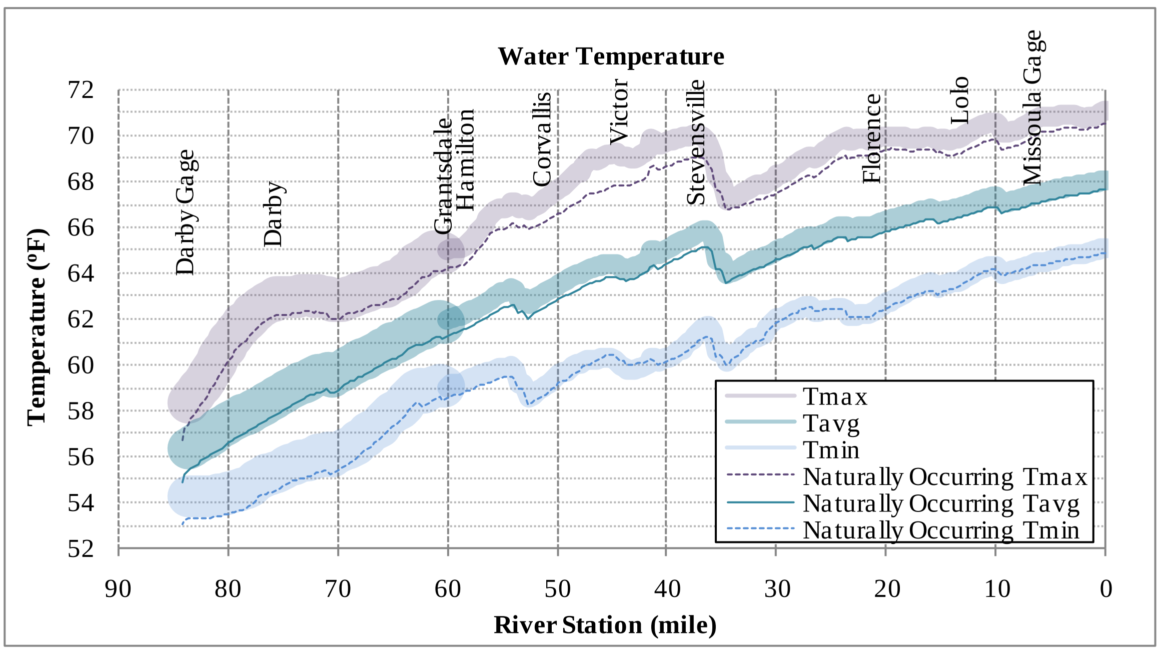


**Figure 10-28. Bitterroot River simulated water temperatures for existing conditions and naturally occurring scenario**

| Table 10-16. Tabular results of differences in water temperatures for existing conditions and naturally occurring scenario | | |
|---|---|---|
| **River/Creek** | **Maximum Change in Maximum Daily Water Temperature (°F)** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | -1.00 | 80 to 84 |
| Bitterroot River Middle Reach | -1.53 | 44.5 to 47.5 |
| Bitterroot River Lower Reach | -0.82 | 10 to 12 |

| Table 10-17. Water temperature (daily maximum and mean) comparison, existing conditions and naturally occurring scenario | | |
|---|---|---|
| **Maximum Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60.5 to 84 |
| Bitterroot River Middle Reach | Yes | 21.5 to 60.5 |
| Bitterroot River Lower Reach | Yes | 0 to 21.5 |
| **Mean Daily Water Temperature** | | |
| **River/Creek** | **Difference > 0.5°F** | **Location River Station (mile)** |
| Bitterroot River Upper Reach | Yes | 60.5 to 84 |
| Bitterroot River Middle Reach | Yes | 36 to 60.5 |
| Bitterroot River Lower Reach | No | n/a |

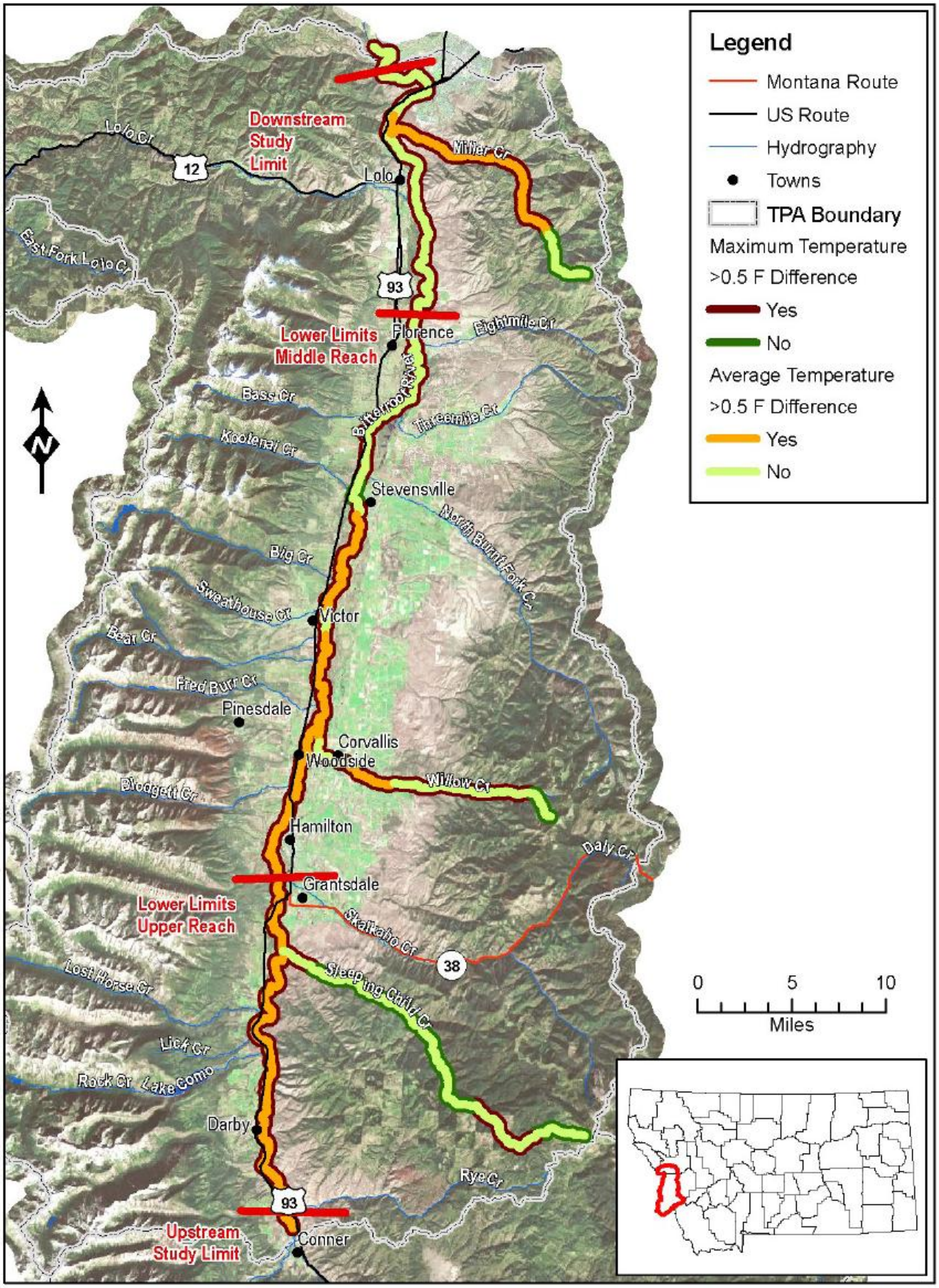


**Figure 10-29. Water temperature (maximum and mean) comparison, existing conditions and naturally occurring scenario**

# 11.0 SCENARIO RESULTS AND DISCUSSION

A difference of more than 0.5$^{o}$F between existing conditions and scenario was determined to be significant, and indicative of impairment based on the existing state temperature standard. The scenarios resulted in anywhere from almost no change in water temperatures to reductions as much as nearly 8$^{o}$F. Some of the reductions in water temperatures were localized and others affected nearly the entire reach.

For the shade scenario, there is no significant change in water temperature in the Bitterroot River. Sleeping Child Creek there is short reach with impacted water temperatures due to reduced shade. Miller Creek and Willow Creek show the greatest extent and impact to water temperatures due to shade reductions.

The headwater and tributary water temperature reduction scenario provided some reduction in water temperatures primarily in the middle reach of the Bitterroot River. This reduction in water temperature was attenuated by the downstream end of the Bitterroot River to less than 0.2$^{o}$F.

Flow scenarios representing irrigation efficiency changes were performed on the Bitterroot River. Again the middle reach showed the greatest potential for improvement. The 15, 20, and 25 percent reductions in water use resulted in a water temperature decrease of around 1$^{o}$F in the middle reach, while the 100 percent reduction resulted in a 1$^{o}$F to 3$^{o}$F reduction throughout the river.

Multiple WWTP scenarios were also performed on the Bitterroot River. All the combinations of zero to doubled flow from one to all of the WWTPs resulted in almost no change to water temperatures. The greatest change was 0.02$^{o}$F at Hamilton, the WWTP with the largest flow.

The natural condition scenario resulted in the greatest decrease in water temperatures as this scenario combined the effects of the individual scenarios. The Bitterroot River showed significant decreases in water temperatures generally throughout the entire reach.

For the naturally occurring scenario, the maximum decrease in water temperatures is about half of the natural condition scenario. The scenario still shows significant reductions in water temperatures are achievable throughout the reach. The areas with the greatest changes demonstrate the most sensitive areas. For the Bitterroot River the greatest change is 1.5$^{o}$F in the middle reach near Victor, river mile 44.5 to 47.5. The last 0.5 miles of Miller Creek near the confluence with Bitterroot River has the greatest change of 7.6$^{o}$F. For Sleeping Child Creek about 5 miles below the headwaters, river mile 18.5 to 20, has the greatest change of 1.0$^{o}$F. About 4 to 4.5 miles above the confluence of Willow Creek with the Bitterroot River near existing canals has the greatest change of 7.3$^{o}$F. This demonstrates the scenario may be feasible and beneficial to meeting water temperature standards for the Bitterroot River.

# 12.0 REFERENCES


Brain. D.W. and D.M. Dutton. 2000. Hydrogeology and Aquifer Sensitivity of the Bitterroot Valley, Ravalli County, Montana. Helena, MT: USGS Water Resources Investigations Report 99-4219.

Chapra, S., G.J. Pelletier, and H. Tao. 2007. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.11: Documentation and Users Manual. Civil and Environmental Engineering Dept., Medford, MA: Tufts University.

CWAIC. 2009. Clean Water Act Information Center. Montana Department of Environmental Quality. http://cwaic.mt.gov/Default.aspx (accessed February 2, 2009)

DEQ. 2005a. Sampling and Analysis Plan for Aerial Photography Interpretation of Ground-Truthing Sites. Helena, MT: Montana Department of Environmental Quality.

DEQ. 2005b. Water Quality Restoration Plan and Total Maximum Daily Loads for the Bitterroot Headwaters Planning Area. Helena, MT: Montana Department of Environmental Quality.

DEQ. 2007. Aerial Photography Interpretation for the Bitterroot River Basin, Shade / Temperature Model: Methods and Results. Helena, MT: Montana Department of Environmental Quality.

Ecology. 2008. Shade: A Tool for Estimating Shade from Riparian Vegetation. Olympia, WA: Washington State Department of Ecology. http://www.ecy.wa.gov/programs/eap/models.html (accessed April 29, 2008)

HDR. 2005. Tri-State Water Quality Council, Bitterroot River Model Project, Water Quality Model, Final Report. Boise, ID: HDR.

LaFave, J. 2008. Bitterroot Valley Aquifers Assessed. Butte, MT: Montana Bureau of Mines and Geology. http://www.bitterrootstar.com/backissues/1_23_08/pageone.html (accessed February 2, 2009)

McMurtrey, R.G., R.L. Konizeski, and F. Stermitz. 1959. Preliminary Report on the Geology and Water Resources of the Bitterroot Valley, Montana. Butte, MT: Bulletin 9, Montana Bureau of Mines and Geology.

McMurtrey, R.G., R.L. Konizeski, M.V. Johnson, and J.H. Bartells. 1972. Geology and Water Resources of the Bitterroot Valley, Southwest Montana. Helena, MT: USGS Water Supply Paper 1889.

NOAA. 2009. National Oceanic and Atmospheric Administration, Cooperative Observer Program. http://www.nws.noaa.gov/om/coop/ (accessed February 2, 2009)

ODEQ. 2001. TTools 3.0 User Manual. Salem, OR: State of Oregon Department of Environmental Quality.

Sandals, K.M. 1947. Reconnaissance Conservation Report on Water Control, Use and Disposal, Bitterroot River Drainage Basin, Ravalli County, Montana. Lincoln, NE: United States Department of Agriculture, Soil Conservation Service.

USFS. 2009. Bitterroot National Forest Travel Management Planning Project Draft Environmental Impact Statement (Affected Environment and Environmental Consequences – Water Resources). USDA Forest Service, Bitterroot National Forest, Hamilton, MT.

USGS. 2004. Estimated Water Use in Montana in 2000. Denver, CO: Scientific Investigations Report 2004-5223.

USGS. 2009. National Water Information System Web Interface. http://waterdata.usgs.gov/nwis/sw (accessed March 2, 2009)

WRCC. 2009. (Western Regional Climate Center). http://www.wrcc.dri.edu/ (accessed March 2, 2009)

# ATTACHMENT C – MODELING STREAMFLOW AND WATER TEMPERATURE IN THE BITTERROOT RIVER, MONTANA – ADDENDUM A

# MODELING STREAMFLOW AND WATER TEMPERATURE IN THE BITTERROOT RIVER, MONTANA – ADDENDUM A.

Darrin Kron and Kyle Flynn

TMDL Technical Report
Montana Department of Environmental Quality
Water Quality Planning Bureau
Watershed Modeling Program
1520 East Sixth Avenue, PO Box 200901
Helena, MT 59620-0901
December 2009

Suggested Citation:

Kron, D. and Flynn, K. 2010. Modeling Streamflow and Water Temperature in the Bitterroot River, Montana – Addendum A. TMDL Technical Report. Montana Department of Environmental Quality.

**SUMMARY**

A QUAL2K model was completed to support temperature TMDL development for the Bitterroot River and several of its tributaries by the Montana Department of Environmental Quality (Kasch et al, 2009). Model calibration was completed and restoration scenarios were simulated during a prior effort. This addendum adds an additional wastewater treatment plant discharge scenario to the prior effort. The results of this addendum are used to demonstrate the effects of future wastewater conditions upon the Bitterroot River and will be used as a technical basis for the Bitterroot River TMDL wasteload allocation (WLA) approach.

# 1.0 INTRODUCTION

A QUAL2K model was competed to support TMDL development for the Bitterroot River and several of its tributaries by the Montana Department of Environmental Quality (Kasch et al, 2009). An additional scenario was needed for TMDL analysis. This addendum represents a scenario to determine the thermal impacts of future wastewater treatment plant (WWTP) effluent conditions to the Bitterroot River. Results will be used for technical justification of thermal WLAs to the Bitterroot River.

# 2.0 METHODS AND MATERIALS

This addendum uses the same study area and exact model as described in the report *Modeling Streamflow and Water Temperature in the Bitterroot River* (Kasch, M. et al, 2009). All climate, shade, water discharge, water temperature, stream network and calibrated model parameters were identical to those used during the 2009 modeling effort. The baseline comparison in this report is the same as the calibrated baseline model scenario with all the WWTP discharges turned off provided in *Table 10-23* of *Kasch et al, 2009*.

Additionally, mixing calculations for existing peak hourly WWTP discharge rates mixed with a 7Q10 instream flow condition during average summer afternoons are provided in **Table 2-1** for comparison to the additional WWTP discharge scenario provided below. Although, this is not the condition which the additional scenario is compared to within the model framework for this report, the mixing calculations are a useful tool for comparison of existing thermal effects to future effects if WWTP sources were to discharge at WLA conditions.

**Table 2-1**. Data and mixing calculations for existing WWTP discharge at hourly peak flow conditions

| | Darby | Hamilton | Stevensville | Lolo |
|---|---|---|---|---|
| Upstream Discharge at 7Q10 (cfs) | 120 | 152 | 159 | 392 |
| Upstream Temperature (F˚) | 63.4 | 66.7 | 68.5 | 70.2 |
| Effluent Discharge hourly Peak Flow (cfs) | 1.18 | 3.54 | 2.12 | 1.23 |
| Effluent Temperature (F˚) | 69.0 | 70.5 | 69.0 | 70.5 |
| Mixed Instream Temperature (F˚) | 63.5 | 66.8 | 69.5 | 70.2 |
| Mixed Instream Δ T due to Effluent (F˚) | 0.055 | 0.087 | -0.007 | 0.001 |

A single additional QUAL2K model scenario was completed in this addendum. The scenario is based upon efforts to determine TMDL thermal wasteload allocations (WLAs) for the Bitterroot River. The WLAs will include individual thermal wasteload allocations to Darby, Hamilton, Stevensville, and Lolo, and in this scenario, all WWTPs were allowed to discharge at double their current rate or their current design flow, whichever was greater (i.e. Effluent Peak Flow from **Table 2-2**). For this scenario, hourly peak discharge rates were estimated based upon average monthly conditions and technical guidance from *DEQ Circular 2*, Figure 1 and used for discharge scenarios since hourly conditions may affect the fishery. **Table 2-2** provides model input conditions of each effluent along with mixing calculation results for 7Q10 instream flow condition.

| **Table 2-2**. WWTP scenario input data for estimated future increased discharge rates and mixing calculations for a 7Q10 flow | | | | |
|---|---|---|---|---|
| | Darby | Hamilton | Stevensville | Lolo |
| Upstream Discharge at 7Q10 (cfs) | 120 | 152 | 159 | 392 |
| Upstream Temperature (F˚) | 63.4 | 66.7 | 68.5 | 70.2 |
| Effluent Discharge hourly Peak Flow (cfs) | 2.36 | 10.30 | 4.25 | 2.47 |
| Effluent Temperature (F˚) | 69.0 | 70.5 | 69.0 | 70.5 |
| Mixed Instream Temperature (F˚) | 63.5 | 66.9 | 69.5 | 70.2 |
| Mixed Instream Δ T due to Effluent (F˚) | 0.108 | 0.241 | -0.013 | 0.002 |

The mixing calculations provide some utility regarding the effects of each discharge upon critical low-flow conditions. Yet it is also prudent to run the proposed WLA scenario within the temperature QUAL2K model to represent interactions between discharges and compare results to a condition without WWTP discharges. The modeled stream flow condition described in *Kasch et al, 2009* differs from the 7Q10, but is typical of a moderately dry water year during summer low flow conditions. Therefore, the mixing calculation results in **Table 2-1** are provided to identify the initial effects of the wastewater effluents upon instream temperatures at a critical low flow. These do not however reflect cumulative system impacts. Undoubtedly, affects from additional heat load, heat attenuation from the stream, and volumetric heat capacity of the stream are of importance. Hence, the QUAL2K model scenario was completed to determine the cumulative impacts of wastewater sources and associated changes in volumetric heat capacity of the Bitterroot River. The combined results from both the mixing calculations at 7Q10 critical flow and the additional QUAL2K WWTP modeling scenario will be used in conjunction as a technical basis for justification of thermal wasteload allocations to the Bitterroot River.

# 3.0 Results and Discussion

When comparing modeling results from the additional WWTP scenario to a scenario where no WWTP sources are present, the total cumulative thermal impact from all WWTP WLAs was determined. Modeling results indicate the initial thermal shift due to each effluent when compared to the condition with no WWTP effluents is small (approximately <±0.15 degrees C) (**Figure 3-1**). The modeled initial thermal impacts are fairly small magnitude and are somewhat similar to those found at critical low flow 7Q10 conditions provided in **Table 2-2** despite the fact that there was a much higher stream discharge rate in the modeled scenario. Likewise, depending on whether the receiving water temperature was above or below that of the wastewater discharge, there was either an initial increase or decrease in temperature due to the difference in temperatures.

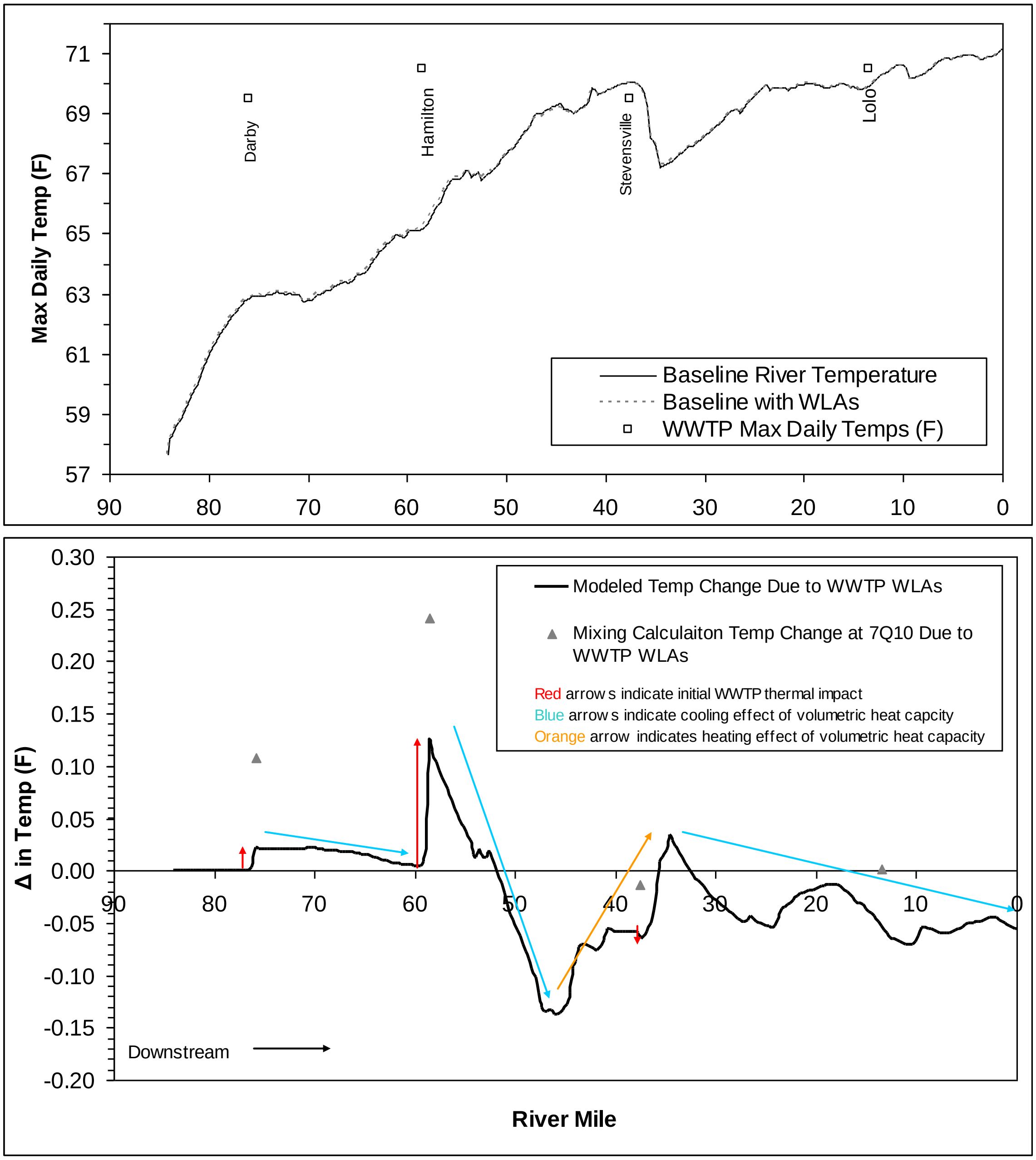


**Figure 3-1**. Comparison of QUAL2K modeling result scenarios using daily maximum temperatures: Baseline without WWTP discharges to Baseline with proposed WWTP WLAs conditions.

Yet, after the initial wastewater and associated heat load was added, some interesting effects occurred which were attributed to the added volumetric heat capacity of the receiving water (i.e. more volume which requires more heat or cooling to manifest associated changes). So, given the same nonpoint solar and passive heat inputs along the stream corridor, the increased volume of water provided via the effluents has the potential to reduce temperatures as water flows downstream. This is illustrated in blue in **Figure 3-1**. Alternatively stated, the more water present in the stream with the same heat applied from solar radiation equates to lower instream temperatures as it flows downstream. Yet an overall cooling affect only occurs after the initial heat influence from the point source can be overcome by this affect. Another influencing factor comes into play when interpreting the comparison of the two scenarios. The increased instream flow due to added effluent volume reduces the cooling effect of cold groundwater influences near Stevensville. This effect is produced by a larger volume of warmer stream flow which reduces the overall cooling influence by reducing the proportion of cool groundwater at this point. This effect is noted by an orange arrow in **Figure 3-1**.

## 3.1 Summary

The complex interactions between WWTP initial thermal loads and changes to volumetric heat capacity provide both heating and cooling affects upon instream temperatures. The results of the mixing calculations and modeling results indicate that if WWTPs were to double existing discharge rates or discharge up to their existing design capacity, whichever is higher, they would likely only heat the stream to approximately their initial thermal impact at each discharge point. Cumulatively at the modeled discharge rates the WWTPs influences would cumulatively stay well below ½°F. As heat load allocations are developed for the TMDL, they will consider the results from this modeling effort along with initial mixing conditions at 7Q10.

# 4.0 References


Kasch, M., Flynn, K. Starr, B, Kron, D. 2009. Modeling Streamflow and Water Temperature in the Bitterroot River, Montana. TMDL Technical Report. Montana Department of Environmental Quality.

Montana Department of Environmental Quality. 1999. Circular DEQ 2. Design Standards for Wastewater Facilities.

# ATTACHMENT D - BITTERROOT RIVER TMDL PLANNING AREA MISSOULA MS4 TEMPERATURE AND THERMAL LOADING ASSESSMENT

# BITTERROOT RIVER

# TMDL PLANNING AREA

# MISSOULA MS4 TEMPERATURE AND THERMAL LOADING ASSESSMENT

JANUARY 11, 2011

**PREPARED BY:**
**MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY**
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The City of Missoula meets requirements for a small municipal separate storm sewer system (MS4). This effort provides a coarse estimate of the thermal inputs to the Bitterroot River from the City of Missoula (MS4) area. A portion of this MS4 permitted area lies within the Bitterroot Watershed. This permit (MTR040007) is combined and includes the following entities: City of Missoula, Missoula County, Montana Department of Transportation (MDT), and the University of Montana.

Much of the city drains to the Clark Fork River, yet a portion drains to the Bitterroot River. Also, much of the MS4 area in the Bitterroot Watershed is serviced by dry wells. There are two discrete surface sewer discharge locations that drain to the Bitterroot River. One was constructed by Montana Department of Transportation and another was developed by the City of Missoula. Other areas of the MS4 may provide limited surface runoff to a Bitterroot River tributary south of the two discharge locations and an irrigation system to the north of the two discharge locations, yet these areas likely do not provide significant stormwater runoff. The two major outfalls collect most of the MS4 surface water discharge draining to the Bitterroot River (**Map 1**). These outfalls also collect baseflow and runoff from natural areas above the city.

The discharge location on the north side of HWY 93 was built by Montana Department of Transportation. MDT used the rational method to determine peak runoff volume when a sewer main was added under Reserve Street during reconstruction. MDT estimates a two year flood event would produce a peak flow of approximately 29 cfs and a ten year event would produce a peak flow of approximately 57 cfs at this location. No comparable small (~2yr) runoff event data was available for the other outfall location at the time of this report, yet large event estimates were comparable to larger storm events of the HWY 93 location. DEQ estimates that doubling the peak two-year HWY 93 outfall (58 cfs) estimate would account for the other outfall, plus the other two potential contributive areas described above. The smallest event modeled by MDT is used to represent a storm that reoccurs periodically, yet is sizable.

DEQ then estimated the initial wash off volume of potential heat contribution to the Bitterroot River from a typical summer thunderstorm by estimating the first 20% of runoff volume of the two year event using a time of concentration of 1.5 hours and a simple geometric assessment. The initial wash off is assessed because most summer thunderstorms cooled air temps considerably, approaching in-stream water temperatures, within an hour via evaporation and sunlight interception. Therefore, the initial urban wash off pollutant theory likely applies to thermal load and temperature impacts to surface water. The results indicate a flow of 36 cfs is associated with the highest associated flow of the first 20% runoff volume during a two year event from all surface water contributions of the MS4.

Weather data from the Missoula airport weather station was assessed to determine air temperatures, and thus rainfall temperatures during mid-summer (July through August) thunderstorms where air temperatures were above 75 and 80˚F and rainfall was greater than a $1/10^{th}$ of an inch for the total storm event. Over a four year period, three such events were found with air temperatures above 80˚F and five were found with air temperatures above 75˚F. Air temperatures dropped 10-16˚F during the first hour of each storm event and were usually near 70˚F by the end of the first hour during days where temperatures were initially above 80˚F (**Table 1**).

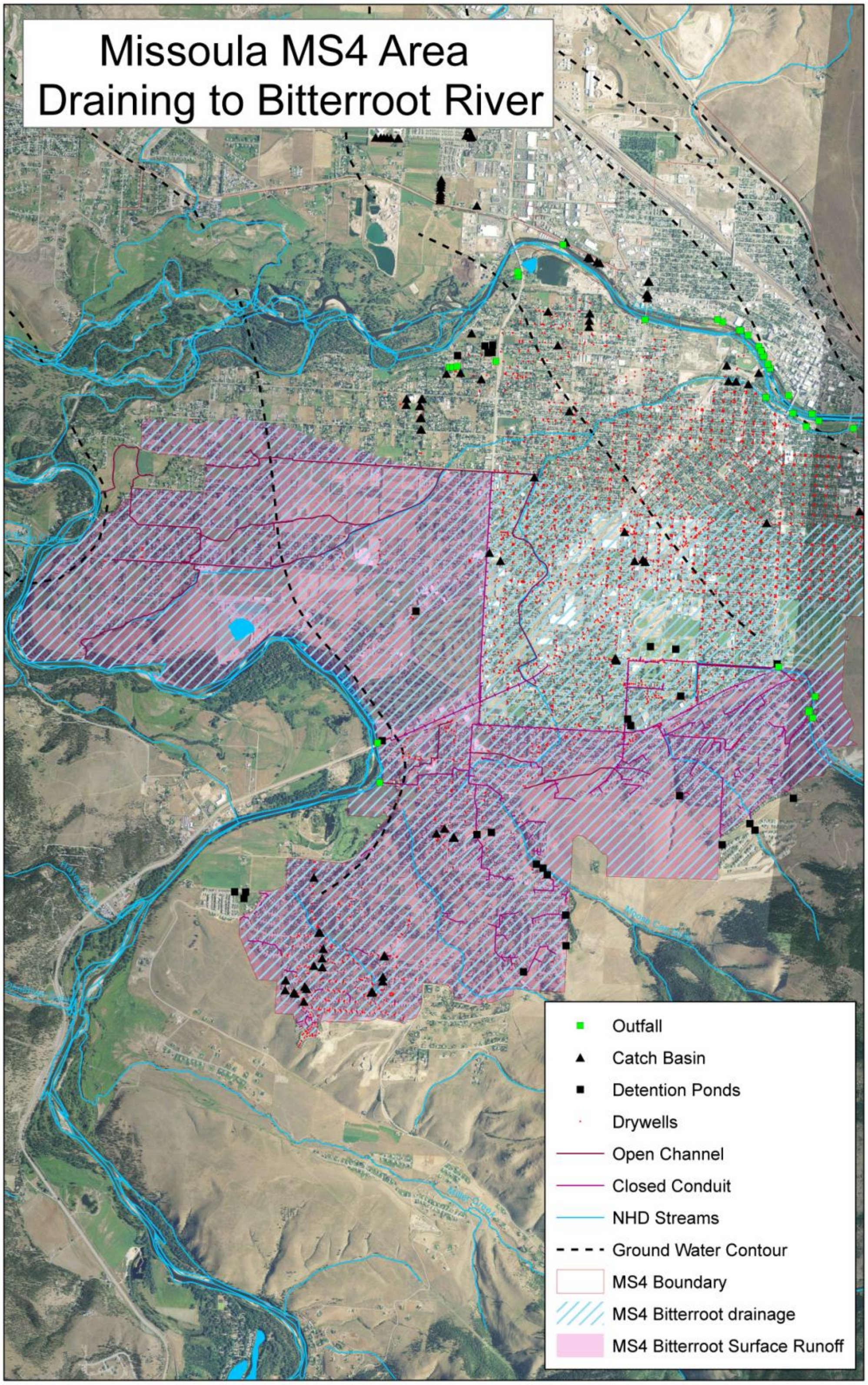
**Table 1**. Summer (July-August, 2007-2010) Storm Events with greater than $^{1}/_{10}{}^{th}$ in rainfall on days with 80˚F air temperature

| 7/26/2009 | | | 7/31/2010 | | | 8/18/2010 | | |
|---|---|---|---|---|---|---|---|---|
| Hour | Temp (F) | Precip (in) | Hour | Temp (F) | Precip (in) | Hour | Temp (F) | Precip (in) |
| 0 | 62 | | 0 | 63 | | 0 | 59 | |
| 1 | 66 | | 1 | 64 | | 1 | 60 | |
| 2 | 62 | | 2 | 63 | | 2 | 57 | |
| 3 | 63 | | 3 | 61 | | 3 | 60 | |
| 4 | 62 | | 4 | 58 | | 4 | 57 | |
| 5 | 61 | | 5 | 58 | | 5 | 54 | |
| 6 | 59 | | 6 | 60 | | 6 | 54 | |
| 7 | 63 | | 7 | 60 | | 7 | 57 | |
| 8 | 68 | | 8 | 67 | | 8 | 62 | |
| 9 | 70 | | 9 | 73 | | 9 | 67 | |
| 10 | 75 | | 10 | 78 | | 10 | 71 | |
| 11 | 78 | | 11 | 80 | | 11 | 74 | |
| 12 | 79 | | 12 | 82 | | 12 | 80 | |
| 13 | 81 | | 13 | 86 | | 13 | 87 | |
| 14 | 82 | | 14 | 88 | | 14 | 87 | |
| 15 | 85 | T | 15 | 77 | 0.01 | 15 | 88 | |
| 16 | 83 | | 16 | 72 | 0.14 | 16 | 81 | T |
| 17 | 84 | | 17 | 72 | | 17 | 71 | 0.13 |
| 18 | 82 | | 18 | 68 | 0.09 | 18 | 69 | 0.02 |
| 19 | 80 | T | 19 | 66 | 0.01 | 19 | 64 | 0.02 |
| 20 | 64 | 0.59 | 20 | 65 | | 20 | 65 | |
| 21 | 63 | T | 21 | 65 | | 21 | 63 | |
| 22 | 62 | | 22 | 64 | | 22 | 61 | |
| 23 | 61 | | 23 | 64 | | 23 | 60 | |
| 24 | 62 | 0.01 | 24 | 63 | | 24 | 59 | |

An effort in Minnesota was conducted to determine the runoff temperatures from paved areas (Janke et. al, 2006). Initial rainfall temperatures in this effort were estimated at 70˚F and run across 100m of asphalt pavement with an initial temperature of 80˚F. Over the first hour, the water was warmed on average, about 6˚F (Janke et. al, 2006). The area drained by the outfalls is estimated at about 20% imperviousness. Runoff from other types of surfaces that do not collect as much heat as asphalt contribute to runoff, such as rooftops, bare ground and concrete (Herb et. al, 2007). Also, pervious areas may contribute limited runoff volumes. Yet, impervious areas will likely result in much of the first flush runoff. Therefore, the cited heating effect is applied to half of the first flush of urban runoff. This coarse estimate accounts for percentage of impervious area, asphalt composition of the impervious area compared to other impervious surfaces, and that first flush is most likely derived largely, but not entirely from, impervious areas. Results indicate average urban runoff temperatures during typical summer storms would be about 73˚F during the first flush when entering stormwater conduits. Alternatively, some heat is attenuated via open channels and especially in buried conduits where ground temperatures are closer to 55˚F. Therefore, 72˚F will be used to represent stormwater temperatures for mixing calculations to determine thermal impacts to the Bitterroot River.

Using the estimates provided above and modeling and monitoring results for the Bitterroot River thermal conditions, simple mixing calculations were completed to simulate the thermal affect of the MS4 area upon the Bitterroot River at 7Q10 flow (392 cfs). The resulting thermal change in the Bitterroot River would be about a 0.23˚F increase in temperature at extreme low flow. At typical summer stream flows (550), the increase in temperature would be about 0.17˚F. However, the increase would be very short lived and fish would be provided a recovery shortly after the event due to cooling conditions from the storm itself.

Due to the short duration, the infrequency, and the relative magnitude of these storm events, it is important to consider the relatively small effect these have on the Bitterroot River fishery. Unlike other WWTP point sources in the watershed, the MS4 stormwater discharge is not a continuously flowing. When storms do occur, the thermally elevated runoff dissipates after one or two hours. Significant rainfall events occurring when air temperatures are or have been above 80$^{o}$F are relatively rare, occurring approximately once per summer in the four years of hourly rainfall data reviewed. Separately, a storm of the magnitude required to produce this volume of runoff occurs on average once every two years (i.e. the 2-year storm). Combine these two, and it is likely that large storms capable of producing thermally elevated discharges occur a few times per decade. The runoff produced by these storms is also going to be mitigated by the very fact that they are major storms. The remaining 80% of the runoff hydrograph from the MS4 area (everything after the first flush) is much larger than the first flush volume and is not thermally elevated. Additionally, the Bitterroot River will increase in discharge following a large storm event, thus dissipating thermal effects from the MS4 area. Storms also cool air temperatures, which are a primary influence of instream temperature. Due to these factors, it is likely that this source will not severely affect the fishery. Yet, controlling first flush urban surface runoff volume from entering the Bitterroot River should be a concern due to the moderate magnitude of heating that may occur.




Map1. Missoula Area MS4 map.

Janke, B., Herb, W.R., Mohseni, O., and H. Stefan, 2006. Quasi 2-D model for runoff temperature from a paved surface, St. Anthony Falls Laboratory Report 477, 78 pp

Herb, W.R., Janke, B., Mohseni, O., and H.G. Stefan, 2007. Estimation of runoff temperatures and heat export from different land and water surfaces, St. Anthony Falls Laboratory Project Report 488, 34 pp.